SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
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March 31, 2019

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

Subject: SMCWPPP Urban Creeks Monitoring Report and Electronic Monitoring Data Submittal for **Water Year 2018**

Dear Mr. Montgomery:

On behalf of all San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) Permittees, I am pleased to submit SMCWPPP's Urban Creeks Monitoring Report (UCMR) and Electronic Monitoring Data for the water quality monitoring projects conducted in Water Year (WY) 2018 (October 1, 2017 through September 30, 2018).

The UCMR is submitted in compliance with Provision C.8.h.iii of the Municipal Regional Stormwater Permit (MRP, NPDES #CAS612008, Order R2-2015-0049) which became effective on January 1, 2016. The UCMR contains summaries of monitoring conducted in WY 2018 pursuant to Provision C.8 of the MRP, including: Creek Status Monitoring (Provision C.8.d), Stressor/Source Identification Projects (Provision C.8.e), Pollutants of Concern Monitoring (Provision C.8.f), and Pesticides and Toxicity Monitoring (C.8.g). The UCMR consists of a main report and several appendices.

Electronic Monitoring Data are submitted in compliance with Provision C.8.h.ii of the MRP. Please note that although the UCMR summarizes data collected by SMCWPPP and third-party organizations[1], the electronic data files include only those data collected by SMCWPPP pursuant to the MRP provisions listed in Table 1.

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[1] See the Third-Party Monitoring Statement attached at end of this letter.

Table 1. Project, date range, and applicable MRP provision for data included in the Water Year 2017 Electronic Monitoring Data submittal.

Project	Date Range	MRP Provision
Creek Status Monitoring	April - September 2018	C.8.d
Stressor/Source Identification Study	January – July 2018	C.8.e
Pollutants of Concern Monitoring	January – May 2018	C.8.f
Pesticides and Toxicity Monitoring	January - July 2018	C.8.g

The quality of all Creek Status Monitoring (MRP Provision C.8.d), Stressor/Source Investigation (MRP Provision C.8.e), Pesticides and Toxicity Monitoring (MRP Provision C.8.g) data, and Pollutants of Concern (MRP Provision C.8.f) nutrient and copper data in the electronic data files was evaluated consistent with the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition's *Creek Status Monitoring Program Quality Assurance Project Plan* (QAPP), which is comparable with the latest version of the State of California's Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP). The quality of all Pollutants of Concern Monitoring (MPR Provision C.8.f) PCBs and mercury data in the electronic data files was evaluated consistent with the Clean Watersheds for Clean Bay (CW4CB) project QAPP.

In compliance with Provision C.8.h.ii (Electronic Reporting) of the MRP, all CEDEN-acceptable data (i.e., data collected from a receiving water) were provided to the Regional Data Center for the California Environmental Data Exchange Network (CEDEN), located at the San Francisco Estuary Institute (SFEI), via upload to their FTP site.[2] These data are submitted in a format comparable with the SWAMP database. Pollutants of Concern Monitoring data collected in non-receiving waters are included in the attached electronic files but will not be submitted to the Regional Data Center at this time. For more details on the non-receiving waters data submittal to CEDEN see the BASMAA letter to CEDEN (dated March 20, 2017) which was cc'd to several of your staff.

Monitoring data included in this submittal suggest that water quality conditions in San Mateo County creeks vary substantially among sites and between monitoring events. Temporal and spatial variability adds to the challenge of interpreting and evaluating the data and using it to help identify potential persistent water quality issues warranting a programmatic response from stormwater agencies. The UCMR includes detailed analyses of the monitoring data.

We look forward to discussing the findings, conclusions, and recommended next steps included in the UCMR and to continuing to work with you and your staff to successfully address new challenges regarding water quality monitoring. Please contact me if you have any comments or questions.

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[2] The data were also provided directly to the Marine Pollution Studies Laboratory at Moss Landing Marine Laboratories (MPSL-MLML) which is assisting SFEI with CEDEN uploads in 2019.

Certification Regarding SMCWPPP Program Urban Creeks Monitoring Report

"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 gathered and evaluated the information submitted. Based on my inquiry of the person or persons who managed 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,

Matthew Fabry

Matthew Fabry, P.E.
Program Manager

Attachments: SMCWPPP UCMR Water Year 2018 (uploaded to ftp site)
Electronic Data Report for Water Year 2018 Creek Status Monitoring, Stressor/Source Identification, Pollutants of Concern Monitoring, and Pesticides and Toxicity Monitoring (uploaded to ftp site)
Third Party Monitoring Statement (one page)

Third Party Monitoring Statement

Please note that consistent with Provision C.8.a.iii of the MRP, one water quality monitoring requirement was partially fulfilled by third party monitoring in Water Year 2018:

- The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) conducted a portion of the data collection in Water Year 2018 on behalf of Permittees, pursuant to MRP Provision C.8.f – Pollutants of Concern Monitoring. The results of that monitoring are summarized in Section 5 of the attached UCMR. Data collected from stations monitored by the RMP will be submitted to the California Environmental Data Exchange Network directly by the RMP following completion of their quality assurance review.
- Data collected by the State of California's Surface Water Ambient Monitoring Program (SWAMP) through its Stream Pollutant Trend (SPoT) Monitoring Program at the San Mateo location is used to partially fulfill MRP Provision C.8.f - Pollutants of Concern Monitoring requirements addressing trends evaluation. Data collected from stations monitored by the SPoT Program will be submitted directly to the California Environmental Data Exchange Network according to the SWAMP schedule for review and reporting of data, which may not occur for several years.

Urban Creeks Monitoring Report

Water Quality Monitoring

Water Year 2018 (October 2017 – September 2018)

Submitted in Compliance with
NPDES Permit No. CAS612008 (Order No. R2-2015-0049),
Provision C.8.h.iii

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

A Program of the City/County Association of Governments

March 31, 2019

CREDITS

This report is submitted by the participating agencies in the

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program
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Town of Atherton
City of Belmont
City of Brisbane
City of Burlingame
Town of Colma
City of Daly City
City of East Palo Alto
City of Foster City
City of Half Moon Bay
Town of Hillsborough
City of Menlo Park
City of Millbrae
City of Pacifica
Town of Portola Valley
City of Redwood City
City of San Bruno
City of San Carlos
City of San Mateo
City of South San Francisco
Town of Woodside
County of San Mateo
SMC Flood Control District

Prepared for:
San Mateo Countywide Water Pollution Prevention Program (SMCWPPP)
555 County Center, Redwood City, CA 94063
A Program of the City/County Association of Governments (C/CAG)

Prepared by:
EOA, Inc.
1410 Jackson St., Oakland, CA 94610

Preface

In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA) joined together to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by the San Francisco Bay Area regional municipal stormwater permit, which is a National Pollutant Discharge Elimination System (NPDES) permit (in this document the permit is referred to as the Municipal Regional Permit, or MRP)[1]. The RMC is comprised of the following participants:

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

This Urban Creeks Monitoring Report complies with MRP provision C.8.h.iii for reporting of all data in Water Year 2018 (October 1, 2017 through September 30, 2018). Data were collected pursuant to Provision C.8 of the MRP. Data presented in this report were generated by water quality monitoring programs conducted under the direction of the RMC and the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), using probabilistic and targeted monitoring designs as described herein.

Monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Project Plan (QAPP; BASMAA 2016a) and the BASMAA RMC Standard Operating Procedures (SOPs; BASMAA 2016b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP)[2]. Data presented in this report were also submitted in electronic SWAMP-comparable formats by SMCWPPP to the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) on behalf of SMCWPPP Permittees and pursuant to Provision C.8.h.ii of the MRP.

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[1] The San Francisco Bay Regional Water Quality Control Board (Regional Water Board) issued the MRP to 76 cities, counties, and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). On November 19, 2015, the Regional Water Board updated and reissued the MRP (SFRWQCB 2015). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley, which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

[2] The current SWAMP QAPrP, dated May 2017, is available at: https://www.waterboards.ca.gov/water_issues/programs/swamp/qapp/swamp_QAPrP_2017_Final.pdf

List of Acronyms

ACCWP	Alameda County Clean Water Program
AFDM	Ash Free Dry Mass
AFR	Alternative Flame Retardant
ASCI	Algae Stream Condition Index
BASMAA	Bay Area Stormwater Management Agency Association
BAHM	Bay Area Hydrological Model
BMI	Benthic Macroinvertebrate
BMP	Best Management Practice
BSM	Bioretention Soil Media
CADDIS	Causal Analysis/Diagnosis Decision Information System
C/CAG	San Mateo City/County Association of Governments
CCCWP	Contra Costa Clean Water Program
CEC	Chemicals of Emerging Concern
CEDEN	California Environmental Data Exchange Network
CSCI	California Stream Condition Index
CW4CB	Clean Watersheds for a Clean Bay
DO	Dissolved Oxygen
DPR	California Department of Pesticide Regulation
ECWG	Emerging Contaminant Workgroup
FIB	Fecal Indicator Bacteria
FSURMP	Fairfield Suisun Urban Runoff Management Program
GIS	Geographic Information system
HDS	Hydrodynamic Separator
IBI	Index of Biological Integrity
IMR	Integrated Monitoring Report
IPI	Index of Physical Habitat Integrity
IPM	Integrated Pest Management
LID	Low Impact Development
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Water Sewer System
MST	Microbial Source Tracking
MWAT	Maximum Weekly Average Temperature
NPDES	National Pollution Discharge Elimination System
PAHs	Polycyclic Aromatic Hydrocarbons
PBDEs	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
PEC	Probable Effect Concentration
PFAS	Perfluoroalkyl Sulfonates
PFOS	Perfluorooctane Sulfonates
PHAB	Physical Habitat
POC	Pollutant of Concern
QAPP	Quality Assurance Project Plan
QAPrP	Quality Assurance Program Plan
RAA	Reasonable Assurance Analysis
RCD	San Mateo Resource Conservation District
RMC	Regional Monitoring Coalition

RMP	Regional Monitoring Program for Water Quality in San Francisco Bay
RWSM	Regional Watershed Spreadsheet Model
S&T	Status and Trends
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFEI	San Francisco Estuary Institute
SFRWQCB	San Francisco Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	Standard Operating Procedures
SPLWG	Sources, Pathways, and Loadings Work Group
SPoT	Statewide Stream Pollutant Trend Monitoring
SRP	San Mateo Countywide Stormwater Resource Plan
SSC	Suspended sediment concentration
SSID	Stressor/Source Identification
STLS	Small Tributaries Loading Strategy
SWAMP	Surface Water Ambient Monitoring Program
SWPP	DPR Surface Water Protection Program
TEC	Threshold Effect Concentration
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TRC	Technical Review Committee
TRE	Toxicity Reduction Evaluation
TU	Toxic Unit (equivalent)
UCD	University of California, Davis
UCMR	Urban Creeks Monitoring Report
USEPA	Environmental Protection Agency
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
WLA	Waste Load Allocation
WMA	Watershed Management Areas
WQO	Water Quality Objective
WY	Water Year

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Table E.1. Water Year 2018 Creek Status Monitoring Stations

In compliance with Provision C.8.h.iii.(1), this table of all creek status monitoring stations sampled in Water Year 2018 is provided immediately following the Table of Contents. See Section 3.0 for additional information on creek status monitoring.

Map ID [1]	Station ID	Bayside or Coastside	Watershed	Creek Name	Land Use [2]	Latitude	Longitude	Probabilistic	Targeted				
								Bioassessment, Nutrients, General WQ	Chlorine	Pesticides & Toxicity	Temp [3]	Cont WQ [4]	Pathogen Indicators
584	202R00584	Coastal	Pilarcitos Creek	Pilarcitos Creek	NU	37.49547	-122.38512	X	X				
614	202R00614	Coastal	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860	X	X				
3404	202R03404	Coastal	San Pedro Creek	San Pedro Creek	U	37.58203	-122.48719	X	X				
3656	202R03656	Coastal	Pilarcitos Creek	Pilarcitos Creek	U	37.46781	-122.42269	X	X				
3880	202R03880	Coastal	San Gregorio Cr	La Honda Creek	U	37.38759	-122.27219	X	X				
3916	202R03916	Coastal	San Pedro Creek	San Pedro Creek	U	37.59144	-122.50333	X	X				
3508	204R03508	Bayside	Mills Creek	Mills Creek	U	37.59105	-122.37406	X	X				
3528	204R03528	Bayside	San Mateo Creek	San Mateo Creek	U	37.54808	-122.34661	X	X				
3624	205R03624	Bayside	San Francisquito Cr	Bear Creek	U	37.41883	-122.26498	X	X				
3864	205R03864	Bayside	San Francisquito Cr	Hamms Gulch	U	37.36498	-122.22906	X	X				
5	202SPE005	Coastside	San Pedro Creek	San Pedro Creek	U	37.59441	-122.50520			X			
10	204COR010	Bayside	Cordilleras Creek	Cordilleras Creek	U	37.47977	-122.25986			X			
138	202PES138	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860						X
142	202PES142	Coastside	Pescadero Creek	McCormick Creek	NU	37.27757	-122.28635						X
144	202PES144	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27592	-122.28550						X
150	202PES150	Coastside	Pescadero Creek	Jones Gulch	NU	37.27424	-122.26811						X
154	202PES154	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27446	-122.26798						X
19	202SPE019	Coastside	San Pedro Creek	San Pedro Creek	U	37.58853	-122.49943				X		
40	202SPE040	Coastside	San Pedro Creek	San Pedro Creek	U	37.58200	-122.48708				X	X	
50	202SPE050	Coastside	San Pedro Creek	San Pedro Creek	U	37.58198	-122.47819				X		
70	202SPE070	Coastside	San Pedro Creek	San Pedro Creek	NU	37.57974	-122.47371				X	X	
85	202SPE085	Coastside	San Pedro Creek	San Pedro Creek	NU	37.57826	-122.47156				X		

[1] Map ID applies to Figure 3.1.

[2] U = urban, NU = non-urban

[3] Temperature monitoring was conducted continuously (i.e., hourly) April through September.

[4] Continuous water quality monitoring (temperature, dissolved oxygen, pH, specific conductivity) was conducted during two 2-week periods (spring and late summer).

Executive Summary

This Urban Creeks Monitoring Report (UCMR) was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) in compliance the National Pollutant Discharge Elimination System stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP; Order No. R2-2015-0049). This report, including all appendices and attachments, fulfills the requirements of Provision C.8.h.iii of the MRP for reporting of all data collected in Water Year 2018 (WY 2018; October 1, 2017 through September 30, 2018) pursuant to Provision C.8 of the MRP. Data presented in this report were also submitted in electronic SWAMP-comparable formats by SMCWPPP to the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) on behalf of SMCWPPP Permittees and pursuant to Provision C.8.h.ii of the MRP.

Water quality monitoring required by Provision C.8 of the MRP is intended to

- assess the condition of water quality in Bay Area receiving waters (creeks and the Bay);
- identify and prioritize stormwater runoff associated impacts, stressors, sources, and loads;
- identify appropriate management actions; and
- detect trends in water quality over time and the effects of stormwater control measure implementation.

The organization of this Executive Summary follows the sub-provisions of Provision C.8 (Water Quality Monitoring) of the MRP. Each section very briefly describes what was done and summarizes key results. More details are provided in the body of the report and in its corresponding appendices.

Compliance Options (C.8.a)

Provision C.8.a (Compliance Options) of the MRP allows Permittees to address monitoring requirements through a “regional collaborative effort,” their countywide stormwater program, and/or individually. On behalf of San Mateo County Permittees, SMCWPPP conducts creek water quality monitoring and monitoring projects in San Mateo County in collaboration with the Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition (RMC), and actively participates in the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), which focuses on assessing Bay water quality and associated impacts.

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

Creek status and pesticides & toxicity monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Project Plan (QAPP) and the BASMAA RMC Standard Operating Procedures (SOP). Where applicable, and in compliance with Provision C.8.b, methods described in the QAPP and SOP are comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP).

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

In accordance with Provision C.8.c of the MRP, Permittees are required to provide financial contributions towards implementing an Estuary receiving water monitoring program on an annual basis that, at a minimum, is equivalent to the RMP. SMCWPPP complies with this provision by making financial contributions to the RMP. Additionally, SMCWPPP and other BASMAA RMC representatives actively participate in RMP committees, workgroups, and strategy teams, such as the Small Tributaries Loading Strategy (STLS), to help oversee RMP activities and look out for MRP Permittee interests.

Creek Status Monitoring (C.8.d)

The RMC's creek status monitoring strategy includes both a regional ambient/probabilistic monitoring design and a local "targeted" monitoring design. The probabilistic monitoring design was developed to remove bias from site selection such that ecosystem conditions can be objectively assessed on local (i.e., San Mateo County) and regional (i.e., RMC) scales. The targeted monitoring design focuses on sites selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns. Monitoring results are compared to "triggers" listed in Provision C.8.d of the MRP. Some triggers are equivalent to regulatory Water Quality Objectives (WQOs); others are thresholds above (or below) which potential impacts to aquatic life or other beneficial uses may occur. Sites were triggers are exceeded (or not met) are considered for future stressor/source identification (SSID) projects.

During WY 2018, SMCWPPP conducted biological assessments at ten probabilistic sites. Bioassessments include the collection of benthic macroinvertebrate and algae samples, physical habitat measurements, collection of grab creek water samples for water chemistry (i.e., nutrient analyses), and measurement of general water quality parameters using a pre-calibrated multi-parameter field probe. The California Stream Condition Index (CSCI), a statewide tool that translates benthic macroinvertebrate data into an overall measure of stream health, was used to assess biological condition at all probabilistic sites. Of the ten sites monitored in WY 2018, five sites (50%) scored below the CSCI threshold score of 0.795 and were rated as altered or degraded. Low CSCI scores are related to impacts to physical habitat typical for urbanized areas, such as creek channel modifications (e.g., lining with concrete) and contributing watersheds with a high percentages of impervious surface.

Targeted monitoring parameters consist of water temperature, general water quality, and pathogen indicators. In WY 2018, continuous temperature data were collected at five targeted stations in San Pedro Creek and continuous general water quality data (pH, dissolved oxygen, specific conductance, and temperature) were collected at two targeted stations in this creek. San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County. There were no exceedances of the MRP trigger thresholds for temperature or any of the general water quality parameters, which is consistent with water quality conditions that support relevant aquatic habitat beneficial uses of the creek (e.g., juvenile steelhead rearing and spawning life stages).

In WY 2018, pathogen indicator (i.e., enterococci, *E. coli*) grab water samples were collected at five stations in the Pescadero Creek watershed. The MRP trigger threshold for *E. coli* was not exceeded at any site in WY 2018; however, the MRP trigger threshold for enterococci was exceeded at two sites.

Impacts to urban streams identified through creek status monitoring are likely the result of long-term changes in stream hydrology, channel geomorphology, in-stream habitat complexity, and other modifications associated with the urban development, and, to a lesser extent, pollutant discharges typically found in urban watersheds. SMCWPPP Permittees are actively implementing many stormwater management programs to address these and other stressors and associated sources of water quality conditions observed in local creeks, with the goal of protecting these natural resources. Through the continued implementation of MRP-associated and other watershed stewardship programs, SMCWPPP anticipates that stream conditions and water quality in local creeks will continue to improve over time.

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

Provision C.8.e of the MRP requires that Permittees evaluate creek status (Provision C.8.d) and pesticides and toxicity (Provision C.8.g) monitoring data with respect to triggers defined in the MRP and maintain a list of all results exceeding trigger thresholds. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are therefore considered as candidates for future SSID projects. The MRP requires SMCWPPP and its RMC partners to collectively initiate a region-wide minimum of eight SSID projects. In WY 2018, SMCWPPP worked with the San Mateo Resource Conservation District (RCD) to implement the Pillar Point Watershed Pathogen Indicator SSID Project Work Plan. The field investigation included sample collection from up to 14 stations during four monitoring events to identify spatial and biotic sources of fecal indicator bacteria. Based on the WY 2018 field results, several additional field investigations were recommended and are being implemented in WY 2019. These include targeted dye studies of sanitary sewer lines, pet waste reconnaissance visits, and additional microbial source tracking (MST) sampling.

Pollutants of Concern Monitoring (C.8.f)

Pollutants of Concern (POC) monitoring is required by Provision C.8.f of the MRP. POC monitoring is intended to assess inputs of POCs to the Bay from local tributaries and urban runoff, provide information to support implementation of Total Maximum Daily Load (TMDL) water quality restoration plans and other pollutant control strategies, assess progress toward achieving wasteload allocations (WLAs) for TMDLs, and help resolve uncertainties associated with loading estimates for POCs. In WY 2018, SMCWPPP met or exceeded the MRP's minimum yearly requirements for all POC monitoring parameters.

The MRP requires that Permittees provide a list of management areas in which new PCBs and mercury control measures will be implemented during the permit term. These management areas are designated “Watershed Management Areas” (WMAs), and are defined as all San Mateo County catchments containing high interest parcels (i.e., properties with land uses associated with PCBs such as old industrial, electrical and recycling) and/or existing or planned PCBs and mercury controls. During WY 2018, SMCWPPP collected 13 composite samples of stormwater runoff from outfalls at the bottom of WMAs and 50 samples of urban sediments (from manholes, storm drain inlets, driveways, streets, and sidewalks) within WMAs. As part of continuing to develop strategies for reducing PCBs and mercury loads in stormwater runoff, SMCWPPP evaluated these data, along with additional WY 2018 stormwater runoff sample data collected through the STLS, and data from previous water years collected by SMCWPPP and through the STLS. Objectives included attempting to identify source properties within WMAs, identifying which WMAs provide the greatest opportunities for implementing cost-effective PCBs controls, and prioritizing WMAs for future investigations. Each WMA was provisionally designated as high, medium, or low priority. It is important to emphasize the provisional nature of these prioritizations, and especially the uncertainty surrounding designating a WMA as low priority due to a single bottom-of-catchment composite stormwater runoff sample having a low PCBs particle ratio. Low PCBs concentrations in any single stormwater runoff sample could be a false negative, especially if the storm was too small to mobilize sediments with associated PCBs. For example, based upon WY 2018 resampling results, two WY 2016 RMP STLS stormwater runoff samples located in South San Francisco may have been false negatives.

The PCBs monitoring data collected to-date has informed identification of several potential source properties located in the City of San Carlos. The Countywide Program is working with the City regarding next steps at these sites. This included recently developing and submitting to the Regional Water Board referrals of two areas for potential further PCBs investigation and abatement:

- 270 Industrial Road (Delta Star) / 495 Bragato Road (Tiegel), which are adjacent properties in San Carlos.
- 977 and 1007/1011 Bransten Road, another set of adjacent properties in San Carlos.

The mean and median PCBs concentrations in WY 2018 sediment samples (n = 50) were somewhat lower than in previous years. In addition, in WY 2018 only 1 of the 50 sediment samples collected had a PCBs concentration that exceeded 1.0 mg/kg. One other sample had a PCBs concentration between 0.5 and 1.0 mg/kg. All of the remaining samples had a PCBs concentration below 0.5 mg/kg. In general, the WY 2018 POC monitoring data suggest that the PCBs monitoring program in the public ROW in San Mateo County may be approaching diminishing returns in terms of identifying new source properties.

However, the stormwater runoff resamples in South San Francisco suggest the possibility of false negatives for PCBs in some WMAs provisionally designated low priority based on stormwater runoff data from previous years. The RMP's ongoing “Advanced Data Analysis” is evaluating normalizing results based upon storm intensity and the results may help inform planning any future stormwater runoff monitoring of this type.

In WY 2018, two creeks were sampled for copper and nutrient analyses during two types of flow events (storm event and baseflow) for a total of four grab water samples. Copper and nutrients were higher in the storm event samples compared to the baseflow samples, suggesting an influence of stormwater runoff. The similarity in the magnitude of concentrations between the sites was consistent with a lack of localized sources of copper or nutrients.

None of the WY 2018 POC monitoring water samples exceeded applicable WQOs.

Pesticides and Toxicity Monitoring (C.8.g)

In WY 2018, SMCWPPP conducted pesticides and toxicity monitoring in compliance with Provision C.8.g of the MRP and in coordination with the RMC. The monitoring was conducted at two stations, one near the mouth of Cordilleras Creek and the other near the mouth of San Pedro Creek. Dry weather pesticides and toxicity monitoring was conducted at the Cordilleras Creek station (one water sample for toxicity and one sediment sample for toxicity, pesticides and other pollutants including metals). Wet weather pesticides and toxicity monitoring was conducted during a January 2018 storm event at both stations (one water sample from each station for toxicity and pesticides).

Statistically significant toxicity to *C. dubia* was observed in the water sample collected from Cordilleras Creek during the dry season. During wet weather monitoring, statistically significant toxicity to *H. azteca* was observed in the water samples collected from both creeks and toxicity to *P. promelas* was observed in the water sample collected from San Pedro Creek. However, the magnitude of the toxic effects in the samples compared to laboratory controls did not exceed MRP trigger criteria of 50 Percent Effect. The cause of the observed toxicity is unknown. Pesticide concentrations in the sediment and water samples were all relatively low, with most below the method detection limits (MDLs). Toxic Unit (TU) equivalents were also relatively low. Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) quotients were calculated for all metals and total poly aromatic hydrocarbons (PAHs) measured in the sediment sample. TEC and PEC trigger exceedances were observed for chromium and nickel but are likely related to natural occurrences of these metals associated with the area’s serpentine geology.

1.0 Introduction

This Urban Creeks Monitoring Report (UCMR), was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), on behalf of the 22 San Mateo County MRP Permittees (20 cities/towns, the County of San Mateo, and the San Mateo County Flood Control District) subject to the National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP).

The MRP was first adopted by the San Francisco Regional Water Quality Control Board (SFRWQCB or Regional Water Board) on October 14, 2009 as Order R2-2009-0074 (SFRWQCB 2009). On November 19, 2015, the SFRWQCB updated and reissued the MRP as Order R2-2015-0049 (SFRWQCB 2015). This report fulfills the requirements of Provision C.8.h.iii of the MRP for comprehensively interpreting and reporting all monitoring data collected during the foregoing October 1 – September 30 period (i.e., Water Year 2018). Data were collected pursuant to water quality monitoring requirements in Provision C.8 of the MRP. Monitoring data presented in this report were submitted electronically to the Regional Water Board by SMCWPPP and, if collected from a receiving water, may be obtained via the San Francisco Bay Area Regional Data Center of the California Environmental Data Exchange Network (CEDEN).[3]

Major sections in this report are organized according to the following topics and MRP sub-provisions. Some topics are summarized briefly in this report but described more fully in the appendices.

1.0 Introduction
2.0 San Francisco Estuary Receiving Water Monitoring (MRP Provision C.8.c)
3.0 Creek Status Monitoring (MRP Provision C.8.d) and Pesticides and Toxicity Monitoring (MRP Provision C.8.g) (**Appendix A**)
4.0 Stressor/Source Identification (SSID) Projects (MRP Provision C.8.e) (**Appendix B**)
5.0 Pollutants of Concern (POC) Monitoring (MRP Provision C.8.f) (**Appendices C, D, E and F**)
6.0 Recommendations and Next Steps

Figure 1.1 maps locations of monitoring stations associated with Provision C.8 compliance in Water Year (WY) 2018, including creek status monitoring, pesticides and toxicity monitoring, the SSID Project, and POC monitoring conducted by SMCWPPP and the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). This figure shows the geographic extent of monitoring conducted in San Mateo County in WY 2018.

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[3] http://www.ceden.org/

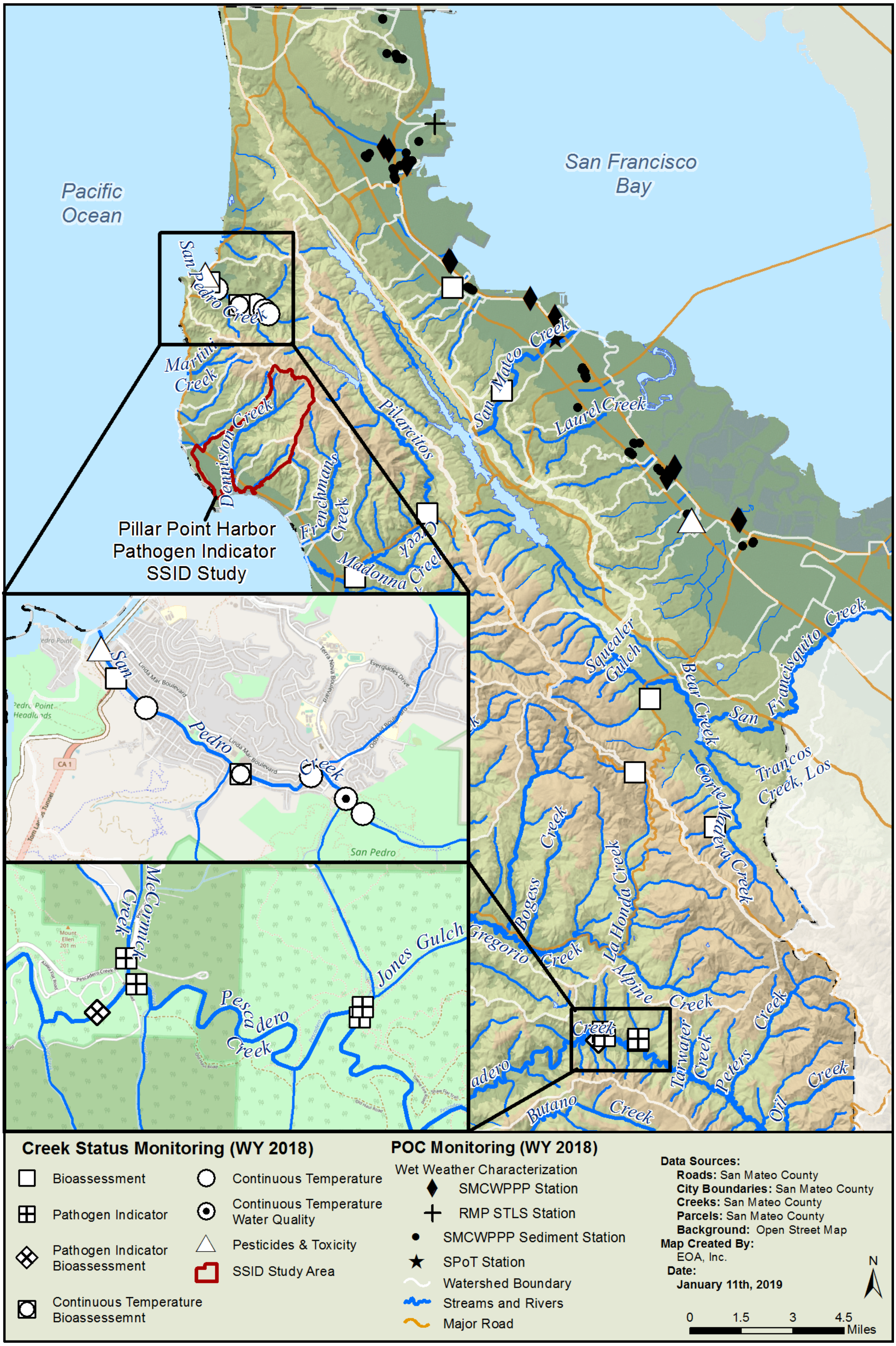

Figure. 1.1. San Mateo County MRP Provision C.8 monitoring locations: Creek Status Monitoring, Pesticides and Toxicity Monitoring, Stressor/Source Identification (SSID), and POC Monitoring, WY 2018.

1.1 RMC Overview (C.8.a)

Provision C.8.a (Compliance Options) of the MRP allows Permittees to address monitoring requirements through a “regional collaborative effort,” their countywide stormwater program, and/or individually. In June 2010, Permittees notified the Regional Water Board in writing of their agreement to participate in a regional monitoring collaborative to address requirements in Provision C.8. The regional monitoring collaborative is referred to as the Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition (RMC). In a November 2, 2010 letter to the Permittees, the Regional Water Board’s Assistant Executive Officer (Dr. Thomas Mumley) acknowledged that all Permittees have opted to conduct monitoring required by the MRP through a regional monitoring collaborative, the BASMAA RMC. Participants in the RMC are listed in Table 1.1.

In February 2011, the RMC developed a Multi-Year Work Plan (RMC Work Plan; BASMAA 2011) to provide a framework for implementing regional monitoring and assessment activities required under Provision C.8 of the 2009 MRP. The RMC Work Plan summarizes RMC projects planned for implementation between Fiscal Years 2009-10 and 2014-15 (BASMAA 2011). Projects were collectively developed by RMC representatives to the BASMAA Monitoring and Pollutants of Concern Committee (MPC), and were conceptually agreed to by the BASMAA Board of Directors (BASMAA BOD). Although there are no plans to update the Multi-Year Work Plan, several additional regional projects were identified to be conducted in compliance with the 2015 MRP. Current regional projects relevant to Provision C.8 compliance include projects to maintain and update the regional database, coordinate the RMC Workgroup meetings, conduct POC monitoring, and develop/implement a regional SSID study.

Regionally implemented activities in the RMC Work Plan are conducted under the auspices of BASMAA, a 501(c)(3) non-profit organization that represents the municipal stormwater programs in the San Francisco Bay Area. Scopes, budgets, and contracting or in-kind project implementation mechanisms for BASMAA regional projects follow BASMAA’s Operational Policies and Procedures and are approved by the BASMAA BOD. MRP Permittees, often through their stormwater program representatives on the BOD and its subcommittees, collaboratively authorize and participate in BASMAA regional projects or tasks. Regional project costs are usually shared by either all BASMAA members or among those Phase I municipal stormwater programs that are subject to the MRP.

Table 1.1 Regional Monitoring Coalition (RMC) 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
Contra Costa Clean Water Program (CCCWP)	Cities 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 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

1.2 Coordination with Third-party Monitoring Programs

SMCWPPP strives to work collaboratively with its water quality monitoring partners to find mutually beneficial monitoring approaches. Provision C.8.a.iii of the MRP allows Permittees to use data collected by third-party organizations to fulfill monitoring requirements, provided the data are demonstrated to meet the required data quality objectives.

In WY 2018, SMCWPPP continued to coordinate with water quality monitoring programs conducted by third parties that supplement Bay Area stormwater monitoring conducted via the MRP. These programs include the RMP's Small Tributaries Loading Strategy (STLS), and the Stream Pollutant Trends (SPoT) monitoring conducted by the State of California's Surface Water Ambient Monitoring Program (SWAMP). Water quality data from these programs are reported in this document and were utilized to comply with or supplement MRP Provision C.8 monitoring, consistent with Provision C.8.a.iii.[4, 5] These data are described in Section 5.0 (POC Monitoring) of this report.

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[4] Data reported by these programs are summarized in this report but are not included in the SMCWPPP electronic data submittal.

[5] In most years, the SPoT Program collects sediment samples from one station in San Mateo Creek and analyzes for one or more of the constituents required by Provision C.8.f of the MRP. In WY 2018, the SPoT station sample was analyzed for two of those constituents (mercury and copper).

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

In accordance with Provision C.8.c of the MRP, Permittees are required to provide financial contributions towards implementing an Estuary receiving water monitoring program on an annual basis that at a minimum is equivalent to the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Since the adoption of the 2009 MRP, SMCWPPP has complied with this provision by making financial contributions to the RMP. Additionally, SMCWPPP representatives actively participate in RMP committees, workgroups, and strategy teams as described in the following sections, which also provide a brief description of the RMP and associated monitoring activities conducted during WY 2018.

The RMP is a long-term (1993 – present) discharger-funded monitoring program that 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 municipal separate stormwater sewer systems (MS4s), publicly owned treatment works (POTWs), dredger, and industrial dischargers. The San Francisco Estuary Institute (SFEI) is the implementing entity for the RMP and the fiduciary agent for RMP stakeholder funds. SFEI helps identify stakeholder information needs, develops workplans that address these needs, and implements the workplans. SFEI's work is overseen by a Board and various committees that include representatives from the dischargers and regulators.

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: (1) Status and Trends and (2) Pilot/Special Studies. The following sections provide a brief overview of these programs. The *RMP 2018 Detailed Workplan and Budget*[6] provides more details and establishes deliverables for each component of the current RMP budget. The RMP publishes annual summary reports. In odd years, the *Pulse of the Estuary/Bay Report* focuses on Bay water quality and summarizes information from all sources. In even years, the *RMP Update Report* has a narrower and specific focus on a selected topic. The *2018 RMP Update*[7] includes: a brief summary of noteworthy findings of the multifaceted RMP; a description of the management context that guides the RMP; and a summary of progress to date and future plans for

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[6] https://www.sfei.org/documents/2018-rmp-detailed-workplan-and-budget

[7] https://www.sfei.org/documents/rmp-update-2018

addressing priority water quality topics. It also includes an article on per- and polyfluoroalkyl substances (PFAS) in San Francisco Bay wildlife, one of the pollutants of concern identified in MRP Provision C.8.f.

2.1 RMP Status and Trends Monitoring Program

The Status and Trends Monitoring Program (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, implemented thereafter, and was redesigned in 2007 based on a more rigorous statistical design that enables the detection of trends. The RMP Technical Review Committee (TRC), in which the BASMAA RMC participates, continues to assess the efficacy and value of the various elements of the S&T Program and to recommend modifications to S&T Program activities based on ongoing findings. The current S&T sampling schedule, established in 2014, is summarized in Table 2.1 with 2018 accomplishments and 2019 goals.

Table 2.1. RMP Status and Trends Monitoring Schedule.

Program Element	Schedule	2018 Sampling	2019 Sampling
Water	Every two years	No	Yes
Bird Eggs	Every three years	Yes	No
Sediment	Every four years	Yes	No
Sport Fish	Every five years	No	Yes
Bivalves	Every two years	Yes	No
Support to the USGS for suspended sediment, nutrient, and phytoplankton monitoring	Every year	Yes	Yes

Additional information on the S&T Program and associated monitoring data are available for download via the RMP website at http://www.sfei.org/content/status-trends-monitoring.

2.2 RMP Pilot and Special Studies

The RMP also conducts Pilot and Special Studies[8] on an annual basis. Studies are typically 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, workgroups, and strategy teams identify as priority for further study. These studies are developed through an open selection process at the workgroup level and selected for funding through the TRC and the RMP Steering Committee.

In 2018, Pilot and Special Studies focused on the following topics:

- Nutrients Management Strategy
    - Continuous monitoring of nutrients, phytoplankton biomass, and dissolved oxygen at moored sensors

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[8] Results and summaries of the most pertinent Pilot and Special Studies can be found on the RMP website (http://www.sfei.org/rmp/rmp_pilot_specstudies).

  - Continuous monitoring of dissolved oxygen in shallow margin habitats
  - Ship-based nutrient sampling
  - Data analysis and quantitative mechanistic interpretations to identify factors contributing to observed conditions
- Small Tributary Loadings Strategy (see Section 5.0 for more details)
  - Watershed characterization reconnaissance monitoring for Pollutants of Concern (POC)
  - Advanced analysis of PCBs data
  - Planning support for alternative flame retardants conceptual model
  - Development of a trends strategy
  - Regional Watershed Spreadsheet Model (RWSM) support
- Emerging Contaminant Strategy
  - Review and update of the RMP's Tiered Risk and Management Action Framework
  - Chemicals of emerging concern (CEC) monitoring (imidacloprid, fragrance ingredients, PFAS, nonionic surfactants, pharmaceuticals) in water, sediment, and/or wastewater
  - Non-targeted analysis of Bay sediment to help identify new CECs
- Monitoring of microplastics in bivalves
- Development of toxicity reference values for screening dredged material bioassay results
- Development of conceptual PCBs models for prioritized Bay margin units
- Hosting and support for Dredged Material Management Office (DMMO) database
- Improved Lower South Bay suspended sediment flux measurements
- San Leandro Bay fish diet analysis to help understand PCBs accumulation
- Development of the Selenium Strategy

Results and summaries of the most pertinent Pilot and Special Studies can be found on the RMP website (http://www.sfei.org/rmp/rmp_pilot_specstudies).

In WY 2018, the RMP continued to devote a considerable amount of resources towards overseeing and implementing Special Studies associated with the RMP's Small Tributary Loading Strategy (STLS). Pilot and Special Studies associated with the STLS are intended to fill data gaps associated with loadings of Pollutants of Concern (POC) from relatively small local tributaries to San Francisco Bay. Additional information on STLS-related studies is included in Section 5.0 (POC Monitoring) of this report.

2.3 Participation in Committees, Workgroups and Strategy Teams

In WY 2018, BASMAA and/or SMCWPPP representatives actively participated in the following RMP Committees and workgroups:

- Steering Committee (SC)
- Technical Review Committee (TRC)
- Sources, Pathways and Loadings Workgroup (SPLWG)
- Emerging Contaminant Workgroup (ECWG)
- Nutrient Technical Workgroup
- Strategy Teams (e.g., PCBs/Dioxins, Selenium, Microplastics, Small Tributaries)

Committee, workgroup, and strategy team representation was provided by Permittee, countywide stormwater program (including SMCWPPP) staff, and/or individuals designated by RMC participants and the BASMAA BOD. Representation typically includes participating in meetings, reviewing technical reports and work products, co-authoring or reviewing RMP articles and publications, and providing general program direction to RMP staff. Representatives of the RMC also provided timely summaries and updates to, and received input from, stormwater program and Permittee representatives during BASMAA Monitoring and Pollutants of Concern Committee (MPC) and/or BASMAA BOD meetings to ensure Permittees' interests were represented.

3.0 Creek Status Monitoring (C.8.d) and Pesticides and Toxicity Monitoring (C.8.g)

This section summarizes the results of creek status monitoring and pesticides and toxicity monitoring required by Provisions C.8.d and C.8.g of the MRP, respectively. Creek status and pesticides and toxicity monitoring stations are listed in Table E.1 and mapped in Figure 3.1. Detailed methods and results are provided in **Appendix A**. Consistent with Provision C.8.h.ii of the MRP, creek status and pesticides and toxicity monitoring data were submitted to the Regional Water Board by SMCWPPP in electronic SWAMP-comparable formats. These data were also provided to the Regional Data Center (i.e., SFEI) for upload to CEDEN.

Creek Status Monitoring (C.8.d)

Provision C.8.d of the MRP requires Permittees to conduct creek status monitoring that is 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, durations and minimum number of sampling sites for each Bay Area countywide stormwater program are described in Provision C.8.d of the MRP. The RMC's regional monitoring strategy for complying with creek status monitoring requirements is described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). The strategy includes a regional ambient/probabilistic monitoring component and a component based on local "targeted" monitoring. The combination of these monitoring designs allows each individual RMC participating countywide stormwater program to assess the status of beneficial uses in local creeks within its 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). Implementation began in WY 2012.

The probabilistic monitoring design was developed to remove bias from site selection such that ecosystem conditions can be objectively assessed on local (i.e., San Mateo County) and regional (i.e., RMC) scales. Probabilistic parameters consist of bioassessments, nutrients, and conventional analytes conducted according to methods described in the SWAMP SOP (Ode et al. 2016). Free chlorine and total chlorine residual were also measured at probabilistic sites. Ten probabilistic sites were sampled by SMCWPPP in WY 2018 (Table E.1).

The targeted monitoring design focuses on sites selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns. Targeted monitoring parameters consist of water temperature, general water quality, and pathogen indicators using methods, sampling frequencies, and numbers of stations required in Provision C.8.d of the MRP. Hourly water temperature measurements were recorded during the dry season at five sites using HOBO® temperature data loggers in the San Pedro Creek watershed. General water quality monitoring (temperature, dissolved oxygen, pH and specific conductivity) was conducted using YSI® continuous water quality equipment (sondes) for two 2-week periods (spring and late summer) at two sites in the same watershed. Water samples for analysis of pathogen indicators (*E. coli* and enterococcus) were collected at five sites located in the Pescadero Creek watershed.

Pesticides and Toxicity Monitoring (C.8.g)

Provision C.8.g of the MRP requires Permittees to conduct wet weather and dry weather pesticides and toxicity monitoring. Test methods, sampling frequencies, and number of stations required are described in the MRP. In WY 2018, SMCWPPP conducted dry weather pesticides and toxicity monitoring at one bottom-of-the-watershed station. SMCWPPP also coordinated with its RMC partners to complete the wet weather monitoring requirements. SMCWPPP conducted wet weather pesticides and toxicity monitoring at two of the eight regional stations.

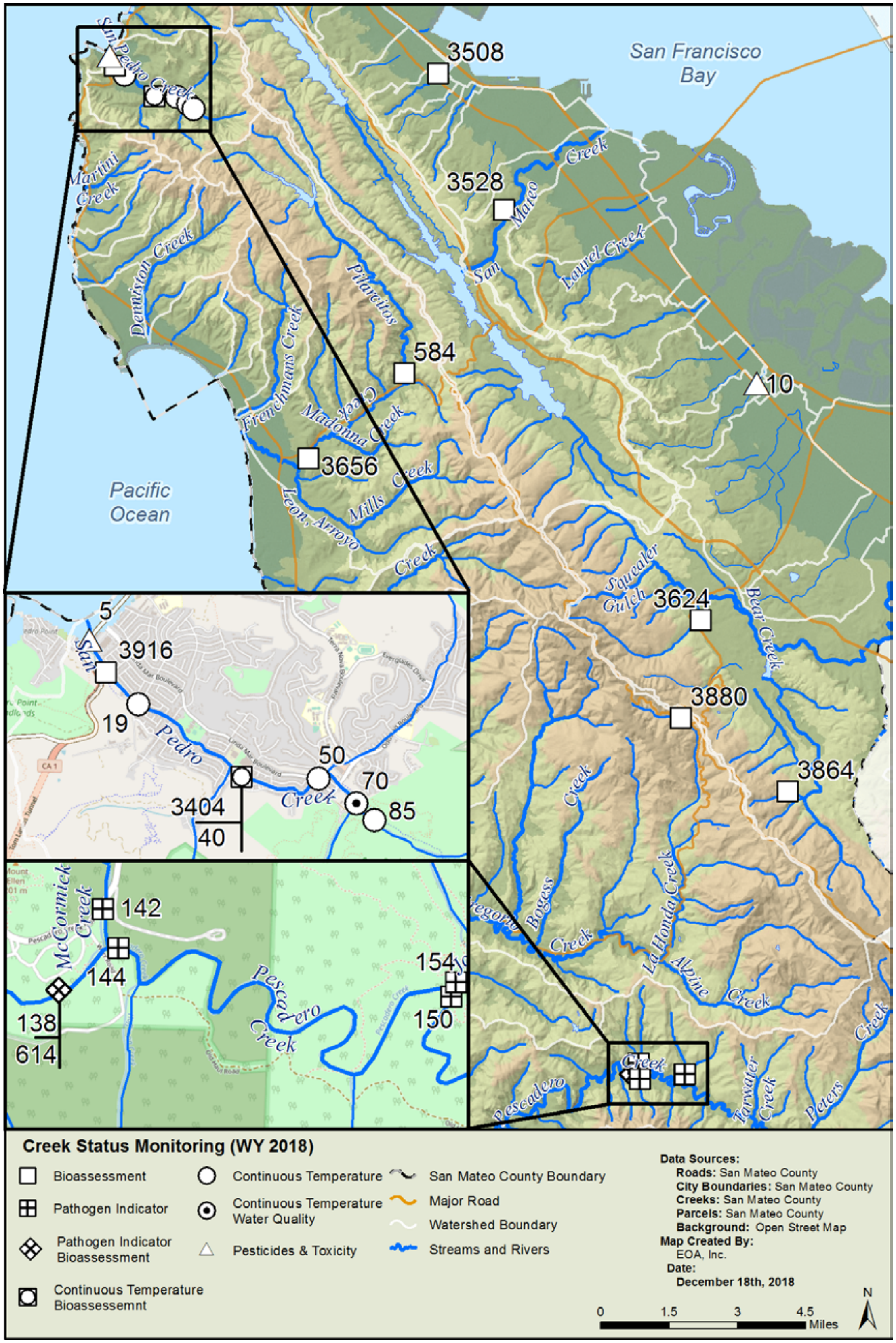

Figure 3.1. SMCWPPP Creek Status and Pesticides and Toxicity monitoring stations, WY 2018.

3.1 Approach to Management Questions

The first MRP creek status management question (*Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?*) is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in the MRP. The MRP also defines triggers for pesticides and toxicity monitoring data. A summary of trigger exceedances observed for each site is presented below in Table 3.1. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future stressor/source identification (SSID) projects (see Section 4.0 for a discussion of SSID projects).

The second MRP creek status management question (*Are conditions in local receiving waters supportive of or likely supportive of beneficial uses?*) is addressed primarily by assessing indicators of aquatic biological health using benthic macroinvertebrate (BMI) and algae bioassessment data collected at probabilistic sites. The indices of biological integrity based on BMI and algae data (i.e., CSCI and ASCI, see Section 3.2.1) are direct measures of aquatic life beneficial uses. Biological condition scores were compared to physical habitat and water quality data collected synoptically with bioassessments to evaluate whether any correlations exist that may explain the variation in biological condition scores. Continuous monitoring data (temperature, dissolved oxygen, pH, and specific conductance) are evaluated with respect to COLD and WARM Beneficial Uses. And pathogen indicator data are used to assess REC-1 (water contact recreation) Beneficial Uses. Although a total of 70 probabilistic sites in San Mateo County have been sampled since WY 2012, the analysis presented in **Appendix A** is limited to the ten sites monitored in WY 2018.

The BASMAA RMC recently completed a *regional* analysis of biological condition using a five-year dataset (WY 2012 – WY 2016). The BASMAA regional study included the following analyses:

- Assessed the biological condition of streams in the region and each county using indices of biological integrity (IBIs) based on benthic macroinvertebrate and algae data collected by each countywide program and SWAMP.
- Evaluated IBIs in distinct groupings such as type of stream (urban/non-urban).
- Assessed stressors associated with poor stream condition using multivariate modeling analyses (i.e., random forest).
- Evaluated the five-year dataset for trends.
- Introduced the analyses that will be needed to evaluate and potentially recommend changes to the probabilistic monitoring design.

The BASMAA RMC Five-Year Bioassessment Report (5-Year Report) is summarized in and attached to the WY 2018 Creek Status Monitoring Report **(Appendix A)**.

3.2 Monitoring Results and Conclusions

3.2.1 Bioassessment Monitoring Results/Conclusions

Bioassessment monitoring in WY 2018 was conducted in compliance with Provision C.8.d.i of the MRP. Ten sites were sampled for benthic macroinvertebrates, benthic algae, and nutrients. Physical habitat was also assessed at each of the 10 stations, and general water quality parameters were measured using a pre-calibrated multi-parameter field probe. All of this work was conducted using methods consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b). Stations were randomly selected using a probabilistic monitoring design. Eight of the sites (80%) were classified as urban and two (20%) were classified as non-urban.

The following conclusions are based on the WY 2018 data. An assessment of biological condition is provided and potential stressors are compared to applicable water quality objectives (WQOs) and triggers identified in the MRP. Sites with monitoring results that exceed WQOs and triggers are considered as candidates for further investigation as SSID projects, consistent with Provision C.8.e of the MRP. See **Appendix A** for detailed explanations of the findings.

Biological Condition Assessment

Stream condition was assessed using three different types of indices/tools: the BMI-based California Stream Condition Index (CSCI), the draft benthic algae-based Algae Stream Condition Index (ASCI), and the Index of Physical Habitat Integrity (IPI). Of these three, the CSCI is the only tool with a MRP trigger threshold for follow-up SSID consideration.

- **CSCI** – The benthic (i.e., bottom-dwelling) macroinvertebrates collected through bioassessment monitoring are organisms that live on, under, and around the rocks and sediment in the stream bed. Examples include dragonfly and stonefly larvae, snails, worms, and beetles. Each BMI species has a unique response to water chemistry and physical habitat condition. Some are relatively sensitive to poor habitat and pollution; others are more tolerant. Therefore, the abundance and variety of BMIs in a stream are used as an indicator of the biological condition of the stream. The CSCI is a statewide tool that translates the BMI taxa data into an overall measure of stream health. The CSCI is currently the most robust method available for assessing aquatic biological health in California.
    - Five of the ten (50%) sites monitored in WY 2018 had CSCI scores in the two higher condition categories: “possibly intact” and “likely intact”. These higher scoring sites were relatively undeveloped, with imperviousness in their drainage areas ranging between 1% and 5%.
- **ASCI** – Similar to BMI’s, the abundance and type of benthic algae species living on a streambed can indicate stream health. When evaluated with the CSCI, biological indices based on benthic algae can provide a more complete picture of the streams biological condition because algae respond more directly to nutrients and water chemistry. In contrast, BMIs are more responsive to physical habitat. The State Water Board and the Southern California Coastal Water Research Project (SCCWRP) recently developed the draft ASCI which uses benthic algae data as a measure of biological condition for streams in California (Theroux et al. in prep.). The ASCI is a non-predictive scoring tool that consists of three multimetric indices: diatoms, soft algae, and the combined “hybrid.” The ASCI is currently under review by the Biostimulatory-Biointegrity Policy Science Advisory Panel and the State Water Board. Therefore, scores presented in this report are considered provisional.
    - Seven of the ten (70%) bioassessment sites had hybrid ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred primarily in drainages with low levels of urbanization, ranging from 1% to 7% impervious area.

- **IPI** - The State Water Board recently developed the IPI as an overall measure of physical habitat condition. Similar to the CSCI, the IPI is calculated using a combination of physical habitat data collected in the field and environmental data generated in GIS following the methods described in Rehn et al. (2018).
    - Seven of the ten sites (70%) had IPI scores in the two upper condition categories. IPI scores were positively correlated with CSCI scores, and slightly less so with hybrid ASCI scores.
- **Overall Condition** - The number of sites in the top two condition categories varied substantially by index, with as many as 9 of 10 sites for the diatom ASCI to as few as 5 of 10 sites for the CSCI and 4 of 8 sites for the soft algae ASCI. Excluding the soft algae ASCI, for sites with lower urbanization (< 5% impervious area) there was relatively good consistency among the indices in terms of which sites were placed in the top two condition categories. However, all three ASCI indices and the IPI were relatively variable (i.e., both high and low scoring) at the more developed sites. Further evaluation of the newer indices and their association with stressor data is needed to better understand how these indicators can be used to effectively assess site conditions.

Stressor Assessment

Relationships between potential stressors (water chemistry, physical habitat, landscape variables such as imperviousness) and biological condition were explored using the WY 2018 dataset. Potential correlations were evaluated using simple regression models. Sites with stressor levels exceeding applicable WQOs and triggers identified in the MRP will be considered as candidates for SSID projects. The correlations between biological condition and stressor indicators are not expected to be very strong due to small sample size.

- **General water quality** - pH, temperature, dissolved oxygen, specific conductance. None of the water quality measurements exceeded WQOs or MRP trigger thresholds. None of the water quality measurements were correlated with CSCI or hybrid ASCI scores.

- **Nutrients and conventional analytes** - ammonia, unionized ammonia, chloride, Ash-Free Dry Mass (AFDM), chlorophyll a, nitrate, nitrite, TKN, ortho-phosphate, phosphorus, silica. There were no water quality objective exceedances for the water chemistry parameters (unionized ammonia as N, nitrate, chloride). Total nitrogen concentrations ranged from 0.22 to 1.1 mg/L. Total phosphorus concentrations ranged from <0.01 to 0.12 mg/L. None of the nutrient parameters were correlated with CSCI or hybrid ASCI scores.

- **Physical habitat metric scores** were generated from the physical habitat data. CSCI scores were positively correlated with flow type and negatively correlated with filamentous algae cover. Hybrid ASCI scores were poorly correlated with all 11 physical habitat metrics.

- **Landscape variables** were calculated for each of the watershed areas draining into the bioassessment sites. CSCI scores were moderately correlated (negatively) with impervious area and road density.

BASMAA RMC Five Year Bioassessment Study

A comprehensive analysis of bioassessment data collected by the RMC partners is included in the RMC 5-Year Report (BASMAA 2019) (Attachment 2 of Appendix A). The BASMAA-funded study evaluated bioassessment data collected throughout the Bay Area by the RMC over the first five years of monitoring (WY 2012 – WY 2016). Bioassessment data from 354 sites were compiled and evaluated to address the three study questions:

1) What is the biological condition of streams in the region?
2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of the BASMAA study are intended to help stormwater programs better understand the current condition of wadable streams, prioritize stream reaches in need of protection or restoration, and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area.

The BASMAA report also evaluated the existing RMC probabilistic monitoring design and identified a range of potential options for revising the design (if desired) to better address the questions posed. These redesign options are intended to inform discussions of water quality monitoring requirements during the reissuance of the Municipal Regional Permit, which expires at the end of 2020.

Biological Condition Assessment

Results of the survey indicate that much of the stream length in the RMC area is in poor biological condition. Aquatic life uses may not be fully supported at a majority of sites sampled by the RMC. Two biological indicators were used to assess conditions:

- The BMI-based CSCI shows that 58% of the stream length region-wide was ranked in the lowest CSCI condition category (“very likely altered”), and 74% of the sampled stream length exhibited CSCI scores below 0.795, the MRP trigger for potential follow-up activity.

- The Southern California algae indices for diatoms (D18) and soft algae (S2) were evaluated for biological conditions[9]. Based on D18 and S2 scores, stream conditions region-wide appear somewhat less degraded than the CSCI scores indicated, with approximately 40% ranked in the lowest algae condition category. The algal indices also had greater stream length in the “likely intact” condition class (19-21%) compared to CSCI score (15%).

These findings should be interpreted with the understanding that the survey focused on urban stream conditions. Approximately 80% of the samples (284 of 354) were collected at urban sites. Although the low non-urban sample size precludes making any definitive comparisons, bioassessment scores in the non-urban area were generally higher than scores in the urban area for each County.

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[9] The ASCI was not yet available during development of the RMC 5-Year Report.

Stressor Assessment

The association between biological indicators (CSCI and D18) and stressor data was evaluated in the RMC 5-Year study using random forest statistical analyses. The results indicate that each of the biological indicators respond to different types of stressors.

- Biological condition, based on CSCI scores, was correlated with physical habitat and land use variables. Overall, the largest influence on CSCI scores in the random forest model was percent impervious area in a 5 km radius of the bioassessment sampling site.
- Biological condition, based on D18 scores, was moderately correlated with water quality variables and poorly correlated with the physical or landscape variables.

In general, CSCI scores at urban sites were consistently low, indicating that degraded physical habitat conditions do not support healthy BMI assemblages. D18 scores at urban sites were more variable, indicating that healthy diatom assemblages potentially can occur at sites with poor habitat.

None of the nutrient variables (e.g., nitrate, total nitrogen, orthophosphate, phosphorus) correlated strongly with CSCI scores, or were highly ranked variables in the CSCI random forest analysis. Phosphorus and ash-free dry mass (which increases in response to biostimulation) were important in predicting D18 scores based on the random forest analysis; however, no statistically significant relationships were observed. This finding suggests that the nutrient targets being developed by the State Water Board as part of the Biostimulatory/Biointegrity Project may not be appropriate in urban streams in the Bay Area.

Trend Assessment

The short time frame of the survey (five years) limited the ability to detect trends. However, the five-year bioassessment dataset does provide a baseline to compare with future assessments.

A potential application of bioassessment monitoring may be to assess trends in stream conditions as additional stormwater treatment (e.g., green infrastructure) and creek restoration projects are implemented across the urban landscape over time. Peak flow volumes and intensities will be reduced following the implementation of stormwater treatment via green infrastructure and low impact development (LID), as required by the MRP. Future creek status monitoring may provide insight into the potential positive impacts of green infrastructure and creek restoration to support WQOs and beneficial uses in urban creeks.

Assessment of the RMC Monitoring Design

Over the first five years of monitoring, the RMC evaluated about 25% (1,455 out of 5,740) of the sites in the sample frame to obtain 354 samples. Approximately 46% (873 out of 1,896) of the total number of urban sites in the sample frame were evaluated during that time. Based on rejection rates from previous years, the sample frame is anticipated to be exhausted during WY 2019. Revision of the RMC monitoring design could seek to reduce the future rejection rate through development of a new sample frame that excludes areas of low management interest or regions that would not be candidates for sampling (such as due to lack of permissions or physical barriers to access). This would improve the spatial balance of samples that more closely represents the proportion of the sample frame that can be reliably assessed.

The RMC sample design was created to probabilistically sample all streams within the RMC area, which resulted in a master list with 33% urban sites and 67% non-urban sites. However, because participating municipalities are primarily concerned with runoff from urban areas, the RMC focused sampling efforts on urban sites (80%) over non-urban sites (20%). As a result, non-urban samples are under-represented in the dataset resulting in much lower overall biological condition scores than would be expected for a spatially balanced dataset.

Based on evaluation of data collected during the first five years of the survey, there are several options to revise the RMC Monitoring Design. The RMC will assess the options during discussions with Regional Water Board staff during the MRP reissuance process beginning in 2019.

3.2.2 Continuous Monitoring for Temperature and General Water Quality

Continuous monitoring of water temperature and general water quality in WY 2018 was conducted in compliance with Provisions C.8.d.iii – iv of the MRP. Hourly temperature measurements were recorded at five sites in the San Pedro Creek watershed from April through September. Continuous (15-minute) general water quality measurements (pH, DO, specific conductance, temperature) were recorded at two sites in the San Pedro Creek watershed during two 2-week periods in May (Event 1) and August (Event 2). Targeted monitoring stations were deliberately selected and were the same as those monitored in WY 2017.

Conclusions and recommendations from targeted monitoring in WY 2018 are listed below. The sections below are organized on the basis of two management questions. See **Appendix A** for detailed explanations of the findings.

1. *What is the spatial and temporal variability in water quality conditions during the spring and summer season?*
2. *Do general water quality measurements indicate potential impacts to aquatic life?*

Sites with targeted monitoring results exceeding the MRP trigger criteria and/or WQOs are identified as candidate SSID projects. San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County. Overall, water quality appears to be consistent with conditions that support relevant aquatic habitat beneficial uses of the creek (e.g., juvenile steelhead rearing and spawning life stages).

Spatial and Temporal Variability of Water Quality Conditions

- **Spatial**. There was minimal spatial variability in water temperature across the five stations in the San Pedro Creek watershed. Temperature increased slightly at each downstream site but remained 4 to 7 °C below the MRP instantaneous maximum trigger threshold. Likewise, pH and specific conductivity increased slightly in the downstream direction and dissolved oxygen decreased slightly in the downstream direction.
- **Temporal**. Water temperature increased gradually at all five stations between April and early-September, likely in response to periods of warmer air temperatures. Differences in general water quality measurements (pH, specific conductivity, dissolved oxygen) between the two two-week monitoring periods (May/June and August/September) were less pronounced. WY 2018 monitoring results were very similar to those recorded in WY 2017 at the same stations.

Potential Impacts to Aquatic Life

- Potential impacts to aquatic life were assessed through analysis of continuous temperature data collected at five targeted stations and continuous general water quality data (pH, dissolved oxygen, specific conductance, and temperature) collected at two targeted stations in San Pedro Creek. San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County.
- None of the temperature stations in San Pedro Creek exceeded the MRP trigger threshold for the Maximum Weekly Average Temperature of 17°C. None of the stations exceeded the MRP instantaneous maximum trigger threshold of 24°C.
- None of the general water quality parameters (temperature, pH, dissolved oxygen, and specific conductance) exceeded any of the MRP trigger thresholds.

3.2.3 Pathogen Indicator Monitoring Results/Conclusions

Pathogen indicator monitoring in WY 2018 was conducted in compliance with Provision C.8.d.v of the MRP. Pathogen indicator grab samples were collected at five sites in the Pescadero Creek watershed during a sampling event on July 27, 2018.

- The selection of sites was based on information provided by County Parks staff about high bacteria concentrations previously found in creeks within Memorial County Park. All three creeks sampled by SMCWPPP in WY 2018 are designated for both contact (REC-1) and non-contact (REC-2) recreation Beneficial Uses and several swimming holes are located along Pescadero Creek in and around Memorial County Park.

- The MRP trigger threshold for *E. coli* was not exceeded at any site in WY 2018; however, the MRP trigger threshold for enterococci was exceeded at two sites. These sites will be added to the list of candidate SSID projects.

- Pathogen indicator data should be interpreted cautiously due to the high variability found in creeks. In addition, wildlife sources in the WY 2018 monitoring area may contribute to the elevated concentrations of pathogen indicators in the creek but pose very little human health risk to recreators, relative to human sources of fecal contamination.

3.2.4 Chlorine Monitoring Results/Conclusions

Free chlorine and total chlorine residual were measured concurrently with bioassessments at the ten probabilistic sites in compliance with Provision C.8.c.ii. While chlorine residual has generally not been a concern in San Mateo County creeks, prior monitoring results suggest there are occasional trigger exceedances of free chlorine and total chlorine residual in the County. Trigger exceedances may be the result of one-time potable water discharges, and it is generally challenging to determine the source of elevated chlorine from such episodic discharges. Furthermore, chlorine in surface waters can dissipate from volatilization and reaction with dirt and organic matter. In WY 2018, there were no exceedances of the MRP trigger for chlorine (0.1 mg/L). SMCWPPP will continue to monitor chlorine in compliance with the MRP and, as in the past, will follow-up with municipal illicit discharge staff as needed.

3.2.5 Pesticides and Toxicity Monitoring Results/Conclusions

In WY 2018, SMCWPPP conducted pesticides and toxicity monitoring in compliance with Provision C.8.g of the MRP and in coordination with the RMC. The monitoring was conducted at two stations, one near the mouth of Cordilleras Creek and the other near the mouth of San Pedro Creek. Dry weather pesticides and toxicity monitoring was conducted at the Cordilleras Creek station (one water sample for toxicity and one sediment sample for toxicity, pesticides and other pollutants including metals). Wet weather pesticides and toxicity monitoring was conducted during a January 2018 storm event at both stations (one water sample from each station for toxicity and pesticides).

Statistically significant toxicity to *C. dubia* was observed in the water sample collected from Cordilleras Creek during the dry season. During wet weather monitoring, statistically significant toxicity to *H. azteca* was observed in the water samples collected from both creeks and toxicity to *P. promelas* was observed in the water samples collected from San Pedro Creek. However, the magnitude of the toxic effects in the samples compared to laboratory controls did not exceed MRP trigger criteria of 50 Percent Effect. The cause of the observed toxicity is unknown. Pesticide concentrations in the sediment sample were all very low, most below the MDL, and TU equivalents, with the exception of bifenthrin, did not exceed 0.1. Likewise, all pesticides (except fipronil and its degradates) analyzed in the wet weather samples were below the MDL.

Sediment chemistry results are evaluated to identify potential stressors based on TEC quotients and PEC quotients, according to criteria in Provision C.8.g.iv of the MRP. SMCWPPP also evaluated TU equivalents of pyrethroids and fipronil. TEC and PEC quotients were calculated for all metals and total polyaromatic hydrocarbons (PAHs) measured in the sediment sample. Two TEC quotients exceeded the MRP threshold of 1.0 (chromium and nickel), but no PEC quotients exceeded this threshold. Decisions about which SSID projects to pursue should be informed by the fact that the TEC and PEC quotient exceedances are likely related to naturally occurring chromium and nickel due to serpentine soils in local watersheds. Except for bifenthrin (with a TU equivalent of 0.251), all of the calculated TU equivalents were less than 0.1. Bifenthrin is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the California Department of Pesticide Regulation (DPR) Surface Water Protection Program (SWPP) (Ensminger 2017).

Pesticide analytes targeted by wet weather monitoring in WY 2018 were generally found at concentrations below the MDL, except for bifenthrin and fipronil compounds. As no WQOs are specified in the Water Quality Control Plan for the San Francisco Bay Region (Basin Plan) (SFRWQCB 2017) for these pollutants, they are not currently being used to identify SSID project locations. The wet weather pesticide monitoring data in WY 2018 was compared to pesticide data collected by the DPR SWPP and the United States Environmental Protection Agency (USEPA) aquatic benchmarks used in DPR SWPP studies to allow for interpretation of the WY 2018 results in the context of larger statewide datasets (see Appendix A for further details). However, sites sampled during the WY 2018 wet weather pesticide monitoring where exceedances of the USEPA benchmarks were observed were not added to the list of candidate SSID projects. In future years, data collected by the DPR SWPP and contained on the DPR SURF database can be queried to allow for comparison of MRP pesticide monitoring results.

SMCWPPP will continue to sample one station per year for dry weather pesticides and toxicity throughout the remainder of the permit term.

3.3 Trigger Assessment

The MRP requires analysis of the monitoring data to identify candidate sites for SSID projects. Trigger thresholds against which to compare the data are provided for most monitoring parameters in the MRP and are described in the foregoing sections of this report. Stream condition was assessed based on CSCI scores that were calculated using BMI data. Nutrient data were evaluated using applicable water quality standards from the Basin Plan (SFRWQCB 2017). Water and sediment chemistry and toxicity data were evaluated using numeric trigger thresholds specified in the MRP. In compliance with Provision C.8.e.i of the MRP, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects maintained throughout the permit term. Follow-up SSID projects will be selected from this list. Table 3.1 lists candidate SSID projects based on WY 2018 creek status and pesticides and toxicity monitoring data.

Additional data analysis is provided in the foregoing sections of this report and should be considered prior to selecting and defining SSID projects. The analyses include review of physical habitat and water chemistry data to identify potential stressors that may be contributing to degraded or diminished biological conditions. Analyses in this report also include historical and spatial perspectives that help provide context and greater understanding of the trigger exceedances.

Table 3.1. Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2018. “No” indicates samples were collected but did not exceed the MRP trigger; “Yes” indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Bioassessment [1]	Nutrients [2]	Chlorine [3]	Water Toxicity [4]	Water Chemistry [5]	Sediment Toxicity [4]	Sediment Chemistry [5]	Continuous Temperature [6]	Dissolved Oxygen [7]	pH [8]	Specific Conductance [9]	Pathogen Indicators [10]
202R00584	Pilarcitos Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R00614	Pescadero Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R03404	San Pedro Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
202R03656	Pilarcitos Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
202R03880	La Honda Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R03916	San Pedro Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
204R03508	Mills Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
204R03528	San Mateo Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
205R03624	Bear Creek	No	No	No	--	--	--	--	--	--	--	--	--
205R03864	Hamms Gulch	No	No	No	--	--	--	--	--	--	--	--	--
202SPE005	San Pedro Creek	--	--	--	No	No		--	--	--	--	--	--
204COR010	Cordilleras Creek	--	--	--	No	No	No	Yes	--	--	--	--	--
202PES138	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	Yes
202PES142	McCormick Creek	--	--	--	--	--	--	--	--	--	--	--	Yes
202PES144	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	No
202PES150	Jones Gulch	--	--	--	--	--	--	--	--	--	--	--	No
202PES154	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	No
202SPE019	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--
202SPE040	San Pedro Creek	--	--	--	--	--	--	--	No	No	No	No	--
202SPE050	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--
202SPE070	San Pedro Creek	--	--	--	--	--	--	--	No	No	No	No	--
202SPE085	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--

1. CSCI score ≤ 0.795.
2. Unionized ammonia (as N) ≥ 0.025 mg/L, nitrate (as N) ≥ 10 mg/L, chloride > 250 mg/L.
3. Free chlorine or total chlorine residual ≥ 0.1 mg/L.
4. Test of Significant Toxicity = Fail and Percent Effect ≥ 50 %.
5. TEC or PEC quotient ≥ 1.0 for any constituent.
6. Two or more MWAT ≥ 17.0°C or 20% of results ≥ 24°C.
7. DO < 7.0 mg/L in COLD streams or DO < 5.0 mg/L in WARM streams.
8. pH < 6.5 or pH > 8.5.
9. Specific conductance > 2000 uS.
10. Enterococcus ≥ 130 cfu/100ml or *E. coli* ≥ 410 cfu/100ml.

3.4 Recommendations

The following recommendations are based on findings from WY 2018 creek status and pesticides and toxicity monitoring conducted by SMCWPPP, as well as reflections on other monitoring, data analysis, and policy development projects being conducted in the region (e.g., RMC 5-Year Report) and statewide.

- In WY 2019, SMCWPPP will continue to coordinate with RMC partners on implementation of monitoring requirements in MRP Provisions C.8.d and C.8.g.
- A major component of the WY 2019 monitoring will be bioassessment surveys and data assessment. In WY 2019, SMCWPPP will conduct biological assessments at both probabilistic and targeted sites. To date, a total of 80 probabilistic sites have been monitored by SMCWPPP (n=7) and SWAMP (n=10). This exceeds the number of samples necessary for a statistically representative dataset. Therefore, SMCWPPP has the option to select up to 20 percent of sample locations on a targeted basis to evaluate trends or address other aquatic life related concerns.
- In WY 2018, BASMAA funded a study to evaluate five years of regional bioassessment data (WY 2012 – WY 2016). Findings from the RMC 5-Year Report are summarized in this report and included as Attachment 2 to Appendix A. In WY 2019, SMCWPPP will apply some of the tools used in the RMC 5-Year Report (i.e., random forest models) to analyze bioassessment data collected in San Mateo County over all eight years of MRP monitoring (WY 2012 – WY 2019). Results of the analyses will be described in the Integrated Monitoring Report (IMR) which will be developed following WY 2019 and must be submitted by March 31, 2020 (the fifth year of the Permit term) in lieu of an annual UCMR.
- For the past two years (WY 2017 and WY 2018), SMCWPPP has conducted continuous temperature and water quality monitoring in the San Pedro Creek Watershed. In WY 2019, SMCWPPP will work with San Mateo County MRP Permittees to select a different creek or reach to target, perhaps where targeted bioassessment monitoring sites are located.
- Provision C.8.g pesticides and toxicity monitoring will be conducted during the dry season at a bottom-of-the-watershed station. In order to expand the geographic extent of these data, a new station will be selected.

3.5 Management Implications

The creek status and pesticides and toxicity monitoring programs (consistent with MRP Provisions C.8.d and C.8.g, respectively) focus on assessing the water quality condition of urban creeks in San Mateo County and identifying stressors and sources of impacts observed. The bioassessment station sample size from WY 2018 (overall n=10; urban n=8) was not sufficient to develop statistically representative conclusions regarding the overall condition of all creeks, but more comprehensive analysis that includes data from previous years is included in the BASMAA RMC 5-Year Report (Section 3.2.1 and Attachment 2 to Appendix A).

Like previous years, WY 2018 data suggest that most urban streams have likely or very likely altered populations of aquatic life indicators (e.g., benthic macroinvertebrates). These conditions are likely the result of long-term changes in stream hydrology, channel geomorphology, in-stream habitat complexity, and other modifications to the watershed and riparian areas associated with the urban development that has occurred over the past 50 plus years.

SMCWPPP Permittees are actively implementing many stormwater management programs to address these and other stressors and associated sources of water quality conditions observed in local creeks, with the goal of protecting these natural resources. For example:

- In compliance with MRP Provision C.3, new and redevelopment projects in the Bay Area are now designed to more effectively reduce water quality and hydromodification impacts associated with urban development. Low impact development (LID) methods, such as rainwater harvesting and use, infiltration and biotreatment are required as part of development and redevelopment projects. In addition, planning for and implementing green infrastructure projects in the public right-of-way (e.g., during street projects) is increasingly being incorporated into the municipal master planning process. All of these measures are expected to reduce the impacts of urbanization on stream health.
- In compliance with MRP Provision C.9, Permittees are implementing pesticide toxicity control programs that focus on source control and pollution prevention measures. The control measures include the implementation of integrated pest management (IPM) policies/ordinances, public education and outreach programs, pesticide disposal programs, supporting the adoption of formal State pesticide registration procedures, and sustainable landscaping requirements for new and redevelopment projects. These efforts should reduce pyrethroids and other pesticides in urban stormwater runoff and reduce the magnitude and extent of toxicity in local creeks.
- Trash loadings to local creeks have been reduced through implementation of new control measures in compliance with MRP Provision C.10 and other efforts by Permittees to reduce the impacts of illegal dumping directly into waterways. These actions include the installation and maintenance of trash capture systems, the adoption of ordinances to reduce the impacts of litter prone items, enhanced institutional controls such as street sweeping, and the on-going removal and control of direct dumping. The MRP establishes a mandatory trash load reduction schedule, minimum areas to be treated by full trash capture systems, and requires development of receiving water monitoring programs for trash.
- In compliance with MRP Provisions C.2 (Municipal Operations), C.4 (Industrial and Commercial Site Controls), C.5 (Illicit Discharge Detection and Elimination), and C.6 (Construction Site Controls), Permittees continue to implement Best Management Practices (BMPs) that are designed to prevent non-stormwater discharges during dry weather and reduce the exposure of stormwater runoff to contaminants during rainfall events.
- In compliance with MRP Provision C.13, copper in stormwater runoff is reduced through implementation of controls such as architectural and site design requirements, prohibition of discharges from water features treated with copper, and industrial facility inspections.
- Mercury and polychlorinated biphenyls (PCBs) in stormwater runoff are being reduced through implementation of the respective TMDL water quality restoration plans. In compliance with MRP Provisions C.11 (mercury) and C.12 (PCBs), the Countywide Program will continue to identify sources of these pollutants and will implement control actions designed to achieve load reduction goals. Monitoring activities conducted in WY 2018 that specifically target mercury and PCBs are described in Section 5.0 of this report.

In addition to controls implemented in compliance with the MRP, numerous other efforts and programs designed to improve the biological, physical and chemical condition of local creeks are underway. For example, C/CAG finalized the San Mateo Countywide Stormwater Resource Plan

(SRP) in 2017 to satisfy state requirements and guidelines to ensure C/CAG and San Mateo county MRP Permittees are eligible to compete for future voter-approved bond funds for stormwater or dry weather capture projects. The SRP identifies and prioritizes opportunities to better utilize stormwater as a resource in San Mateo County through a detailed analysis of watershed processes, surface and groundwater resources, input from stakeholders and the public, and analysis of multiple benefits that can be achieved through strategically planned stormwater management projects. These projects aim to capture and manage stormwater more sustainably, reduce flooding and pollution associated with runoff, improve biological functioning of plants, soils, and other natural infrastructure, and provide many community benefits, including cleaner air and water and enhanced aesthetic value of local streets and neighborhoods.

Through the continued implementation of MRP-associated and other watershed stewardship programs, SMCWPPP anticipates that stream conditions and water quality in local creeks will continue to improve over time. In the near term, toxicity observed in creeks should decrease as pesticide regulations better incorporate water quality concerns during the pesticide registration process. In the longer term, control measures implemented to “green” the “grey” infrastructure and disconnect impervious areas constructed over the course of the past 50 plus years will take time to implement. Consequently, it may take several decades to observe the outcomes of these important, large-scale improvements to our watersheds in our local creeks. Long-term creek status monitoring programs designed to detect these changes over time are therefore beneficial to our collective understanding of the condition and health of our local waterways.

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

Provision C.8.e of the MRP requires that Permittees evaluate creek status (Provision C.8.d) and pesticides and toxicity (Provision C.8.g) monitoring data with respect to triggers defined in the MRP. Permittees are required to maintain a list of all results exceeding trigger thresholds. Table 3.1 lists the results of the trigger evaluation for WY 2018 data. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are therefore considered as candidates for future Stressor/Source Identification (SSID) projects. SSID projects are selected from the list of trigger exceedances based on criteria such as magnitude of threshold exceedance, parameter, and likelihood that stormwater management action(s) could address the exceedance. Pollutants of concern monitoring results (Provision C.8.f) may be considered as appropriate.

The MRP requires that Permittees initiate a minimum number of SSID projects during the permit term. As a regional collaborative, SMCWPPP and its RMC partners must collectively initiate a region-wide minimum of eight new SSID projects during the permit term, with a minimum of one for toxicity. RMC programs have agreed that the distribution of the eight required SSID projects will be as follows, with most projects conducted by individual Programs addressing local needs and one conducted regionally:

- 2 each: ACCWP and SCVURPPP
- 1 each: CCCWP and SMCWPPP
- 1 jointly: FSURMP and Vallejo Permittees
- 1 regionally: all RMC partners

In compliance with Provision C.8.e.iii, half of the required number of SSID projects (i.e., four) were initiated with a work plan by the third year of the permit term (i.e., 2018). All SSID projects initiated in compliance with the 2015 MRP are summarized in the BASMAA RMC Regional SSID Report (**Appendix B**).

SSID projects must identify and isolate potential sources and/or stressors associated with observed water quality impacts. They are intended to be oriented to taking action(s) to alleviate stressors and reduce sources of pollutants. The MRP describes the stepwise process for conducting SSID projects:

- Step 1: Develop a work plan for each SSID project that defines the problem to the extent known, describes the SSID project objectives, considers the problem within a watershed context, lists candidate causes of the problem, and establishes a schedule for investigating the cause(s) of the trigger exceedance. The MRP recommends study approaches for specific triggers. For example, toxicity studies should follow guidance for Toxicity Reduction Evaluations (TRE) or Toxicity Identification Evaluations (TIE), physical habitat and conventional parameter (e.g., dissolved oxygen, temperature) studies should generally follow Step 5 (Identify Probable Causes) of the Causal Analysis/Diagnosis Decision Information System (CADDIS), and pathogen indicator studies should generally follow the *California Microbial Source Identification Manual* (Griffith et al. 2013).
- Step 2: Conduct SSID investigation according to the schedule in the SSID work plan and report on the status of SSID investigations annually in each UCMR.
- Step 3: Conduct follow-up actions based on SSID investigation findings. These may include development of an implementation schedule for new or improved BMPs. If a

> Permittee determines that MS4 discharges are not contributing to an exceedance of a water quality standard, the Permittee may end the SSID project upon written concurrence of the Executive Officer. If the SSID investigation is inconclusive, the Permittee may request that the Executive Officer consider the SSID project complete.

In 2017, SMCWPPP initiated the Pillar Point Watershed Pathogen Indicator SSID Project. In 2018, BASMAA began development of a regional SSID project addressing releases and spills of PCBs from electrical utility equipment. The status of these projects are summarized below.

4.1 Pillar Point Watershed Pathogen Indicator SSID Project

The Pillar Point Watershed Pathogen Indicator SSID Project was triggered by fecal indicator bacteria (FIB) densities exceeding WQOs that have been measured in receiving waters and tributaries to Pillar Point Harbor. A SSID work plan (SMCWPPP 2018a) was submitted with the SMCWPPP WY 2017 UCMR dated March 31, 2018. The work plan describes steps to investigate urban sources of fecal indicator bacteria in the Pillar Point Watershed. SMCWPPP implemented the work plan in WY 2018 with assistance from and in close coordination with the San Mateo County Resource Conservation District (RCD). Consistent with Provision C.8.e.iii.(1)(g), the study generally follows the *California Microbial Source Identification Manual* (Griffith et al. 2013).

The objective of the SSID study is to build on a Proposition 50 Clean Beaches Initiative Grant-funded study that was conducted by the RCD and University of California, Davis (UCD) in 2008 and 2011-12. The RCD/UCD study indicated that high FIB measured at Pillar Point beaches was likely due to influences from storm drains and creeks rather than from sources at the beaches and within the harbor itself. The Pillar Point SSID study was designed to identify whether urban areas drained by the MS4 in the urban community of El Granada are an important source of bacteria to Pillar Point Harbor and whether the sources of bacteria are controllable (especially human and dog, as opposed to wildlife sources). These are key steps towards the longer-term goal of reducing FIB densities in Pillar Point Harbor and, more specifically, reducing the risk of illness for recreators at the local beaches. The study includes a desktop analysis consisting of historical data review and mapping and a water sampling program that targets multiple sites in study area watersheds (Figure 4.1).

The WY 2018 field investigation included two wet weather sampling events and two dry season sampling events at 14 stations. Samples were analyzed for *E. coli* and bacteroidales associated with humans and dogs (two sources considered controllable). Preliminary review of the field and analytical data suggest that human and dog sources are rare at the sampled stations. In general, *E. coli* densities are higher during wet weather compared to the dry season and increase in the downstream direction; however, these findings are not consistent throughout the study area. Based on the WY 2018 field results, several additional field investigations were identified and are being implemented in WY 2019. These include targeted dye studies of sanitary sewer lines, pet waste reconnaissance visits, and additional microbial source tracking (MST) sampling.

It is anticipated that the SSID Project Report will be finalized by June 30, 2019 and will be submitted to the Regional Water Board with the Integrated Monitoring Report on March 31, 2020.

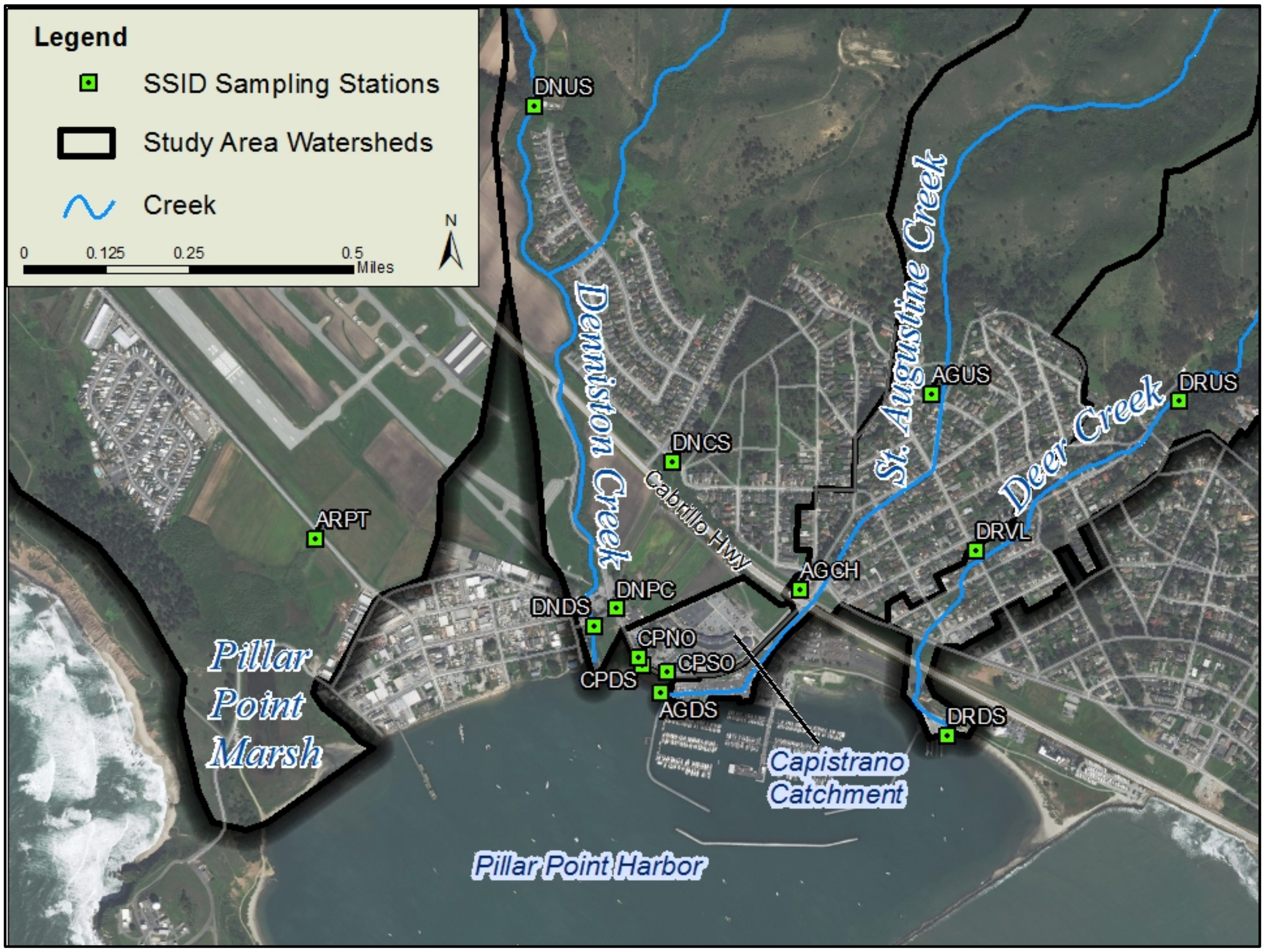

Figure 4.1. Pillar Point Watershed Pathogen Indicator SSID Project monitoring stations.

4.2 Electrical Utilities as a Potential PCBs Source SSID Project

During WY 2018, BASMAA scoped and budgeted for conducting a regional SSID project addressing releases and spills of PCBs from electrical utility equipment. The Regional SSID Project – Electrical Utilities as a Potential PCBs Source to Stormwater in the San Francisco Bay Area – is one of many efforts responding to the Bay being designated as impaired on the Clean Water Act Section 303(d) list and the adoption of a TMDL for PCBs in 2008. Subsequent PCBs monitoring by the BASMAA RMC partners and the RMP suggests that diffuse sources of PCBs to stormwater runoff are present throughout the region. One potential source of PCBs to stormwater runoff is releases and spills from electrical utility equipment.

PCBs were historically used as insulator fluids in several types of electrical utility equipment, some of which still contain PCBs. Although much of the PCB-containing oils and/or equipment with PCBs oils have been removed from service, some remain in use, and PCBs loadings in stormwater runoff associated with releases and spills from the equipment could potentially exceed the TMDL waste load allocation for stormwater runoff. However, the information currently available is not adequate to fully quantify the scope and magnitude of electrical utility releases as a source of PCBs to stormwater runoff. This information gap is partially because PCBs levels typically used for reporting and cleanup of PCBs spills may exceed the levels needed to address the PCBs TMDL requirements. Furthermore, stormwater Programs don’t have the authority to compel electrical utilities to provide information about spills, equipment replacement programs, and cleanup protocols, or to implement additional controls. Therefore, BASMAA identified the need to develop and implement a regional SSID work plan to further understand the magnitude and extent of this potential PCBs source, and identify controls (if necessary) that utilities could be compelled to implement to reduce the water quality impacts of this source.

The work plan is included as **Appendix G**. It presents a framework for working with the Regional Water Board, which does have jurisdictional authority in relation to water quality issues over electrical utility companies. Implementation of the regional SSID work plan will begin in WY 2019.

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

Pollutants of Concern (POC) monitoring is required by Provision C.8.f of the MRP. POC monitoring is intended to assess inputs of POCs to the Bay from local tributaries and urban runoff, provide information to support implementation of Total Maximum Daily Load (TMDL) water quality restoration plans and other pollutant control strategies, assess progress toward achieving wasteload allocations (WLAs) for TMDLs, and help resolve uncertainties associated with loading estimates for POCs. The MRP identifies five priority POC management information needs that need to be addressed though POC monitoring:

1. **Source Identification** – identifying which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff;
2. **Contributions to Bay Impairment** – identifying which watershed source areas contribute most to the impairment of San Francisco Bay beneficial uses (due to source intensity and sensitivity of discharge location);
3. **Management Action Effectiveness** – providing support for planning future management actions or evaluating the effectiveness or impacts of existing management actions;
4. **Loads and Status** – providing information on POC loads, concentrations, and presence in local tributaries or urban stormwater discharges; and
5. **Trends** – evaluating trends in POC loading to the Bay and POC concentrations in urban stormwater discharges or local tributaries over time.

MRP Provision C.8.f requires monitoring of the following POCs: polychlorinated biphenyls (PCBs), mercury, copper, emerging contaminants, and nutrients.[10] The MRP defines yearly and total (i.e., over the MRP permit term) minimum number of samples for each POC and specifies the minimum number of samples for each POC that must address each information need.

To help meet these requirements, and to develop mutually beneficial monitoring approaches, SMCWPPP continued to work collaboratively with other organizations and projects that conduct water quality monitoring in the Bay Area. Provision C.8.a.iii of the MRP allows Permittees to use data collected by third-party organizations to fulfill monitoring requirements, provided the data are demonstrated to meet the required data quality objectives. Samples collected in San Mateo County through the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP), Clean Watersheds for a Clean Bay (CW4CB), a recently completed project that was funded by a grant from USEPA), and the State's Stream Pollution Trends (SPoT) Monitoring Program supplemented SMCWPPP's efforts towards achieving Provision C.8.f monitoring requirements.

In particular, SMCWPPP continued to be an active participant in the RMP's Small Tributary Loading Strategy (STLS). The STLS typically conducts annual monitoring for POCs on a region-wide basis, including collecting composite samples of stormwater runoff and analyzing for PCBs and mercury. As in past years, during WY 2018 SMCWPPP helped the STLS select its PCBs and mercury monitoring stations that are located in San Mateo County and evaluated the data from those stations along with PCBs and mercury data collected directly by SMCWPPP.

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[10] Emerging contaminant monitoring requirements will be met through participation in RMP special studies and will address at least PFOS, PFAS, and alternative flame retardants being used to replace PBDEs.

5.1 SMCWPPP POC Monitoring

In WY 2018, SMCWPPP complied with Provision C.8.f of the MRP by conducting POC monitoring for PCBs, mercury, copper, and nutrients. Specific activities included:

- Collection of stormwater runoff samples from the bottom of selected urban catchments for PCBs and mercury analysis (n=13);
- Collection of grab sediment samples in selected urban catchments for PCBs and mercury analysis (n=50);
- Collection of wet and dry weather creek water samples for nutrients and copper analysis (n=4);
- Participation in BASMAA regional study to analyze infrastructure caulk and sealant samples for PCBs (n=5; ¼ of project total) (see Section 5.2);
- Participation in BASMAA regional study to evaluate the PCBs and mercury removal effectiveness of hydrodynamic separator (HDS) units and biochar-amended bioretention soil media (BSM) (n = 8; ¼ of project total) (see Section 5.2);
- Participation in SWAMP's Stream Pollutant Trends monitoring program; and
- Continued participation in the RMP's STLS (see Section 5.3).

Progress toward POC monitoring requirements accomplished in WY 2018 and the planned allocation of effort for WY 2019 are described in a report dated October 15, 2018 (SMCWPPP 2018c) which was submitted to the Regional Water Board in compliance with MRP Provision C.8.h.iv. The yearly minimum number of samples specified in MRP Provision C.8.f was exceeded for all POCs. A report with further details about WY 2018 POC monitoring conducted by SMCWPPP is included as **Appendix C**. Reports describing the results of BASMAA's BMP effectiveness studies are summarized in Section 5.2 and included as **Appendices D** and **E**. A report documenting the WY 2015 – 2018 POC monitoring conducted by the STLS is summarized in Section 5.3 and included as **Appendix F**.

General methods employed for POC monitoring and quality assurance/quality control (QA/QC) procedures were similar to previous years (SMCWPPP 2015, 2017, 2018b). A comprehensive QA/QC program was implemented by SMCWPPP covering all aspects of POC monitoring with similar protocols to previous years. Overall, the results of the QA/QC review suggested that most of the POC monitoring data generated during WY 2018 were of sufficient quality. Although some data were flagged in the project database, none were rejected according to Data Quality Objectives (DQOs). Additional details about the QA/QC review are provided in **Appendix C.**

5.1.1 PCBs and Mercury

MRP Provisions C.11.a.iii and C.12.a.iii require that Permittees provide a list of management areas in which new PCBs and mercury control measures will be implemented during the permit term. These management areas are designated "Watershed Management Areas" (WMAs) in this report, and are defined as all catchments containing high interest parcels (i.e., properties with land uses associated with PCBs such as old industrial, electrical and recycling) and/or existing or planned PCBs and mercury controls.

WMAs are the framework used by SMCWPPP to plan its current PCBs and mercury monitoring program in San Mateo County. During WY 2018, SMCWPPP collected 13 composite samples of stormwater runoff from outfalls at the bottom of WMAs and 50 sediment samples (of which 5 were duplicates) within WMAs. As part of continuing to develop strategies for reducing PCBs and mercury loads in stormwater runoff, SMCWPPP evaluated these data, along with additional WY 2018 stormwater runoff sample data collected through the STLS, and data from previous water years collected by SMCWPPP and through the STLS. Objectives included attempting to identify source properties within WMAs, identifying which WMAs provide the greatest opportunities for implementing cost-effective PCBs controls, and prioritizing WMAs for future investigations.

Stormwater Runoff Monitoring

During WY 2018, SMCWPPP collected 13 composite samples of stormwater runoff from outfalls at the bottom of WMAs that contain high interest parcels. An additional two stormwater runoff samples were collected in San Mateo County through the RMP's STLS, also from WMAs with high interest parcels. These combined 15 samples primarily help to address Management Questions #1 (Source Identification) and #2 (Contributions to Bay Impairment). Data will also be used by the RMP STLS to improve calibration of the Regional Watershed Spreadsheet Model (RWSM) which is a land use based planning tool for estimation of overall POC loads from small tributaries to San Francisco Bay at a regional scale (i.e., Management Question #4 – Loads and Status).

WMAs were identified and prioritized for stormwater runoff sampling by evaluating several types of data, including: land use data, PCBs and mercury concentrations from prior sediment and stormwater runoff sampling efforts, municipal storm drain data showing pipelines and access points (e.g., manholes, outfalls, pump stations), and logistical/safety considerations. Composite samples, consisting of six to eight aliquots collected during the rising limb and peak of the storm hydrograph (as determined through field observations), were analyzed for the 40 PCBs congeners designated by the RMP as those most likely to be found in the Bay[11] (method EPA 1668C, total PCBs were calculated as the sum of these 40 congeners), total mercury (method EPA 1631E), and suspended sediment concentration (SSC; method ASTM D3977-97). Detailed results are presented in **Appendix C**.

Sediment Sampling

During WY 2018, SMCWPPP collected 50 grab sediment samples (of which 5 were duplicates) as part of the program to attempt to identify source properties within WMAs, potentially for referral to the Regional Water Board for further investigation and potential abatement. These samples were collected in the public right-of-way (ROW), including locations adjacent to high interest parcels with land uses associated with PCBs such as old industrial, electrical and recycling and/or other characteristics potentially associated with pollutant discharge (e.g., poor housekeeping, unpaved areas). Individual and composite sediment samples were collected from manholes, storm drain inlets, driveways, streets, and sidewalks.

Each sample was analyzed for total mercury and for the 40 PCBs congeners designated by the RMP as those most likely to be found in the Bay (see the previous section). Total PCBs were

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[11] PCBs congeners 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, l05, 110, 118, 128, 132, 138, 141, 149, l51, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, 203.

calculated as the sum of the 40 congeners. The laboratory sieved all samples to 2 mm prior to analysis. Detailed results are presented in **Appendix C**.

Watershed Management Area Prioritization

The Countywide Program evaluated PCBs stormwater runoff and sediment monitoring data to help prioritize WMAs for further investigation and control measure implementation. Based upon the data collected in San Mateo County to-date by the Countywide Program and other parties (e.g., the RMP's STLS), WMAs with one or more sediment and/or stormwater runoff samples with PCBs concentrations (particle ratios for stormwater runoff) greater than 0.5 mg/kg (or 500 ng/g) were provisionally designated high priority. WMAs with samples in the 0.2 – 0.5 mg/kg (200 – 500 ng/g) range were provisionally designated medium priority. WMAs with stormwater runoff sample PCBs particle ratios less than 0.2 mg/kg (200 ng/g) were provisionally designated low priority. It is important to emphasize the provisional nature of these prioritizations, and especially designating a WMA as low priority due to a single stormwater runoff sample having a low PCBs particle ratio. Low PCBs results in any single stormwater runoff sample could be a "false negative" in that they result from the storm not being large enough to mobilize sediments with associated PCBs, or other factors. For example, based upon WY 2018 resampling results, two WY 2016 RMP STLS stormwater runoff samples located in South San Francisco may have been false negatives. In addition, sediment sample results were not used to designate a WMA lower priority due to the high potential for false negatives. Figure 5.1 is a map illustrating the current status of WMAs in San Mateo County, based on this provisional prioritization scheme and sediment and stormwater runoff monitoring results to-date.12 Only WMAs with high interest parcels were included in Figure 5.1.

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[12] Where sediment and stormwater runoff particle ratio analysis results conflict, the higher result was conservatively applied.

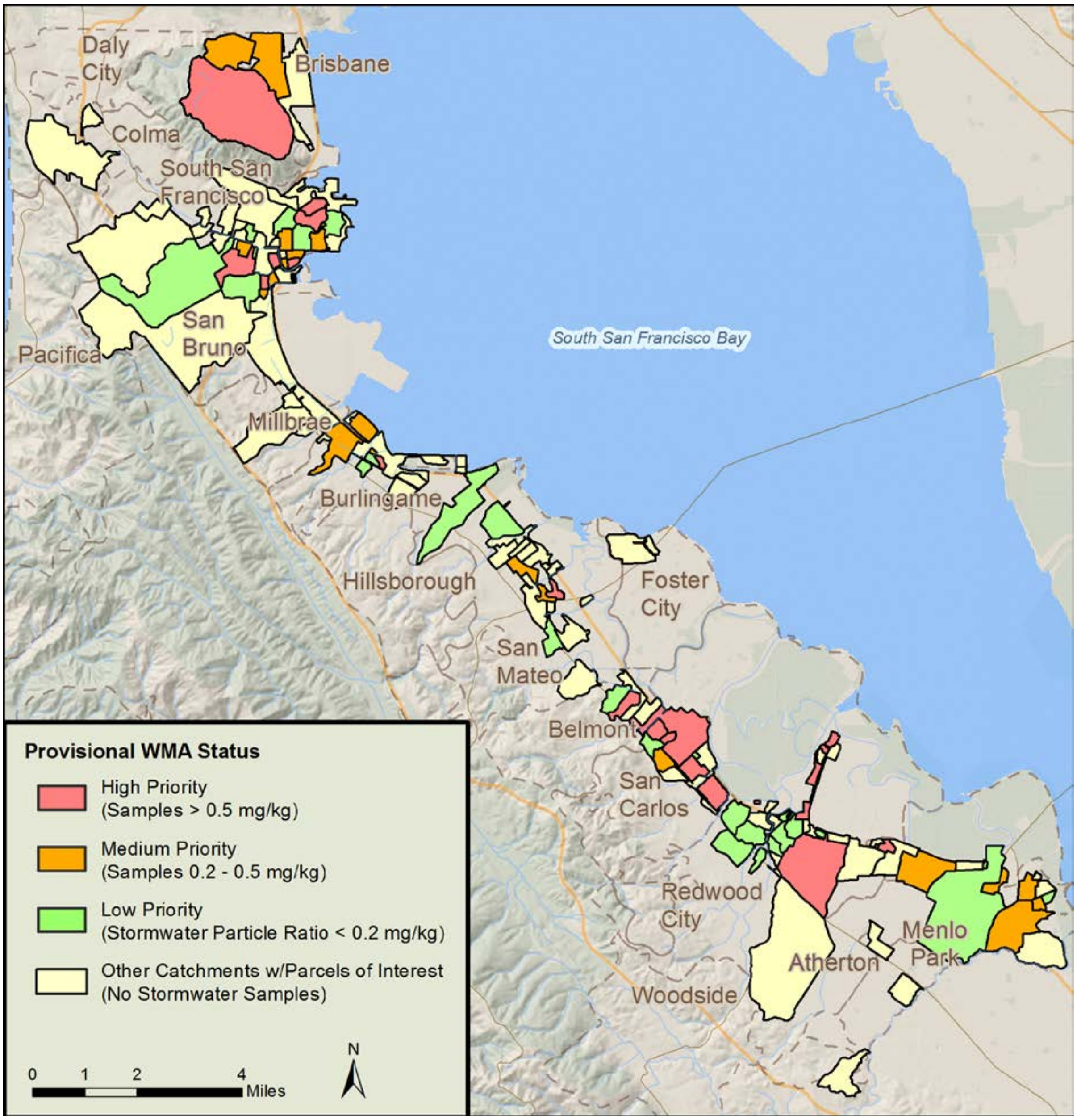

Figure 5.1. San Mateo County PCBs WMA status based on sediment and stormwater runoff data collected through WY 2018.

5.1.2 Copper

In WY 2018, the Countywide Program collected a total of four grab creek water samples for copper analysis. Bottom-of-the-watershed stations on San Pedro Creek and Cordilleras Creek were sampled during a large storm event on January 8, 2018, concurrent with nutrient POC monitoring and Provision C.8.g.iii Wet Weather Pesticides and Toxicity Monitoring. The same two stations were sampled again during dry season base flows. The goal of this approach is to address Management Question #5 (Trends) by comparing copper concentrations during different seasonal flow events. Management Question #4 (Loads and Status) is also addressed by characterizing copper concentrations in mixed-use watersheds.

Based on the laboratory results, the following findings were noted:

- As expected, dissolved copper concentrations are lower than total copper concentrations. The dissolved portion of the total copper concentration is higher in the spring base flow samples compared to the storm samples. This finding is consistent with copper's affinity to suspended sediment. Suspended sediment concentration is generally higher during storm events.
- Copper concentrations at both stations were higher during the January storm event compared to the spring base flow event, suggesting an influence by stormwater runoff.
- Copper concentrations were similar (i.e., within the same order of magnitude) in both creeks. This finding is consistent with a lack of local sources of copper.
- All dissolved copper concentrations were below hardness-dependent acute and chronic WQOs.

5.1.3 Nutrients

In WY 2018, SMCWPPP collected four nutrient samples (concurrent with the above copper sampling) from bottom-of-the-watershed stations on San Pedro Creek and Cordilleras Creek. Samples were collected during the January 8, 2018 storm event and during dry season base flows. Nutrient analyses include: ammonium[13], nitrate, nitrite, total Kjeldahl nitrogen (TKN), dissolved orthophosphate, and total phosphorus. The goal was to address loads and status (Management Question #4).

Based on the laboratory results, the following findings were noted:

- Concentrations of all nutrient at both stations were higher during the January storm event compared to the spring base flow event, suggesting an influence by stormwater runoff. This finding is consistent with the draft conceptual model developed by the San Francisco Bay Nutrient Management Strategy which suggests that nutrient loads to San Francisco Bay from creeks are highest during the wet season, but considerably less than loads from publicly owned wastewater treatment works (POTWs) (Senn and Novick 2014).
- Organic nitrogen (TKN) made up a greater proportion of the total nitrogen concentration during the January storm event compared to the May event. It is likely that organically-

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[13] Ammonium was calculated as the difference between ammonia and un-ionized ammonia. Un-ionized ammonia was calculated using the formula provided by the American Fisheries Society Online Resources (http://fishculture.fisheries.org/resources/fish-hatchery-management-calculators/).

bound nitrogen that washed off surfaces during the January storm had not yet had time to cycle through the ammonification and nitrification processes before samples were collected.

- No applicable WQOs were exceeded.

5.1.4 SMCWPPP WY 2018 POC Monitoring - Conclusions

In WY 2018, SMCWPPP collected and analyzed POC samples in compliance with Provision C.8.f of the MRP. Yearly minimum requirements were met for all monitoring parameters. In addition, SMCWPPP continued helping the RMP's STLS to select its WY 2018 PCBs and mercury monitoring stations that are located in San Mateo County. The data from those stations were evaluated along with PCBs and mercury data collected directly by SMCWPPP. Conclusions from WY 2018 POC monitoring included the following:

- SMCWPPP's PCBs and mercury monitoring focuses on San Mateo County WMAs containing high interest parcels with land uses potentially associated with PCBs such as old industrial, electrical and recycling. During WY 2018 SMCWPPP collected 13 composite samples of stormwater runoff from outfalls at the bottom of WMAs and 50 grab sediment samples within the WMAs. SMCWPPP evaluated the PCBs stormwater runoff and sediment monitoring data to help prioritize WMAs for further investigation and identify which WMAs provide the greatest opportunities for implementing cost-effective PCBs controls.
- Based on the sediment and stormwater runoff monitoring data collected to-date in San Mateo County by SMCWPPP and other parties (e.g., the RMP's STLS), WMAs were provisionally designated as high, medium, or low priority. Figure 5.1 is a map illustrating the current status of WMAs in San Mateo County, based on this provisional prioritization scheme.
- The PCBs monitoring data collected to-date has informed identification of several potential source properties located in the City of San Carlos. The Countywide Program is working with the City regarding next steps at these sites. This included recently developing and submitting to the Regional Water Board referrals of two areas for potential further PCBs investigation and abatement:
    - 270 Industrial Road (Delta Star) / 495 Bragato Road (Tiegel), which are adjacent properties in San Carlos.
    - 977 and 1007/1011 Bransten Road, another set of adjacent properties in San Carlos.
- The mean and median PCBs concentrations in WY 2018 sediment samples (n = 50) were somewhat lower than in previous years. In addition, in WY 2018 only 1 of the 50 sediment samples collected had a PCBs concentration that exceeded 1.0 mg/kg. One other sample had a PCBs concentration between 0.5 and 1.0 mg/kg. All of the remaining samples had a PCBs concentration below 0.5 mg/kg. In general, the WY 2018 POC monitoring data suggest that the PCBs monitoring program in the public ROW in San Mateo County may be approaching diminishing returns in terms of identifying new source properties.
- However, the stormwater runoff resamples in South San Francisco suggest the possibility of false negatives for PCBs in some WMAs provisionally designated low priority based on stormwater runoff data from previous years. The RMP's ongoing "Advanced Data Analysis" is evaluating normalizing results based upon storm intensity

and the results may help inform planning any future stormwater runoff monitoring of this type.

- Four creek water samples were collected for copper analysis from two creeks (San Pedro and Cordilleras Creeks) during a large January 2018 storm event and during spring base flows. Copper concentrations were higher in both creeks during the storm event compared to the base flow event, suggesting an influence by stormwater runoff.
- The San Pedro and Cordilleras Creek stations were concurrently sampled for nutrients during the large January 2018 storm event and the spring base flow event. Nutrient concentrations in both creeks were higher during the January storm sampling event compared to the spring baseflow event, suggesting that nutrient loads to San Francisco Bay from these creeks is higher during storm events.
- None of the WY 2018 water samples exceeded applicable water quality objectives (WQOs).

5.1.5 POC Monitoring Planned by SMCWPPP in WY 2019

In WY 2019, SMCWPPP will continue to collect and analyze POC samples in compliance with Provision C.8.f of the MRP. Yearly minimum requirements will be met for all monitoring parameters. In addition, SMCWPPP will continue helping the RMP's STLS to select its WY 2019 PCBs and mercury monitoring stations that are located in in San Mateo County. POC monitoring activities in WY 2019 will include the following:

- SMCWPPP, in coordination with the RMP STLS, will continue conducting PCBs and mercury monitoring that focuses on San Mateo County WMAs containing high interest parcels with land uses potentially associated with PCBs such as old industrial, electrical and recycling. This will include collecting additional composite samples of stormwater runoff from outfalls at the bottom of WMAs and grab sediment samples within the WMAs. Objectives will include attempting to identify source properties within WMAs, identifying which WMAs provide the greatest opportunities for implementing cost-effective PCBs controls, and prioritizing WMAs for potential future investigations.
- SMCWPPP will continue to participate in the STLS Trends Strategy Team in developing a regional monitoring strategy to assess trends in POC loading to San Francisco Bay from small tributaries (see Section 5.2.3). The STLS Trends Strategy will initially focus on PCBs and mercury, but will not be limited to those POCs. Analysis of recent and historical data collected at region-wide loadings stations suggests that PCB concentrations are highly variable. Therefore, a monitoring design to detect trends with statistical confidence may require more samples than is feasible with current resources. The STLS Trends Strategy Team is continuing to evaluate available data from the Guadalupe River watershed to explore more economical monitoring opportunities. The Team is also considering modeling options that could be used in concert with monitoring to detect and predict trends in POC loadings.
- SMCWPPP will also continue to work with the State's Stream Pollution Trends (SPoT) Monitoring Program to help address Management Question #5 (Trends). SPoT conducts annual dry season monitoring (subject to funding constraints) of sediments collected from a statewide network of large rivers. The goal of the SPoT Monitoring Program is to investigate long-term trends in water quality. Sites are targeted in bottom-of-the-watershed locations with slow water flow and appropriate micromorphology to allow deposition and accumulation of sediments, including a station near the mouth of San

Mateo Creek. In most years, sediment analytes include PCBs, mercury, toxicity, pesticides (Phillips et al. 2014).

- SMCWPPP will collect at least two copper and nutrient water samples in WY 2019.
- SMCWPPP will continue to participate in the RMP, including the RMP's STLS and CEC Strategy (see Section 2.5).

5.2 BASMAA Monitoring

In WY 2018, SMCWPPP participated in the BASMAA "POC Monitoring Project for Source Identification and Management Action Effectiveness" project. This regional project includes two somewhat independent monitoring studies designed during WY 2017 and implemented during WY 2018. BASMAA developed two study designs to implement these projects and a shared Sampling and Analysis Plan and Quality Assurance Project Plan (SAP/QAPP). The SAP/QAPP describes field and laboratory methods, measurement quality objectives, quality control procedures, and data management aspects. As one of four largest Countywide Programs subject to provision C.8.f POC Monitoring requirements, SMCWPPP's POC monitoring accomplishments include ¼ of the total number of samples collected through these regional studies.

5.2.1 PCBs in Infrastructure Caulk Study

The BASMAA Regional Infrastructure Caulk and Sealant Sampling Program was developed to satisfy the provision C.12.e requirement to collect 20 composite caulk/sealant samples throughout the MRP permit area and evaluate (at a screening level) whether PCBs are present in right-of-way infrastructure caulk and sealants in the Bay Area. This study also helps to address Management Question #1 (Source Identification). The sampling program was designed to specifically target roadway and storm drain structures that were constructed during the most recent time period when PCBs were potentially used in caulk and sealant materials (i.e., prior to 1980, with a focus on the 1960s and 1970s).

In WY 2018, the BASMAA project team collected 54 samples of caulk/sealant materials from ten types of roadway and storm drain infrastructure in the public right-of-way (ROW). Structures sampled included concrete bridges/overpasses, sidewalks, curbs and gutters, roadway surfaces, above and below ground storm drain structures (i.e., flood control channels and storm drains accessed from manholes), and electrical utility boxes or poles attached to concrete sidewalks. The individual samples were grouped by structure type and sample appearance (color and texture) into 20 composites and analyzed for the RMP 40 PCB congeners using a modified method EPA 8270C (Figure 5.2).

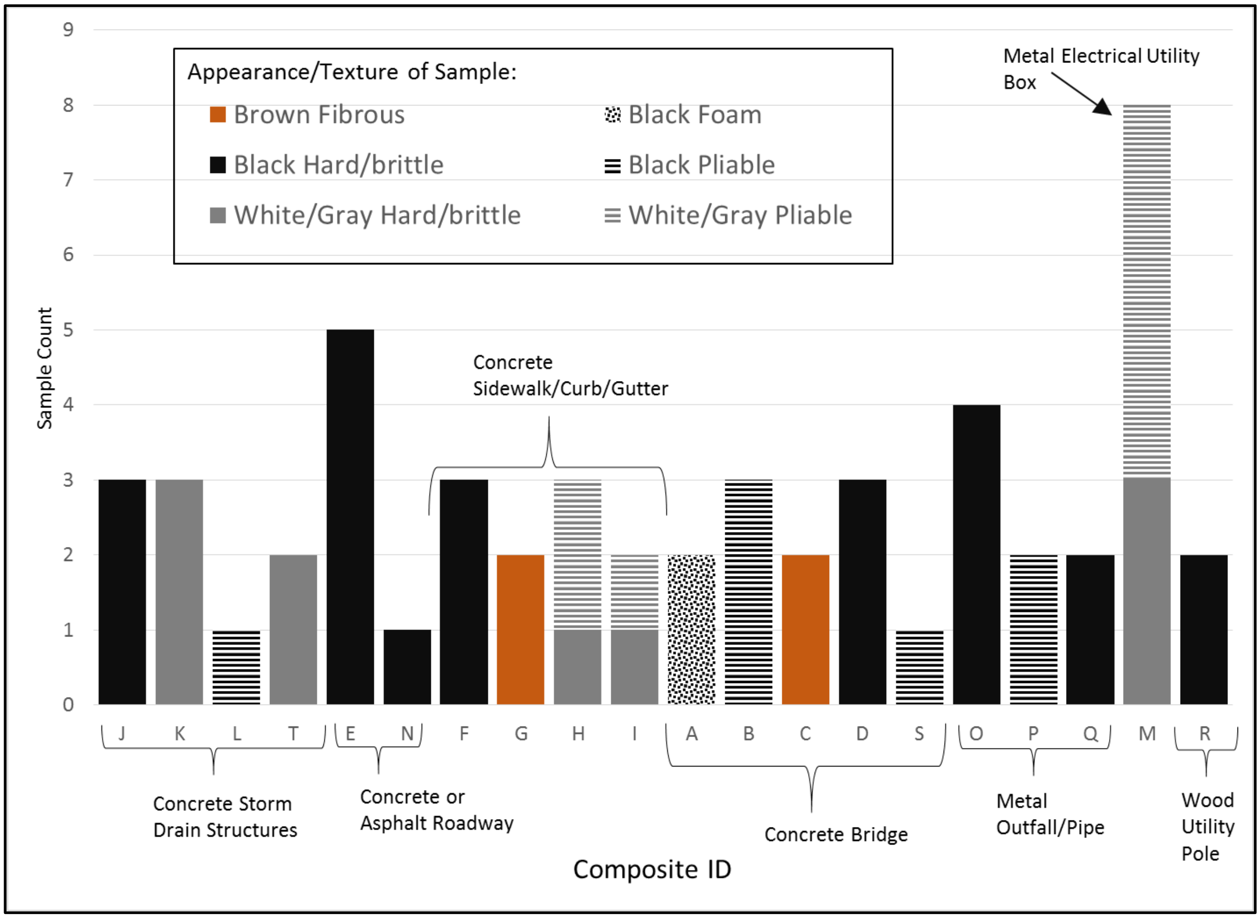

Figure 5.2. Structure types and sample appearance for the caulk and sealant samples included in each composite.

Total PCBs concentrations across the 20 composite samples ranged from non-detect (ND) to > 4,000 mg/Kg. The majority of the composites had PCBs concentrations that were below 0.2 mg/Kg. PCBs were not detected in ten of the composite samples, representing nearly 60% of the individual samples collected during the program. PCBs in twenty-five percent (5 of 20) of the composites were above 1 mg/Kg. Of these, two composites had very high PCBs concentrations (> 1,000 mg/Kg) that indicate PCBs were likely part of the original caulk or sealant formulations. Both of these composites were comprised of black, pliable joint filler materials that were collected from concrete bridges/overpasses. These results demonstrate that PCBs-containing caulks and sealants were used to some degree in Bay Area roadway and storm drain infrastructure in the past, but the full extent and magnitude of this use is unknown. The conclusions from this sampling program are limited by the small number of structures that were sampled (n=54), compared with the vast number of roadway and storm drain structures throughout the Bay Area that were originally constructed during the peak period of PCBs production and use (1950 – 1980).

Given the limitations of the project, much more information would be needed to estimate the total mass of PCBs in infrastructure caulk and sealant materials, to better understand the fate and transport of PCBs in these materials, and to calculate stormwater loading estimates. Nevertheless, this screening-level sampling program was the first step towards understanding if infrastructure caulk and sealants are a potential source of PCBs to urban stormwater. Although limited by the small sample number, the results of this sampling program indicate: (1) the majority of roadway and storm drain structure types that were sampled in this project did not have PCBs-containing caulks or sealants at concentrations of concern, and (2) only black, pliable joint fillers found on concrete bridges/overpasses sampled had PCBs concentrations of potential concern. If further investigation is conducted, focus on this type of application may be a reasonable place to continue such efforts.

The final project report was included with the Program's Fiscal Year 2017/18 Annual Report, submitted to the Regional Water Board on September 30, 2018 (BASMAA 2018).

5.2.2 Best Management Practices (BMP) Effectiveness Study

The BASMAA Best Management Practices (BMP) Effectiveness Study was developed to satisfy provision C.8.f requirements to collect at least eight PCBs and mercury samples (per participating county) that address Management Question #3 (Management Action Effectiveness). A major consideration of the study was collection of data in support of conducting the Reasonable Assurance Analysis (RAA) that is required by provision C.12.c.iii.(3). The RAA must be submitted with the 2020 Annual Report (September 30, 2020). The study design, developed in September 2017, describes monitoring and sample collection activities designed to evaluate, at a pilot scale, the effectiveness of two treatment options that were identified in the CW4CB study as having the potential to reduce PCBs discharges: biochar- enhanced bioretention filters and hydrodynamic separator (HDS) units. In WY 2018, the BASMAA project team implemented the BMP Effectiveness Study by collecting a total of 34 samples. Results of the study are summarized in two reports addressing the two targeted treatment options. These reports are submitted with this WY 2018 Urban Creeks Monitoring Report as **Appendices D and E**.

Biochar-Amended Bioretention Soil Media Column Study

This regional study evaluated the effectiveness of biochar-amended bioretention soil media (BSM) to remove PCBs and mercury from stormwater runoff collected within the region covered by the MRP. A prior BASMAA study, the CW4CB project, found that BSM amended with biochar substantially improved PCBs removal compared to the standard BSM specified in MRP Provision C.3 (BASMAA 2017a). Only one biochar source was tested in the CW4CB study, so it was unknown whether there would be substantial performance differences among differing biochar sources.

The goal of this study was to identify readily available biochar media amendments that improve PCBs and mercury load removal by bioretention BMPs. Stormwater runoff was collected in March and April of 2018, and the bench scale BSM testing was conducted in April and May of 2018. Twenty-six samples consisting of influent/effluent pairs from column tests of biochar-enhanced BSM were analyzed. Stormwater runoff was run through six columns with five different biochar-enhanced BSM mixes and one standard BSM as a control to evaluate which mix was most effective at removing PCBs and mercury. Dilutions were run on two columns to assess removal efficiencies with decreasing influent pollutant concentrations. Samples were analyzed for the RMP 40 PCB congeners (method EPA 1668C), total mercury (method EPA 1631E), SSC (method ASTM D3977-97), and total organic carbon (method EPA 9060).

All five biochar-BSM blends showed evidence of overall improved PCBs and mercury performance compared to the standard BSM; however, the increased benefit relative to increased cost was not analyzed. Hydraulics were found to be a critical factor in achieving good pollutant removal in the columns suggesting that outlet controls could be used to enhance the performance of BMPs. Furthermore, this study suggested that an irreducible minimum concentration of PCBs may be 1,000 pg/L.

The final project report is included as **Appendix D**.

HDS Unit Study

The goal of the BASMAA Evaluation of Mercury and PCBs Removal Effectiveness of Full Trash Capture HDS Units study was to evaluate the mercury and PCBs removal effectiveness of HDS units due to removal of solids captured within HDS sumps. The information provided by this monitoring effort will be used by MRP Permittees and the Regional Water Board to better quantify the pollutant load reductions achieved by existing and future HDS units installed in urban watersheds of the Bay Area to remove trash.

The study combined sampling and modeling efforts to evaluate the mercury and PCBs removal performance of HDS units as follows:

- First samples of the solids captured and removed from eight HDS unit sumps during cleanouts were collected and analyzed for the RMP 40 PCB congeners (method EPA 1668), total mercury (method EPA 1631E), total solids[14] (method EPA 160.3), total organic carbon (method EPA 415.1), and bulk density (method ASTM E1109-86). If the sample was comprised of sediments only, it was also analyzed for grain size (method ASTM D422M/PSEP). If the sample contained organic/leaf debris, it was also analyzed for total organic matter (method EPA 160.4) in order to calculate the inorganic fraction (i.e., the mineral fraction assumed to be associated with POCs).

- Second, maintenance records and construction plans for the HDS units were reviewed to develop estimates of the average volume of solids removed per cleanout. This information was combined with the monitoring data to calculate the mass of POCs removed during cleanouts.

- Third, the annual mercury and PCBs loads discharged from each HDS unit catchment were estimated under two different loading scenarios. For the first loading scenario (Land Use x Yield), the POC loads discharged from each catchment were calculated from land-use based POC yields. For the second loading scenario (Flow x EMC), the POC loads discharged from each catchment were calculated from modeled stormwater volumes and POC event mean concentrations (EMCs) for a given land-use type.

- Finally, HDS unit performance was evaluated under each loading scenario by calculating the average annual percent removal of POCs due to cleanout of solids from the HDS unit sumps.

Across all eight units, the median percent PCBs removal for calculated catchment loads ranged from 5% to 32%. These results will be considered in the update to the Interim Accounting Methodology that is being conducted as part of a separate BASMAA regional study in support

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[14] Samples were analyzed for total solids so that dry weight calculations could be made.

of Reasonable Assurance Analysis development.

The final project report is included as **Appendix E**.

5.3 Small Tributaries Loading Strategy

The RMP Small Tributaries Loading Strategy was developed in 2009 by the STLS Team, which includes representatives from BASMAA, Regional Water Board staff, RMP staff, and technical advisors and is overseen by the Sources, Pathways, and Loadings Workgroup (SPLWG). The objective of the STLS is to develop a comprehensive planning framework to coordinate POC monitoring/modeling between the RMP and RMC participants. In 2018, the following management policies were identified:

- Refining pollutant loading estimates for future TMDL updates;
- Informing provisions of the current and future versions of the MRP;
- Identifying small tributaries to prioritize for management actions; and
- Informing decisions on the BMPs for reducing pollutant concentrations and loads.

Work conducted by the STLS is framed by the same five priority POC management information needs identified in the MRP (see beginning of Section 5.0).

The sections below describe the tasks implemented by the RMP STLS in 2018 to address the relevant management policies.

5.3.1 Wet Weather Characterization

With a goal of identifying watershed sources of PCBs and mercury, STLS field monitoring in WYs 2015 - 2018 focused on collection of stormwater runoff composite samples in the downstream reaches of catchments located throughout the Bay Area. In WY 2018, 10 catchments were sampled during storm events. The 10 catchments ranged in size from 0.02 km^2 to 36.67 km^2 and represented engineered MS4 drainage areas, flood control channels, and creeks. Half of the WY 2018 samples were collected at previously sampled stations in order to compare to concentrations previously measured. Stormwater runoff composite samples were analyzed for concentrations of PCBs (i.e., RMP 40 congeners), total mercury, and suspended sediment concentration. In addition, a pilot study was continued at a subset of locations (two stations) to collect fine sediments using specialized settling chambers. A full description of the methods and results from WY 2015 through WY 2018 monitoring is included in **Appendix F** (Pollutants of Concern Reconnaissance Monitoring Final Progress Report, Water Years 2015 - 2018).

In WY 2018, two catchments, both in the City of South San Francisco and previously sampled in WY 2016, were targeted based on recommendations by SMCWPPP staff evaluating prior monitoring results and land uses in San Mateo County. PCBs concentrations in the WY 2016 samples were relatively low, and concentrations (total PCBs and particle ratio) were roughly an order of magnitude higher in WY 2018, except that the PCBs particle ratio for one sample was similar for both events (for more details see Section 5.1.1 and Appendix C). SMCWPPP is applying these data to the WMA prioritization process (see Section 5.1.1 and Appendix C), which will inform future POC monitoring in San Mateo County and PCBs control measure planning.

Wet weather characterization monitoring by the RMP STLS is planned to continue in WY 2019.

Findings

The RMP STLS has a growing database of nearly 83 stations that have been sampled at least once during wet weather events for PCBs, mercury, and SSC since 2003. Some stations have also been sampled for a larger suite of constituents. Prior to WY 2015, most of the stations were located in natural creeks, whereas 49 of the 60 stations sampled in WY 2015 through WY 2018 were located in small catchments draining primarily old industrial land uses. At 15 of the stations, a second sample was collected with either a Hamlin or Walling tube (or both) remote sediment sampler.

Acknowledging that dynamic climatic conditions and individual storm characteristics may affect data interpretation, the following conclusions have been identified:

- PCBs concentrations positively correlate with impervious cover, old industrial land use, and mercury. They inversely correlate with watershed area.
- The positive relationship between PCBs and mercury concentration is relatively weak, probably due to the larger role of atmospheric recirculation in the mercury cycle and the differences in use history of each POC.
- Neither PCBs nor mercury have strong correlations with other trace metals (As, Cu, Cd, Pb, and Zn). Therefore, there is no support for the use of trace metals as surrogate investigative tools for either PCBs or mercury sources.
- Remote samplers generally characterized sites similarly to the composite stormwater sampling methods and in the future could potentially be used exclusively for preliminary screening of new stations to identify watershed sources of PCBs and mercury.
- Continued focus on resampling of some stations (i.e., those that return lower than expected concentrations) is recommended to test for false negatives.

5.3.2 STLS Trends Strategy

In 2018, the STLS Trends Strategy team continued to meet. The STLS Trends Strategy was initiated in 2015 per a recommendation from the SPLWG. The SPLWG advised the STLS to define where and how trends may be most effectively measured in relation to management effort so that data collection methods deployed over the next several years will support this management information need. The STLS Trends Strategy team is comprised of SFEI staff, RMC participants, and Regional Water Board staff. Invitations to key meetings are extended to additional interested parties (e.g., EPA) and technical advisors (e.g., USGS), whose staff are consulted to review specific technical work products.

The Trends Strategy document (and Technical Appendix), initially drafted in WY 2016, serves as a foundation for this team. The main document summarizes the background, management questions, and guiding principles of the Trends Strategy. It also describes coordination between the RMP and BASMAA within the context of the MRP, proposed tasks to answer the management questions, anticipated deliverables, and the overall timeline. The current priority POCs are PCBs and mercury and trend indicators under consideration (i.e., PCB concentrations and particle ratios) were identified within the context of existing datasets (e.g., POC loading station data) and TMDL timelines. However, the Strategy recognizes that priorities can change in the future. A “Technical Appendix to the Small Tributaries Trend Design” (Melwani et al. 2016) presents an evaluation of variability and statistical power for detecting trends based on

POC loading station PCBs data. It presents sample size and revisits frequency scenarios needed to detect declining trends in PCBs in 25 years with > 80% statistical power. Due to high variability in baseline PCB concentrations, the modeled sampling scenarios would likely be cost-prohibitive to implement. Therefore, the Technical Appendix recommends additional analyses and monitoring that should be considered prior to developing a trends monitoring design.

In 2018, the STLS Trends Strategy team followed up on some of the recommendations from the Technical Appendix. A statistical model for trends in PCB loads in the Guadalupe River (as a case study) was finalized. The model incorporates the significant turbidity-PCBs relationships that exist and evaluates climatic, seasonal, and inter-annual factors as potential drivers of PCB loads. More intensive review of the Guadalupe River dataset resulted in two main findings: 1) No trends in PCB loads were apparent for the period of 2003 through 2014: 2) A monitoring design that includes sampling at least two storms in 13 out of 20 years (with 4 to 6 grab samples per storm) would detect inter-annual trends of 25% or more over 20 years with > 80% power[15] (Melwani et al. 2018). Results of the statistical analyses were presented at key stages in the analysis to USGS technical advisors with expertise in trends analysis of water data. It is uncertain how the Guadalupe River model and analysis could be applied to other watersheds with different characteristics.

In 2018, the Trends Strategy team updated the Trends Strategy document to include an evaluation of how various tasks to date have and could be used to address the five POC information needs from the MRP (see list at the beginning of Section 5.0). This review included empirical data collection (i.e., POC loads monitoring via loading stations and wet weather characterization, BASMAA source identification and BMP effectiveness monitoring, and SPoT monitoring) and modeling approaches (i.e., RWSM, the Guadalupe River statistical analysis, and Reasonable Assurance Analysis). The updated document describes the pros and cons of various methods available to identify and predict trends. Due to concerns about the limitations of extrapolating monitoring results from a relatively small number of watersheds to the entire region, regional modeling was proposed as the most efficient tool to estimate POC loading over time and space for trends evaluation at the desired spatial scales. The 2018 Trends Strategy document reviews and compares currently available models and modeling platforms relative to their ability to answer key management questions, including countywide stormwater program RAA modeling efforts, the Bay Area Hydrological Model (BAHM), the RWSM, and HSPF and SWMM platforms. Based on the goals of the STLS Trends Strategy team, the BAHM (which is based on the HSPF platform) is recommended as the most suitable starting point to develop a regional POC trends model.

A preliminary multi-year workplan for regional POC trends assessment, with estimates of annual budget allocations, was developed in 2018. The workplan recommends development of a Model Implementation Plan in 2019, model development beginning in 2020, and “no-regrets” monitoring based on the Model Implementation Plan beginning in 2020.

5.3.3 Advanced Data Analysis

In 2018, the STLS began a new task to provide a deeper analysis of the growing set of PCBs data collected by BASMAA and the RMP. The Advanced Data Analysis task includes two

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[15] Power is defined as the probability of detecting a trend of a certain magnitude during a specified monitoring period (years), where a Type I error rate is set at 5%.

parallel lines of investigation: site inter-comparison methodologies and PCBs congener profile comparisons.

Site Inter-Comparison Methodologies

Most of the wet weather characterization data used by the Countywide Program and other BASMAA RMC partners to identify and prioritize Watershed Management Areas where PCBs source investigations will be conducted are based on composite samples collected during a single storm event. See Section 5.1.1 for more information on the wet weather sampling programs implemented by the Countywide Program and the WMA characterization process. Since only one storm has been sampled at most sites, differing storm characteristics (intensity, duration, antecedent rainfall conditions) may confound comparisons of PCBs source intensity among watersheds. For example, if the targeted storm was relatively small, it is possible that measured PCBs concentrations (and/or PCB particle ratios) will be lower than they would be in a sample collected at the same station during a larger storm, when more sediments and associated pollutants may be mobilized. The main goal of this investigation was to develop a method to account for the differences in targeted storm characteristics at the various sampled stations.

In 2018, the STLS began development of a method to generate comparable yield estimates for small industrial watersheds where only a single storm has been sampled. The draft method entails five steps:

1. Estimate stormwater runoff volume in the sampled watershed.
2. Compute estimates of stormwater runoff PCBs load for the sampled storm.
3. Adjust estimates of storm load to a standard sized storm.
4. Normalize standardized storm loads to the land uses and source areas of interest to generate storm yields.
5. Compare these yields between watersheds taking into account all the uncertainties associated with the field conditions and the methods used to interpret the data.

This stepwise method was developed using Santa Clara County as a case study and pilot tested with a focus on nested sites within the Guadalupe River watershed. Further development, review, and testing in a greater number of areas, with a wider range of conditions, is recommended for 2019. A report describing the loads-based site inter-comparison method is anticipated in 2019.

PCBs Congener Profile Comparisons

PCBs samples collected by BASMAA and the STLS are routinely analyzed for 40 individual PCBs congeners (i.e., the “RMP 40”). Although most data analyses are conducted using the sum of those congeners, BASMAA and the STLS recognize the value of generating the more robust RMP 40-based dataset and the potential for future data exploration possibilities. For example, PCBs congener profiles can be used to help identify source areas that contribute most to the PCB mass exported from the watershed via stormwater, and to illustrate variability in PCBs mobilization from source areas over time. It is important to note that weathering of PCBs in the environment over time and other factors may introduce uncertainties into these types of analyses.

In 2018, the STLS began development of a method to estimate the contributions of different Aroclor[16] mixtures to the congener profiles of samples of stormwater and sediment. The method is based on the use of indicator congeners that are representative of each of the four most commonly used Aroclors. Data from the Pulgas Creek Pump Station watershed in San Carlos were used to pilot test the method. At this station, stormwater and sediment had high concentrations with a relatively unique pattern, dominated by congeners indicative of a combination of Aroclors 1242 and 1260. The concentrations and congener profiles in sediment suggest that there are at least two distinct source areas in the watershed that combine to create the mix of 1242 and 1260 that is dominant in stormwater runoff at the Pump Station (Figure 5.3). The data suggest that if PCBs flux from one of these areas could be eliminated, loads from the watershed would be reduced by 50% or more.

For the Coyote Creek watershed in San Jose, the similarity in congener profiles between the highest concentration sediment samples and the stormwater runoff samples suggest that the important source areas in the watershed have been identified, and that reduction of loading from an area at the south end of the Charcot Avenue Storm Drain watershed would yield the greatest reduction in export at the Coyote Creek station. The concentrations and congener profiles in stormwater runoff and sediment from the Guadalupe River watershed indicate the presence of one source area that is likely a significant contributor to PCBs export from the watershed, but suggest that all of the significant sources areas may not yet have been identified.

A report describing the PCB congener profile comparison method is anticipated in 2019.

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[16] PCBs were manufactured and used as complex mixtures of individual PCBs compounds (referred to as PCBs congeners). In North America, the only producer was the Monsanto Company, which marketed PCBs under the trade name Aroclor from 1930 to 1977. A series of different Aroclor mixtures was produced, with varying degrees of overall chlorine content, and these different mixtures were used for different purposes. As a consequence of the use of Aroclor mixtures, PCBs are also present in the environment as complex mixtures of congeners.

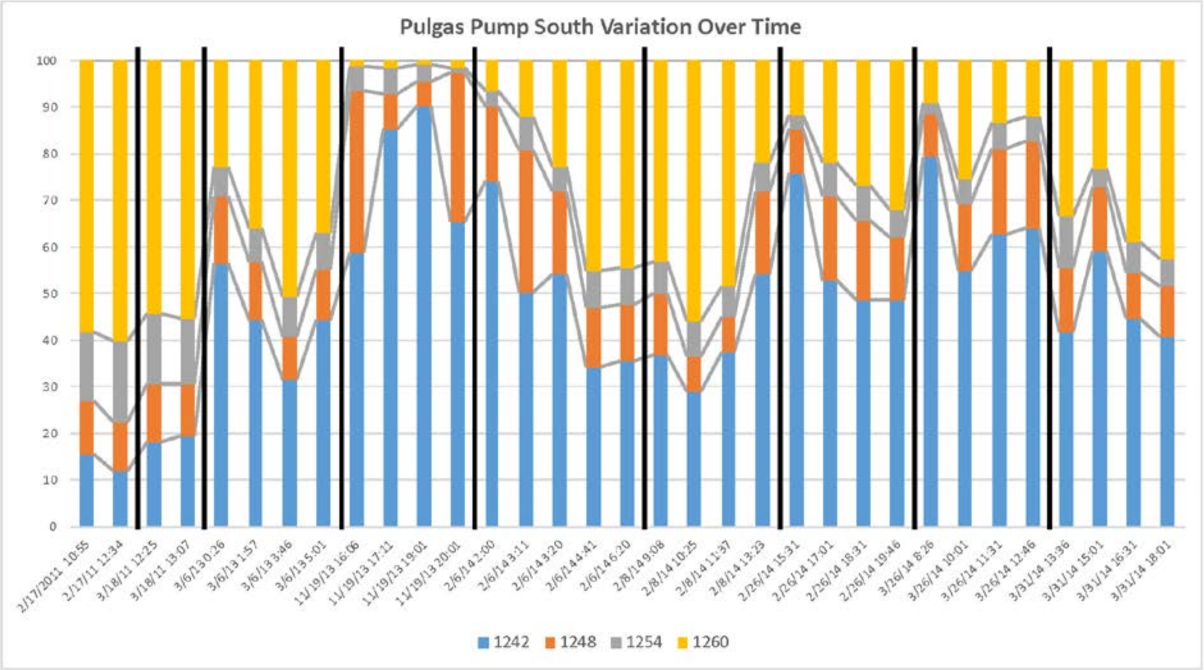

Figure 5.3. Aroclor indices in stormwater at the outlet of Pulgas Creek Pump Station South over time (figure produced by SFEI, 2018).

5.3.4 Alternative Flame Retardant Conceptual Model

Alternative flame retardants (AFRs) came into use following state bans and nationwide phase-outs of polybrominated diphenyl ether (PBDE) flame retardants in the early 2000's. They include many categories of compounds, including organophosphate esters. In 2018 the RMP STLS and the Emerging Contaminant Workgroup (ECWG) worked together to conduct a special study to inform ECWG's planning activities related to AFRs. The special study compiled and reviewed available data and previously developed conceptual models for PBDE to support a stormwater-related AFR conceptual model being developed by the ECWG. Organophosphate esters were prioritized for further investigation due to their increasing use, persistent character, and ubiquitous detections at concentrations exceeding PBDE concentrations in the Bay. Limited stormwater runoff data from two watersheds in Richmond and Sunnyvale suggest that urban runoff may be an important source of these compounds. Additional monitoring and modeling were recommended. Results of the AFR special study were published in a technical report in 2018 (Lin and Sutton 2018).

5.3.5 Regional Watershed Spreadsheet Model

The Regional Watershed Spreadsheet Model (RWSM) is a land use based planning tool for regional scale estimation of annual POC loads from small tributaries to San Francisco Bay. Development of the RWSM began in 2010 and, in 2018, the STLS Team continued to provide support of the RWSM tool-kit that was published in 2017.

The RWSM is based on the idea that to accurately assess total contaminant loads entering San Francisco Bay, it is necessary to estimate loads from local watersheds. "Spreadsheet models" of stormwater quality provide a useful and relatively inexpensive means of estimating regional scale watershed loads. Spreadsheet models have advantages over mechanistic models because the data for many of the input parameters required by mechanistic models may not currently exist; mechanistic models also require large calibration datasets which require a significant investment of time and resources to collect.

The RWSM is based on the assumption that an estimate of mean annual runoff **volume** for each land use type within a watershed can be combined with an estimate of mean annual pollutant **concentration** for that same land use type to derive a pollutant **load** which can be aggregated for a watershed or many watersheds within a region of interest. It may be used to provide hypotheses about which sub-regions or watersheds export relatively higher or lower loads to the Bay relative to area. It can also serve as a baseline for analyzing changes in loadings due to large scale changes in land use (e.g., associated with redevelopment and new development) and runoff (e.g., associated with climate change and changes in impoundment). However, the RWSM is less reliable for predicting loadings from individual watersheds and for estimating load changes in relation to implementation of treatment BMPs.

The RWSM beta tool-kit, published in June 2017 includes:

- Hydrology Model coded using ArcPy and drawing on a user interface accessible through ArcGIS;
- Pollutant Model Spreadsheet for taking the outputs from the Hydrology Model and inputting land use coefficients to estimate pollutant loads;
- Two optional calibration tools – a spreadsheet for manual calibration, and an R script for an optimized automated calibration; and
- User Manual.

Testing of the RWSM beta tool-kit by some of the BASMAA RMC partners began in WY 2017 and continued into WY 2018. The STLS will continue to support the RWSM in WY 2019. If warranted, and in consultation with the STLS and the SPLWG, a more sophisticated dynamic simulation model (i.e., SWMM, HSPF) may be developed in future years. As the modeling team at SFEI becomes more proficient with alternative water-based platforms (i.e., SWMM, HEC-RAS) through development of the Green Plan-IT tool, a more sophisticated basis may be adopted in future years. Decisions on model improvements will be made in consultation with the STLS and the SPLWG.

6.0 Next Steps

Water quality monitoring required by Provision C.8 of the MRP is intended to assess the condition of water quality in Bay Area receiving waters (creeks and the Bay); identify and prioritize stormwater associated impacts, stressors, sources, and loads; identify appropriate management actions; and detect trends in water quality over time and the effects of stormwater control measure implementation. On behalf of San Mateo County Permittees, SMCWPPP conducts creek water quality monitoring and other monitoring projects in San Mateo County in collaboration with the BASMAA Regional Monitoring Coalition, and actively participates in the Regional Monitoring Program for Water Quality in San Francisco Bay, which focuses on assessing Bay water quality and associated impacts.

In WY 2019, SMCWPPP will continue to comply with water quality monitoring requirements of the MRP. Specifically, in WY 2019 SMCWPPP will continue to:

- Collaborate with the RMC (MRP Provision C.8.a);
- Where applicable, collect and report monitoring data that are compatible with SWAMP (MRP Provision C.8.b);
- Provide financial contributions towards the RMP and will assist San Mateo County Permittees and BASMAA to actively participate in the RMP committees and work groups described in Sections 2.0 and 5.0 (MRP Provision C.8.c);
- Conduct probabilistic and targeted creek status monitoring consistent with the specific requirements of MRP Provision C.8.d;
- Conduct pesticides and toxicity monitoring consistent with MRP Provision C.8.g;
- Review water quality monitoring results and maintain a list of all results exceeding trigger thresholds (MRP Provision C.8.e.i). SMCWPPP will coordinate with the RMC to initiate eight new SSID projects by the end of the permit term (MRP Provision C.8.e.iii). This will include implementation of the Pillar Point Harbor Bacteria SSID Project and participation in the regional SSID project addressing releases of PCBs from electrical utility equipment.
- Participate in the STLS and SPLWG which address MRP Provision C.8.f POC management information needs and monitoring requirements through wet weather characterization monitoring, refinement of the RWSM, and development and implementation of the STLS Trends Strategy.
- Implement a POC monitoring framework to comply with Provision C.8.f of the MRP. The monitoring framework addresses the annual and total minimum number of samples required for each POC (i.e., PCBs, mercury, copper, emerging contaminants, nutrients) and each management information need (i.e., Source Identification, Contributions to Bay Impairment, Management Action Effectiveness, Loads and Status, Trends). WY 2019 monitoring will include collection of 25 dry weather grab sediment samples from the public right-of-way to attempt to identify sources of PCBs to urban runoff. The sampling plan will be informed by SMCWPPP's process to prioritize Watershed Management Areas (WMAs). WY 2018 monitoring will also include sampling for nutrients and copper.
- WY 2019 POC monitoring accomplishments and allocation of sampling efforts for POC monitoring in WY 2020 will be submitted in the Pollutants of Concern Monitoring Report that is due to the Water Board by October 15, 2019 (MRP Provision C.8.h.iv).

Results of WY 2019 monitoring will be described in the Programs Integrated Monitoring Report (IMR) that is due to the Water Board by March 31, 2020 in lieu of the annual Urban Creeks Monitoring Report (MRP Provision C.8.h.v). This report will be part of the Report of Waste Discharge for the reissuance of the MRP. The IMR will contain a comprehensive analysis of all data collected pursuant to provision C.8 since the previous IMR which was submitted on March 31, 2014 and included WY 2012 and WY 2013 monitoring data. A major component of the IMR will be evaluation of eight years (WY 2012 – WY 2019) of probabilistic bioassessment monitoring data. Overall stream condition in San Mateo County will be evaluated using the BMI-based CSCI and other available IBIs. Stressors associated with poor condition will be evaluated using the statistical tools implemented by BASMAA in the RMC 5-Year Report.

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Appendix A

SMCWPPP Creek Status Monitoring Report, Water Year 2018

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

Appendix A

SMCWPPP Creek Status Monitoring Report

Water Year 2018 (October 2017 – September 2018)

Submitted in compliance with Provision C.8.h.iii of
NPDES Permit No. CAS612008 (Order No. R2-2015-0049)

March 31, 2019

Preface

In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA) joined together to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (in this document the permit is referred to as MRP)[1]. The RMC is comprised of the following participants:

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

This Creek Status Monitoring Report complies with provision C.8.h.iii of the MRP for reporting of all data in Water Year 2018 (October 1, 2017 through September 30, 2018). Data were collected pursuant to Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) of the MRP. Data presented in this report were produced under the direction of the RMC and the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) using probabilistic and targeted monitoring designs as described herein.

Consistent with the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), monitoring data were collected in accordance with the most recent versions of the BASMAA RMC Quality Assurance Project Plan (QAPP; BASMAA, 2016a) and BASMAA RMC Standard Operating Procedures (SOPs; BASMAA, 2016b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP)[2]. Data presented in this report were also submitted in electronic SWAMP-comparable formats by SMCWPPP to the San Francisco Bay Regional Water Quality Control Board on behalf of San Mateo County Permittees and pursuant to Provision C.8.h.ii of the MRP.

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[1] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB or Regional Water Board) issued the MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). On November 19, 2015, the Regional Water Board updated and reissued the MRP (SFRWQCB 2015). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley, which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

[2] The current SWAMP QAPrP is available at: https://www.waterboards.ca.gov/water_issues/programs/swamp/qapp/swamp_QAPrP_2017_Final.pdf

List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
AFDM	Ash Free Dry Mass
AFS	American Fisheries Society
ASCI	Algae Stream Condition Index
BASMAA	Bay Area Stormwater Management Agency Association
BMI	Benthic Macroinvertebrate
C/CAG	City/County Association of Governments
CCCWP	Contra Costa Clean Water Program
CDFW	California Department of Fish and Wildlife
COLD	Cold Freshwater Habitat
CSCI	California Stream Condition Index
DO	Dissolved Oxygen
DPR	Department of Pesticide Regulation
EDD	Electronic Data Delivery
FSURMP	Fairfield Suisun Urban Runoff Management Program
GIS	Geographic Information System
GRTS	Generalized Random Tessellation Stratified
IBI	Index of Biological Integrity
IPI	Index Physical Habitat Integrity
IPM	Integrated Pest Management
LID	Low Impact Development
MDL	Method Detection Limit
MIGR	Fish Migration
MPC	Monitoring and Pollutants of Concern Committee
MPN	Most Probable Number
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
MUN	Municipal Beneficial Use
MWAT	Maximum Weekly Average Temperature
NPDES	National Pollutant Discharge Elimination System
NT	Non-Target
O/E	Observed to Expected
PAH	Polycyclic Aromatic Hydrocarbons

PCBs	Polychlorinated Biphenyls
PEC	Probable Effects Concentrations
PHAB	Physical Habitat Assessments
pMMI	Predictive Multimetric Index
PSA	Perennial Streams Assessment
QAPP	Quality Assurance Project Plan
QAPrP	Quality Assurance Program Plan
QA/QC	Quality Assurance/Quality Control
RARE	Preservation of Rare and Endangered Species
RM	Reporting Module
RMC	Regional Monitoring Coalition
RWB	Reachwide Benthos
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFRWQCB	San Francisco Bay Regional Water Quality Control Board
SMC	Southern California Monitoring Coalition
SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Protocol
SPWN	Fish Spawning
SRP	Stormwater Resource Plan
SSID	Stressor/Source Identification
SWAMP	Surface Water Ambient Monitoring Program
SWPP	Surface Water Protection Program
TEC	Threshold Effects Concentrations
TMDL	Total Maximum Daily Load
TNS	Target Non-Sampleable
TOC	Total Organic Carbon
TS	Target Sampleable
TU	Toxicity Unit
UCMR	Urban Creeks Monitoring Report
USEPA	Environmental Protection Agency
WARM	Warm Freshwater Habitat
WQO	Water Quality Objective
WY	Water Year

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Attachment 1. QA/QC Report

Attachment 2. RMC 5-Year Report

1.0 Introduction

This Creek Status Monitoring Report was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP or Program). SMCWPPP is a program of the City/County Association of Governments (C/CAG) of San Mateo County. Each incorporated city and town in the county and the County of San Mateo share a common National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP). The MRP was first adopted by the San Francisco Regional Water Quality Control Board (SFRWQCB or Regional Water Board) on October 14, 2009 as Order R2-2009-0074 (SFRWQCB 2009; referred to as MRP 1.0). On November 19, 2015, the Regional Water Board updated and reissued the MRP as Order R2-2015-0049 (SFRWQCB 2015; referred to as MRP 2.0). This report fulfills the requirements of Provision C.8.h.iii of the MRP for comprehensively interpreting and reporting all Creek Status and Pesticides & Toxicity monitoring data collected during the foregoing October 1 – September 30 (i.e., Water Year 2018) [3]. Data were collected pursuant to water quality monitoring requirements in Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) of the MRP. Monitoring data presented in this report were submitted electronically to the Regional Water Board by SMCWPPP and may be obtained via the San Francisco Bay Area Regional Data Center of the California Environmental Data Exchange Network (CEDEN).[4]

Sections of this report are organized according to the following topics:

- **Section 1.0** – Introduction including overview of the Program goals, background, monitoring approach, and statement of data quality
- **Section 2.0** – Biological condition assessment and stressor analysis at probabilistic sites
- **Section 3.0** – Continuous water quality monitoring (temperature, general water quality)
- **Section 4.0** – Pathogen indicators
- **Section 5.0** – Chlorine monitoring
- **Section 6.0** – Pesticides & Toxicity monitoring
- **Section 7.0** – Conclusions and recommendations

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[3] Monitoring data collected pursuant to other C.8 provisions (e.g., Pollutants of Concern Monitoring, Stressor/Source Identification Monitoring Projects) are reported in the SMCWPPP Urban Creeks Monitoring Report (UCMR) for WY 2018 to which this Creek Status Monitoring Report is appended.

[4] http://water100.waterboards.ca.gov/ceden/sfei.shtml

1.1 Monitoring Goals

Provision C.8.d of the MRP requires Permittees to conduct creek status monitoring that is 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 water supportive of or likely supportive of beneficial uses?***

The first management question is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in the MRP. (A summary of trigger exceedances observed for each site is presented in Table 7.1.) Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of Stressor/Source identification (SSID) projects.

The second management question is addressed by assessing indicators of beneficial uses. For example, the indices of biological integrity based on benthic macroinvertebrate and algae data are direct measures of aquatic life beneficial uses. Continuous monitoring data (temperature, dissolved oxygen, pH, and specific conductance) are evaluated with respect to COLD and WARM Beneficial Uses. Pathogen indicator data are used to assess REC-1 (water contact recreation) Beneficial Uses.

Creek Status and Pesticides & Toxicity monitoring parameters, methods, occurrences, durations and minimum number of sampling sites are described in Provisions C.8.d and C.8.g of the MRP, respectively. The monitoring requirements in the 2015 MRP are similar to the 2009 MRP requirements (which began implementation on October 1, 2011) and build upon earlier monitoring conducted by SMCWPPP. Creek Status and Pesticides & Toxicity monitoring is coordinated through the Regional Monitoring Coalition (RMC). Monitoring results are evaluated to determine whether triggers are met and further investigation is warranted as a potential Stressor/Source Identification (SSID) Project, as described in Provision C.8.e of the MRP. Results of Creek Status Monitoring conducted in Water Years 2012 through 2017 were submitted in prior reports (SMCWPPP 2018, SMCWPPP 2017, SMCWPPP 2016, SMCWPPP 2015, SMCWPPP 2014).

1.2 Regional Monitoring Coalition

Provision C.8.a (Compliance Options) of the MRP allows Permitees to address monitoring requirements through a regional collaborative effort, their Stormwater Program, and/or individually. The RMC was formed in early 2010 as a collaboration among a number of the Bay Area Stormwater Management Agencies Association (BASMAA) members and MRP Permittees (Table 1.1) to develop and implement a regionally coordinated water quality monitoring program to improve stormwater management in the region and address water quality monitoring required by the MRP[5]. Implementation of the RMC's Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012) allows Permittees and the Regional Water Board to improve their ability

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[5] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the first five-year MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). 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.

to collectively answer core management questions in a cost-effective and scientifically rigorous way. Participation in the RMC is facilitated through the BASMAA Monitoring and Pollutants of Concern (MPC) Committee.

Table 1.1. Regional Monitoring Coalition participants.

Stormwater Programs	RMC Participants
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and, Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and, Zone 7
Contra Costa Clean Water Program (CCCWP)	Cities 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 County Wide Water Pollution Prevention Program (SMCWPPP)	Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees	City of Vallejo and Vallejo Flood and Wastewater District

The goals of the RMC are to:

1. Assist Permittees in complying with requirements in MRP Provision C.8 (Water Quality Monitoring);

2. Develop and implement regionally consistent creek monitoring approaches and designs in the Bay Area, through the improved coordination among RMC participants and other agencies (e.g., Regional Water Board) that share common goals; and

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

The RMC's monitoring strategy for complying with Creek Status monitoring is described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). The strategy includes regional ambient/probabilistic monitoring and local "targeted" monitoring. The combination of these two components allows each individual RMC participating program to assess the status of beneficial uses in local creeks within its 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). The 2015 MRP, specifically prescribes the probabilistic/targeted approach and most of the other details of the RMC Creek Status and Long-Term Trends Monitoring Plan. Table 1.2 provides a list of which parameters are included in the probabilistic and targeted programs in the 2015 MRP. This report includes data collected in San Mateo County under both monitoring components. Data are organized into report sections that reflect the format of monitoring requirements in the MRP.

Table 1.2. Creek Status Monitoring parameters in compliance with MRP Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) and associated monitoring component.

Monitoring Elements	Monitoring Component		Report Section
	Regional Ambient (Probabilistic)	Local (Targeted)	
Creek Status Monitoring (C.8.d)			
Bioassessment & Physical Habitat Assessment	X	(X)[1]	2.0
Nutrients	X	(X)[1]	2.0
General Water Quality (Continuous)		X	3.0
Temperature (Continuous)		X	3.0
Pathogen Indicators		X	4.0
Chlorine	X	(X)[2]	5.0
Pesticides & Toxicity Monitoring (C.8.g)			
Water Toxicity		X	6.0
Water Chemistry		X	6.0
Sediment Toxicity		X	6.0
Sediment Chemistry		X	6.0

Notes:
[1] Provision C.8.d.i.(6) allows for up to 20% of sample locations to be selected on a targeted basis.
[2] Provision C.8.d.ii.(2) provides options for probabilistic or targeted site selection. In WY 2018, chlorine was measured at probabilistic sites.

1.3 Monitoring and Data Assessment Methods

1.3.1 Monitoring Methods

Water quality data were collected in accordance with California Surface Water Ambient Monitoring Program (SWAMP) comparable methods and procedures described in the BASMAA RMC Standard Operating Procedures (SOPs; BASMAA 2016b) and the associated Quality Assurance Project Plan (QAPP; BASMAA 2016a). These documents are updated as needed to maintain their currency and optimal applicability. Where applicable, monitoring data were collected using methods comparable to those specified by the SWAMP Quality Assurance Program Plan (QAPrP)[6], and were submitted in SWAMP-compatible format to the Regional Water Board. The SOPs were developed using a standard format that describes health and safety cautions and considerations, relevant training, site selection, and sampling methods/procedures, including pre-fieldwork mobilization activities to prepare equipment, sample collection, and de-mobilization activities to preserve and transport samples.

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[6] The current SWAMP QAPrP is available at: https://www.waterboards.ca.gov/water_issues/programs/swamp/qapp/swamp_QAPrP_2017_Final.pdf

1.3.2 Laboratory Analysis Methods

RMC participants, including SMCWPPP, agreed to use the same laboratories for individual parameters (except pathogen indicators), developed standards for contracting with the labs, and coordinated quality assurance samples. 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 described in BASMAA (2016a). Analytical laboratory contractors included:

- BioAssessment Services, Inc. – Benthic macroinvertebrate (BMI) identification
- EcoAnalysts, Inc. – Algae identification
- CalTest, Inc. – Sediment chemistry, nutrients, chlorophyll a, ash free dry mass
- Pacific EcoRisk, Inc. - Water and sediment toxicity
- Alpha Analytical – Pathogen indicators

1.3.3 Data Analysis Methods

Monitoring data generated during WY 2018 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or impacted biological conditions, including exceedances of water quality objectives (WQOs). Creek Status Monitoring and Pesticides & Toxicity Monitoring data must be evaluated with respect to numeric thresholds (i.e., triggers), specified in the “Followup” sections in Provision C.8.d and C.8.g of the MRP (SFRWQCB 2015) that, if not met, require consideration for further evaluation as part of a Stressor/Source Identification project. SSID projects are intended to be oriented toward taking action(s) to alleviate stressors and reduce sources of pollutants. A stepwise process for conducting SSID projects is described in Provision C.8.e.iii.

In compliance with Provision C.8.e.i of the MRP, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects that will be maintained throughout the permit term. Follow-up SSID projects are selected from this list.

1.4 Setting

There are 34 watersheds in San Mateo County draining an area of about 450 square miles. The San Mateo Range, which runs north/south, divides the county roughly in half. The eastern half (“Bayside”) drains to San Francisco Bay and is characterized by relatively flat, urbanized areas along the Bay. The western half (“coastside”) drains to the Pacific Ocean and consists of approximately 50 percent parkland and open space, with agriculture and relatively small urban areas.

The complete list of probabilistic and targeted monitoring sites sampled by SMCWPPP in WY 2018 in compliance with Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides and Toxicity Monitoring) is presented in Table 1.3. Monitoring locations with monitoring parameter(s) are mapped in Figure 1.1. Probabilistic station numbers, generated from the RMC Sample Frame, are provided for all bioassessment locations. Targeted stations numbers, based on SWAMP station numbering methods (BASMAA 2016b), are provided for all targeted monitoring sites.

Table 1.3. Sites and parameters monitored in WY 2018 in San Mateo County.

Map ID [1]	Station ID	Bayside or Coastside	Watershed	Creek Name	Land Use	Latitude	Longitude	Probabilistic	Targeted				
								Bioassessment, Nutrients, General WQ	Chlorine	Pesticides & Toxicity	Temp [2]	Cont WQ [3]	Pathogen Indicators
584	202R00584	Coastal	Pilarcitos Creek	Pilarcitos Creek	NU	37.49547	-122.38512	X	X				
614	202R00614	Coastal	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860	X	X				
3404	202R03404	Coastal	San Pedro Creek	San Pedro Creek	U	37.58203	-122.48719	X	X				
3656	202R03656	Coastal	Pilarcitos Creek	Pilarcitos Creek	U	37.46781	-122.42269	X	X				
3880	202R03880	Coastal	San Gregorio Cr	La Honda Creek	U	37.38759	-122.27219	X	X				
3916	202R03916	Coastal	San Pedro Creek	San Pedro Creek	U	37.59144	-122.50333	X	X				
3508	204R03508	Bayside	Mills Creek	Mills Creek	U	37.59105	-122.37406	X	X				
3528	204R03528	Bayside	San Mateo Creek	San Mateo Creek	U	37.54808	-122.34661	X	X				
3624	205R03624	Bayside	San Francisquito Cr	Bear Creek	U	37.41883	-122.26498	X	X				
3864	205R03864	Bayside	San Francisquito Cr	Hamms Gulch	U	37.36498	-122.22906	X	X				
5	202SPE005	Coastside	San Pedro Creek	San Pedro Creek	U	37.59441	-122.50520			X			
10	204COR010	Bayside	Cordilleras Creek	Cordilleras Creek	U	37.47977	-122.25986			X			
138	202PES138	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860						X
142	202PES142	Coastside	Pescadero Creek	McCormick Creek	NU	37.27757	-122.28635						X
144	202PES144	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27592	-122.28550						X
150	202PES150	Coastside	Pescadero Creek	Jones Gulch	NU	37.27424	-122.26811						X
154	202PES154	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27446	-122.26798						X
19	202SPE019	Coastside	San Pedro Creek	San Pedro Creek	U	37.58853	-122.49943				X		
40	202SPE040	Coastside	San Pedro Creek	San Pedro Creek	U	37.58200	-122.48708				X	X	
50	202SPE050	Coastside	San Pedro Creek	San Pedro Creek	U	37.58198	-122.47819				X		
70	202SPE070	Coastside	San Pedro Creek	San Pedro Creek	NU	37.57974	-122.47371				X	X	
85	202SPE085	Coastside	San Pedro Creek	San Pedro Creek	NU	37.57826	-122.47156				X		

U = urban, NU = non-urban

[1] Map ID applies to Figure 3.1.

[2] Temperature monitoring was conducted continuously (i.e., hourly) April through September.

[3] Continuous water quality monitoring (temperature, dissolved oxygen, pH, specific conductivity) was conducted during two 2-week periods (spring and late summer).

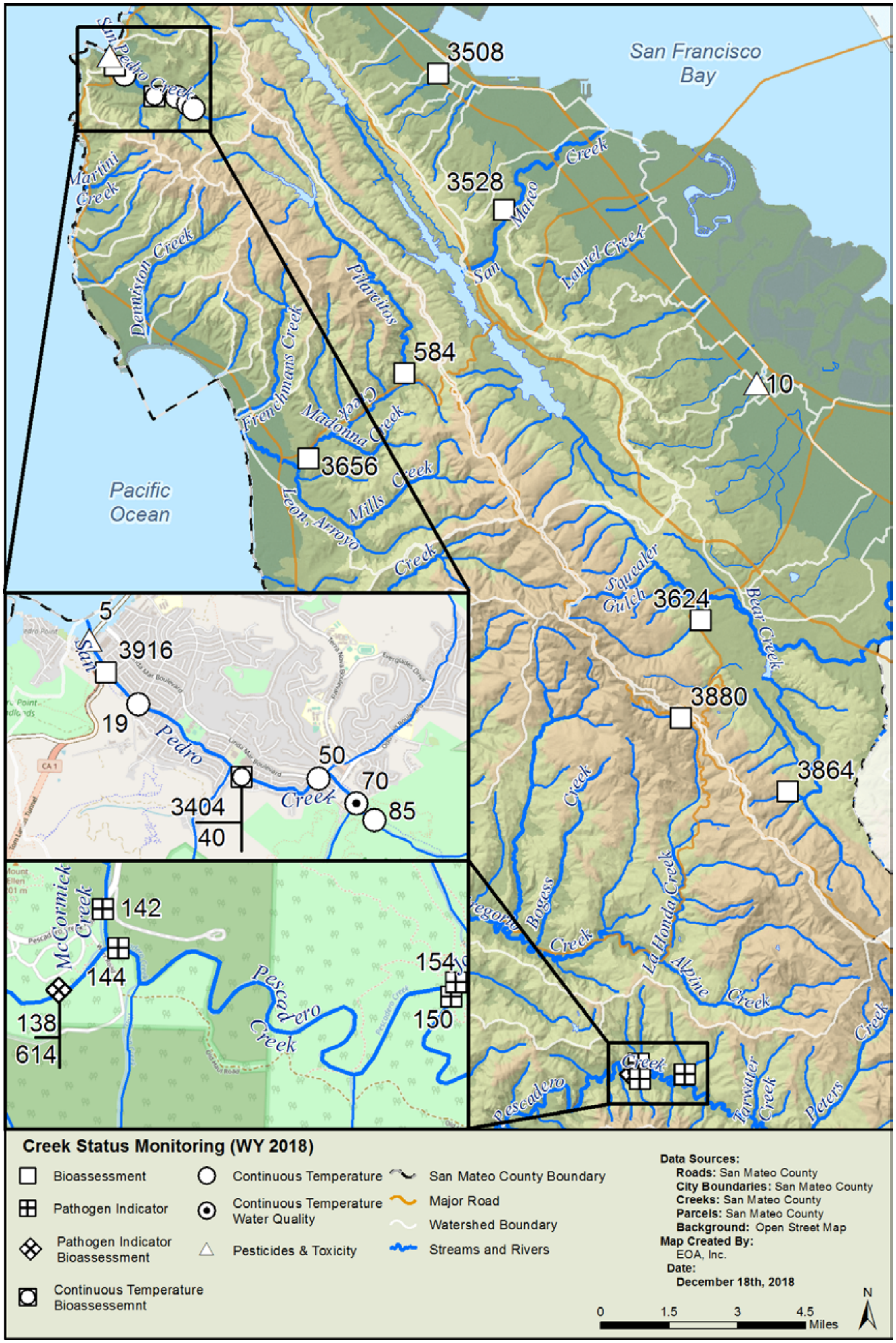

Figure 1.1. Map of SMCWPPP sites monitored in WY 2018.

1.4.1 Designated Beneficial Uses

Beneficial Uses in San Mateo County creeks are designated by the Regional Water Board for specific water bodies and generally apply to all its tributaries. Uses include aquatic life habitat, recreation, agriculture, and municipal supply. Table 1.4 lists Beneficial Uses designated by the SFRWQCB (2017) for water bodies monitored by SMCWPPP in WY 2018.

Table 1.4. Creeks Monitored by SMCWPPP in WY 2018 and their Beneficial Uses (SFRWQCB 2017).

Waterbody	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
Coastside Creeks																			
Pilarcitos Creek	E	E							E			E	E	E	E	E	E	E	
Pescadero Creek	E	E							E			E	E	E	E	E	E	E	
San Pedro Creek		E							E			E	E	E	E	E	E	E	
La Honda Creek									E			E	E	E	E	E	E	E	
Bayside Creeks																			
San Mateo Creek			E						E			E	E	E	E	E	E	E	
Bear Creek									E			E	E	E	E	E	E	E	
Hamms Gulch[1]									E			E	E	E	E	E	E	E	
Mills Creek															E	E	E	E	
Cordilleras Creek															E	E	E	E	

Notes:

[1] No Beneficial Uses listed specifically for waterbody. Table shows Beneficial Uses for receiving waterbody (Bear Creek).

E = Existing Use, P = Potential Use, L = Limited Use

AGR = Agricultural Supply
COLD = Cold Fresh Water Habitat
FRSH = Freshwater Replenishment
GWR - Groundwater Recharge
MIGR = Fish Migration
MUN = Municipal and Domestic Water
SHELL = Shellfish Harvesting
IND = Industrial Service Supply
EST = Estuarine
NAV = Navigation
RARE= Preservation of Rare and Endangered Species
REC-1 = Water Contact Recreation
SPWN = Fish Spawning
COMM = Commercial, and Sport Fishing
REC-2 = Non-contact Recreation
WARM = Warm Freshwater Habitat
WILD = Wildlife Habitat
PROC = Industrial Process Supply
MAR = Marine Habitat

1.4.2 Climate

San Mateo County experiences a Mediterranean-type climate with cool, wet winters and hot, dry summers. The area is characterized by microclimates created by topography, ocean currents, fog exposure, and onshore winds. The wet season typically extends from October through April with local long-term, mean annual precipitation ranging from 20 inches near the Bay to over 40 inches along the highest ridges of the San Mateo Mountain Range (PRISM Climate Group 30-year normals, 1981-2010[7]). Figure 1.2 illustrates the geographic variability of mean annual precipitation in the area. It is important to understand that mean annual precipitation depths are statistically calculated or modeled; actual measured precipitation in a given year rarely equals

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[7] http://www.prism.oregonstate.edu/normals/

the statistical average. Figure 1.3 illustrates the temporal variability in annual precipitation measured at the San Francisco International Airport (SFO) from WY 1946 to WY 2018. This record illustrates that extended periods of drought are common and often punctuated by above average years. Creek Status Monitoring in compliance with the MRP began in WY 2012 which was the first year of a severe statewide drought that persisted through WY 2016. WY 2018 rainfall was below average at SFO but it was preceded by a wet year in WY 2017.

The overall Bay Area climate and the specific conditions within any given year are influenced by global climate change. The Climate Change Assessment report for the Bay Area highlights several impacts of climate change that are already being felt: the Bay Area's average annual maximum temperature increased by nearly 1°C from 1950 – 2005, coastal fog along the coast may be less frequent, sea level in the Bay Area has risen over 8 inches (Ackerly et al. 2018). These changes are projected to increase significantly in the coming decades. As a consequence, heat extremes, high year-to-year variability in precipitation, droughts, intense storms, and other events will also increase.

Climate patterns (e.g., extended droughts) and individual weather events (e.g., extreme storms, hot summers) influence biological communities (i.e., vegetation, wildlife) and their surrounding physical habitat and water quality. They should therefore be considered when evaluating the type of data collected by the Creek Status Monitoring Program. For example, periods of drought (rather than individual dry years) can result in changes in riparian and upland vegetation communities. Long drought periods are associated with increased streambed sedimentation which can persist directly or indirectly for many years, depending on the occurrence and magnitude of flushing flow events. Furthermore, in response to prolonged drought, the relative proportion of pool habitat can increase at the expense of riffle habitat.

It is uncertain what effect these factors have on indices of biotic integrity (IBIs) that are calculated using data collected by the Creek Status Monitoring Program, such as benthic macroinvertebrates or algae. A study evaluating 20 years of bioassessment data collected in northern California showed that, although benthic macroinvertebrate taxa with certain traits may be affected by dry (and wet) years and/or warm (and cool) years, IBIs based on these organisms appear to be resilient (Mazor et al. 2009, Lawrence et al. 2010). However, this study did not specifically examine the impact of longer *periods* of extended drought or heat on IBIs, which would require analysis of a dataset with a much longer period of record. The Herbst Lab at the Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara is currently exploring how changing climate affects Sierra Nevada stream ecosystems.

Figure 1.2. Average annual precipitation in San Mateo County, modeled by the PRISM Climate Group for the period of 1981-2010.

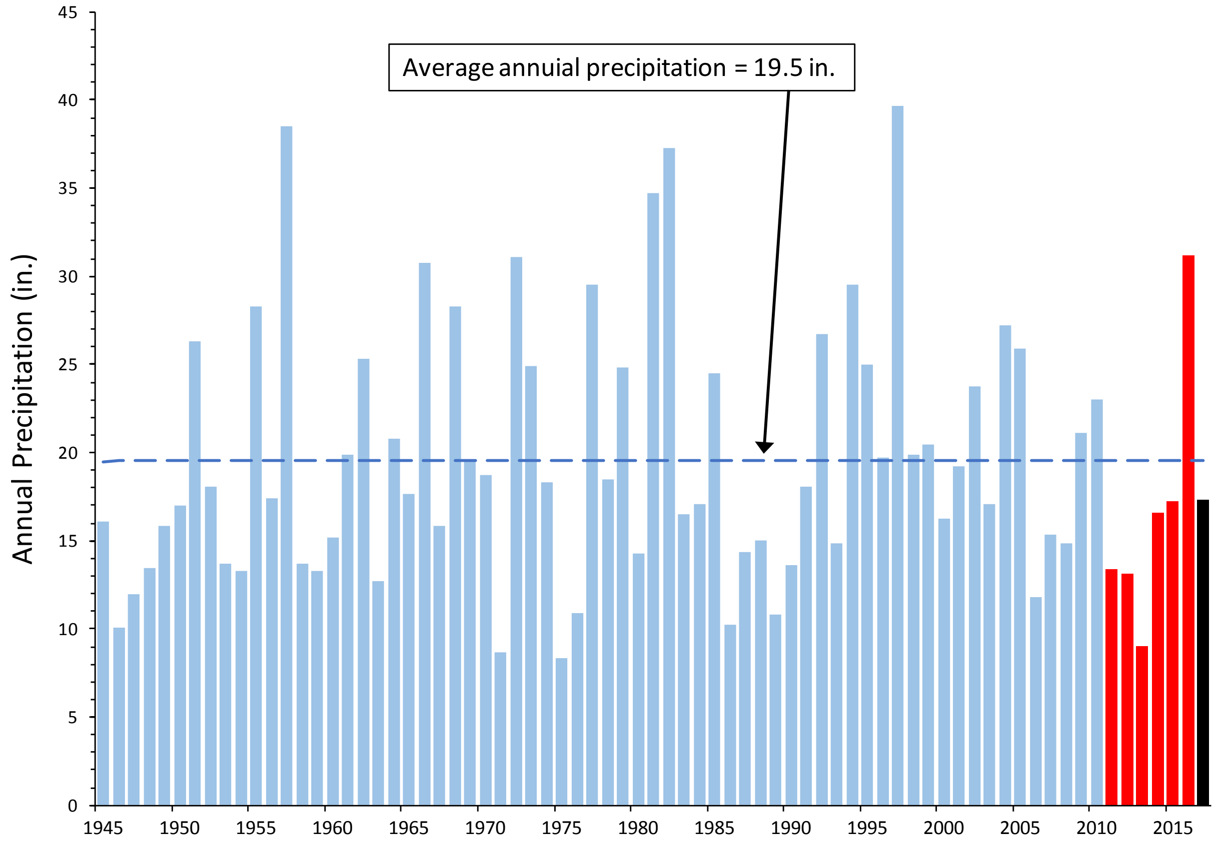

Figure 1.3. Annual rainfall recorded at the San Francisco International Airport, WY 1946 – WY 2018.

1.5 Statement of Data Quality

A comprehensive Quality Assurance/Quality Control (QA/QC) program was implemented by SMCWPPP covering all aspects of the probabilistic and targeted monitoring. In general QA/QC procedures were implemented as specified in the BASMAA RMC QAPP (BASMAA, 2016a), and monitoring was performed according to protocols specified in the BASMAA RMC SOPs (BASMAA, 2016b), and in conformity with methods specified by the SWAMP QAPrP[8]. A detailed QA/QC report is included as Attachment 1.

Based on the QA/QC review, no WY 2018 data were rejected, but some data were flagged. Overall, WY 2018 data met QA/QC objectives.

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

2.0 Biological Condition Assessment

2.1 Introduction

In compliance with Creek Status Monitoring Provision C.8.d.i, SMCWPPP conducted bioassessment monitoring in WY 2018. All bioassessment monitoring was performed at sites selected randomly using the probabilistic monitoring design[9]. The probabilistic monitoring design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its program area (County boundary) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks. The survey design provides an unbiased framework for data evaluation that will allow a condition assessment of ambient aquatic life uses within known estimates of precision. The monitoring design was developed to address the management questions for both RMC participating county and overall RMC area described below:

1. *What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?*
   i. *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?*
   ii. *What is the condition of aquatic life in RMC participant counties; are water quality objectives met and are beneficial uses supported?*
   iii. *To what extent does the condition of aquatic life in urban and non-urban creeks differ in the RMC area?*
   iv. *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?*
   i. *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?*

The first question (i.e., *What is the condition of aquatic life in creeks in the RMC?*) is addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. Once a sufficient number of samples have been collected, ambient biological condition can be estimated for streams at a regional scale. Over the past seven years (WY 2012 through WY 2018), SMCWPPP and the Regional Water Board have sampled 80 probabilistic sites in San Mateo County, providing a sufficient sample size to estimate ambient biological condition for urban streams countywide. There are still an insufficient number of samples to accurately assess the biological condition of non-urban streams in the county, or of individual watersheds or smaller jurisdictional areas (i.e., cities).[10]

The second question (i.e., *What are major stressors to aquatic life in the RMC area?*) is addressed by the collection and evaluation of physical habitat and water chemistry data

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[9] The option to conduct 20% of bioassessment surveys at targeted sites was not exercised in WY 2018.

[10] For each of the strata, it is necessary to obtain a sample size of at least 30 in order to evaluate the condition of aquatic life within known estimates of precision. This estimate is defined by a power curve from a binomial distribution (BASMAA 2012).

collected at the probabilistic sites, as potential stressors to biological health. In addition, the stressor levels can be compared to biological indicator data through correlation and relative risk analyses. Assessing the extent and relative risk of stressors can help prioritize stressors at a regional scale and inform local management decisions.

The third question (i.e., *What are the long-term trends in water quality in creeks over time?*) is addressed by assessing the change in biological condition over several years. Changes in biological condition over time can help evaluate the effectiveness of management actions. Although, long-term trend analysis for the RMC probabilistic survey will require more than seven years of data collection, preliminary trend analysis of biological condition may be possible for some stream reaches using a combination of historical targeted data with the probabilistic data.

This report presents biological indicator data and potential stressor data collected at ten sites in WY 2018. Data are compared to triggers and water quality objectives identified in the MRP.

A more comprehensive evaluation of regional bioassessment data is presented in the BASMAA RMC 5-Year Bioassessment Report (WY 2012 – WY 2016) (Attachment 2). Summary findings from the report are included in Section 7.1.

2.2 Methods

2.2.1 Probabilistic Survey Design

The RMC probabilistic design was created using the Generalized Random Tessellation Stratified (GRTS) approach developed by the United States Environmental Protection Agency (USEPA) and Oregon State University (Stevens and Olson 2004). GRTS offers multiple benefits for coordinating among 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 in California by several agencies including the statewide Perennial Streams Assessment (PSA) conducted by Surface Water Ambient Monitoring Program (Ode et al. 2011) and the Southern California Stormwater Monitoring Coalition's (SMC) regional monitoring program conducted by municipal stormwater programs in Southern California (SCCWRP 2007).

Sample sites were selected using the GRTS approach from a sample frame consisting of a creek network geographic information system (GIS) data set within the 3,407-square mile RMC area (BASMAA 2012). The sample frame includes non-tidally influenced perennial and non-perennial creeks within five management units representing areas managed by the stormwater programs associated with the RMC (listed in Table 1.1). There is approximately one site for every stream kilometer in the sample frame. The National Hydrography Plus Dataset (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.

Once the master draw was performed, the list of sites was classified by county and land use (i.e., urban and non-urban) to allow for comparisons between these strata. Urban areas were delineated by combining urban area boundaries and city boundaries defined by the U.S. Census (2000). Non-urban areas were defined as the remainder of the RMC area. Some sites classified as urban fall near the non-urban edge of the city boundaries and have little upstream development. For the purposes of consistency, these urban sites were not re-classified. Therefore, data values within the urban classification represent a wide range of conditions.

The RMC participants weight their annual sampling efforts so that approximately 80% are in in urban areas and 20% in non-urban areas. In addition, between WY 2012 and WY 2015, SWAMP conducted 34 bioassessments throughout the RMC region at non-urban sites selected from the sample frame, including 10 sites in San Mateo County[11].

2.2.2 Site Evaluations

Sites identified in the regional sample draw are evaluated by each RMC participant in chronological order using a two-step process described in RMC Standard Operating Procedure FS-12 (BASMAA 2016b), consistent with the procedure described by Southern California Coastal Water Research Project (SCCWRP) (2012). Each site is evaluated to determine if it meets the following RMC sampling location criteria:

1. The location (latitude/longitude) provided for a site is located on or is within 300 meters of a non-impounded receiving water body[12];
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[13].

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 three categories:

- **Target** – Target sites were grouped into two subcategories:
  - **Target Sampleable (TS)** - Sites that met all seven criteria and were successfully sampled.
  - **Target Non-Sampleable (TNS)** - Sites that met criteria 1 through 4, but did not meet at least one of criteria 5 through 7 were classified as TNS.
- **Non-Target (NT)** - Sites that did not meet at least one of criteria 1 through 4 were classified as non-target status.
- **Unknown (U)** - Sites were classified with unknown status 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.

All site evaluation information was documented on field forms and entered into a standardized database. The overall percent of sites classified into the three categories can be evaluated to

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[11] SFRWQCB SWAMP staff have indicated that they will not conduct RMC related bioassessment monitoring during MRP 2.0.

[12] The evaluation procedure permits certain adjustments of actual site coordinates within a maximum of 300 meters.

[13] If landowners do not respond to at least two attempts to contact them either by written letter, email, or phone call, permission to access the respective site is effectively considered to be denied.

determine the statistical significance of local and regional average ambient conditions calculated from the multi-year dataset.

2.2.3 Field Sampling Methods

Bioassessment survey methods were consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b).

In accordance with the RMC QAPP (BASMAA 2016a) bioassessments were planned during the spring index period (approximately April 15 – July 15) with the goal to sample a minimum of 30 days after any significant storm (defined as at least 0.5-inch of rainfall within a 24-hour period). A 30-day grace period allows diatom and soft algae communities to recover from peak flows that may scour benthic algae from the bottom of the stream channel. During WY 2018, there was a small but significant storm on April 8, just prior to the index period; however, field sampling in San Mateo County was conducted between May 14 and May 22, more than 30 days following the storm.

Each bioassessment sampling site consisted of an approximately 150-meter stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. Benthic macroinvertebrate (BMI) and algae samples were collected at 11 evenly spaced transects using the Reachwide Benthos (RWB) method described in the SWAMP SOP (Ode et al. 2016). The most recent SWAMP SOP (i.e., Ode et al. 2016) combines the BMI and algae methods that are referenced in the MRP (Ode et al. 2007, Fetscher et al. 2009), provides additional guidance, and adds two new physical habitat analytes (assess scour and engineered channels). The full suite of physical habitat data was collected within the sample reach using methods described in Ode et al. (2016).

Immediately prior to biological and physical habitat data collection, water samples were collected for nutrients, conventional analytes, ash free dry mass, and chlorophyll a analysis using the Standard Grab Sample Collection Method as described in SOP FS-2 (BASMAA 2016b). Water samples were also collected and analyzed in the field for free and total chlorine using a Pocket Colorimeter^{TM} II and DPD Powder Pillows according to SOP FS-3 (BASMAA 2016b) (see Section 5.0 for chlorine monitoring results). In addition, general water quality parameters (dissolved oxygen, pH, specific conductivity and temperature) were measured at or near the centroid of the stream flow using a pre-calibrated multi-parameter probe.

Biological and water samples were sent to laboratories for analysis. The laboratory analytical methods used for BMIs followed Woodward et al. (2012), using the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) Level 1 Standard Taxonomic Level of Effort, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family (Chironomidae). Soft algae and diatom samples were analyzed following SWAMP protocols (Stancheva et al. 2015). The taxonomic resolution for all data was compared SWAMP master taxonomic list. All taxa identified in samples collected were on the SWAMP Master List and are included in the data submittal for WY 2018.

2.2.4 Data Analysis

BMI and algae data were analyzed to assess the biological condition (i.e., aquatic life Beneficial Uses) of the sampled reaches using condition index scores. Physical habitat data were used to characterize physical habitat conditions using a newly developed multimetric index scoring tool. Physical habitat and water chemistry data were also evaluated as potential stressors to biological health using triggers and water quality objectives identified in the MRP (see Stressor Variable section below). Data analysis methods are described below.

Biological Indicators

Benthic Macroinvertebrates

The benthic (i.e., bottom-dwelling) macroinvertebrates collected through this monitoring program are organisms that live on, under, and around the rocks and sediment in the stream bed. Examples include dragonfly and stonefly larvae, snails, worms, and beetles (Figure 2.1). Each BMI species has a unique response to water chemistry and physical habitat condition. Some are relatively sensitive to poor habitat and pollution; others are more tolerant. Therefore, the abundance and variety of BMIs in a stream indicates the biological condition of the stream.

The California Stream Condition Index (CSCI) is an assessment tool that was developed by the State Water Resources Control Board (State Water Board) to support the development of California's statewide Biological Integrity Plan[14]. The CSCI translates benthic macroinvertebrate data into an overall measure of stream health. The CSCI was developed using a large reference data set that represents the full range of natural conditions in California and site-specific models for predicting biological communities. The CSCI combines two types of indices: 1) taxonomic completeness, as measured by the ratio of observed-to-expected taxa (O/E); and 2) ecological structure and function, measured as a predictive multimetric index (pMMI) that is based on reference conditions. The CSCI score is computed as the average of the sum of the O/E and pMMI.

CSCI scores for each station are calculated using a combination of biological and environmental data following methods described in Rehn et al. (2015). Biological data consist of the BMI data collected and analyzed using the protocols described in the previous section. Environmental predictor data are generated in GIS using drainage areas upstream of each BMI sampling location. The environmental predictors and BMI data were formatted into comma delimited files and used as input for the RStudio statistical package and the necessary CSCI program scripts, developed by Southern California Coastal Water Research Project (SCCWRP) staff (Mazor et al. 2016).

The State Water Board is continuing to evaluate the performance of CSCI in a regulatory context. In the current MRP, the Regional Water Board defined a CSCI score of 0.795 as a threshold for identifying sites with potentially degraded biological condition that may be considered as candidates for a Stressor/Source Identification project.

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[14] The Biological Integrity Assessment Implementation Plan has been combined with the Biostimulatory Substances Amendment project. The State Water Board is proposing to adopt a statewide water quality objective for biostimulatory substances (e.g., nitrate) along with a program of implementation. A draft policy document for public review is anticipated in late 2019.

Odonata cordulegastridae "Spiketail Dragonfly"

Megaloptera corydalidae "Dobsonflies"

Ephemeroptera ephemerellidae "Spiny Crawler Mayflies"

Trichoptera limnephilidae "Northern Caddisflies"

Diptera ceratopogonidae "Biting Midges"

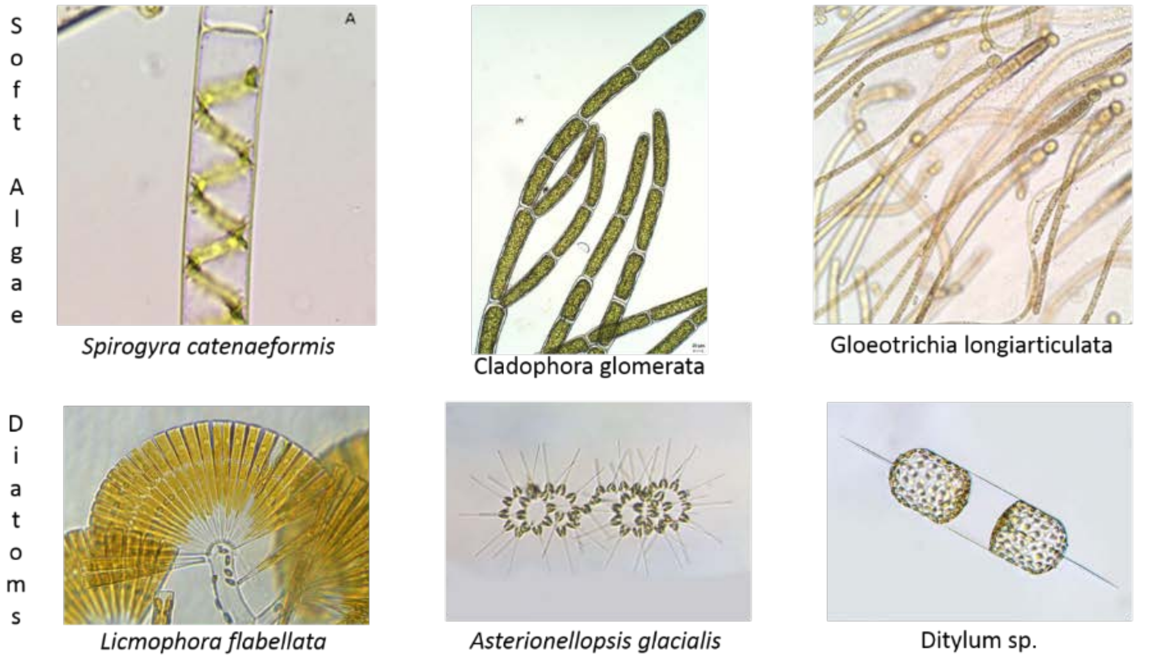
Coleoptera psephenidae "Water Penny Beetle"

Source: http://www.dfg.ca.gov/abl/Reference/California/CA_digital_ref_familylevel_home.asp

Figure 2.1. Examples of benthic macroinvertebrates.

Benthic Algae

Similar to BMI's, the abundance and type of benthic algae species living on a streambed can indicate stream health. When evaluated with the CSCI, biological indices based on benthic algae can provide a more complete picture of the streams biological condition because algae respond more directly to nutrients and water chemistry. In contrast, BMIs are more responsive to physical habitat. Figure 2.2 shows examples of benthic algae common in Bay Area streams.



Spirogyra catenaeformis

Cladophora glomerata

Gloeotrichia longiarticulata

Licmophora flabellata

Asterionellopsis glacialis

Ditylum sp.

Source: http://dbmuseblade.colorado.edu/DiatomTwo/sbsac_site/IDResourceTool.html
http://nathistoc.bio.uci.edu/Diatoms

Figure 2.2. Examples of soft algae and diatoms.

The State Water Board and SCCWRP recently developed the draft Algae Stream Condition Index (ASCI) which uses benthic algae data as a measure of biological condition for streams in California (Theroux et al. in prep.). The ASCI is a non-predictive[15] scoring tool that consists of three multimetric indices (MMI) comprised of single-assemblage metrics associated with either diatoms or soft algae, or combinations of metrics representing both assemblages (i.e, “hybrid”). The individual metrics associated with hybrid MMI include five of the six metrics used for the diatom MMI. The soft algae metrics used in the hybrid MMI are different than metrics used in the soft algae MMI.

The ASCI is very similar to the algae Indices of Biological Integrity (IBIs) developed in Southern California (Fetscher et al. 2014), with the exception that metric development and testing was conducted using data collected throughout California. Analysis of the three ASCI tools (i.e., diatom, soft algae, hybrid) conducted by SCCWRP suggests that the hybrid ASCI index is the most responsive algae index, especially for nutrient stressor gradients (Theroux et al. in prep.). Additional study is needed however, to determine the best approach to apply the ASCI tools to evaluate bioassessment data. For example, it is not clear if the ASCI should be used as a second line of evidence to understand CSCI scoring results, or if it would be more effective as an independent indicator to evaluate different types of stressors (e.g., nutrients) to which BMIs

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[15] Predictive indices (e.g., CSCI) utilize environmental variables that characterize immutable natural gradients as predictors for biological conditions. A predictive O/E and MMI algae model was developed and tested, but ultimately not recommended due to low precision and accuracy.

are not very responsive. The ASCI is currently under review by the Biostimulatory-Biointegrity Policy Science Advisory Panel and the State Water Board.

The algae data collected in San Mateo County during 2018 were evaluated using the diatom ASCI, soft algae ASCI, and hybrid ASCI. ASCI scores were generated using the beta version reporting module developed by SCCWRP. These scores are considered provisional until the ASCI has been fully evaluated and finalized.

Physical Habitat Indicators

The condition of physical habitat is a major contributor to stream ecosystem health. Physical habitat components such as streambed substrate, channel morphology, microhabitat complexity, in-stream cover-type complexity, and riparian vegetation cover contribute to the overall physical and biological integrity of a stream. The physical characteristics of a stream reach are affected by both natural factors (e.g., climate, slope, geology) and human disturbance (e.g., channelization, development, stream crossings, hydromodification).

Physical habitat conditions are generally evaluated using endpoint variables, or metrics, which are calculated using reach-scale averages of transect-based measurements and observations. The State Water Board has developed a SWAMP Bioassessment Reporting Module (SWAMP RM), a custom Microsoft Access^{TM} application, that produces approximately 170 different metrics that are based on physical habitat measurements collected using both EPA's Environmental Monitoring and Assessment Program (EMAP) for freshwater wadeable streams (Kaufmann et al. 1999) and the SWAMP "Full" habitat protocol (Ode et al 2007) that was implemented by SMCWPPP at bioassessment stations. The metrics are classified into five thematic groups representing different physical attributes: substrate, riparian vegetation (including structure and shading), flow habitat variability, in-channel cover, and channel morphology.

The State Water Board recently developed the Index of Physical Habitat Integrity (IPI) as an overall measure of physical habitat condition. Similar to the CSCI, the IPI is calculated using a combination of physical habitat data collected in the field and environmental data generated in GIS following the methods described in Rehn et al. (2018). The IPI is based on five of the metrics generated by the SWAMP RM. The metrics were selected for their ability to discriminate between reference and stressed sites and provide unbiased representation of waterbodies across the different ecoregions of California. Scoring for these metrics were then calibrated using environmental variables that were associated with drainage areas for each sampling location.

Biological and Physical Habitat Condition Thresholds

Existing thresholds for CSCI scores (Mazor 2015) and ASCI scores (Mazor et al. in review) were used to evaluate the BMI and algae data collected in San Mateo County and analyzed in this report (Table 2.1). Provisional thresholds for IPI scores (Rehn et al 2018) were used to evaluate physical habitat conditions. The thresholds for all three indices were based on the distribution of scores for data collected at reference calibration sites located throughout California. Four condition categories are defined by these thresholds: "likely intact" (greater than 30th percentile of reference site scores); "possibly intact" (between the 10th and the 30th percentiles); "likely altered" (between the 1st and 10th percentiles); and "very likely altered" (less than the 1st percentile).

A CSCI score below 0.795 is referenced in the MRP as a threshold indicating a potentially degraded biological community, and thus should be considered for a SSID Project. The MRP threshold is the division between “possibly intact” and “likely altered” condition category described in Mazor (2015). Further investigation is needed to evaluate the applicability of this threshold to sites in highly urban watersheds and/or modified channels that are frequent throughout the SMCWPPP study area.

Table 2.1. Condition categories used to evaluate CSCI, ASCI, and IPI scores.

Biological Indicator	Tool	Likely Intact	Possibly Intact	Likely Altered	Very Likely Altered
BMI	CSCI	≥ 0.92	≥ 0.79 to < 0.92	≥ 0.63 to < 0.79	< 0.63
Diatoms	ASCI	≥ 0.92	≥ 0.80 to < 0.92	≥ 0.63 to < 0.80	< 0.63
Soft Algae		≥ 0.93	≥ 0.82 to < 0.93	≥ 0.68 to < 0.82	< 0.68
Hybrid		≥ 0.93	≥ 0.83 to < 0.93	≥ 0.70 to < 0.83	< 0.70
Physical Habitat	IPI	≥ 0.94	≥ 0.84 to < 0.94	≥ 0.71 to < 0.83	< 0.70

Stressor Variables

Physical habitat, landscape characteristics, general water quality, and water chemistry data collected during the bioassessment surveys were compiled and evaluated as potential stressor variables affecting biological condition.

Physical habitat stressor variables include 11 of the metrics developed by the SWAMP RM (described above) that were selected based on their ability to discriminate between reference and stressed sites and also showed little bias among ecoregions (Andy Rehn, personal communication, 2017) (Table 2.2). Additional physical habitat variables include the reachwide qualitative assessment (PHAB) that consists of three separate attributes: channel alteration, epifaunal substrate, and sediment deposition. Each attribute is individually scored on a scale of 0 to 20, with a score of 20 representing good condition. The total PHAB score is the sum of three individual attribute scores with a score of 60 representing the highest possible score.

Table 2.2. Physical habitat metrics used to assess physical habitat data collected at bioassessment sites in WY 2018. The five metrics used to calculate IPI scores are also shown.

Type	Variable Name	Variables used for IPI Score
Channel Morphology	Evenness of Flow Habitat Types	x
	Percent Fast Water of Reach	
Habitat Complexity and Cover	Mean Filamentous Algae Cover	
	Natural Shelter cover - SWAMP	
	Shannon Diversity (H) of Aquatic Habitat Types	x
	Riparian Cover Sum of Three Layers	x
Human Disturbance	Combined Riparian Human Disturbance Index - SWAMP	
Substrate Size and Composition	Evenness of Natural Substrate Types	
	Percent Gravel - coarse	
	Percent Substrate Smaller than Sand (<2 mm)	x
	Shannon Diversity (H) of Natural Substrate Types	x

Landscape variables were generated in GIS using three different scales of drainage area upstream of each sampling location: 1 km, 5 km, and entire watershed. Land use and transportation data layers were overlayed with the drainage areas to calculate landscape variables, including percent urban area, percent impervious area, total number of road crossings, and road density.

Water quality stressor variables include the general parameters measured in the field with sondes (i.e., dissolved oxygen, pH, temperature and specific conductivity), free chlorine and total chlorine residual, and water chemistry analyzed at laboratories (nutrients and anions). Additional water quality variables included chlorophyll a and ash free dry mass, both measured from filtration of the benthic algae composite samples.

Some of the water quality stressor variables used in the analysis were calculated or converted from other analytes or units of measurement:

- Conversion of measured total ammonia to the more toxic form of unionized ammonia was calculated to compare with the 0.025 mg/L annual median standard provided in the San Francisco Basin Water Quality Control Plan (Basin Plan) (SFRWQCB 2017). The conversion was based on a formula provided by the American Fisheries Society (AFS; https://fisheries.org/wp-content/uploads/2016/03/Copy-of-pub_ammonia_fwc.xls). The calculation requires total ammonia and field-measured values of pH, temperature, and specific conductance.
- Total nitrogen concentration was calculated by summing nitrate, nitrite, and Total Kjeldahl Nitrogen concentrations.
- The volumetric concentrations (mass/volume) for ash free dry mass and chlorophyll a (as measured by the laboratory) were converted to an area concentration (mass/area). Calculations required using both algae sampling grab size and composite volume.

Another potential stressor is climate. During the first five years of probabilistic sampling (WY 2012 – WY 2016), average precipitation was lower than average. Drought conditions changed with an above average wet season in WY 2017, followed by average season in WY 2018. Comparison of sampling results from recent wet years will provide useful information to evaluate the impacts of drought on biological integrity of the streams.

Stressor Thresholds

In compliance with Provision C.8.h.iii.(4), water chemistry data collected at the bioassessment sites during WY 2018 were compared to stressor thresholds and applicable water quality standards (Table 2.3). Thresholds for pH, specific conductance, dissolved oxygen (DO), and temperature (for waters with COLD Beneficial Use only) are listed in Provision C.8.d.iv of the MRP. With the exception of temperature and specific conductance, these conform to Water Quality Objectives (WQOs) in the Basin Plan (SFRWQCB 2017). Of the eleven nutrients analyzed synoptically with bioassessments, WQOs only exist for three: ammonia (unionized form), and chloride and nitrate (for waters with MUN Beneficial Use only). See Table 1.4 for a list designated Beneficial Uses of creeks monitored in WY 2018. Pescadero Creek, Pilarcitos Creek and San Pedro Creeks are the only creeks sampled in WY 2018 with MUN designated.

Table 2.3. Thresholds for nutrient and general water quality variables.

	Units	Threshold	Direction	Source
Nutrients and Ions				
Nitrate as N [a]	mg/L	10	Increase	Basin Plan
Un-ionized Ammonia [b]	mg/L	0.025	Increase	Basin Plan
Chloride [a]	mg/L	250	Increase	Basin Plan
General Water Quality				
Oxygen, Dissolved	mg/L	5.0 or 7.0	Decrease	Basin Plan
pH		6.5 and 8.5		Basin Plan
Temperature, instantaneous maximum [c]	°C	24	Increase	MRP
Specific Conductance [c]	µS/cm	2000	Increase	MRP

[a] Nitrate and chloride WQOs only apply to waters with MUN designated Beneficial Uses.

[b] This threshold is an annual median value and is not typically applied to individual samples.

[c] The MRP thresholds (or triggers) for temperature and specific conductance apply when 20 percent of instantaneous results are in exceedance. Application to individual samples is provisional.

Stressor Assessment

The association of stressors with biological indicator scores was evaluated using simple regression models. Linear regressions were run between variables within each of the stressor data types (e.g., landscape, physical habitat and water chemistry) and biological conditions indicators (i.e., CSCI and ASCI scores). Scatter plots showing trend lines are presented for some of the variables that had the greatest positive or negative correlation. However, the correlations were not expected to be very strong or significant due to the small WY 2018 sample size (n=10). More sophisticated statistical analyses using non-parametric measures of correlation (e.g., random forest models) are applied to the regional WY 2012 – WY 2016 dataset in the RMC 5-Year Report, summarized in Section 7.1 and included as Attachment 2.

2.3 Results and Discussion

The section below summarizes results from bioassessment sampling conducted during WY 2018. Conclusions and recommendations for this section are presented in Section 7.0.

A comprehensive analysis of bioassessment data collected by SMCWPPP over a five-year period is presented in the RMC Five-Year Bioassessment Report (5-Year Report) (BASMAA 2019). This BASMAA-funded project evaluated bioassessment data collected at all RMC (n=312) and Water Board (n=45) probabilistic monitoring sites sampled between WY 2012 and WY 2016. The data were evaluated to assess overall biological condition of streams within the RMC, as well as the extent and influence of stressor data on biological condition scores. In addition, the 5-Year Report evaluated the RMC Sample Frame and provided potential recommendations for revising the monitoring design in the future. Additional analysis of the full SMCWPPP MRP bioassessment dataset will be conducted for the Integrated Monitoring Report which will be developed following WY 2019 and submitted by March 31, 2020 (the fifth year of the Permit term) in lieu of an annual UCMR.

2.3.1 Site Evaluations

During WY 2018, SMCWPPP conducted site evaluations at a total of 23 potential probabilistic sites in San Mateo County that were drawn from the Sample Frame. Of these sites, ten were sampled in WY 2018 (rejection rate of 57%). Seven of the evaluated sites were rejected due to access issues and three sites were rejected due to low flow conditions. Two of the sampled sites were classified as non-urban land use and the remaining sites were classified as urban. Two non-urban and four urban sites were located in coastal watersheds draining into the Pacific Ocean, including two sites in Pilarcitos Creek and two sites in San Pedro Creek. The remaining four sites were located in urban watersheds draining into the San Francisco Bay. Two of the urban sites were located in San Francisquito Creek watershed. Land use classification, sampling location, and date for each sampled site are listed are Table 2.4. Sites are mapped in Figure 1.1.

Table 2.4. SMCWPPP bioassessment sampling locations and dates in San Mateo County in WY 2018.

Station Code	Drainage	Watershed	Creek	Land Use	Sample Date	Latitude	Longitude
202R00584	Ocean	Pilarcitos Creek	Pilarcitos Creek	NU	5/15/2018	37.49547	-122.38512
202R00614		Pescadero Creek	Pescadero Cr	NU	5/14/2018	37.27410	-122.28860
202R03404		San Pedro Creek	San Pedro Cr	U	5/17/2018	37.58203	-122.48719
202R03656		Pilarcitos Creek	Pilarcitos Creek	U	5/15/2018	37.46781	-122.42269
202R03880		San Gregorio Cr	La Honda Creek	U	5/22/2018	37.38759	-122.27219
202R03916		San Pedro Creek	San Pedro Cr	U	5/17/2018	37.59144	-122.50333
204R03508	Bayside	Mills Creek	Mills Creek	U	5/16/2018	37.59105	-122.37406
204R03528		San Mateo Creek	San Mateo Cr	U	5/16/2018	37.54808	-122.34661
205R03624		San Francisquito Cr	Bear Creek	U	5/21/2018	37.41883	-122.26498
205R03864		San Francisquito Cr	Hamms Gulch	U	5/22/2018	37.36498	-122.22906

NU = non-urban, U = urban

Since WY 2012, a total of 80 probabilistic sites were sampled by SMCWPPP (n=70) and SWAMP (n=10) in San Mateo County. During the seven-year sampling period, SMCWPPP sampled 57 urban sites and 13 non-urban sites; SWAMP sampled 10 non-urban sites.

2.3.2 Biological Condition Assessment

A total of 112 unique BMI taxa were identified in samples collected at the ten bioassessment sites in San Mateo County during WY 2018. A total of 139 benthic algae taxa were identified in samples collected at the sites, including 119 diatom and 20 soft algae taxa. The total number of unique BMI, diatom, and soft algae taxa identified at each bioassessment location is presented in Table 2.4. BMIs and diatoms were relatively well represented across all sites, with BMIs ranging from 14 to 54 taxa, and diatoms ranging from 26 to 48 taxa. Soft algae taxa were less common across sites, ranging from 1 to 11 taxa, with five sites having 3 or fewer taxa.

Low diversity of soft algae at San Mateo County sites has been frequently observed in prior years, particularly in the upper reaches of coastal creeks with dense riparian canopies. Factors causing low algal diversity are unknown and may include: sand-dominated substrate, low flow conditions related to prolonged drought, dense canopy cover limiting exposure to sunlight, and competition with diatoms.

Table 2.5. The total number of unique BMI, diatom, and soft algae taxa identified in samples collected at 10 bioassessment sites in San Mateo County during WY 2018.

RMC Station	Creek Name	Land Use	BMI	Diatoms	Soft Algae
202R00584	Pilarcitos Creek	NU	45	41	3
202R00614	Pescadero Creek	NU	54	38	11
202R03404	San Pedro Creek	U	18	47	5
202R03656	Pilarcitos Creek	U	26	47	2
202R03880	La Honda Creek	U	42	32	3
202R03916	San Pedro Creek	U	21	45	2
204R03508	Mills Creek	U	14	26	5
204R03528	San Mateo Creek	U	24	48	8
205R03624	Bear Creek	U	51	33	4
205R03864	Hamms Gulch	U	49	32	1

NU = non-urban, U = urban

The total number of BMI taxa (i.e., BMI richness) was slightly positively correlated with site elevation (r^2=0.27, p-value = 0.124) (Figure 2.3).[16] In contrast, total taxa for diatoms generally decreased with increasing site elevation (r^2=0.24, p-value = 0.146). BMI richness was not correlated with diatom or soft algae richness across the 10 bioassessment sites sampled in WY 2018. Similarly, diatom richness did not appear to have any correlation with soft algae richness.

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[16] R-squared represents the amount of variance in the dependent variable. The higher the R-square the better the model. The p-value represents the statistical significance of the result. A small p-value (≤ 0.05) indicates strong evidence; a large p-value (> 0.05) indicates weak evidence.

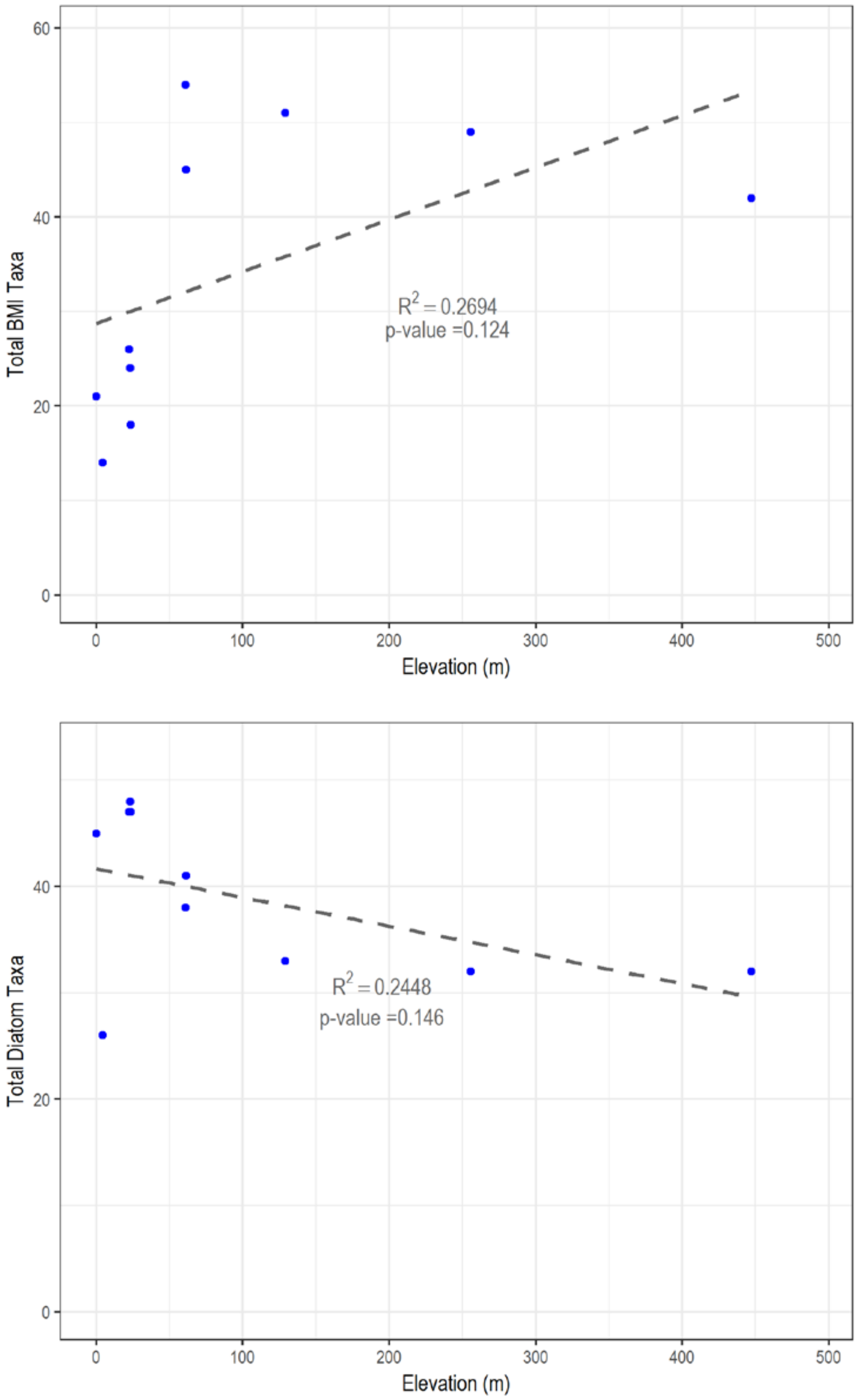

Figure 2.3. Total BMI (top) and soft algae (bottom) taxa compared to elevation of bioassessment sites, SMCWPPP, WY 2018.

Biological condition, as represented by CSCI and ASCI (diatom, soft algae, and hybrid) scores, for the 10 probabilistic sites sampled by SMCWPPP in WY 2018 are listed in Table 2.6 and mapped in Figure 2.6. Scores in the two higher condition categories (i.e., above the 10th percentile of reference sites) for each indicator are highlighted and bold.

Table 2.6. Biological condition scores, presented as CSCI and ASCI (diatom, soft algae and hybrid) for 10 probabilistic sites sampled in San Mateo during WY 2018. Site characteristics related to percent impervious watershed area, channel modification and flow condition are also presented. Bold highlighted values indicate scores in the two higher condition categories.

Station Code	Creek	Land Use	Impervious Watershed Area (%)	Modified Channel [1]	CSCI Score	ASCI Score		
						Diatom	Soft Algae	Hybrid
202R00584	Pilarcitos Creek	NU	1%	N	**0.86**	**0.92**	0.79	**0.88**
202R00614	Pescadero Creek	NU	1%	N	**1.17**	**1.17**	**0.84**	**0.98**
202R03404	San Pedro Creek	U	13%	N	0.65	**0.86**	**0.98**	**0.89**
202R03656	Pilarcitos Creek	U	2%	N	0.71	**0.90**	NS	0.80
202R03880	La Honda Creek	U	5%	N	**0.99**	**0.89**	**0.91**	**0.94**
202R03916	San Pedro Creek	U	15%	N	0.68	**0.87**	0.79	0.82
204R03508	Mills Creek	U	47%	Y	0.35	**0.81**	0.71	0.82
204R03528	San Mateo Creek	U	7%	N	0.60	**1.05**	0.71	**1.00**
205R03624	Bear Creek	U	3%	N	**1.2**	**0.82**	**1.01**	**0.89**
205R03864	Hamms Gulch	U	1%	N	**1.14**	0.78	NS	**0.90**

NS - No score was calculated due to inadequate number of soft algal taxa.

NU = non-urban, U = urban

[1] Highly modified channel is defined as having armored bed and banks (e.g., concrete, gabion, rip rap) for majority of the reach or characterized as highly channelized earthen levee.

CSCI Scores

The CSCI scores ranged from 0.35 to 1.2 across the ten bioassessment sites sampled in WY 2018 (Table 2.6). Five of the ten (50%) sites had CSCI scores in the two higher condition categories: “possibly intact” and “likely intact”. These combined classifications are above the MRP trigger threshold value of 0.795. Three of these sites were located in protected open space or County Park land and two sites were in private property near the urban boundary line.

Three sites had CSCI scores in the “likely altered” conditions category (0.63 – 0.79). These sites are located in urban reaches of San Pedro Creek (City of Pacifica) and Pilarcitos Creek (City of Half Moon Bay. Two sites had CSCI scores in the “very likely altered” category (< 0.63). The site with the lowest CSCI score (0.35), was in a highly developed reach of Mills Creek (City of Burlingame).

Sites with CSCI scores below 0.795 will be considered as candidates for SSID projects.

ASCI Scores

The benthic algae taxa identified in the ten samples collected in San Mateo County were used to calculate scores for the provisional statewide ASCI. Scores for three ASCI indices (diatoms, soft algae and hybrid) are shown in Table 2.6. In general, ASCI scores across the three indices were relatively high (> 0.7) across the ten bioassessment sites.

- **Diatoms.** Nine of the ten bioassessment sites had diatom ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred over a wide gradient of urbanization, ranging from 1% to 47% impervious area (Table 2.6).

- **Soft Algae**. Four of the ten bioassessment sites had soft algae ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred over a wide gradient of urbanization, ranging from 1% to 13% impervious area. Soft algae ASCI scores were not calculated for two sites; both sites had two or fewer soft algae taxa identified in the samples (Table 2.6).

- **Hybrid**. Seven of the ten bioassessment sites had hybrid ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred primarily in drainages with low ubanization, ranging from 1% to 7% impervious area, with the exception of site 202R03404 in San Pedro Creek (13%). Five of the seven sites also received CSCI scores that were in two higher condition categories (Table 2.6).

CSCI scores were poorly correlated with ASCI scores. A comparison of CSCI and hybrid ASCI scores is shown in Figure 2.4.

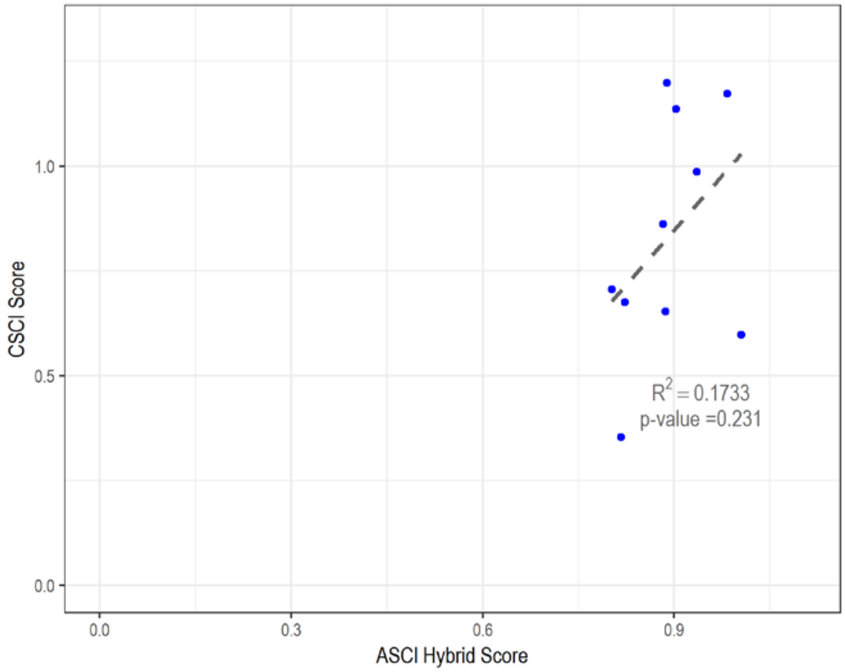

Figure 2.4. CSCI Scores compared to hybrid ASCI Scores for 10 bioassessment sites sampled in San Mateo County in WY 2018.

A statewide bioassessment data analysis evaluated the CSCI and the three ASCI indices and concluded that the hybrid ASCI index was the most responsive index[17], especially for nutrient stressor gradients (Theroux et al. in prep.). Additional guidance is needed however, to determine the best application of the ASCI tool in evaluating bioassessment data. For example, it is not clear if one or more of the ASCI indices should be used to assess biological condition. Furthermore, it is not clear if ASCI should be used as a second line of evidence to the CSCI scoring results, or if it would be more effective as an independent indicator to evaluate different types of stressors (e.g., nutrients).

IPI Scores

Physical habitat conditions, as represented by IPI scores, are listed in Table 2.7. The qualitative habitat (PHAB) scores, including individual scores for channelization, epifaunal substrate and sedimentation attributes, and total PHAB (sum of the three attributes scores) are also presented in the table. Biological condition scores for CSCI and the hybrid ASCI are included in the table for comparison. The two higher condition categories for all three indices (i.e., above the 10th percentile of reference sites) are shown in shaded cells with bold text.

Table 2.7. IPI scores for ten probabilistic sites sampled by SMCWPPP in WY 2018. Qualitative PHAB scores are also listed. CSCI and hybrid ASCI scores are provided for comparison.

Station Code	Creek	CSCI Score	ASCI Hybrid	IPI Score	Channel Alteration	Epifaunal Substrate	Sediment Deposition	Total PHAB Score
202R00584	Pilarcitos Creek	0.86	0.88	0.8	12	15	10	37
202R00614	Pescadero Creek	1.17	0.98	1.04	14	13	13	40
202R03404	San Pedro Creek	0.65	0.89	1	15	16	6	37
202R03656	Pilarcitos Creek	0.71	0.80	0.7	14	4	3	21
202R03880	La Honda Creek	0.99	0.94	1.15	18	17	9	44
202R03916	San Pedro Creek	0.68	0.82	1.06	17	9	10	36
204R03508	Mills Creek	0.35	0.82	0.62	6	7	14	27
204R03528	San Mateo Creek	0.60	1.00	0.92	16	14	7	37
205R03624	Bear Creek	1.20	0.89	1.21	11	15	12	38
205R03864	Hamms Gulch	1.14	0.90	1.16	20	15	11	46

IPI scores, composed of metrics that are primarily based on physical habitat measurements, were positively correlated with the qualitative habitat assessment PHAB scores ($r^2 = 0.69$, p-value = 0.003) (Figure 2.5). IPI scores were also positively correlated with CSCI scores, and slightly less so with hybrid ASCI scores. ($r^2 = 0.57$, p value = 0.125 and $r^2 = 0.2$, p value = 0.193, respectively) (Figure 2.5).

Individual physical habitat variables and metrics are evaluated as stressors in the next section of the report.

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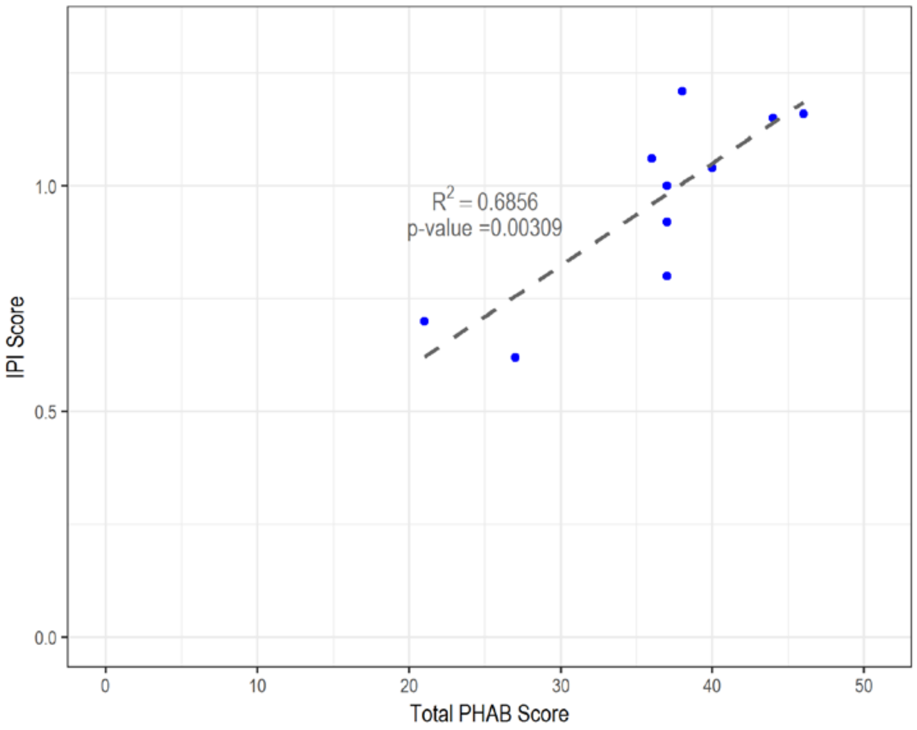
[17] For the remainder of this report, the hybrid ASCI will be used to evaluate stressor association with biological condition.



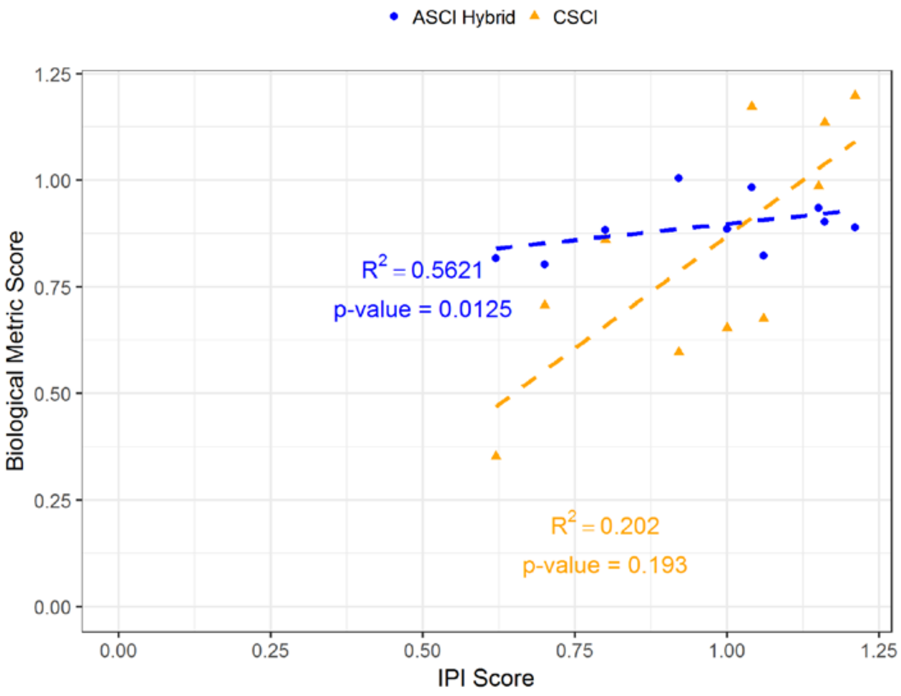


Figure 2.5. Total PHAB scores compared with IPI scores (top) and CSCI and hybrid ASCI scores (bottom) plotted with IPI scores for ten bioassessment sites sampled in WY 2018.

Overall Condition

The condition categories for two of the biological indicators (CSCI, hybrid ASCI) and the IPI, as defined in Table 2.1, are mapped in Figure 2.6. There were four sites with scores in the two higher condition categories for all three indices (green and yellow symbols in Figure 2.6). Two of the high-scoring sites were located in Mid-Peninsula Open Space District land, including La Honda Creek Preserve (site 202R03880) and Hamms Gulch at Windy Hill Preserve (site 205R03864). The third site was located in Pescadero Creek County Park (site 202R00614). The fourth site was on Bear Creek, near the urban boundary of the Town of Woodside (site 205R03624). All four sites were relatively undeveloped (less than < 5% impervious area).

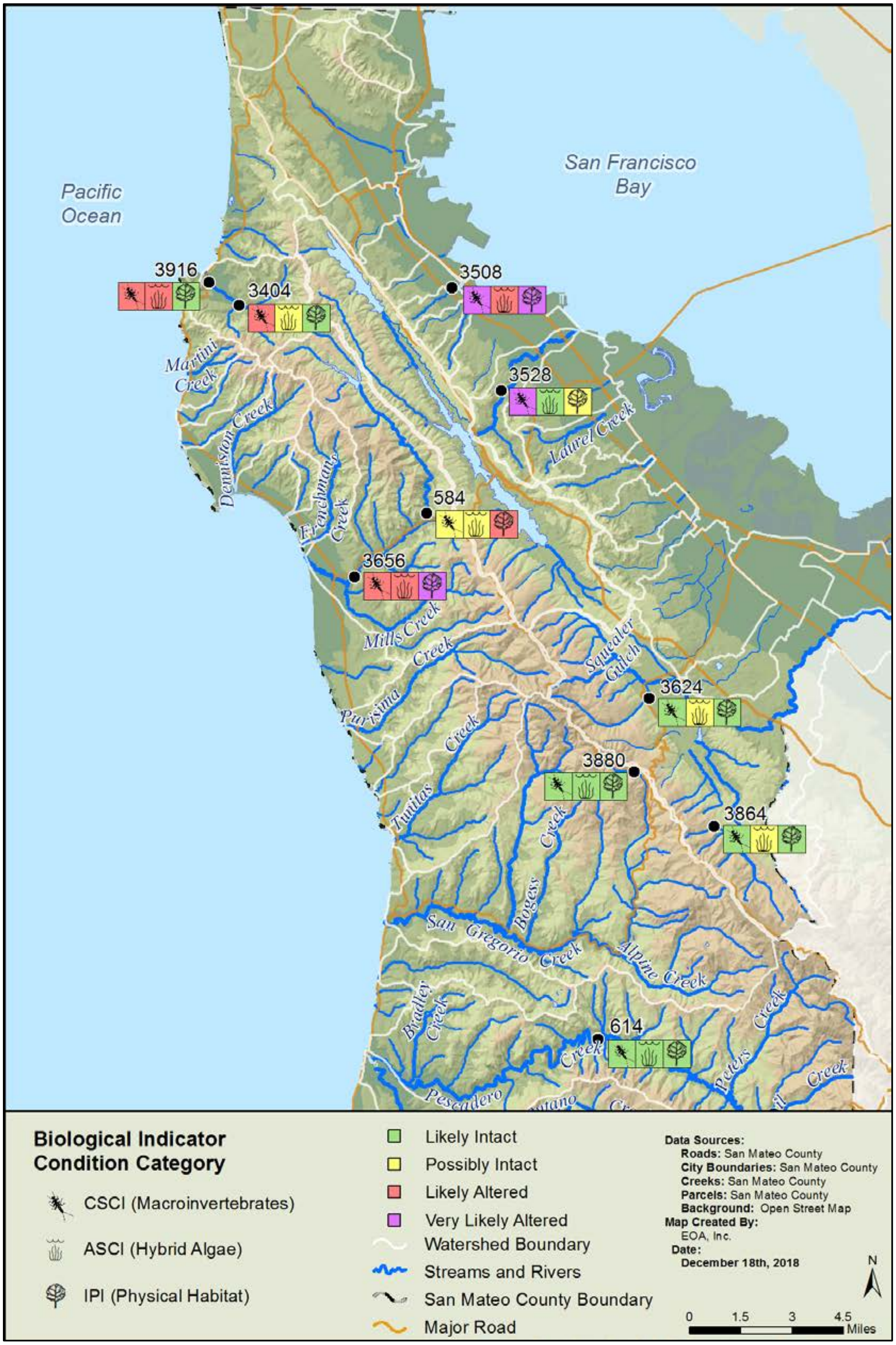


Figure 2.6. Condition category as represented by CSCI, hybrid ASCI and IPI Scores for ten probabilistic sites sampled in San Mateo County in WY 2018.

2.3.3 Stressor Assessment

This section summarizes results for stressor data collected at 10 bioassessment sites during WY 2018. Stressors were evaluated using simple linear regressions between variables within each of the stressor data types (e.g., landscape, physical habitat and water chemistry) and biological conditions indicators (i.e., CSCI and ASCI scores). Scatter plots showing trend lines are presented for some of the variables that had the greatest positive or negative correlation. However, due to the small number of samples, associations with biological condition are not expected to be very strong.

General Water Chemistry

General water quality measurements sampled at the ten bioassessment sites in WY 2018 are listed in Table 2.8. None of the water quality measurements exceeded water quality objectives or MRP trigger thresholds. Nor were any of the water quality measurements well correlated with CSCI or hybrid ASCI scores.

Table 2.8. General water quality measurements for ten probabilistic sites in San Mateo County sampled in WY 2018.

Station Code	Creek Name	Temp (C)	DO (mg/L)	pH	Specific Conductance (uS/cm)
202R00584	Pilarcitos Creek	13.3	9.5	7.5	321
202R00614	Pescadero Creek	13.7	10.5	8.0	644
202R03404	San Pedro Creek	13.5	10.0	7.9	459
202R03656	Pilarcitos Creek	12.8	10.3	7.7	379
202R03880	La Honda Creek	10.7	12.5	8.2	497
202R03916	San Pedro Creek	14.1	10.1	8.1	456
204R03508	Mills Creek	13.2	10.0	7.9	664
204R03528	San Mateo Creek	13.2	10.7	7.8	244
205R03624	Bear Creek	12.7	10.5	8.2	562
205R03864	Hamms Gulch	10.9	10.4	7.8	694

Landscape Variables

Landscape variables associated with the drainage area for each bioassessment site sampled in WY 2018 are presented in Table 2.9. Landscape variables include: percent urban area, percent impervious area, total number of road crossings, and road density (road length/watershed area). The total drainage area and CSCI scores are presented for comparison. Based on the simple regression models, the strongest relationships between CSCI scores and landscape variables were for impervious area ($r^2 = 0.55$, p value < 0.015) and road density ($r^2 = 0.47$, p value < 0.03) (Figure 2.7). The same two landscape variables were poorly correlated with the ASCI scores (not shown)

Table 2.9. Landscape variables for watershed areas of the 10 bioassessment sites sampled in San Mateo County during WY 2018.

Station Code	Creek Name	CSCI Score	Drainage Area (km2)	Percent Urban	Percent Impervious	Road Crossings Watershed	Road Density (km/km2)
202R00584	Pilarcitos Creek	0.86	23	0%	1%	1	0.4
202R00614	Pescadero Creek	1.17	107	0%	1%	45	1.4
202R03404	San Pedro Creek	0.65	13	23%	13%	19	2.8
202R03656	Pilarcitos Creek	0.71	46	1%	2%	17	0.7
202R03880	La Honda Creek	0.99	3	10%	4%	0	2.4
202R03916	San Pedro Creek	0.68	20	26%	15%	24	3.5
204R03508	Mills Creek	0.35	3	91%	47%	4	11.8
204R03528	San Mateo Creek	0.60	81	10%	7%	38	2.4
205R03624	Bear Creek	1.20	7	6%	3%	1	1.1
205R03864	Hamms Gulch	1.14	1	0%	1%	0	0.9

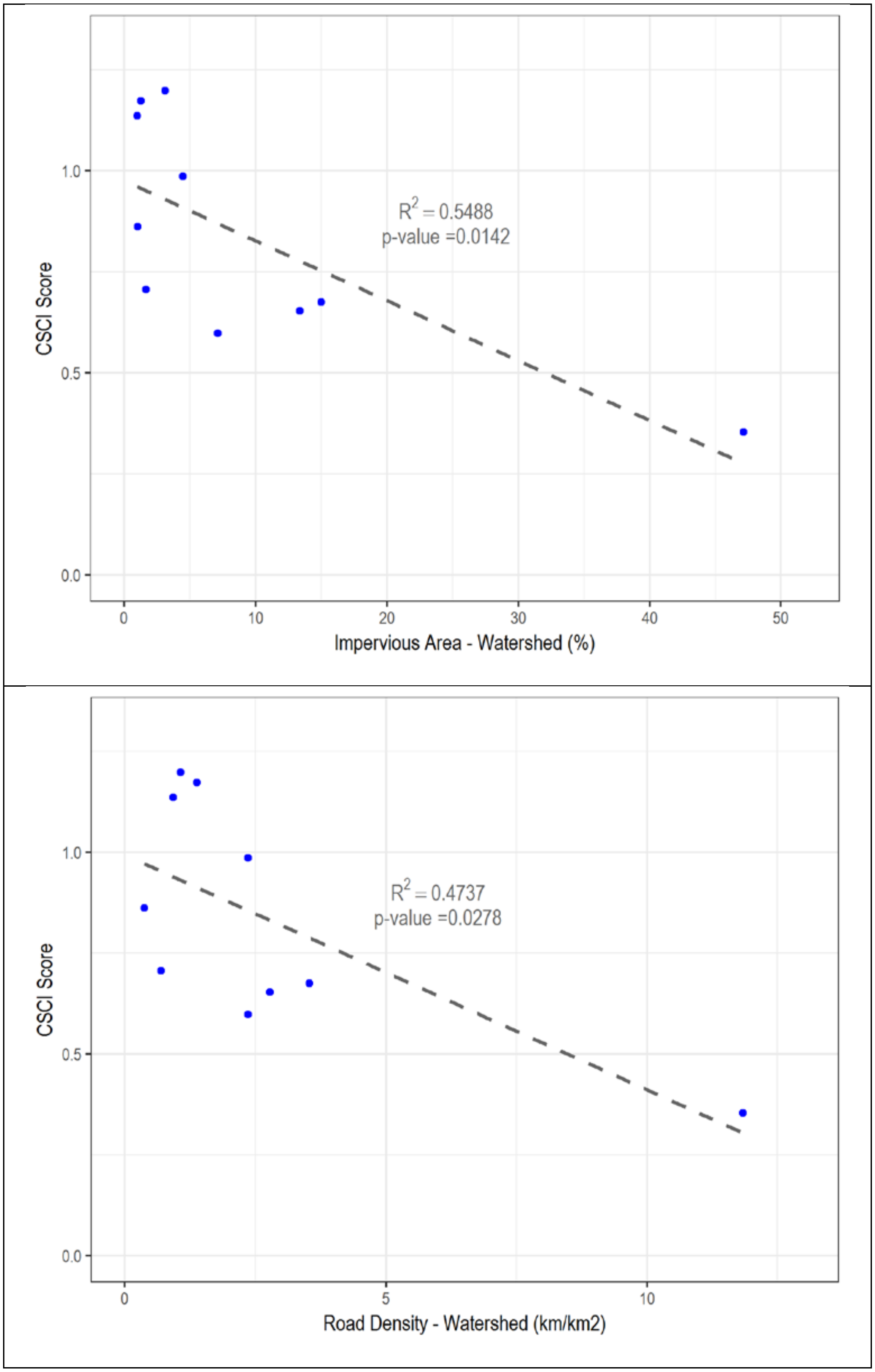
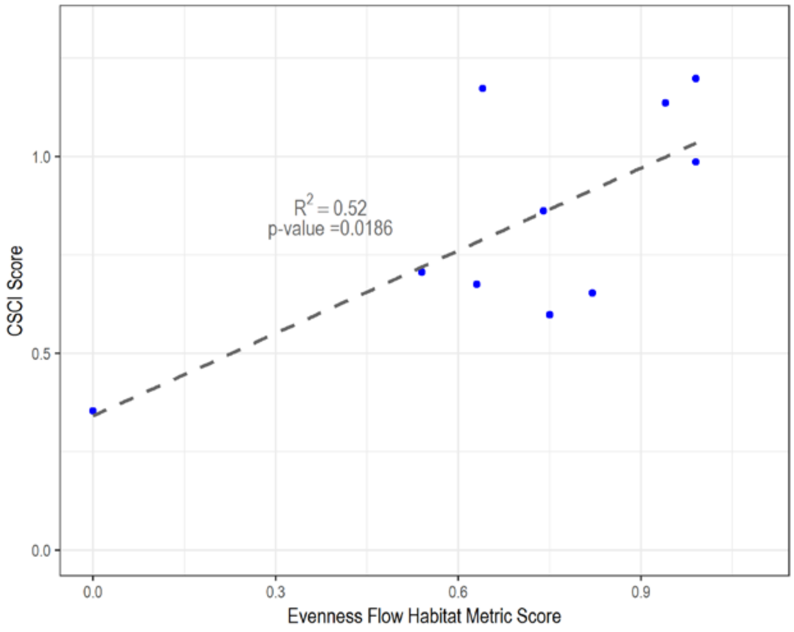


Figure 2.7. CSCI scores compared to landscape variables (percent impervious and road density) for 10 bioassessment sites sampled in San Mateo County in WY 2018.

Physical Habitat

Scores for eleven physical habitat metrics that were generated from the physical habitat data collected at bioassessment sites in WY 2018 are listed in Table 2.10. Based on the simple regression models, the strongest relationships between CSCI scores and physical habitat were for *Evenness Flow Habitat* ($r^2 = 0.52$, p-value <0.02) and negatively correlated with *Mean Filamentous Algae Cover* ($r^2 = 0.41$, p-value < 0.05) (Figure 2.8). The same two landscape variables were less correlated with the ASCI scores (not shown).



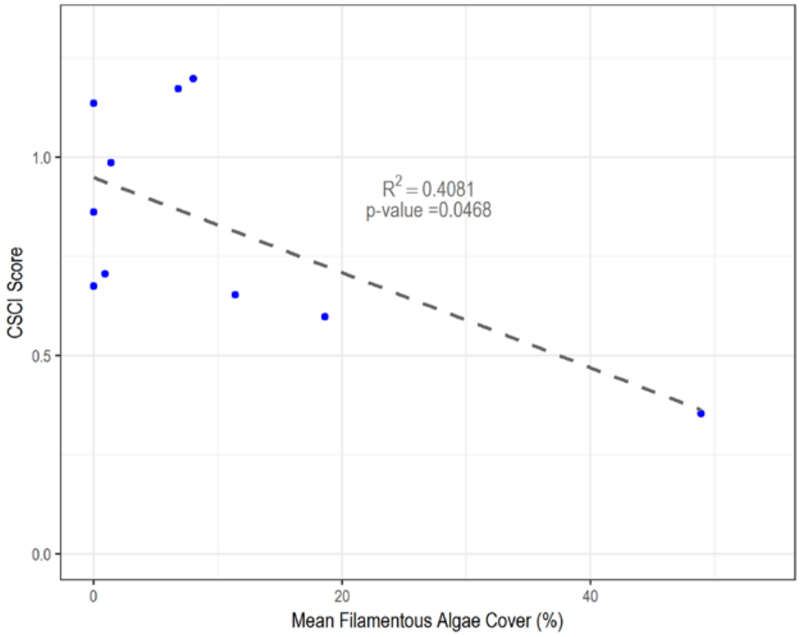


Figure 2.8. CSCI Scores compared to PHAB metric scores (Evenness Flow Habitat and Mean Filamentous Algae Cover) for 10 bioassessment sites sampled in San Mateo County in WY 2018.

Water Chemistry (Nutrients)

Nutrient and conventional analyte concentrations measured in water samples collected at ten bioassessment sites in San Mateo County during WY 2018 are listed in Table 2.11. There were no water quality objective exceedances for water chemistry parameters.

Total nitrogen concentrations ranged from 0.22 to 1.1 mg/L. Total phosphorus concentrations ranged from <0.01 to 0.12 mg/L. Neither of the nutrient parameters were correlated with CSCI or hybrid ASCI scores.

In an effort to assess whether nutrient concentrations (measured during bioassessments) are affecting indicators of biomass (i.e., chlorophyll a, ash free dry mass, percent algae cover), simple regression models were run. Neither of the biomass indicators were correlated with algae cover or nutrients for the WY 2018 dataset.

Table 2.10. Scores for 11 PHAB metrics calculated from physical habitat data collected at ten probabilistic sites in San Mateo County during WY 2018.

Station Code	CSCI Score	Channel Morphology		Habitat Complexity and Cover				Substrate Size and Composition				Human Disturbance
		Evenness of Flow Habitat Types[1]	Percent Fast Water of Reach	Shannon Diversity of Aquatic Habitat Types[1]	Natural Shelter Cover	Mean Filamentous Algae Cover	Riparian Cover Sum of 3 Layers[1]	Evenness of Natural Substrate Types	Shannon Diversity of Natural Substrate Types[1]	Percent Gravel - Coarse	Percent Substrate Smaller than Sand (<2 mm)[1]	Riparian Human Disturbance Index
202R00584	0.86	0.7	66	1.6	81	0	45	0.9	1.7	25	42	2.7
202R00614	1.17	0.6	74	1.9	21	7	105	0.9	1.6	39	19	1.7
202R03404	0.65	0.8	48	1.7	44	11	94	0.8	1.7	22	29	2.5
202R03656	0.71	0.5	78	1.5	77	1	96	0.8	1.2	17	65	3.1
202R03880	0.99	1.0	44	1.5	66	1	234	0.7	1.5	32	32	0.6
202R03916	0.68	0.6	10	1.6	26	0	102	0.8	1.5	44	32	2.5
204R03508	0.35	0.0	0	0.9	17	49	59	0.8	1.4	34	17	5.3
204R03528	0.60	0.8	67	1.8	35	19	71	0.9	1.5	30	44	2.3
205R03624	1.20	1.0	55	1.6	39	8	157	0.9	1.6	30	22	4.3
205R03864	1.14	0.9	36	1.4	29	0	145	0.9	1.7	30	27	0.0

[1] One of the five metrics used for development of the Index for Physical Habitat Integrity (IPI)

Table 2.11. Nutrient and conventional constituent concentrations in water samples collected at ten sites in San Mateo County during WY 2018. No water quality objectives were exceeded. See Table 2.1 for WQO values.

Station Code	Creek	Ammonia as N	Unionized Ammonia (as N)	Chloride	AFDM	Chlorophyll a	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen As N	Total Nitrogen	Ortho-Phosphate as P	Phosphorus as P	Silica as SiO2	Macro Algae Cover
		mg/L	mg/L	mg/L	g/m2	mg/m2	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Water Quality Objective:		*NA*	*0.025* [b]	*250* [a]	*NA*	*NA*	*10* [a]	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
202R00584	Pilarcitos Creek	0.03	< 0.001	23	26	2	0.46	0.003 J	0.31	0.77	0.02	0.08	32.38	0
202R00614	Pescadero Creek	0.05	0.001	38	48	30	0.06	0.001 J	0.44	0.50	0.10	0.12	12.38	32
202R03404	San Pedro Creek	0.05	0.001	26	43	10	0.49	0.007	0.44	0.94	0.02	< 0.007	0.95	12
202R03656	Pilarcitos Creek	0.04	< 0.001	33	40	< 2.5	0.85	0.003 J	0.26	1.11	0.04	0.08	0.00	1
202R03880	La Honda Creek	0.77	0.021	22	19	12	0.09	< 0.001	0.13	0.22	0.02	0.01	1.90	0
202R03916	San Pedro Creek	0.08	0.002	28	58	9	0.50	0.006	0.35	0.86	0.03	< 0.007	40.00	2
204R03508	Mills Creek	0.04	0.001	51	38	86	0.11	0.002 J	0.4	0.51	0.05	0.03	7.62	40
204R03528	San Mateo Creek	0.07	0.001	16	33	14	0.14	0.001 J	0.35	0.49	0.01	< 0.007	2.86	8
205R03624	Bear Creek	0.03	0.001	17	64	31	0.16	< 0.001	0.35	0.51	0.09	0.10	0	3
205R03864	Hamms Gulch	0.77	0.009	33	92	< 3.0	0.10	< 0.001	0.35	0.45	0.09	0.09	0	0
Number of exceedances		NA	0	0	NA	NA	0	NA	NA	NA	NA	NA	NA	NA

NA = Not Applicable

J = The reported result is an estimate.

[a] Chloride and nitrate WQOs only apply to waters with MUN designated Beneficial Uses.

[b] This threshold is an annual median value and is not typically applied to individual samples.

3.0 Continuous Water Quality Monitoring

3.1 Introduction

During WY 2018 water temperature and general water quality were monitored in compliance with Creek Status Monitoring Provisions C.8.d.iii – iv of the MRP. Monitoring was conducted at selected sites using a targeted design based on the directed principle[18] to address the following management questions:

1. *What is the spatial and temporal variability in water quality conditions during the spring and summer season?*
2. *Do general water quality measurements indicate potential impacts to aquatic life?*

The first management question is addressed primarily through evaluation of water quality results in the context of existing aquatic life uses. Temperature and general water quality data were evaluated for potential impacts to different life stages and overall population of fish community present within monitored reaches.

The second management question is addressed primarily through the evaluation of targeted data with respect to water quality objectives and thresholds from published literature. Sites where exceedances occur may indicate potential impacts to aquatic life or other beneficial uses and are considered as candidates for future Stressor/Source Identification projects.

3.2 Study Area

In compliance with the MRP, temperature was monitored at four sites, and general water quality was monitored at two sites. The targeted monitoring design focuses on sites selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns.

3.2.1 Temperature and General Water Quality

Continuous (hourly) temperature measurements were recorded from April 5 through September 25, 2018, at five locations[19] in San Pedro Creek. Continuous (15-minute) general water quality measurements (temperature, dissolved oxygen, pH, specific conductance) were recorded at two of the temperature stations during two two-week sampling events (Events 1 and 2). Sample Event 1 occurred from May 4 through May 17, 2018. Sample Event 2 occurred from August 10 through August 21, 2018. The same locations were monitored for continuous temperature and water quality as part of MRP Creek Status Monitoring during WY 2017. Temperature and general water quality monitoring stations for both years are illustrated in Figure 3.1.

San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County (Titus et al. 2010). The San Pedro Creek watershed is approximately 8 square miles and encompasses the urban communities of

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

[19] SMCWPPP typically monitors water temperature at more stations than the MRP requires to mitigate for potential equipment loss.

Linda Mar, Sun Valley and Park Pacifica. The majority of South and Middle Fork subwatersheds are located within the undeveloped and public lands of San Pedro Valley County Park; these sub-watersheds account for approximately 25% of the total watershed area.

Although degradation of physical habitat and the presence of fish barriers such as bridge culverts may threaten the steelhead population in San Pedro Creek, restoration efforts are helping to reestablish and enhance habitat. For example, in 2005 the City of Pacifica removed a fish passage and migration barrier at Capistrano Avenue Bridge and restored approximately 1,300 linear feet of channel. The City also implemented the San Pedro Creek Flood Control Project which reconstructed a meandering channel and active floodplain in the lower 3,100-feet of San Pedro Creek.

In WY 2018, SMCWPPP conducted bioassessment monitoring at two locations on San Pedro Creek: one near the mouth of creek and one just upstream of the confluence with Brooks Creek (also known as the Sanchez Fork) (Figure 3.1). CSCI scores were in the “likely altered” condition categories. In WY 2015, SCMWPPP conducted bioassessment monitoring farther up in the watershed at two locations on the Middle Fork of San Pedro Creek. CSCI scores were in the “possibly intact” and “likely intact” stream condition categories. The mouth of San Pedro Creek was also targeted for wet weather Pesticides and Toxicity monitoring in WY 2018 (see Section 6.0) and dry weather Pesticides and Toxicity monitoring in WY 2017.

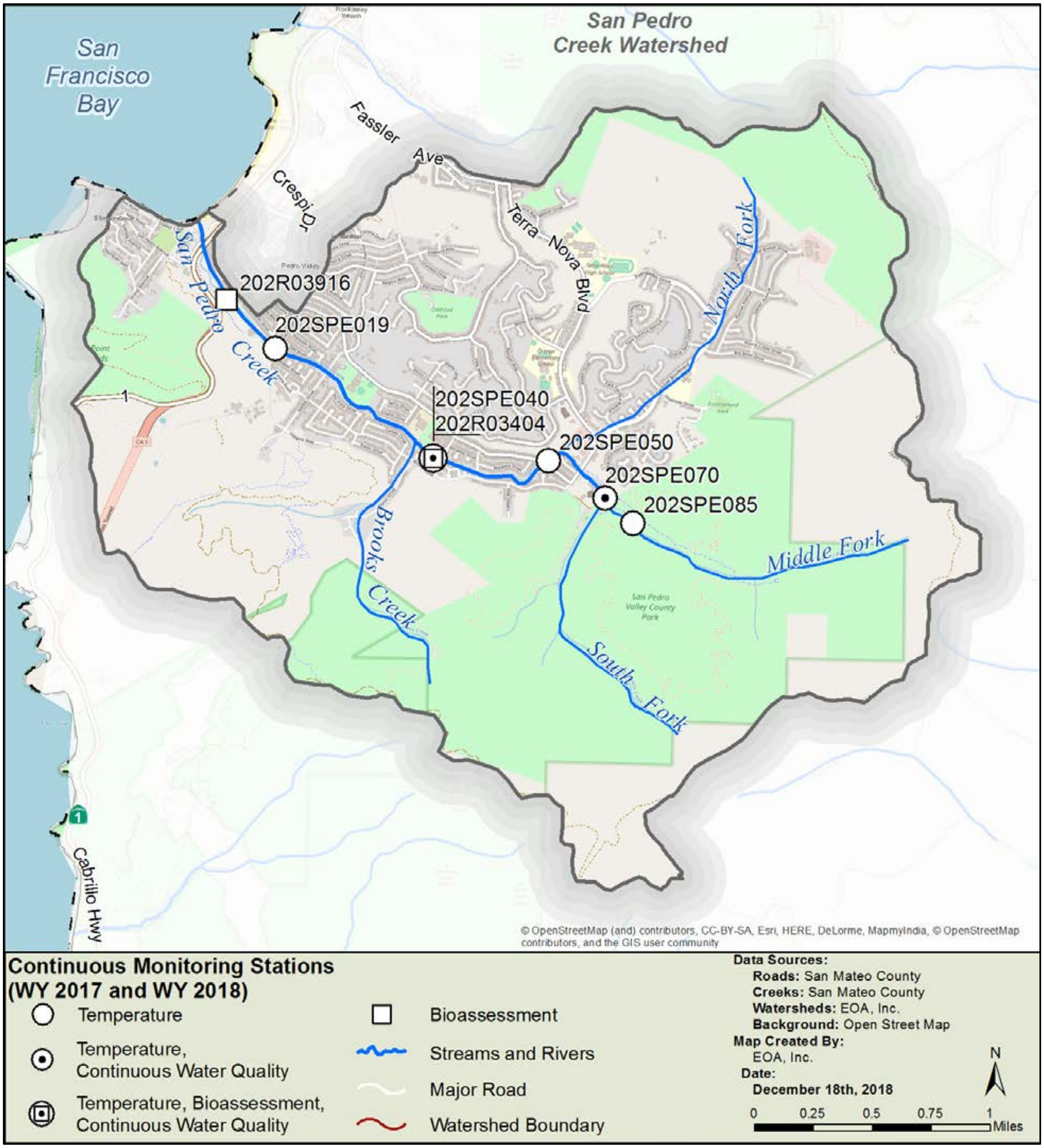

Figure 3.1. Continuous temperature and water quality stations in the San Pedro Creek watershed, San Mateo County, WY 2018.

3.3 Methods

Water quality data were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b) and associated QAPP (BASMAA 2016a). Data were evaluated with respect to the MRP Provision C.8.d "Follow-up" triggers for each parameter.

3.3.1 Continuous Temperature

Digital temperature loggers (Onset HOBO Water Temp Pro V2) programmed to record data at 60-minute intervals. The loggers were deployed at targeted sites from April 5 through September 25, 2018. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-5 (BASMAA 2016b).

3.3.2 Continuous General Water Quality

Water quality monitoring equipment recording dissolved oxygen, temperature, conductivity, and pH(YSI 6600 data sondes) were programmed to record data at 15-minute intervals. The sondes were deployed at targeted sites for two 2-week periods: once during spring season (Event 1) and once during summer season (Event 2) in 2018. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-4 (BASMAA 2016b).

3.3.3 Data Evaluation

Continuous temperature and water quality data generated during WY 2018 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or impacted biological conditions, including exceedances of water quality objectives. Provision C.8.d of the MRP identifies trigger criteria as the principal means of evaluating the creek status monitoring data to identify sites where water quality impacts may have occurred. Sites with targeted monitoring results exceeding the trigger criteria are identified as candidate SSID projects. The relevant trigger criteria for continuous temperature and water quality data are listed in Table 3.1.

Table 3.1. Water Quality Objectives and thresholds used for trigger evaluation.

Monitoring Parameter	Objective/Trigger Threshold	Units	Source
Temperature	Two or more weekly average temperatures exceed the MWAT of 17.0°C for a Steelhead stream, or when 20% of the results at one sampling station exceed the instantaneous maximum of 24°C.	^{0}C	MRP Provision C.8.d.iii.
General Water Quality Parameters	20% of results at each monitoring site exceed one or more established standard or threshold - applies individually to each parameter		
Conductivity	2000	uS/cm	MRP Provision C.8.d.iii.
Dissolved Oxygen	WARM < 5.0, COLD < 7.0	mg/L	SF Bay Basin Plan Ch. 3, p. 3-4
pH	> 6.5, < 8.5 [1]	pH	SF Bay Basin Plan Ch. 3, p. 3-4
Temperature	Same as Temperature (See Above)		

[1] Special consideration will be used at sites where imported water is naturally causing higher pH in receiving waters.

3.4 Results and Discussion

The section below summarizes results from continuous temperature and water quality monitoring conducted during WY 2018. Conclusions and recommendations for this section are presented in Section 7.0.

3.4.1 Continuous Temperature

Temperature loggers were deployed at five sites in the San Pedro Creek watershed on April 5, checked and downloaded on June 21, and removed on September 25, 2018. During the field check in June, the temperature logger at site 202SPE019 was not recovered, and another logger was re-deployed. As a result, only 13 weeks of data were recorded at that site.

Summary statistics for continuous water temperature data collected at the five sites are listed in Table 3.2. None of the recorded temperatures exceeded the instantaneous maximum temperature trigger of 24°C.

Table 3.2 Descriptive statistics for continuous water temperature measured between April 5 through September 25, 2018 at five sites in San Pedro Creek, San Mateo County.

Site ID (202SPE)		019	040	050	070	085
Start Date		6/21/2018	4/5/2018	4/5/2018	4/5/2018	4/5/2018
End Date		9/24/2018	9/25/2018	9/25/2018	9/25/2018	9/25/2018
Temperature (°C)	Minimum	11.4	10.9	11.3	9.4	9.0
	Median	15.2	14.2	14.2	13.1	13.3
	Mean	15.3	14.3	14.2	13.1	13.3
	Maximum	18.9	17.9	17.0	16.0	18.0
	Max 7-day mean	16.7	16.1	15.7	14.7	15.9
	N (# individual measurements)	2204	4149	4150	4148	4149
# Measurements > 24°C		0	0	0	0	0

Maximum Weekly Average Temperature (MWAT) values were calculated for each of the five monitoring sites (Table 3.3). Consistent with MRP requirements, the MWAT was calculated for non-overlapping, seven-day periods. The MWAT values across all the sites ranged from 10.7 °C to 13.4 °C during the month of April to 13.3 °C to 15.7°C during the month of August. Time series plots of the MWAT values are shown for all five sites in San Pedro Creek (Figure 3.2). Similar to the results from WY 2017, the MWAT trigger was never exceeded at any of the sites.

Table 3.3. MWAT values for water temperature data collected at five stations monitored in San Pedro Creek watershed, WY 2018. MRP trigger is 17°C.

Station	202SPE019	202SPE040	202SPE050	202SPE070	202SPE085
Date	Maximum Weekly Average Temperature (°C)				
4/5/2018		13.1	13.1	12.1	11.9
4/12/2018		12.3	12.4	11.0	10.7
4/19/2018		12.8	12.9	11.5	11.1
4/26/2018		13.3	13.4	12.1	11.7
5/3/2018		13.5	13.6	12.2	11.9
5/10/2018		13.8	13.9	12.6	12.4
5/17/2018		13.4	13.6	12.4	12.0
5/24/2018		13.8	13.8	12.6	12.3
5/31/2018		13.7	13.7	12.4	12.2
6/7/2018		14.0	14.0	12.9	12.7
6/14/2018		14.2	14.1	13.0	13.1
6/21/2018	14.8	14.5	14.3	13.2	13.4
6/28/2018	15.4	14.9	14.6	13.6	13.9
7/5/2018	15.8	15.2	14.9	13.8	14.5
7/12/2018	16.3	15.7	15.3	14.3	15.3
7/19/2018	16.7	16.1	15.7	14.7	15.9
7/26/2018	14.6	14.6	14.6	13.7	14.4
8/2/2018	14.7	14.4	14.3	13.3	13.8
8/9/2018	15.4	14.9	14.8	13.8	14.3
8/16/2018	15.5	15.2	15.0	14.0	14.7
8/23/2018	15.7	15.3	15.2	14.2	14.9
8/30/2018	15.3	15.2	15.1	14.0	14.7
9/6/2018	14.6	14.4	14.4	13.3	13.5
9/13/2018	14.7	14.6	14.6	13.6	13.9
9/20/2018		13.3	13.4	12.2	11.9
Total Weeks	13	25	25	25	25
MWAT >17	0	0	0	0	0
% Exceed	0%	0%	0%	0%	0%
> MRP Trigger	N	N	N	N	N

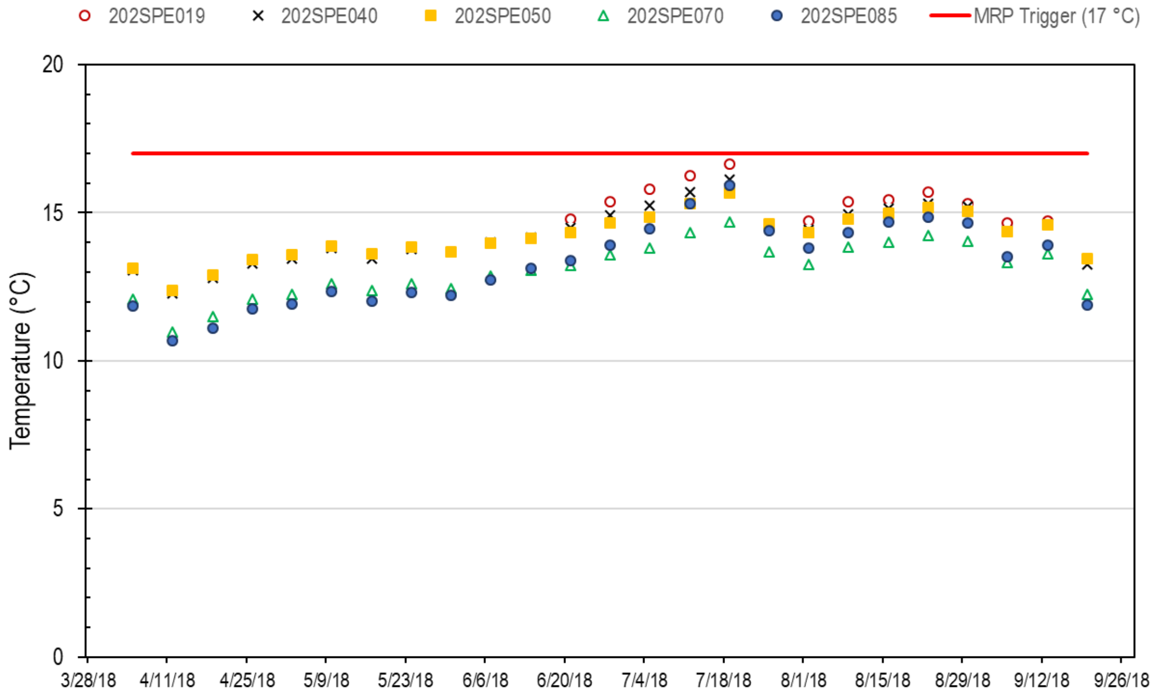

Figure 3.2. Maximum Weekly Average Temperature (MWAT) values calculated for water temperature collected at five sites in San Pedro Creek over 26 weeks of monitoring in WY 2018. The MRP trigger (17°C) is shown for comparison.

Water temperature data, calculated as a daily average, for monitoring sites in San Pedro Creek collected during WY 2018, are shown in Figure 3.3. Daily average temperatures for data collected in WY 2017 are also presented for comparison. In WY 2018, water temperatures generally increased from the start of the monitoring period through the end of August followed by a slow decline in early September. Water temperatures showed a similar pattern in 2017, with the exception of a period of high temperatures observed during the month of September, reflecting the occurrence of a heatwave that exhibited some of the highest air temperatures on record.

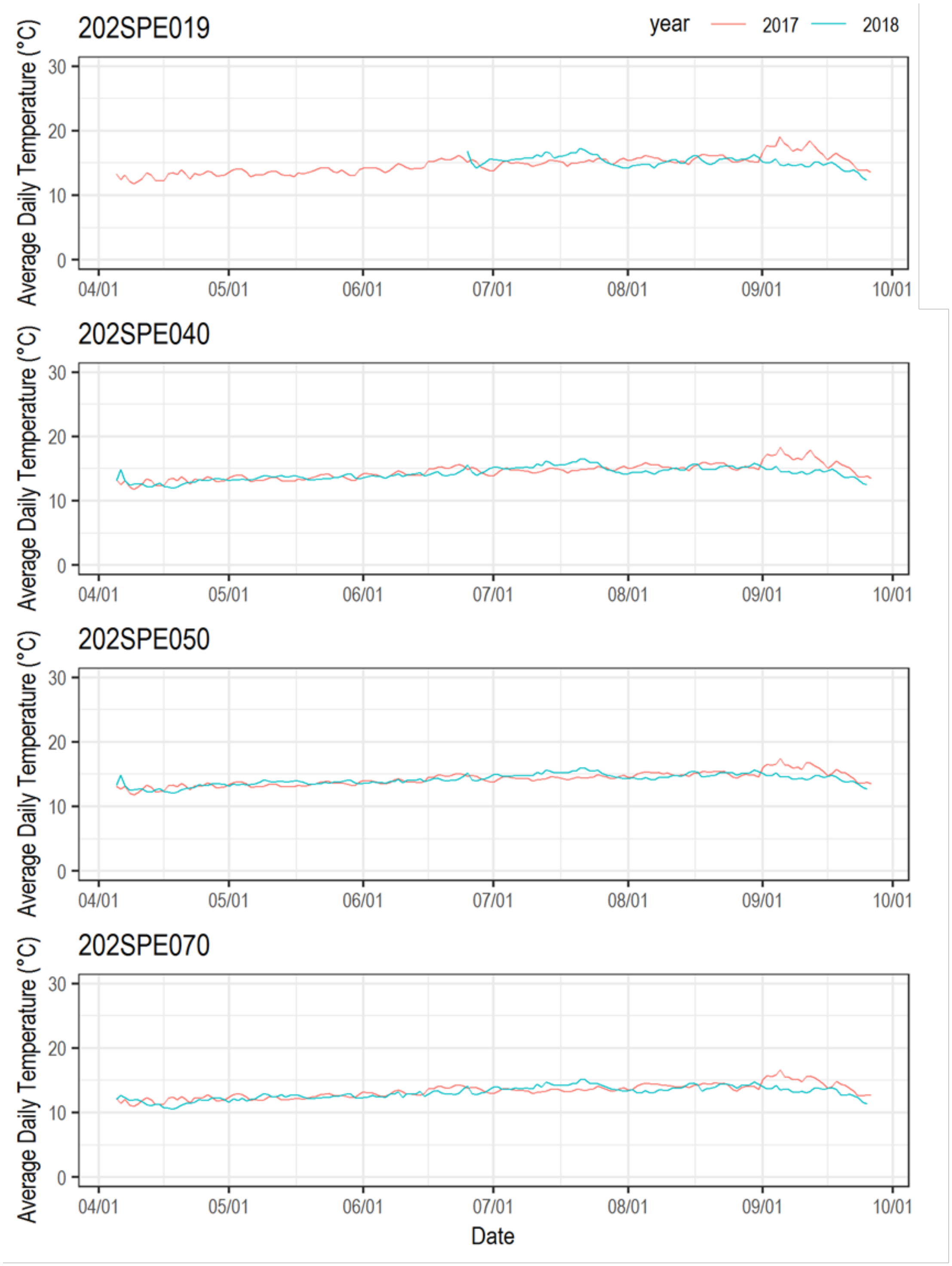

Figure 3.3 Water temperature, shown as daily average, collected between April and September 2017 and 2018 at five sites in San Pedro Creek, San Mateo County.[20]

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[20] Datalogger at site 019 was not recovered during field check in June; data was collected June – September.

Instantaneous water temperatures collected at monitoring sites in San Pedro Creek for both years, are presented as bean plots in Figure 3.4. The pattern for water temperatures across all sites was relatively consistent for both years, with the median temperature generally increasing with decreasing site elevation.

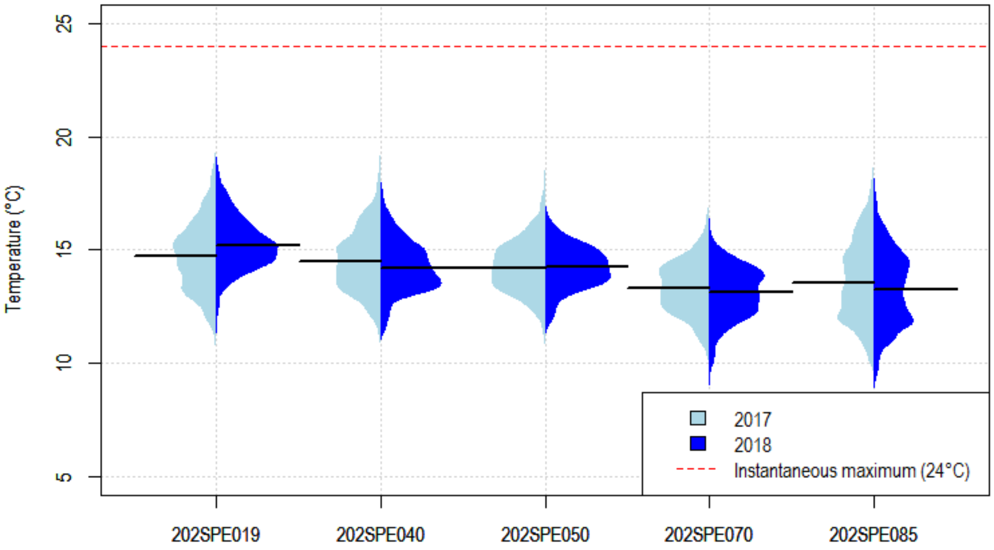

Figure 3.4. Water temperature data, presented as bean plots, collected between April and September at five sites in San Pedro Creek during WY 2017 and WY 2018. Solid black lines indicate median temperature.

The Basin Plan (SFRWQCB 2017) designates several Beneficial Uses for San Pedro Creek that are associated with aquatic life uses, including COLD, WARM, MIGR, SPWN and RARE (Table 1.4). Rearing and spawning habitat for steelhead trout is supported predominantly though the habitat of the protected Middle Fork San Pedro Creek. The restored section of the main stem of the creek is best suited for rearing to smolt size. Measured water quality and temperature are likely not limiting factors for steelhead trout in San Pedro Creek.

3.4.2 General Water Quality

Summary statistics for general water quality measurements collected at the two stations in San Pedro Creek are listed in Table 3.4. Station locations are mapped in Figure 3.1. For Event 1, sondes were deployed on May 4 and retrieved on May 17, 2018. For Event 2, sondes were deployed on August 10 and retrieved on August 21, 2018.

Table 3.4. Descriptive statistics for continuous water temperature, dissolved oxygen, pH, and specific conductance measured at two San Pedro Creek sites in San Mateo County during WY 2018. Data were collected every 15 minutes over a two 2-week time periods during May (Event 1) and August (Event 2).

Parameter	Data Type	202SPE040		202SPE070	
		Event 1 WY18	Event 2 WY18	Event 1 WY18	Event 2 WY18
Temperature (°C)	Minimum	12.1	13.7	10.9	11.6
	Median	13.6	15.1	12.4	14
	Mean	13.7	15.1	12.4	13.8
	Maximum	15.6	16.8	13.9	15.1
	% > 24	0%	0%	0%	0%
Dissolved Oxygen (mg/L)	Minimum	9.7	8.7	10.2	9.8
	Median	10.3	9.4	10.6	10
	Mean	10.3	9.4	10.6	10
	Maximum	10.7	9.9	11	10.6
	% < 7	0%	0%	0%	0%
pH	Minimum	7.99	7.7	7.57	7.68
	Median	8.19	7.9	7.87	7.78
	Mean	8.18	7.89	7.87	7.77
	Maximum	8.3	8.07	7.95	7.9
	% < 6.5 or > 8.5	0%	0%	0%	0%
Specific Conductivity (uS/cm)	Minimum	438	390	266	218
	Median	464	399	273	225
	Mean	464	401	273	226
	Maximum	475	490	283	235
	% > 2000	0%	0%	0%	0%
Total number of data points (N)		1229	1039	1191	858

Time series plots of the data for Event 1 and Event 2 are shown in Figures 3.5 and 3.6, respectively. MRP trigger thresholds are shown for reference. Water temperature distributions during Event 2 during WY 2017 and WY 2018 are plotted in Figure 3.7.

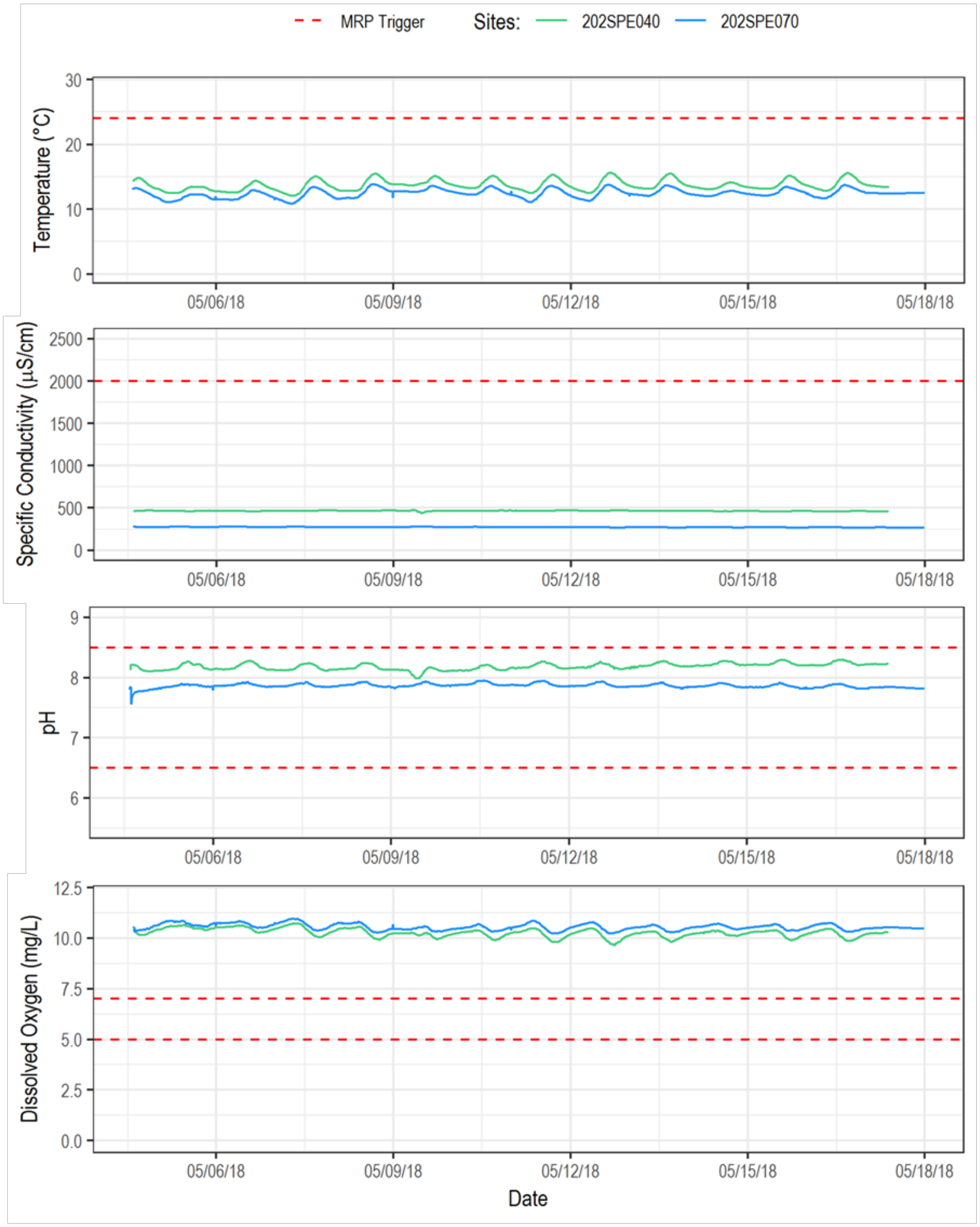

Figure 3.5 Continuous water quality data (temperature, specific conductance, pH, and dissolved oxygen) collected during May 4 – May 17, 2018 (Event 1) at two sites in San Pedro Creek watershed.

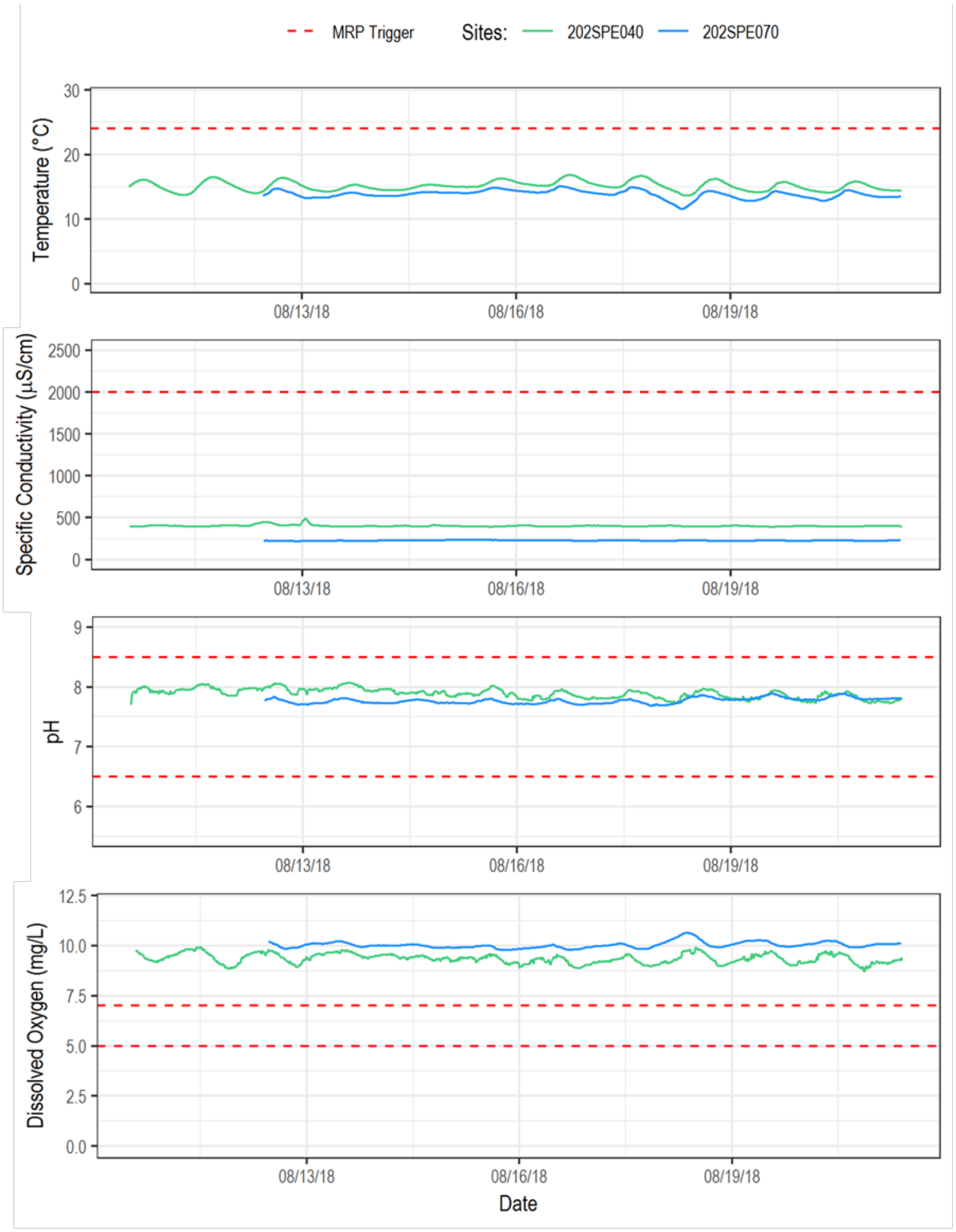

Figure 3.6 Continuous water quality data (temperature, specific conductance, pH, and dissolved oxygen) collected during August 10 – 20, 2018 (Event 2) at two sites in San Pedro Creek watershed.

Temperature

Water temperatures recorded by the sondes never exceeded the 24°C MRP trigger threshold for instantaneous maximum temperature at either site for both sampling events (Figures 3.5 and 3.6). The water temperature data collected by temperature loggers were used to evaluate MWAT (see previous section). As previously stated, the MWAT threshold of 17°C was not exceeded at any of the San Pedro Creek stations.

Specific Conductivity

Specific conductance measurements did not exceed the MRP trigger of 2000 µs/cm during either sampling event. Conductivity was slightly higher at the downstream station (202SPE040) compared to the upstream station (202SPE070). (Figures 3.5 and 3.6). The site is located in a more urbanized part of the creek, and run-off from the surrounding land uses may contribute to the higher specific conductance.

pH

During the two sampling events, all pH measurements fell within the Basin Plan WQOs for pH (< 6.5 and/or > 8.5). Similar to specific conductance, the pH was slightly higher at the downstream site (202SPE040) compared to the upstream station (202SPE070) (Figures 3.5 and 3.6).

Dissolved Oxygen

Dissolved oxygen (DO) concentrations were above the Basin Plan minimum WQOs for WARM (5.0 mg/L) and COLD (7.0 mg/L) at both sites during both sampling events. DO concentrations were similar at both locations, ranging between 8.7 mg/L and 11.0 mg/L (Figures 3.5 and 3.6). The high concentrations are likely a result of the consistent flows observed at both locations during WY 2017, which are supported by several springs in the upper watershed.

4.0 Pathogen Indicator Monitoring

4.1 Introduction

During WY 2018, pathogen indicators were monitored in compliance with Creek Status Monitoring Provision C.8.d.v of the MRP. Monitoring was conducted at sites selected using a targeted design based on the directed principle to address the following management question:

1. *What are the pathogen indicator concentrations at creek sites where there is potential for water contact recreation to occur?*

This management question is addressed primarily through the evaluation of targeted data with respect to trigger thresholds identified in the MRP. Sites where exceedances occur may indicate potential impacts to aquatic life or other beneficial uses and are considered as candidates for future Stressor/Source Identification projects.

4.2 Study Area

In compliance with Provision C.8.d.v of the MRP, pathogen indicator samples were collected during one sampling event (July 27, 2018) at five sites. The selection of sites was based on information on previous sampling results showing high bacteria concentrations that was provided by San Mateo County Parks staff (Figure 4.1). All sites were located in the Pescadero Creek watershed in the vicinity of Memorial County Park. Two sites were located on tributaries to Pescadero Creek: Jones Gulch (202PES150) and McCormick Creek (202PES142). Three sites were located on the main stem of Pescadero Creek upstream and downstream of the confluences with the two sampled tributaries. The sites were selected with coordination from San Mateo County Park staff to characterize geographic patterns of pathogen indicator densities within the Pescadero Creek watershed.

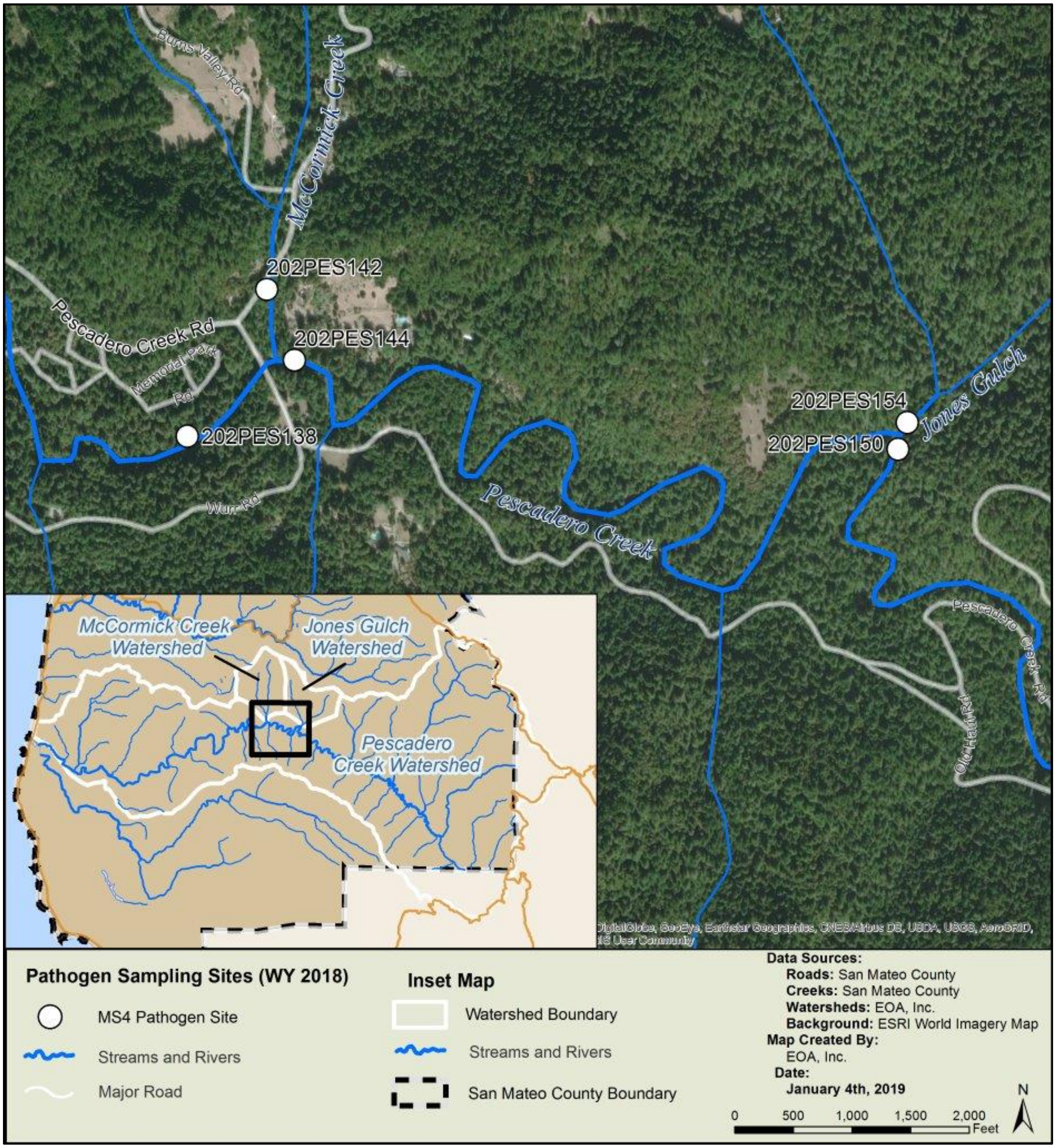

Figure 4.1. Pathogen indicator monitoring sites in WY 2018, Pescadero Creek Watershed.

4.3 Methods

Pathogen indicator data were collected during the dry season in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b) and associated QAPP (BASMAA 2016a). Sampling techniques for pathogen indicators (enterococci and *E. coli*) include direct filling of containers (or use of intermediate sampling containers) and transfer of samples to analytical laboratories within specified holding time requirements. Procedures used for sampling and transporting samples are described in RMC SOP FS-2 (BASMAA 2016b).

Pathogen indicator data generated during WY 2018 were evaluated with respect to MRP Provision C.8.d.v “Followup” triggers to identify potential impacts to water contact recreation (REC-1). The relevant trigger criteria for pathogen indicator data is based on USEPA (2012) recommended statistical threshold value for an estimated illness rate of 36 per 1000 primary contact recreators. For *E. coli*, the trigger threshold is 410 cfu/100 mL. For enterococcus, the trigger threshold is 130 cfu/100 mL. Sites with monitoring results exceeding the trigger criteria are identified as candidate SSID projects.

4.4 Results and Discussion

The section below summarizes results from pathogen indicator monitoring conducted during WY 2018. Conclusion and recommendations for this section are presented in Section 7.0.

Pathogen indicator (*E. coli* and enterococci) densities measured in grab samples collected on July 27, 2018 are listed in Table 3.1. Stations are mapped in Figure 4.1. There were no measurements that exceeded the MRP trigger for *E. coli*; however, two samples exceeded the MRP trigger for enterococci. The enterococci trigger exceedances were observed in McCormick Creek (202PES142) and Pescadero Creek at Memorial Park downstream of the McCormick confluence (202PES138). These sites will be added to the list of candidate SSID sites. It appears likely that McCormick Creek discharges were affecting water quality in Pescadero Creek on July 27, 2018. Potential sources of pathogen indicators include, but are not limited to, pet waste, wildlife, bacterial growth within the creekbed and conveyance systems, and leaking public and private sewer lines or onsite wastewater treatment systems.

It is important to recognize that pathogen indicators do not directly represent actual pathogen concentrations and do not distinguish among sources of bacteria. Testing water samples for specific pathogens is generally not practical for a number of reasons (e.g., concentrations of pathogens from fecal contamination may be small and difficult to detect but still of concern, laboratory analysis is often difficult and expensive, and the number of possible pathogens to potentially test for is large). Therefore, the presence of pathogens is inferred by testing for “pathogen indicator” organisms. The USEPA recommends using *E. coli* and enterococci as indicators of fecal contamination based on historical and recent epidemiological studies (USEPA 2012). The USEPA pathogen indicator thresholds were derived based on human recreation at beaches receiving bacteriological contamination from human wastewater, and may not be applicable to conditions in urban creeks which do not receive wastewater treatment plant discharges. Furthermore, although animal fecal waste contributes to the pathogen indicator load, it is much less likely to contain pathogens of concern to human health than human sources. In most cases, it is the human sources that are associated with REC-1 health risks rather than wildlife or domestic animal sources (USEPA 2012). As a result, the comparison of pathogen indicator results to pathogen indicator thresholds may not be appropriate and should be interpreted cautiously.

The State Water Board recently (August 7, 2018) adopted new WQOs for *E. coli* and enterococci based on USEPA (2012) criteria. The new WQOs, which are based on an estimated illness rate of 32 per 1000 primary contact recreators, will become effective upon approval by the Office of Administrative Law and the USEPA. [21] For freshwaters (i.e., salinity equal to or less than 1 part per thousand (ppth) 95 percent of the year), the six-week rolling geometric mean of *E. coli* must not exceed 100 cfu/100 mL; and the statistical threshold value (STV) of 320 cfu/100 mL must not be exceeded by more than 10 percent of samples collected in a calendar month. For marine and brackish waters (i.e., salinity greater than 1 ppth more than 5 percent of the year), the six-week rolling geometric mean of enterococci must not exceed 30 cfu/100 mL; and the STV of 110 cfu/100 mL must not be exceeded by more than 10 percent of samples collected in a calendar month. These thresholds are included in Table 3.1 for reference.

Table 4.1. Enterococci and *E. coli* levels measured in San Mateo County during WY 2018 (July 27, 2018).

Site ID	Creek Name	Site Name	*Enterococci (cfu/100ml) (MPN/100ml)*[1]	*E. Coli (cfu/100ml) (MPN/100ml)*[1]
MRP Trigger Threshold (USEPA 2012; 36 per 1000 recreators)			*130*	*410*
Newly Adopted WQO (based on 32 per 1000 recreators)			*110*	*320*
202PES154	Pescadero Creek	Pescadero Creek Upstream of Jones Gulch	43	30
202PES150	Jones Gulch	Jones Gulch Upstream of Confluence	36	ND
202PES144	Pescadero Creek	Pescadero Creek Upstream of McCormick Creek	42	19
202PES142	McCormick Creek	McCormick Creek Upstream of Confluence	816	153
202PES138	Pescadero Creek	Pescadero Creek at Memorial Park	435	14

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[21] See http://www.waterboards.ca.gov/bacterialobjectives/ for more information.

5.0 Chlorine Monitoring

5.1 Introduction

Chlorine is added to potable water supplies and wastewater to kill microorganisms that cause waterborne diseases. However, the same chlorine can be toxic to the aquatic species. Chlorinated water may be inadvertently discharged to the MS4 and/or urban creeks from residential activities, such as pool dewatering or over-watering landscaping, or from municipal activities, such as hydrant flushing or water main breaks.

In compliance with Provision C.8.d.ii of the MRP and to assess whether chlorine in receiving waters is potentially toxic to aquatic life, SMCWPPP field staff measured total and free chlorine residual in creeks where bioassessments were conducted. Total chlorine residual is comprised of combined chlorine and free chlorine, and is always greater than or equal to the free chlorine residual. Combined chlorine is chlorine that has reacted with ammonia or organic nitrogen to form chloramines, while free chlorine is chlorine that remains unbound.

5.2 Methods

In accordance with the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), WY2018 field testing for free chlorine and total chlorine residual was conducted at all ten probabilistic sites concurrent with spring bioassessment sampling (May). Probabilistic site selection methods are described in Section 2.0.

Field testing for free chlorine and total chlorine residual conformed to methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b), which are comparable to those specified in the SWAMP QAPP. Per SOP FS-3 (BASMAA 2016b), water samples were collected and analyzed for free and total chlorine using a Pocket Colorimeter^{TM} II and DPD Powder Pillows, which has a manufacturer reported method detection limit of 0.02 mg/L. If concentrations exceed the MRP trigger criteria of 0.1 mg/L, the site was immediately resampled. Per Provision C.8.d.ii(4) of the MRP, "if the resample is still greater than 0.1 mg/L, then Permittees report the observation to the appropriate Permittee central contact point for illicit discharges so that the illicit discharge staff can investigate and abate the associated discharge in accordance with its Provision C.5.e – Spill and Dumping Complaint Response Program."

5.3 Results and Discussion

The section below summarizes results from chlorine monitoring conducted during WY 2018. Conclusion and recommendations for this section are presented in Section 7.0.

In WY 2018, SMCWPPP monitored the ten probabilistic sites for free chlorine and total chlorine residual. These measurements were compared to the MRP trigger threshold of 0.1 mg/L. Results are listed in Table 5.1. The trigger thresholds for free chlorine and total chlorine residual were not exceeded during sampling in WY2018. This indicates that the chlorine levels in the sampled creeks were not of concern during this time frame.

For unknown reasons, the free chlorine result was greater than the total residual chlorine result at one station (202R03624). Potential causes for these inverted results include matrix interferences and colorimeter user error. According to Hach, the supplier of the equipment and reagents, the free chlorine could have false positive results due to a pH exceedance of 7.6 and/or an alkalinity exceedance of 250 mg/L. The pH was measured concurrently with the chlorine sample, but alkalinity was not measured. The pH measured concurrently with chlorine at station 202R03624 exceeded 7.6, which have resulted in a false positive for the free chlorine measurement. It is unlikely that the higher free chlorine readings were caused by user error. The field crew is well trained and aware of potential problems with this testing method, such as wait times between adding reagents and taking the readings and separating the free chlorine and total residual chlorine samples. Overall, the cause of the inverted free chlorine and total chlorine residual results (compared to expected) is unknown. However, it should be noted that colorimetric field instruments are generally not capable of providing accurate measurements of free chlorine and total chlorine residual below 0.13 mg/L, regardless of the method detection limit provided by the manufacturer. For this reason, the Statewide General Permit for drinking Water Discharges (Order WQ 2014-0194-DWQ) uses 0.1 mg/L as a reporting limit for field measurements of total chlorine residual.

Table 5.1. Summary of SMCWPPP chlorine testing results compared to MRP trigger of 0.1 mg/L, WY 2018.

Station Code	Date	Creek	Free Chlorine (mg/L)[1,2]	Total Residual Chlorine (mg/L)[1,2]	Exceeds Trigger Threshold? (0.1 mg/L)[2]
202R00614	5/14/2018	Pescadero Creek	0.03	0.05	No
202R00584	5/15/2018	Pilarcitos Creek	<0.02	<0.02	No
202R03656	5/15/2018	Pilarcitos Creek	<0.02	<0.02	No
204R03508	5/16/2018	Mills Creek	<0.02	<0.02	No
204R03528	5/16/2018	San Mateo Creek	0.03	0.03	No
202R03404	5/17/2018	San Pedro Creek	<0.02	<0.02	No
202R03916	5/17/2018	San Pedro Creek	<0.02	0.06	No
205R03624	5/21/2018	Bear Creek	0.07	0.01	No
202R03880	5/22/2018	La Honda Creek	NS	NS	NA
205R03864	5/22/2018	Hamms Gulch	NS	NS	NA

[1] The method detection limit is 0.02 mg/L; however, the Statewide General Permit for Drinking Water Discharges (Order WQ 2014-0194-DWQ) uses 0.1 mg/L as a reporting limit (minimum level) for field measurements of total chlorine residual.

[2] The MRP trigger threshold of 0.1 mg/L applies to both free chlorine and total chlorine residual measurements

NS= Not Sampled due to failed battery in Pocket Colorimeter^{TM} II instrument. NA = Not Applicable.

A total of 70 stations have been monitored by SMCWPPP for free chlorine and total chlorine residual between WY 2012 and WY 2018 in compliance with MRP 1.0 and MRP 2.0. Occasional exceedances were recorded throughout the years and addressed by the appropriate follow-up process. Figure 4.1 maps of all the samples stations with their associated results. The results exceeding the 2015 MRP 20 trigger threshold of 0.1 mg/L are shown in red. The results exceeding 2009 MRP trigger threshold of 0.08 mg/L (but below the MRP 2.0 trigger) are shown in orange. All the results equal to or below 0.08 mg/L are shown in green. Trigger exceedances tend to occur in high order streams that flow through populated areas. The values range from non-detectable levels of chlorine to 0.58 mg/L. The two highest results occurred on Atherton Creek (WY 2017).

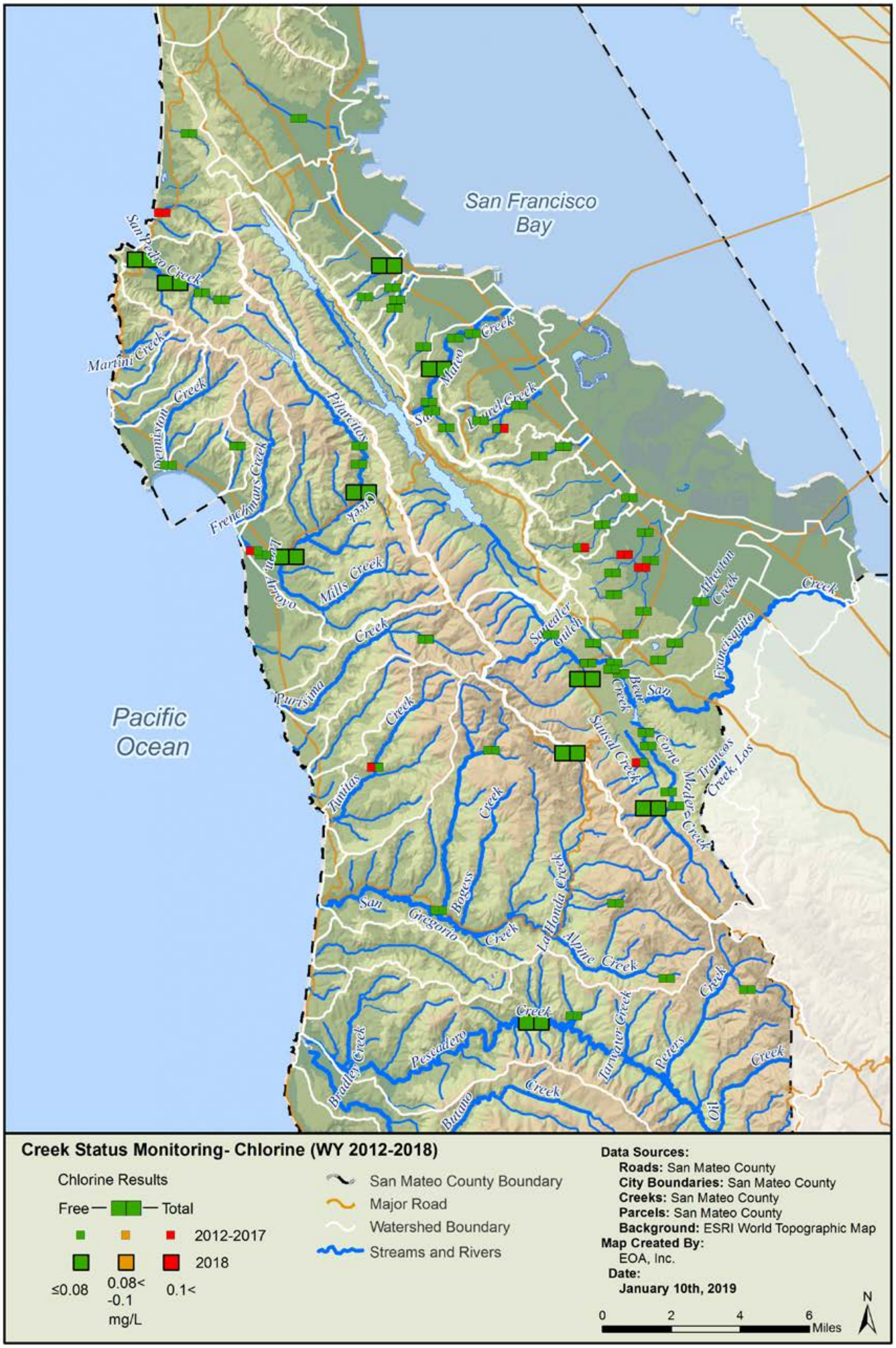

Figure 5.1 Chlorine sample stations WY 2012 – WY 2018 in San Mateo County.

6.0 Toxicity and Sediment Chemistry Monitoring

6.1 Introduction

Toxicity testing provides a tool for assessing the toxic effects (acute and chronic) of all chemicals in samples of receiving waters or sediments, and allows the cumulative effect of the pollutant present in the sample to be evaluated. Because different test organisms are sensitive to different classes of chemicals and pollutants, several different organisms are monitored. Sediment and water chemistry monitoring for a variety of potential pollutants conducted synoptically with toxicity monitoring provides preliminary insight into the possible causes of toxicity should they be found.

Provision C.8.g of the MRP requires both wet and dry weather monitoring of pesticides and toxicity in urban creeks.

Dry Weather

SMCWPPP is required to conduct water toxicity and sediment chemistry and toxicity monitoring at one location per year during the dry season, for each year of the permit term beginning in WY 2016. The permit provides examples of possible monitoring location types, including sites with suspected or past toxicity results, existing bioassessment sites, or creek restoration sites. Dry weather monitoring includes:

- Toxicity testing in water is required using five species: *Ceriodaphnia* dubia (chronic survival and reproduction), *Pimephales promelas* (larval survival and growth), *Selenastrum capricornutum* (growth), *Hyalella azteca* (survival) and *Chironomus dilutes* (survival).
- Toxicity testing in sediment is required using two species: *Hyella azteca* (survival) and *Chironomus dilutes* (survival).
- Sediment chemistry analytes include pyrethroids, fipronil, carbaryl, total polycyclic aromatic hydrocarbons (PAHs), metals, Total Organic Carbon (TOC), and sediment grain size.

Wet Weather

The wet weather monitoring requirements include collection of water column samples during storm events for toxicity testing (using the same five organisms required for dry weather toxicity testing) and analysis of pyrethroids, fipronil, imidacloprid and indoxacarb[22]. The MRP states that monitoring locations should be representative of urban watersheds (i.e., bottom of watersheds).

Provision C.8.g.iii.(3) requires a collective total of ten samples, with at least six samples collected by WY 2018, if the wet weather monitoring is conducted by the RMC on behalf of all Permittees. At the RMC Monitoring Workgroup meeting on January 25, 2016, RMC members agreed to collaborate on implementation of the wet weather monitoring requirements. All ten wet weather samples were collected in WY 2018 during a single storm event on January 8, 2018.

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[22] Standard analytical methods for indoxacarb are not currently available. Indoxacarb analysis will not be required until the water year following notification by the Executive Officer that a method is available.

SCVURPPP and ACCWP each collected three samples, and SMCWPPP and CCCWP each collected two samples.

6.2 Methods

6.2.1 Site Selection

In WY 2018, in compliance with MRP Provisions C.8.g.i and C.8.g.ii, water and sediment toxicity and sediment chemistry samples were collected from one station during dry weather: Cordilleras Creek in the City of San Carlos (see Figure 6.1). The site was selected to represent mixed-land use in an urban watershed that is not already being monitored for toxicity or pesticides by other programs, such as the SWAMP Stream Pollution Trends (SPoT) program. The specific station within the watershed was identified based on the likelihood that they would contain fine depositional sediments during dry season sampling and would be safe to access during wet weather sampling. It is anticipated that SMCWPPP will select a different creek to target for dry weather pesticides and toxicity monitoring in future years of the permit term with the goal of building a geographically diverse dataset.

Additionally in WY 2018, in compliance with MRP Provision C.8.g.iii, water toxicity and pesticides samples were collected from two sites during wet weather: San Pedro Creek in the City of Pacifica and Cordilleras Creek near the City of San Carlos. San Pedro Creek was selected because it was monitored for dry weather pesticides and toxicity in WY 2017. Cordilleras Creek was selected because it was targeted for dry weather monitoring in WY 2018. The goal was to compare dry and wet weather monitoring results.

6.2.2 Sample Collection

Water samples for pesticides and toxicity were collected using standard grab sampling methods. The required number of labeled amber glass bottles were filled and placed on ice to cool to < 6C. The laboratory was notified of the impending sampling delivery to meet sample hold times. Procedures used for sampling and transporting water samples are described in SOP FS-2 (BASMAA 2016b).

Before conducting sediment sampling, field personnel surveyed the proposed sampling area for appropriate fine-sediment depositional areas. Personnel carefully entered the stream to avoid disturbing sediment at collection sub-sites. Sediment samples were collected from the top 2 cm at each sub-site beginning at the downstream-most location and continuing upstream. Sediment samples were placed in a compositing container, thoroughly homogenized, and then aliquoted into separate jars for chemical or toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA 2016b).

Sample were submitted to respective laboratories and field data sheets were reviewed per SOP FS-13 (BASMAA 2016b). The laboratory responsible for analyzing water column pesticide samples in WY 2018 (i.e., Physis Laboratory in Anaheim, CA) was selected by the RMC because it is capable of conducting analyses with reporting limits below the maximum threshold specified in MRP Provision C.8.g.iii.(1).

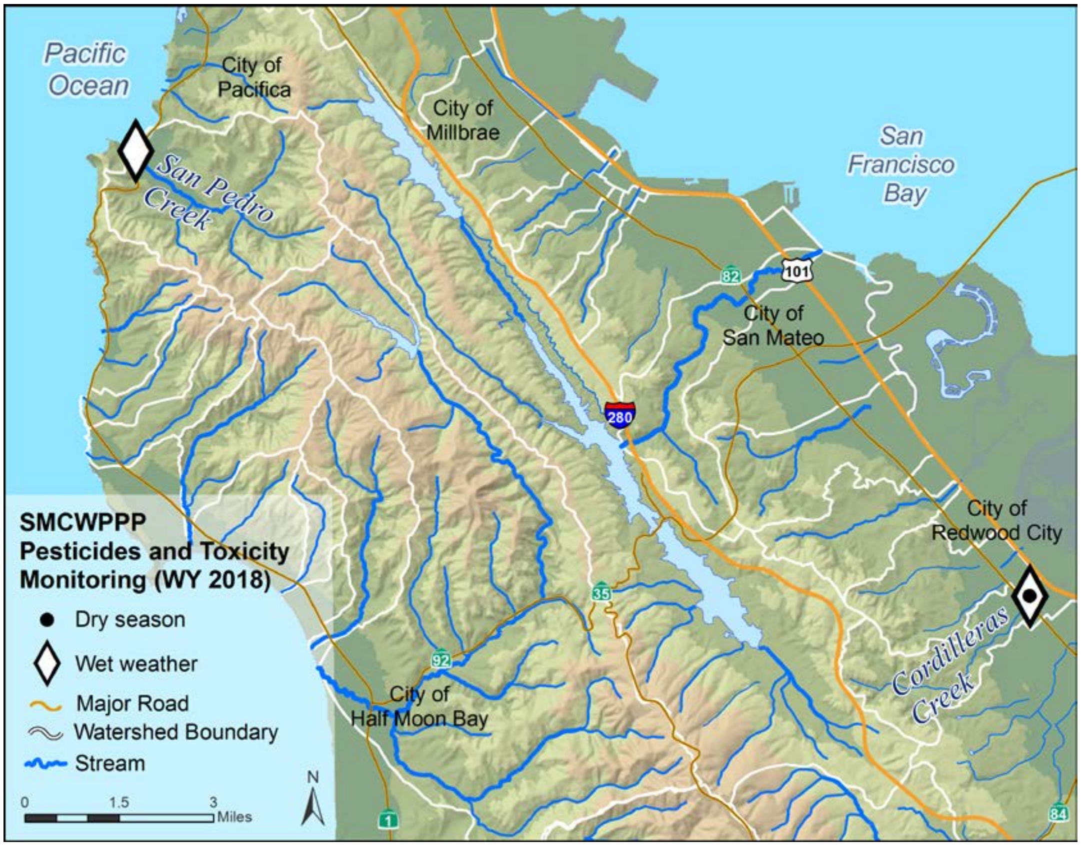

Figure 6.1 Pesticide and toxicity sampling locations in San Mateo County during WY 2018.

6.2.3 Data Evaluation

Water and Sediment Toxicity

Data evaluation required by the MRP involves first assessing whether the samples are toxic to the test organisms relative to the laboratory control treatment via statistical comparison using the Test of Significant Toxicity (TST) statistical approach. For samples with toxicity (i.e., those that "failed" the TST), the Percent Effect is evaluated. The Percent Effect compares sample endpoints (survival, reproduction, growth) to the laboratory control endpoints. Follow-up sampling is required if any test organism is reported as "fail" vis the TST approach *and* the Percent Effect is ≥ 50%. Both the TST result and the Percent Effect are determined by the laboratory. If both the initial and follow-up sample are reported as "fail" with ≥ 50% Percent Effect, the site is added to the list of candidate SSID projects.

Sediment Chemistry

In compliance with MRP Provision C.8.g.iv, sediment sample results are compared to Probable Effects Concentrations (PECs) and Threshold Effects Concentrations (TECs) as defined by MacDonald et al. (2000). PEC and TEC quotients are calculated as the ratio of the measured concentration to the respective PEC and TEC values from MacDonald et al. (2000). All results where a PEC or TEC quotient is equal to or greater than 1.0 are identified and added to the list of candidate SSID projects.

PECs and TECs are listed in MacDonald et al. (2000) for total PAHs, rather than the individual PAHs that are reported by the laboratory. Total PAH concentrations were calculated by summing the concentrations of 24 individual PAHs. Concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data so that calculations and statistics could be computed. Therefore, some of the TEC and PEC quotients may be artificially elevated (and contribute to trigger exceedances) due to the method used to account for non-detect data.

The TECs for bedded sediments are very conservative values that do not consider site specific background conditions, and are therefore not very useful in identifying real water quality concerns in receiving waters in the San Mateo County. All sites in the County are likely to have at least one TEC quotient equal to or greater than 1.0. This is due to high levels of naturally-occurring chromium and nickel in geologic formations (i.e., serpentinite) and soils that contribute to TEC and PEC quotients. These conditions will be considered when making decisions about SSID projects.

The current MRP does not require consideration of pyrethroid, fipronil, or carbaryl sediment chemistry data for follow-up SSID projects, perhaps because pyrethroids are ubiquitous in the urban environment and little is known about fipronil and carbaryl distribution. However, SMCWPPP computed toxicity unit (TU) equivalents for individual pyrethroid results, based on available literature values for pyrethroids in sediment LC50 values.[23,24] Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC50 values were derived on the basis of TOC-normalized concentrations. Therefore, the pesticide concentrations as reported by the lab were divided by the measured total organic carbon (TOC) concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each constituent. Concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data so that these statistics could be computed, potentially resulting in artificially elevated results.

Water Chemistry

MRP Provision C.8.g.iv requires that chemical pollutant data from water and sediment monitoring be compared to the corresponding water quality objectives in the Basin Plan for each analyte sampled. If concentrations in the samples exceed their water quality objectives, then the site at which the exceedances were observed will be added to the list of candidate SSID projects. However, the Basin Plan does not contain numeric water quality objectives for the chemical analytes encompassed within the wet weather pesticide monitoring.

Due to the lack of numeric thresholds for these analytes, the data collected during the WY 2018 wet weather pesticide monitoring cannot be assessed to determine if the sampled sites should be added to the list of candidate SSID projects. However, there exist opportunities to compare and integrate wet weather pesticide monitoring data collected for MRP purposes with other similar data collected throughout the state. The California Department of Pesticide Regulation (DPR) Surface Water Protection Program Monitoring (SWPP) is one of the largest pesticide monitoring and management efforts currently being undertaken in California. Pesticide studies conducted by DPR make use of aquatic benchmarks set by the United States Environmental Protection Agency (USEPA) for many pesticide compounds, including all analytes targeted by

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[23] The LC50 is the concentration of a given chemical that is lethal on average to 50% of test organisms.

[24] No LC50 is published for carbaryl in sediment.

MRP wet weather pesticide monitoring. DPR provides web access to a number of its monitoring reports which contain detailed analyses of USEPA aquatic benchmark exceedance rates. MRP pesticide data were compared to the USEPA benchmarks used by DPR to gain an understanding of how San Mateo County data compare to the larger dataset being developed by DPR; however, sites with USEPA aquatic benchmark exceedances were not added to the list of candidate SSID projects on that basis alone. DPR also maintains the Surface Water Database (SURF) to provide public access to quantitative pesticide data from a wide array of surface water monitoring studies. This database could be queried in the future to allow the leverage of DPR monitoring data in more complex analyses of MRP pesticide data.

6.3 Results and Discussion

Toxicity and pesticides monitoring results are described in the sections below. Conclusions and recommendations are provided in section 7.0.

6.3.1 Toxicity

Table 6.1 provides a summary of toxicity testing results for WY 2018 dry weather water and sediment samples. Table 6.2 provides a summary of toxicity testing results for WY 2018 wet weather water samples. Based on the WY 2018 toxicity monitoring results, it is not necessary to add Cordilleras Creek or San Pedro Creek to the list of potential SSID projects.

The dry weather water sample was significantly toxic to one of the five test organisms (*C. dilutus);* however, the Percent Effect did not exceed the 50% threshold for follow-up. The cause of the water toxicity is unknown. The sediment sample was not toxic to either of the test organisms.

The wet weather water sample collected in San Pedro Creek (202SPE005) was significantly toxic to two of the five test organisms (*P. promelas* and *H. azteca)*, while the sample collected in Cordilleras Creek (204COR010) was significantly toxic to one of the test organisms (*H. azteca*). However, the Percent Effect did not exceed the 50% threshold for follow-up at either site. The cause of the water toxicity is unknown.

Table 6.1. Summary of SMCWPPP dry weather water and sediment toxicity results, Cordilleras Creek, WY 2018.

Site	Organism	Test Type	Unit	Results		% Effect	TST Value	Follow up needed (TST "Fail" and ≥50%)
				Lab Control	Organism Test			
204COR010 Cordilleras Creek July 17, 2018	Water							
	Ceriodaphnia dubia	Survival	%	100	100	0	NA[1]	No
		Reproduction	Num/Rep	23.8	33	-39	Pass	No
	Pimephales promelas	Survival	%	97.5	95	33	Pass	No
		Growth	mg/ind	0.916	0.905	1	Pass	No
	Chironomus dilutus	Survival	%	95	85	11	Fail	No
	Hyalella azteca	Survival	%	98	98	0	Pass	No
	Selenastrum capricornutum	Growth	cells/ml	4610000	8680000	-88	Pass	No
	Sediment							
	Chironomus dilutus	Survival	%	82.5	88.8	-88	Pass	No
	Hyalella azteca	Survival	%	92.5	95	-33	Pass	No

[1] TST analysis is not performed for survival endpoint - a percent effect <25% is considered a "Pass", and a percent effect ≥25% is considered a "Fail"

Table 6.2. Summary of SMCWPPP wet weather water toxicity results, San Pedro Creek and Cordilleras Creek, WY 2018.

Site	Organism	Test Type	Unit	Results		% Effect	TST Value	Follow up needed (TST "Fail" and **≥50%**)
				Lab Control	Organism Test			
202SPE005 San Pedro Creek Jan 20, 2018	Water							
	Ceriodaphnia dubia	Survival	%	100	100	0	NA[1]	No
		Reproduction	Num/Rep	35	34.9	0.3	Pass	No
	Pimephales promelas	Survival	%	100	82.5	18	Pass	No
		Growth	mg/ind	0.791	0.612	23	Fail	No
	Chironomus dilutus	Survival	%	97.5	92.5	5	Pass	No
	Hyalella azteca	Survival	%	100	84	16	Fail	No
	Selenastrum capricornutum	Growth	cells/ml	2560000	4560000	-78	Pass	No
204COR010 Cordilleras Creek Jan 20, 2018	Water							
	Ceriodaphnia dubia	Survival	%	100	100	0	NA[1]	No
		Reproduction	Num/Rep	35	37.2	-6	Pass	No
	Pimephales promelas	Survival	%	100	95	5	Pass	No
		Growth	mg/ind	0.791	0.713	10	Pass	No
	Chironomus dilutus	Survival	%	97.5	97.5	0	Pass	No
	Hyalella azteca	Survival	%	100	80	20	Fail	No
	Selenastrum capricornutum	Growth	cells/ml	2560000	4830000	-88	Pass	No

[1] TST analysis is not performed for survival endpoint - a percent effect <25% is considered a "Pass", and a percent effect ≥25% is considered a "Fail"

6.3.2 Sediment Chemistry

Sediment chemistry results are evaluated as potential stressors based on TEC quotients and PEC quotients according to criteria in Provision C.8.g.iv of the MRP. SMCWPPP also evaluated TU equivalents of pyrethroids and fipronil.

Table 6.3 lists concentrations and TEC quotients for sediment chemistry constituents (metals and total PAHs). TEC quotients are calculated as the measured concentration divided by the highly conservative TEC value, per MacDonald et al. (2000)[25]. TECs are extremely conservative and are intended to identify concentrations below which harmful effects on sediment-dwelling organisms are unlikely to be observed. The site on Cordilleras Creek exceeded the relevant trigger criterion from the MRP of having at least one result exceeding the TEC and will be added to the list of potential SSID projects. However, the TEC exceedances were of chromium and nickel as expected in watersheds draining hillsides underlain by serpentinite formations.

Table 6.4 provides concentrations and PEC quotients for sediment chemistry constituents (metals and total PAHs). PECs are intended to identify concentrations above which toxicity to benthic-dwelling organisms are predicted to be probable. No PEC quotients were greater than 1.0.

Table 6.3. Threshold Effect Concentration (TEC) quotients for WY 2018 sediment chemistry constituents. Bolded and shaded values indicate TEC quotient ≥ 1.0.

	TEC	204COR010 Cordilleras Creek	
		Concentration	Quotient
Metals (mg/kg DW)			
Arsenic	9.79	4.1	0.42
Cadmium	0.99	0.12	0.12
Chromium	43.4	91	2.1
Copper	31.6	25	0.79
Lead	35.8	15	0.42
Nickel	22.7	92	4
Zinc	121	78	0.64
PAHs (ug/kg DW)			
Total PAHs	1,610	290	0.18 [a]

a. Total calculated using ½ MDLs.

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[25] MacDonald et al. (2000) does not provide TEC or PEC values for pyrethroids, fipronil, or carbaryl. Pyrethroids are compared to LC50 values in Table 5.4. However, LC50 values for fipronil and carbaryl in sediment have not been published.

Table 6.4. Probable Effect Concentration (PEC) quotients for WY 2018 sediment chemistry constituents. Bolded and shaded values indicate PEC quotient ≥ 1.0.

	PEC	204COR010 Cordilleras Creek	
		Concentration	Quotient
Metals (mg/kg DW)			
Arsenic	33.0	4.1	0.12
Cadmium	4.98	0.12	0.024
Chromium	111	91	0.82
Copper	149	25	0.17
Lead	128	15	0.12
Nickel	48.6	92	1.9
Zinc	459	78	0.17
PAHs (ug/kg DW)			
Total PAHs	22,800	290	0.013 [a]

a. Total calculated using ½ MDLs.

Table 6.5 lists the concentrations of pesticides measured in sediment samples and calculated TOC-normalized TU equivalents for the pesticides for which there are published LC50 values in the literature. Most of the pesticides measured were below method detection limits (MDLs) and are listed as “<MDL” in Table 5.5. Others were below the reporting limits as noted in Table 5.4. The highest TU equivalent was for bifenthrin (0.251) which is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the DPR SWPP (Ensminger 2017). Except for bifenthrin, all of the calculated TU equivalents were less than 0.1.

Table 6.5. Pesticide concentrations and calculated toxic unit (TU) equivalents, WY 2018.

			204COR010 Cordilleras Creek		
	Unit	LC50[d]	Concentration	Normalized to TOC	TU Equivalent
Total Organic Carbon	%		0.92		
Pyrethroid					
Bifenthrin	µg/g dw	0.52	0.00120	0.13	0.251 [b]
Cyfluthrin	µg/g dw	1.08	<0.00059	0.03	0.028 [a]
Cypermethrin	µg/g dw	0.38	<0.00053	0.028	0.073 [a]
Deltamethrin	µg/g dw	0.79	0.00069	0.075	0.095 [b]
Esfenvalerate	µg/g dw	1.54	<0.00069	0.036	0.024 [a]
Lambda-Cyhalothrin	µg/g dw	0.45	<0.00032	0.017	0.037 [a]
Permethrin	µg/g dw	10.83	0.00081	0.088	0.008 [b]
			Sum of TU Equivalents		0.516 [a]
Other MRP Pesticides of Concern					
Carbaryl	mg/Kg dw	NA	0.01	NA	NA [c]
Fipronil	ng/g dw	410	<0.53	27.72	0.068 [a]
Fipronil Desulfinyl	ng/g dw	NA	<0.53	NA	NA [c]
Fipronil Sulfide	ng/g dw	NA	<0.53	NA	NA [c]
Fipronil Sulfone	ng/g dw	NA	<0.53	NA	NA [c]

a. Concentration was below the method detection limit (MDL). TOC normalized concentrations and TU equivalents calculated using 1/2 MDL.

b. TU equivalents calculated from concentration below the reporting limit (J-flagged).

c. Currently there is no available LC50 value for Carbaryl or Fipronil degradates, however the observed concentrations were below the detection limits.

d. Sources: Amweg et al. 2005 and Maund et al. 2002.

In compliance with the MRP, a grain size analysis was conducted on the sediment sample (Table 6.6). The sample was 10.7% fines (i.e., 3.4% clay and 7.4% silt).

Table 6.6. Summary of grain size for site 202SPE005 in San Mateo County during WY 2018.

Grain Size (%)		204COR010
		Cordilleras Creek
Clay	<0.0039 mm	3.4%
Silt	0.0039 to <0.0625 mm	7.4%
Sand	V. Fine 0.0625 to <0.125 mm	4.7%
	Fine 0.125 to <0.25 mm	13.4%
	Medium 0.25 to <0.5 mm	26.7%
	Coarse 0.5 to <1.0 mm	27.4%
	V. Coarse 1.0 to <2.0 mm	17.0%
Granule	2.0 to <4.0 mm	10.6%
Pebble	Small 4 to <8 mm	13.1%
	Medium 8 to <16 mm	0%
	Large 16 to <32 mm	0%
	V. Large 32 to <64 mm	0%

Note: Sum of grain size values for both sites is greater than 100% due to the laboratory analytical methods used.

5.3.3 Pesticides in Water

The pesticide concentrations measured at the two sites where wet weather pesticide sampling was conducted in WY 2018 are listed in Table 6.7. The concentrations of most pesticides were below the MDL, meaning that these analytes were reported as non-detects. Imidacloprid was found at detectable levels at one of the two sites (Cordilleras Creek). Additionally, fipronil and its degradation products were found at detectable levels at both sites.

Table 6.7. Summary of wet weather pesticide concentrations for the two locations sampled in San Mateo County during WY 2018.

	Unit	202SPE005 San Pedro Creek	204COR010 Cordilleras Creek	Lowest USEPA Benchmark [a]	
		Concentration	Concentration	Concentration	
Pyrethroid					
Bifenthrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.0013	IC
Cyfluthrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.0074	IC
Cypermethrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.069	IC
Deltamethrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.0041	IC
Esfenvalerate	µg/L	<0.00005 [b]	<0.00005 [b]	0.017	IC
Fenvalerate	µg/L	<0.00005 [b]	<0.00005 [b]	0.017	IC
Lambda-Cyhalothrin	µg/L	<0.00005 [b]	<0.00005 [b]	0.002	IC
Permethrin, cis-	µg/L	<0.0002 [b]	<0.0002 [b]	0.0014	IC
Permethrin, trans-	µg/L	<0.0001 [b]	<0.0001 [b]	0.0014	IC
Other MRP Pesticides of Concern					
Fipronil	µg/L	0.0658	0.0523	0.011	IC
Fipronil Desulfinyl	µg/L	0.0032	0.0038	0.54	FC
Fipronil Sulfide	µg/L	0.0029	0.0032	0.11	IC
Fipronil Sulfone	µg/L	0.0156	0.0145	0.037	IC
Imidacloprid	µg/L	<0.002 [b]	0.0659	0.01	IC

a. Source: USEPA Aquatic Life Benchmarks and Ecological Risk Assessments for Registered Pesticides. IC signifies that the invertebrate chronic USEPA benchmark was the lowest benchmark, while FC signifies that the fish chronic USEPA benchmark was the lowest benchmark.

b. Concentration was below the method detection limit (MDL), and values are displayed as "<MDL".

As previously stated, there are no water quality objectives specified in the San Francisco Bay Basin Plan for water column pesticide analytes. As a result, no analysis of the wet weather pesticide monitoring data collected in WY 2018 relative to WQOs could be performed. However, other studies that quantify pesticide concentrations in water can provide a perspective with which to view the results of the MRP WY 2018 wet weather pesticide monitoring. DPR routinely conducts pesticide monitoring at MS4 and receiving water sites in both Northern and Southern California with the objectives of evaluating pesticide concentrations in water, frequencies with which individual pesticide compounds are detected, and exceedances of USEPA pesticide benchmarks. In WY 2017, DPR monitored locations in Alameda, Contra Costa, Placer, Sacramento, and Santa Clara Counties in Northern California as well as locations in Los Angeles, Orange, and San Diego Counties in Southern California. The pesticide analytes sampled in both studies encompassed the analytes sampled by the MRP wet weather pesticide monitoring.

In the Northern California DPR study, bifenthrin had a detection frequency (DF) of 74%, making it the most frequently detected insecticide. Other pyrethroids sampled during the study were either not detected at all or had significantly lower DF values than bifenthrin. Imidacloprid was the second-most frequently detected insecticide with a DF of 59%. Fipronil, with a DF of 50%, closely followed imidacloprid as the third-most frequently detected insecticide. Fipronil desulfinyl and fipronil sulfone were also detected at rates of 56% and 21%, respectively. Pyrethroid concentrations were generally above their USEPA minimum benchmarks for toxicity to aquatic life with the exception of cyfluthrin, which is generally detected below the USEPA toxicity benchmark. Concentrations of imidacloprid and fipronil were always above their minimum benchmarks when detected by the DPR SWPP. The fipronil degradates were not above their minimum benchmarks except for one fipronil sulfone sample. (Ensminger 2017)

In the Southern California DPR study, bifenthrin was the most frequently detected pyrethroid insecticide with a DF of 79%. The other sampled pyrethroids were again either not detected at all or detected significantly less frequently than bifenthrin. Fipronil also had a DF of 79%, and several of its degradates including fipronil sulfone and fipronil desulfinyl were also detected at comparably high concentrations (72 and 70%, respectively). Imidacloprid was the most frequently detected pesticide at a rate of 81%. (Budd 2018)

The results of the MRP wet weather pesticide monitoring in WY 2018 are similar to the WY 2017 DPR studies with respect to fipronil, fipronil degradates, and imidacloprid results, as these compounds were the only pesticides detected during the MRP monitoring. Additionally, the concentrations of MRP samples for fipronil and imidacloprid were above their USEPA minimum benchmarks. Although bifenthrin was frequently detected during the DPR studies, and it is known to be the leading cause of toxicity in urban watersheds (Ruby 2013), bifenthrin was not detected during the MRP wet weather monitoring in San Pedro Creek and Cordilleras Creek.

7.0 Conclusions and Recommendations

In WY 2018, in compliance with Provisions C.8.d and C.8.g of the MRP and the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), SMCWPPP continued to implement a two-component monitoring design that was initiated in WY 2012. The strategy includes a regional ambient/"probabilistic" bioassessment monitoring component and a component based on local "targeted" monitoring for general water quality parameters and pesticides/toxicity. 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 eventually answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks).

Conclusions from the MRP Creek Status and Pesticides/Toxicity Monitoring conducted during WY 2018 in San Mateo County are based on the management questions presented in Section 1.0 of this report:

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 water supportive of or likely supportive of beneficial uses?*

The first management question is addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to the triggers defined in the MRP. A summary of trigger exceedances observed for each site is presented in Table 7.1. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation of Stressor/Source identification (SSID) projects.

The second management question is addressed primarily by assessing indicators of aquatic biological health using benthic macroinvertebrate and algae data collected at probabilistic sites. The indices of biological integrity based on BMI and algae data (i.e., CSCI and ASCI) are direct measures of aquatic life beneficial uses. Biological condition scores were compared to physical habitat and water quality data collected synoptically with bioassessments to evaluate whether any correlations exist that may explain the variation in biological condition scores. Continuous monitoring data (temperature, dissolved oxygen, pH, and specific conductance) are evaluated with respect to COLD and WARM Beneficial Uses. And pathogen indicator data are used to assess REC-1 (water contact recreation) Beneficial Uses.

7.1 Conclusions

7.1.1 Biological Condition Assessment

Bioassessment monitoring was conducted in compliance with Provision C.8.d.i of the MRP. In WY 2018, all bioassessment monitoring was performed at sites selected randomly using the regional probabilistic monitoring design. The probabilistic monitoring design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its program area (e.g., County boundary) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks. The monitoring 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?*
2. *What are major stressors to aquatic life in the RMC area?*
3. *What are the long-term trends in water quality in creeks over time?*

The first question (i.e., *What is the condition of aquatic life in creeks in the RMC area?*) is addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. Once a sufficient number of samples have been collected (i.e., 30 samples), ambient biological condition can be estimated for streams at countywide and a regional scale within known estimates of precision. Over the past seven years (WY 2012 through WY 2018), SMCWPPP and Regional Water Board have sampled 80 probabilistic sites in San Mateo County, providing a sufficient sample size to estimate ambient biological condition for urban streams countywide. Analysis of the first five years of regional bioassessment monitoring data (WY 2012 – WY 2016) was conducted by BASMAA in the RMC 5-Year Report.

The second question (i.e., *What are major stressors to aquatic life in the RMC area?*) is addressed by the collection and evaluation of physical habitat and water chemistry data collected at the probabilistic sites, as potential stressors to biological health. The stressor levels can be compared to biological indicator data through correlation and relative risk analyses. Assessing the extent and relative risk of stressors can help prioritize stressors at a regional scale and inform local management decisions.

The third question (i.e., *What are the long-term trends in water quality in creeks over time?*) is addressed by assessing the change in biological condition over several years. Changes in biological condition over time can help evaluate the effectiveness of management actions. Based on review of the first five years of probabilistic data, it appears that long-term trend analysis for the probabilistic survey will require more than seven years of data.

The analyses presented in this report are limited to the WY 2018 dataset which does not contain a statistically significant number of records (i.e., approximately 30 samples). A more comprehensive analysis of the much larger bioassessment dataset from the first five years of MRP monitoring (WY 2012 – WY 2016) was conducted by the BASMAA RMC on a regional and countywide basis. The RMC 5-Year Report is summarized below and included with this report as Attachment 2. Analytical tools that BASMAA (2019) found to be useful in evaluating stressor association with biological condition (i.e., random forest models) may be used by SMCWPPP to evaluate the WY 2012 – WY 2019 dataset in the Integrated Monitoring Report which will be submitted in March 2020.

Bioassessment Data (San Mateo County – WY 2018)

Ten sites were sampled for benthic macroinvertebrates, benthic algae, and nutrients. Physical habitat was also assessed at each of the 10 stations, and general water quality parameters were measured using a pre-calibrated multi-parameter field probe. All of this work was conducted using methods consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b). Stations were randomly selected using a probabilistic monitoring design. Eight of the ten sites (80%) were classified as urban and two (20%) were classified and non-urban.

The following conclusions are based on the WY 2018 data. An assessment of biological condition is provided, relationships with potential stressors are explores, and potential stressors are compared to applicable WQOs and triggers identified in the MRP. Sites with monitoring results that exceed WQOs and triggers are considered as candidates for further investigation as SSID projects, consistent with Provision C.8.e of the MRP.

Biological Condition Assessment

Stream condition was assessed using three different types of indices/tools: the BMI-based CSCI, the draft benthic algae-based ASCI (diatom, soft algae, and hybrid), and the physical habitat-based IPI. Of these three, the CSCI is the only tool with a MRP trigger threshold for follow-up SSID consideration.

- **CSCI** - The diversity and abundance of BMI taxa are evaluated as indicators of biological condition of the stream. Five of the ten (50%) sites monitored in WY 2018 had CSCI scores in the two higher condition categories: “possibly intact” and “likely intact”. These higher scoring sites were relatively undeveloped, with imperviousness in their drainage areas ranging between 1% and 5%.
    - The five sites with CSCI scores below the MRP trigger threshold of 0.795 will be considered as candidates for SSID projects.
- **ASCI -** ASCI indices translate benthic algae data (diatoms and soft algae) into overall measures of stream health. Three algae indices (developed using statewide data) were calculated for diatoms, soft algae and hybrid (combination of diatoms and soft algae). The hybrid ASCI appeared to have the best response to stressor data associated with landscape variables (e.g., percent imperviousness), but not with stressors associated with nutrients, which was a finding from statewide data analyses (Theroux et al (in prep)).
    - **Hybrid**. Seven of the ten (70%) bioassessment sites had hybrid ASCI scores that were classified as “possibly intact” or “likely intact” condition. The higher scoring sites occurred primarily in drainages with low levels of urbanization, ranging from 1% to 7% impervious area, with the exception of site 202R03404 in San Pedro Creek (13%). Five of the seven sites also received CSCI scores that were in two higher condition categories
- **IPI –** The Index for Physical Habitat Integrity assesses the overall habitat condition of the sampling reach. IPI scores were positively correlated with qualitative habitat assessment Total PHAB scores.
    - Seven of the ten sites (70%) had IPI scores in the two upper condition categories. IPI scores were positively correlated with CSCI scores, and slightly less so with hybrid ASCI scores.
- **Overall Condition -** There were four sites with biological condition scores in the two higher condition categories all three indices (CSCI, hybrid ASCI, IPI) (Figure 2.6). Two of the sites are located in Mid-Peninsula Open Space District land, including La Honda Creek Preserve (site 202R03880) and Windy Hill Preserve (site 205R03864). The third site is located in Pescadero Creek County Park (site 202R00614). The fourth site was on Bear Creek, near the urban boundary of the Town of Woodside (site 205R03624). All four sites were relatively undeveloped (less than < 5% impervious area).

The number of sites in the top two condition categories varied substantially by index, with as many as 9 of 10 sites for the diatom ASCI to as few as 5 of 10 sites for the CSCI and 4 of 8 sites for the soft algae ASCI. Excluding the soft algae ASCI, there was relatively good consistency among the indices in terms of which sites were placed in the top two condition categories for sites with lower urbanization (< 5% impervious area). However, all three ASCI indices and the IPI were relatively variable (i.e., both high and low scoring) at the more developed sites. Further evaluation of the newer indices and their association with stressor data is needed to better understand how these indicators can be used to effectively assess site conditions.

Stressor Assessment

Relationships between potential stressors (water chemistry, physical habitat, and landscape variables such as imperviousness) and biological condition were explored using the WY 2018 dataset. Correlations were evaluated using simple regression models and are not expected to be very strong due to small sample size. Sites with stressor levels exceeding applicable WQOs and triggers identified in the MRP will be considered as candidates for SSID projects.

- **General water quality** - pH, temperature, dissolved oxygen, specific conductance. None of the water quality measurements exceeded water quality objectives or MRP trigger thresholds. None of the water quality measurements were correlated with CSCI or hybrid ASCI scores.

- **Nutrients and conventional analytes** - ammonia, unionized ammonia, chloride, Ash-Free Dry Mass (AFDM), chlorophyll a, nitrate, nitrite, TKN, ortho-phosphate, phosphorus, silica. There were no water quality objective exceedances for the water chemistry parameters (unionized ammonia, nitrate, chloride). Total nitrogen concentrations ranged from 0.22 to 1.1 mg/L. Total phosphorus concentrations ranged from <0.01 to 0.12 mg/L. None of the nutrient parameters were correlated with CSCI or hybrid ASCI scores.

- **Physical habitat metric scores** were generated from the physical habitat data. CSCI scores were positively correlated with flow type and negatively correlated with filamentous algae cover. Hybrid ASCI scores were poorly correlated with all 11 physical habitat metrics.

- **Landscape variables** were calculated for each of the watershed areas draining into the bioassessment sites. CSCI scores were moderately correlated (negatively) with impervious area and road density.

Regional Bioassessment Data (WY 2012 – WY 2016)

A comprehensive analysis of bioassessment data collected by the RMC partners throughout the Bay area is included in the RMC Five-Year Bioassessment Report (5-Year Report) (BASMAA 2019) (Attachment 2). The BASMAA-funded study evaluated bioassessment data collected throughout the Bay Area by the RMC over the first five years of monitoring (WY 2012 – WY 2016). Bioassessment data from 354 sites were compiled and evaluated to address the three study questions:

1) What is the biological condition of streams in the region?
2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of the BASMAA study are intended to help stormwater programs better understand the current condition of wadable streams, prioritize stream reaches in need of protection or restoration, and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area.

The BASMAA report also evaluated the existing RMC probabilistic monitoring design and identified a range of potential options for revising the design (if desired) to better address the questions posed. These redesign options are intended to inform discussions of water quality monitoring requirements during the reissuance of the Municipal Regional Permit, which expires at the end of 2020.

Biological Condition Assessment

Results of the survey indicate that much of the stream length in the RMC area is in poor biological condition. Aquatic life uses may not be fully supported at a majority of sites sampled by the RMC. Two biological indicators were used to assess conditions:

- The BMI-based CSCI shows that 58% of the stream length region-wide was ranked in the lowest CSCI condition category ("very likely altered"), and 74% of the sampled stream length exhibited CSCI scores below 0.795, the MRP trigger for potential follow-up activity.
- The Southern California algae indices for diatoms (D18) and soft algae (S2) were evaluated for biological conditions[26]. Based on D18 and S2 scores, stream conditions region-wide appear somewhat less degraded than the CSCI scores indicated, with approximately 40% ranked in the lowest algae condition category. The algal indices also had greater stream length in the "likely intact" condition class (19-21%) compared to CSCI score (15%).

These findings should be interpreted with the understanding that the survey focused on urban stream conditions. Approximately 80% of the samples (284 of 354) were collected at urban sites. Although the low non-urban sample size precludes making any definitive comparisons, bioassessment scores in the non-urban area were generally higher than scores in the urban area for each County.

Stressor Assessment

The association between biological indicators (CSCI and D18) and stressor data was evaluated in the RMC 5-Year study using random forest statistical analyses. The results indicate that each of the biological indicators respond to different types of stressors.

- Biological condition, based on CSCI scores, was correlated with physical habitat and land use variables. Overall, the largest influence on CSCI scores in the random forest model was percent impervious area in catchment area within a 5 km radius of the bioassessment sampling site.

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[26] The ASCI was not yet available during development of the RMC 5-Year Report.

- Biological condition, based on D18 scores, was moderately correlated with water quality variables and poorly correlated with the physical or landscape variables.

In general, CSCI scores at urban sites were consistently low, indicating that degraded physical habitat conditions do not support healthy BMI assemblages. D18 scores at urban sites were more variable, indicating that healthy diatom assemblages potentially can occur at sites with poor habitat.

None of the nutrient variables (e.g., nitrate, total nitrogen, orthophosphate, phosphorus) correlated strongly with CSCI scores, or were highly ranked variables in the CSCI random forest analysis. Phosphorus and ash-free dry mass (which increases in response to biostimulation) were important in predicting D18 scores based on the random forest analysis; however, no statistically significant relationships were observed. This finding suggests that the nutrient targets being developed by the State Water Board as part of the Biostimulatory/Biointegrity Project may not be appropriate in urban streams in the Bay Area.

Trend Assessment

The time frame of the survey (five years) is too short to detect trends. However, the five-year bioassessment dataset does provide a baseline to compare with future assessments.

A potential application of bioassessment monitoring may be to assess trends in stream conditions as additional stormwater treatment (e.g., green infrastructure) and creek restoration projects are implemented across the urban landscape over time. Peak flow volumes and intensities will likely be reduced following the implementation of stormwater treatment via green infrastructure and low impact development (LID), as required by the MRP. Future creek status monitoring may provide additional insight into the potential positive impacts of green infrastructure and creek restoration to support WQOs and beneficial uses in urban creeks.

Assessment of the RMC Monitoring Design

Over the first five years of monitoring, the RMC evaluated about 25% (1455 out of 5740) of the sites in the sample frame to obtain 354 samples. Approximately 46% (873 out of 1896) of the total number of urban sites in the sample frame were evaluated during that time. Based on rejection rates from previous years, the sample frame is anticipated to be exhausted during WY 2020. Revision of the RMC monitoring design could seek to reduce the future rejection rate through development of a new sample frame that excludes areas of low management interest or regions that would not be candidates for sampling (such as due to lack of permissions or physical barriers to access). This would improve the spatial balance of samples that more closely represents the proportion of the sample frame that can be reliably assessed.

The RMC sample design was created to probabilistically sample all streams within the RMC area, which resulted in a master list with 33% urban sites and 67% non-urban sites. However, because participating municipalities are primarily concerned with runoff from urban areas, the RMC focused sampling efforts on urban sites (80%) over non-urban sites (20%). As a result, non-urban samples are under-represented in the dataset resulting in much lower overall biological condition scores than would be expected for a spatially balanced dataset.

Based on evaluation of data collected during the first five years of the survey, there are several options to revise the RMC Monitoring Design.

The RMC will assess the options during discussions with Regional Water Board staff during the MRP reissuance process beginning in 2019.

7.1.2 Continuous Monitoring for Temperature and General Water Quality

Continuous monitoring of water temperature and general water quality in WY 2018 was conducted in compliance with Provisions C.8.d.iii – iv of the MRP. Hourly temperature measurements were recorded at five sites in the San Pedro Creek watershed from April through September. Continuous (15-minute) general water quality measurements (pH, DO, specific conductance, temperature) were recorded at two sites in the San Pedro Creek watershed during two 2-week periods in May (Event 1) and August (Event 2). Targeted monitoring stations were deliberately selected and were the same as those monitored in WY 2017.

Conclusions from targeted continuous monitoring in WY 2018 are organized on the basis of the management questions listed in Section 3.0:

1. *What is the spatial and temporal variability in water quality conditions during the spring and summer season?*
2. *Do general water quality measurements indicate potential impacts to aquatic life?*

Sites with targeted monitoring results exceeding the MRP trigger criteria and/or WQOs are identified as candidate SSID projects.

Spatial and Temporal Variability of Water Quality Conditions

- **Spatial**. There was minimal spatial variability in water temperature across the five stations in the San Pedro Creek watershed. Temperature increased slightly at each downstream site but remained 4 to 7 °C below the MRP instantaneous maximum trigger threshold. Likewise, pH and specific conductivity increased slightly in the downstream direction and dissolved oxygen decreased slightly in the downstream direction.
- **Temporal**. Water temperature increased gradually at all five stations between April and early-September, likely in response to periods of warmer air temperatures. Differences in general water quality measurements (pH, specific conductivity, dissolved oxygen) between the two two-week monitoring periods (May/June and August/September) were less pronounced. WY 2018 monitoring results were very similar to those recorded in WY 2017 at the same stations.

Potential Impacts to Aquatic Life

- Potential impacts to aquatic life were assessed through analysis of continuous temperature data collected at five targeted stations and continuous general water quality data (pH, dissolved oxygen, specific conductance, and temperature) collected at two targeted stations in San Pedro Creek. San Pedro Creek, located in the City of Pacifica, was targeted for temperature and general water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County.
- None of the temperature stations in San Pedro Creek exceeded the MRP trigger threshold for the Maximum Weekly Average Temperature of 17°C. None of the stations exceeded the MRP instantaneous maximum trigger threshold of 24°C.

- None of the general water quality parameters (temperature, pH, dissolved oxygen, and specific conductance) exceeded any of the MRP trigger thresholds.

7.1.3 Pathogen Indicators

Pathogen indicator monitoring in WY 2018 was conducted in compliance with Provision C.8.d.v of the MRP. Pathogen indicator grab samples were collected at five sites in the Pescadero Creek watershed during a sampling event on July 27, 2018.

- The selection of sites was based on information provided by County Parks staff about high bacteria concentrations previously found in creeks within Memorial County Park. All three creeks sampled by SMCWPPP in WY 2018 are designated for both contact (REC-1) and non-contact (REC-2) recreation Beneficial Uses and several swimming holes are located along Pescadero Creek in and around Memorial County Park.

- The MRP trigger threshold for *E. coli* was not exceeded at any site in WY 2018; however, the MRP trigger threshold for enterococci was exceeded at two sites. These sites will be added to the list of candidate SSID projects.

- Pathogen indicator data should be interpreted cautiously due to the high variability found in creeks. In addition, wildlife sources in the WY 2018 monitoring area may contribute to the elevated concentrations of pathogen indicators in the creek but pose very little human health risk to recreators, relative to human sources of fecal contamination.

7.1.4 Chlorine Monitoring

Free chlorine and total chlorine residual were measured concurrently with bioassessments at the ten probabilistic sites in compliance with Provision C.8.c.ii. While chlorine residual has generally not been a concern in San Mateo County creeks, prior monitoring results suggest there are occasional trigger exceedances of free chlorine and total chlorine residual in the County. Trigger exceedances may be the result of one-time potable water discharges, and it is generally challenging to determine the source of elevated chlorine from such episodic discharges. Furthermore, chlorine in surface waters can dissipate from volatilization and reaction with dirt and organic matter. In WY 2018, there were no exceedances of the MRP trigger for chlorine (0.1 mg/L). SMCWPPP will continue to monitor chlorine in compliance with the MRP and, as in the past, will follow-up with municipal illicit discharge staff as needed.

7.1.5 Pesticides and Toxicity Monitoring

In WY 2018, SMCWPPP conducted dry weather pesticides and toxicity monitoring at one station (Cordilleras Creek) and wet weather pesticides and toxicity monitoring at two stations (Cordilleras Creek and San Pedro Creek) in compliance with Provision C.8.g of the MRP.

During the dry season, statistically significant toxicity to *C. dubia* was observed in the water sample collected from Cordilleras Creek. During wet weather monitoring, statistically significant toxicity to *H. azteca* was observed in the water samples collected from both creeks during the and toxicity to *P. promelas* was observed in the water sample collected from San Pedro Creek. However, the magnitude of the toxic effects in the samples compared to laboratory controls did not exceed MRP trigger criteria of 50 Percent Effect. The cause of the observed toxicity is unknown. Pesticide concentrations in the sediment sample were all very low, most below the MDL, and TU equivalents, with the exception of bifenthrin, did not exceed 0.1. Likewise, all pesticides (except fipronil and its degradates) analyzed in the wet weather samples were below the MDL

Sediment chemistry results are evaluated to identify potential stressors based on TEC quotients and PEC quotients according to criteria in Provision C.8.g.iv of the MRP. SMCWPPP also evaluated TU equivalents of pyrethroids and fipronil. TEC and PEC quotients were calculated for all metals and total PAHs measured in the sediment samples. Two TEC quotients exceeded the MRP threshold of 1.0 (chromium and nickel), but no PEC quotients exceeded the threshold. Decisions about which SSID projects to pursue should be informed by the fact that the TEC and PEC quotient exceedances are likely related to naturally occurring chromium and nickel due to serpentine soils in local watersheds. Except for bifenthrin (with a TU equivalent of 0.251), all of the calculated TU equivalents were less than 0.1. Bifenthrin is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the California DPR SWPP (Ensminger 2017).

Pesticide analytes targeted by wet weather monitoring in WY 2018 were generally found at concentrations below the MDL, except for bifenthrin and fipronil compounds. As no WQOs are specified in the Basin Plan for these pollutants (SFRWQCB 2017), they are not currently being used to identify SSID project locations. The wet weather pesticide monitoring data in WY 2018 were compared to pesticide data collected by the DPR SWPP and the USEPA aquatic benchmarks used in DPR SWPP studies to allow for interpretation of the WY 2018 results in the context of larger statewide datasets. However, sites sampled during the WY 2018 wet weather pesticide monitoring where exceedances of the USEPA benchmarks were observed were not added to the list of candidate SSID projects. In future years, data collected by the DPR SWPP and contained on the DPR SURF database can be queried to allow for comparison of MRP pesticide monitoring results.

7.2 Trigger Assessment

The MRP requires analysis of the monitoring data to identify candidate sites for SSID projects. Trigger thresholds against which to compare the data are provided for most monitoring parameters in the MRP and are described in the foregoing sections of this report. Stream condition was assessed based on CSCI scores that were calculated using BMI data. Nutrient data were evaluated using applicable water quality standards from the Basin Plan (SFRWQCB 2017). Water and sediment chemistry and toxicity data were evaluated using numeric trigger thresholds specified in the MRP. In compliance with Provision C.8.e.i of the MRP, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects that will be maintained throughout the permit term. Followup SSID projects will be selected from this list. Table 7.1 lists of candidate SSID projects based on WY 2017 Creek Status and Pesticides/Toxicity monitoring data.

Additional analysis of the data is provided in the foregoing sections of this report and should be considered prior to selecting and defining SSID projects. The analyses include review of physical habitat and water chemistry data to identify potential stressors that may be contributing to degraded or diminished biological conditions. Analyses in this report also include historical and spatial perspectives that help provide context and deeper understanding of the trigger exceedances.

Table 7.1. Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2018. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Bioassessment [1]	Nutrients [2]	Chlorine [3]	Water Toxicity [4]	Water Chemistry [5]	Sediment Toxicity [4]	Sediment Chemistry [5]	Continuous Temperature [6]	Dissolved Oxygen [7]	pH [8]	Specific Conductance [9]	Pathogen Indicators [10]
202R00584	Pilarcitos Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R00614	Pescadero Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R03404	San Pedro Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
202R03656	Pilarcitos Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
202R03880	La Honda Creek	No	No	No	--	--	--	--	--	--	--	--	--
202R03916	San Pedro Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
204R03508	Mills Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
204R03528	San Mateo Creek	Yes	No	No	--	--	--	--	--	--	--	--	--
205R03624	Bear Creek	No	No	No	--	--	--	--	--	--	--	--	--
205R03864	Hamms Gulch	No	No	No	--	--	--	--	--	--	--	--	--
202SPE005	San Pedro Creek	--	--	--	No	No	--	--	--	--	--	--	--
204COR010	Cordilleras Creek	--	--	--	No	No	No	Yes	--	--	--	--	--
202PES138	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	Yes
202PES142	McCormick Creek	--	--	--	--	--	--	--	--	--	--	--	Yes
202PES144	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	No
202PES150	Jones Gulch	--	--	--	--	--	--	--	--	--	--	--	No
202PES154	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	--	No
202SPE019	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--
202SPE040	San Pedro Creek	--	--	--	--	--	--	--	No	No	No	No	--
202SPE050	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--
202SPE070	San Pedro Creek	--	--	--	--	--	--	--	No	No	No	No	--
202SPE085	San Pedro Creek	--	--	--	--	--	--	--	No	--	--	--	--

1. CSCI score ≤ 0.795.
2. Unionized ammonia (as N) ≥ 0.025 mg/L, nitrate (as N) ≥ 10 mg/L, chloride > 250 mg/L.
3. Free chlorine or total chlorine residual ≥ 0.1 mg/L.
4. Test of Significant Toxicity = Fail and Percent Effect ≥ 50 %.
5. TEC or PEC quotient ≥ 1.0 for any constituent.
6. Two or more MWAT ≥ 17.0°C or 20% of results ≥ 24°C.
7. DO < 7.0 mg/L in COLD streams or DO < 5.0 mg/L in WARM streams.
8. pH < 6.5 or pH > 8.5.
9. Specific conductance > 2000 uS.
10. Enterococcus ≥ 130 cfu/100ml or *E. coli* ≥ 410 cfu/100ml.

7.3 Recommendations

The following recommendations are based on findings from WY 2018 Creek Status and Pesticides and Toxicity monitoring conducted by SMCWPPP, as well as reflections on other monitoring, data analysis, and policy development projects being conducted in the region (e.g., RMC 5-Year Report) and statewide.

- In WY 2019, SMCWPPP will continue to coordinate with RMC partners on implementation of monitoring requirements in MRP Provisions C.8.d and C.8.g.
- A major component of the WY 2019 monitoring will be bioassessment surveys and data assessment. In WY 2019, SMCWPPP will conduct biological assessments at both probabilistic and targeted sites. To date, a total of 80 probabilistic sites have been monitored by SMCWPPP (n=7) and SWAMP (n=10). This exceeds the number of samples necessary for a statistically representative dataset. Therefore, SMCWPPP is has the option to select up to 20 percent of sample locations on a targeted basis to evaluate trends or address other aquatic life related concerns.
- In WY 2018, BASMAA funded a study to evaluate five years of regional bioassessment data (WY 2012 – WY 2016). Findings from the RMC 5-Year Report are summarized in Section 7.1.1 and the report is included as Attachment 2. In WY 2019, SMCWPPP will apply some of the tools used in the RMC 5-Year Report (i.e., random forest models) to analyze bioassessment data collected in San Mateo County over all eight years of MRP monitoring (WY 2012 – WY 2019). Results of the analyses will be described in the Integrated Monitoring Report (IMR) which will be developed following WY 2019 and must be submitted by March 31, 2020 (the fifth year of the Permit term) in lieu of an annual UCMR.
- For the past two years (WY 2017 and WY 2018), SMCWPPP has conducted continuous temperature and water quality monitoring in the San Pedro Creek Watershed. In WY 2019, SMCWPPP will work with San Mateo County MRP Permittees to select a different creek or reach to target, perhaps where targeted bioassessment monitoring sites are located.
- Provision C.8.g Pesticides and Toxicity monitoring will be conducted during the dry season at a bottom-of-the-watershed station. In order to expand the geographic extent of these data, a new station will be selected.

7.4 Management Implications

The Creek Status and Pesticides and Toxicity Monitoring programs (consistent with MRP Provisions C.8.d and C.8.g, respectively) focus on assessing the water quality condition of urban creeks in San Mateo County and identifying stressors and sources of impacts observed. The bioassessment station sample size from WY 2018 (overall n=10; urban n=8) was not sufficient to develop statistically representative conclusions regarding the overall condition of all creeks. A more comprehensive bioassessment data analyses for the entire eight years of monitoring under the MRP (WY 2012 through WY 2019) will be conducted as part of the Integrated Monitoring Report during WY 2019.

Like previous years, WY 2018 data suggest that most urban streams have likely or very likely altered populations of aquatic life indicators (e.g., benthic macroinvertebrates). These conditions are likely the result of long-term changes in stream hydrology, channel geomorphology, in-stream habitat complexity, and other modifications to the watershed and riparian areas associated with the urban development that has occurred over the past 50 plus years.

SMCWPPP Permittees are actively implementing many stormwater management programs to address these and other stressors and associated sources of water quality conditions observed in local creeks, with the goal of protecting these natural resources. For example:

- In compliance with MRP Provision C.3, new and redevelopment projects in the Bay Area are now designed to more effectively reduce water quality and hydromodification impacts associated with urban development. Low impact development (LID) methods, such as rainwater harvesting and use, infiltration and biotreatment are required as part of development and redevelopment projects. In addition, planning for and implementing green infrastructure projects in the public right-of-way (e.g., during street projects) is increasingly being incorporated into the municipal master planning process. All of these measures are expected to reduce the impacts of urbanization on stream health.
- In compliance with MRP Provision C.9, Permittees are implementing pesticide toxicity control programs that focus on source control and pollution prevention measures. The control measures include the implementation of integrated pest management (IPM) policies/ordinances, public education and outreach programs, pesticide disposal programs, supporting the adoption of formal State pesticide registration procedures, and sustainable landscaping requirements for new and redevelopment projects. These efforts should reduce pyrethroids and other pesticides in urban stormwater runoff and reduce the magnitude and extent of toxicity in local creeks.
- Trash loadings to local creeks have been reduced through implementation of new control measures in compliance with MRP Provision C.10 and other efforts by Permittees to reduce the impacts of illegal dumping directly into waterways. These actions include the installation and maintenance of trash capture systems, the adoption of ordinances to reduce the impacts of litter prone items, enhanced institutional controls such as street sweeping, and the on-going removal and control of direct dumping. The MRP establishes a mandatory trash load reduction schedule, minimum areas to be treated by full trash capture systems, and requires development of receiving water monitoring programs for trash.
- In compliance with MRP Provisions C.2 (Municipal Operations), C.4 (Industrial and Commercial Site Controls), C.5 (Illicit Discharge Detection and Elimination), and C.6 (Construction Site Controls) Permittees continue to implement Best Management Practices (BMPs) that are designed to prevent non-stormwater discharges during dry weather and reduce the exposure of stormwater runoff to contaminants during rainfall events.
- In compliance with MRP Provision C.13, copper in stormwater runoff is reduced through implementation of controls such as architectural and site design requirements, prohibition of discharges from water features treated with copper, and industrial facility inspections.
- Mercury and polychlorinated biphenyls (PCBs) in stormwater runoff are being reduced through implementation of the respective TMDL water quality restoration plans. In compliance with MRP Provisions C.11 (mercury) and C.12 (PCBs), the Countywide Program will continue to identify sources of these pollutants and will implement control actions designed to achieve load reduction goals. Monitoring activities conducted in WY

2018 that specifically target mercury and PCBs are described in the Pollutants of Concern Monitoring Data Report that is included as Appendix D to the WY 2018 UCMR.

In addition to controls implemented in compliance with the MRP, numerous other efforts and programs designed to improve the biological, physical and chemical condition of local creeks are underway. For example, C/CAG recently finalized the San Mateo Countywide Stormwater Resource Plan (SRP) to satisfy state requirements and guidelines to ensure C/CAG and San Mateo county MRP Permittees are eligible to compete for future voter-approved bond funds for stormwater or dry weather capture projects. The SRP identifies and prioritizes opportunities to better utilize stormwater as a resource in San Mateo County through a detailed analysis of watershed processes, surface and groundwater resources, input from stakeholders and the public, and analysis of multiple benefits that can be achieved through strategically planned stormwater management projects. These projects aim to capture and manage stormwater more sustainably, reduce flooding and pollution associated with runoff, improve biological functioning of plants, soils, and other natural infrastructure, and provide many community benefits, including cleaner air and water and enhanced aesthetic value of local streets and neighborhoods.

Through the continued implementation of MRP-associated and other watershed stewardship programs, SMCWPPP anticipates that stream conditions and water quality in local creeks will continue to improve overtime. In the near term, toxicity observed in creeks should decrease as pesticide regulations better incorporate water quality concerns during the pesticide registration process. In the longer term, control measures implemented to “green” the “grey” infrastructure and disconnect impervious areas constructed over the course of the past 50 plus years will take time to implement. Consequently, it may take several decades to observe the outcomes of these important, large-scale improvements to our watersheds in our local creeks. Long-term creek status monitoring programs designed to detect these changes over time are therefore beneficial to our collective understanding of the condition and health of our local waterways.

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ATTACHMENTS

Attachment 1

QA/QC Report

Quality Assurance/Quality Control Report

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Prepared for:

San Mateo Countywide
Water Pollution
Prevention Program

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LIST OF ACRONYMS

BASMAA	Bay Area Stormwater Management Agencies Association
BMI	Benthic Macroinvertebrates
CDFW	California Department of Fish and Wildlife
DPD	Diethyl-p-phenylene Diamine
DQO	Data Quality Objective
EDDs	Electronic data deliverables
EV	Expected Value
KLI	Kinnetic Laboratories, Inc.
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
MPN	Most Probably Number
MQO	Measurement Quality Objective
MRP	Municipal Regional Permit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MV	Measured Value
ND	Non-detect
NIST	National Institute of Standards and Technology
NPDES	National Pollution Discharge Elimination System
NV	Native Value
PAH	Polycyclic Aromatic Hydrocarbon
PR	Percent Recovery
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limit
RMC	Regional Monitoring Coalition
RPD	Relative Percent Difference
SAFIT	Southwest Association of Freshwater Invertebrate Taxonomists
SCCWRP	Southern California Coastal Water Research Project
SFRWQCB	San Francisco Regional Water Quality Control Board
SMCWPPP	San Mateo County Urban Pollution Prevention Program
SOP	Standard Operating Procedures
STE	Standard Taxonomic Effort
SV	Spike Value
SWAMP	Surface Water Ambient Monitoring Program
TKN	Total Kjeldahl Nitrogen
WY	Water Year

1. INTRODUCTION

In Water Year 2018 (WY 2018; October 1, 2017 through September 30, 2018), the San Mateo County Water Pollution Prevention Program (SMCWPPP) conducted Creek Status Monitoring in compliance with Provision C.8.d and Pesticide & Toxicity Monitoring in compliance with Provision C.8.g of the National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP). The monitoring strategy includes regional ambient/probabilistic monitoring and local "targeted" monitoring as described in the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). SMCWPPP implemented a comprehensive data quality assurance and quality control (QA/QC) program, covering all aspects of the probabilistic and targeted monitoring. QA/QC for data collected was performed according to procedures detailed in the BASMAA RMC Quality Assurance Project Plan (QAPP) (BASMAA 2016a) and the BASMAA RMC Standard Operating Procedures (SOP; BASMAA 2016b), SOP FS-13 (Standard Operating Procedures for QA/QC Data Review). The BASMAA RMC QAPP and SOP are based on the QA program developed by the California Surface Water Ambient Monitoring Program (SWAMP; SCCWRP 2008).

Based on the QA/QC review, no WY 2018 data were rejected and some data were flagged. Overall, WY 2018 data met QA/QC objectives. Details are provided in the sections below.

1.1. DATA TYPES EVALUATED

During creek status monitoring, several data types were collected and evaluated for quality assurance and quality control. These data types include the following:

1. Bioassessment data
    a. Benthic Macroinvertebrates (BMI)
    b. Algae
2. Physical Habitat Assessment
3. Field Measurements
4. Water Chemistry
5. Pathogen Indicators
6. Continuous Water Quality (2-week deployment; 15-minute interval)
    a. Temperature
    b. Dissolved Oxygen
    c. Conductivity
    d. pH
7. Continuous Temperature Measurements (5-month deployment; 1-hour interval)

During pesticide & toxicity monitoring the following data types were collected and evaluated for quality assurance and quality control:

1. Water Toxicity (dry weather; MRP Provision C.8.g.i)
2. Sediment Toxicity (dry weather; MRP Provision C.8.g.ii)
3. Sediment Chemistry (dry weather; MRP Provision C.8.g.ii)
4. Water Pesticides (wet weather; MRP Provision C.8.giii)
5. Water Toxicity (wet weather; MRP Provision C.8.giii)

1.2. LABORATORIES

Laboratories that provided analytical and taxonomic identification support to SMCWPPP and the RMC were selected based on demonstrated capability to adhere to specified protocols. Laboratories are certified and are as follows:

- Caltest Analytical Laboratory (nutrients, chlorophyll a, ash free dry mass, sediment chemistry)
- Pacific EcoRisk, Inc. (water and sediment toxicity)

- Alpha Analytical Laboratories, Inc. (pathogen indicators)
- BioAsessment Services (benthic macroinvertebrate (BMI) identification)
- Jon Lee Consulting (BMI identification Quality Control)
- EcoAnalysts, Inc. (algae identification)
- Physis Environmental Laboratories, Inc. (water column pesticides)

1.3. QA/QC ATTRIBUTES

The RMC SOP and QAPP identify seven data quality attributes that are used to assess data QA/QC. They include (1) Representativeness, (2) Comparability, (3) Completeness, (4) Sensitivity, (5) Precision, (6) Accuracy, and (7) Contamination. These seven attributes are compared to Data Quality Objectives (DQOs), which were established to ensure that data collected are of adequate quality and sufficient for the intended uses. DQOs address both quantitative and qualitative assessment of the acceptability of data – representativeness and comparability are qualitative while completeness, sensitivity, precision, accuracy, and contamination are quantitative assessments.

Specific DQOs are based on Measurement Quality Objectives (MQOs) for each analyte. Chemical analysis relies on repeatable physical and chemical properties of target constituents to assess accuracy and precision. Biological data are quantified by experienced taxonomists relying on organism morphological features.

1.3.1. Representativeness

Data representativeness assesses whether the data were collected so as to represent actual conditions at each monitoring location. For this project, all samples and field measurements are assumed to be representative if they are performed according to protocols specified in the RMC QAPP and SOPs.

1.3.2. Comparability

The QA/QC officer ensures that the data may be reasonably compared to data from other programs producing similar types of data. For RMC Creek Status monitoring, individual stormwater programs try to maintain comparability within the RMC. The key measure of comparability for all RMC data is the California Surface Water Ambient Monitoring Program.

1.3.3. Completeness

Completeness is the degree to which all data were produced as planned; this covers both sample collection and analysis. For chemical data and field measurements an overall completeness of greater than 90% is considered acceptable for RMC chemical data and field measurements. For bioassessment-related parameters – including BMI and algae taxonomy samples/analysis and associated field measurement – a completeness of 95% is considered acceptable.

1.3.4. Sensitivity

Sensitivity analysis determines whether the methods can identify and/or quantify results at low enough levels. For the chemical analyses in this project, sensitivity is considered to be adequate if the reporting limits (RLs) comply with the specifications in RMC QAPP Appendix E: RMC Target Method Reporting Limits. For benthic macroinvertebrate data, taxonomic identification sensitivity is acceptable provided taxonomists use standard taxonomic effort (STE) Level I as established by the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT). There is no established level of sensitivity for algae taxonomic identification.

1.3.5. Accuracy

Accuracy is assessed as the percent recovery of samples spiked with a known amount of a specific chemical constituent. Chemistry laboratories routinely analyze a series of spiked samples; the results of these analyses are reported by the laboratories and evaluated using the RMC Database QA/QC Testing Tool. Acceptable levels of accuracy are specified for chemical analytes and toxicity test parameters in

RMC QAPP Appendix A: Measurement Quality Objectives for RMC Analytes, and for biological measurements in Appendix B: Benthic Macroinvertebrate MQOs and Data Production Process.

1.3.6. Precision

Precision is nominally assessed as the degree to which replicate measurements agree, nominally determined by calculation of the relative percent difference (RPD) between duplicate measurements. Chemistry laboratories routinely analyze a series of duplicate samples that are generated internally. The RMC QAPP also requires collection and analysis of field duplicate samples 5% of all samples for all parameters[1]. The results of the duplicate analyses are reported by the laboratories and evaluated using RMC Database QA/QC Testing Tool. Results of the Tool are confirmed manually. Acceptable levels of precision are specified for chemical analytes and toxicity test parameters in RMC QAPP Appendix A: Measurement Quality Objectives for RMC Analytes, and for biological measurements in Appendix B: Benthic Macroinvertebrate MQOs and Data Production Process.

1.3.7. Contamination

For chemical data, contamination is assessed as the presence of analytical constituents in blank samples. The RMC QAPP requires collection and analysis of field blank samples at a rate of 5% for orthophosphate.

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[1] The QAPP also requires the collection of field duplicate samples for 10% of biological samples (BMI and algae). However, there are no prescribed methods for assessing the precision of these duplicate samples.

2. METHODS

2.1. REPRESENTATIVENESS

To ensure representativeness, each member of the SMCWPPP field crew received and reviewed all applicable SOPs and the QAPP. Most field crew members also attended a two-day bioassessment and field sampling training session from the California Water Boards Training Academy. The course was taught by California Department of Fish and Wildlife, Aquatic Bioassessment Laboratory staff and covered procedures for sampling benthic macroinvertebrates, algae, and measuring physical habitat characteristics using the applicable SWAMP SOPs. As a result, each field crew member was knowledgeable of, and performed data collection according to the protocols in the RMC QAPP and SOPs, ensuring that all samples and field measurements are representative of conditions in San Mateo County urban creeks.

2.2. COMPARABILITY

In addition to the bioassessment and field sampling training, SMCWPPP field crew members participated in an inter-calibration exercise with other stormwater programs prior to field assessments at least once during the permit term. During the inter-calibration exercise, the field crews also reviewed water chemistry (nutrient) sample collection and water quality field measurement methods. Close communication throughout the field season with other stormwater program field crews also ensured comparability.

Sub-contractors collecting samples and the laboratories performing analyses received copies of the RMC SOP and QAPP, and have acknowledged reviewing the documents. Data collection and analysis by these parties adhered to the RMC protocols and was included in their operating contracts.

Following completion of the field and laboratory work, the field data sheets and laboratory reports were reviewed by the SMCWPPP Program Quality Assurance staff, and were compared against the methods and protocols specified in the SOPs and QAPP. Specifically, staff checked for conformance with field and laboratory methods as specified in SOPs and QAPP, including sample collection and analytical methods, sample preservation, sample holding times, etc.

Electronic data deliverables (EDDs) were submitted to the San Francisco Regional Water Quality Control Board (SFRWQCB) in Microsoft Excel templates developed by SWAMP, to ensure data comparability with the SWAMP program. In addition, data entry followed SWAMP documentation specific to each data type, including the exclusion of qualitative values that do not appear on SWAMP's look up lists[2]. Completed templates were reviewed using SWAMP's online data checker[3], further ensuring SWAMP-comparability.

2.3. COMPLETENESS

2.3.1. Data Collection

All efforts were made to collect 100% of planned samples. Upon completion of all data collection, the number of samples collected for each data type was compared to the number of samples planned and the number required by the MRP, and reasons for any missed samples were identified. When possible, SMCWPPP staff resampled sites if missing data were identified prior to the close of the monitoring period. Specifically, continuous water quality data were reviewed immediately following deployment, and if data were rejected, samplers were redeployed immediately.

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[2] Look up lists available online at http://swamp.waterboards.ca.gov/swamp_checker/LookUpLists.php

[3] Checker available online at http://swamp.waterboards.ca.gov/swamp_checker/SWAMPUpload.php

For bioassessments, the SMCWPPP field crew made all efforts to collect the required number of BMI and algae subsamples per site; in the event of a dry transect, the samples were slid to the closest sampleable location to ensure 11 total subsamples in each station's composite sample.

2.3.2. Field Sheets

Following the completion of each sampling event, the field crew leader/local monitoring coordinator reviewed any field generated documents for completion, and any missing values were entered. Once field sheets were returned to the office, a second SMCWPPP staff member reviewed the field sheets again and noted any missing data.

2.3.3. Laboratory Results

SMCWPPP staff assessed laboratory reports and EDDs for the number and type of analysis performed to ensure all sites and samples were included in the laboratory results.

2.4. SENSITIVITY

2.4.1. Biological Data

Benthic macroinvertebrates were identified to SAFIT STE Level I.

2.4.2. Chemical Analysis

The reporting limits for analytical results were compared to the target reporting limits in Appendix E (RMC Target Method Reporting Limits) of the RMC QAPP. Results with reporting limits that exceeded the target reporting limit were flagged.

2.5. ACCURACY

2.5.1. Biological Data

Ten percent of the total number of BMI samples collected was submitted to a separate taxonomic laboratory, Jon Lee Consulting, for independent assessment of taxonomic accuracy, enumeration of organisms, and conformance to standard taxonomic level. For SMCWPPP, one sample was evaluated for QC purposes. Results were compared to MQOs in Appendix B (Benthic macroinvertebrate MQOs and Data Production Process).

2.5.2. Chemical Analysis

Caltest and Physis evaluated and reported the percent recovery (PR) of laboratory control samples (LCS; in lieu of reference materials) and matrix spikes (MS), which were recalculated and compared to the applicable MQOs set by Appendix A (Measurement Quality Objectives for RMC Analytes) of the RMC QAPP MQOs. If a QA sample did not meet MQOs, all samples in that batch for that particular analyte were flagged.

For reference materials, percent recovery was calculated as:

$$PR = MV / EV \times 100\%$$

Where: MV = the measured value

EV = the expected (reference) value

For matrix spikes, percent recovery was calculated as:

$$PR = [(MV - NV) / SV] \times 100\%$$

Where: MV = the measured value of the spiked sample

NV = the native, unspiked result

SV = the spike concentration added

2.5.3. Water Quality Data Collection

Accuracy for continuous water quality monitoring sondes was assured via continuing calibration verification for each instrument before and after each two-week deployment. Instrument drift was calculated by comparing the instrument's measurements in standard solutions taken before and after deployment. The drift was compared to measurement quality objectives for drift listed on the SWAMP calibration form, included as an attachment to the RMC SOP FS-3.

Temperature data were checked for accuracy by comparing measurements taken by HOBO temperature loggers with NIST thermometer readings in room temperature water and ice water prior to deployment. The mean difference and standard deviation for each HOBO was calculated, and if a logger had a mean difference exceeding 0.2 ^{o}C, it is replaced.

2.6. PRECISION

2.6.1. Field Duplicates

For creek status monitoring, duplicate biological samples were collected at 10% (one) of the 10 probabilistic sites and duplicate water chemistry samples were collected at 10% (one) of the probabilistic sites sampled to evaluate precision of field sampling methods. The RPD for water chemistry field duplicates was calculated and compared to the MQO (RPD < 25%) set by Table 26-1 in Appendix A of the RMC QAPP. If the RPD of the two field duplicates did not meet the MQO, the results were flagged.

The RMC QAPP requires collection and analysis of duplicate sediment chemistry and toxicity samples at a rate of 5% of total samples collected for the project. One field duplicate was collected in San Mateo County for dry weather sediment chemistry, sediment toxicity, and water toxicity samples and an additional field duplicate was collected in Contra Costa County for wet weather pesticides to account for the 16 pesticide & toxicity sites collectively monitored by the RMC in WY 2018. The sediment sample and field duplicate were collected together using the Sediment Scoop Method described in the RMC SOP, homogenized, and then distributed to two separate containers. For sediment chemistry and water pesticides field duplicates, the RPD was calculated for each analyte and compared to the MQOs (RPD < 25%) set by Tables 26-7 through 26-11 in Appendix A of the RMC QAPP. For sediment and water toxicity field duplicates, the RPD of the batch mean was calculated and compared to the recommended acceptable RPD (< 20%) set by Tables 26-12 and 26-13 in Appendix A. If the RPD of the field duplicates did not meet the MQO, the results were flagged.

The RPD is calculated as:

RPD = ABS ([X1-X2] / [(X1+X2) / 2])

Where: X1 = the first sample result
X2 = the duplicate sample result

No field duplicate is required for pathogen indicators.

2.6.2. Chemical Analysis

Caltest and Physis evaluated and reported the RPD for laboratory duplicates, laboratory control duplicates, and matrix spike duplicates. The RPDs for all duplicate samples were recalculated and compared to the applicable MQO set by Appendix A of the RMC QAPP. If a laboratory duplicate sample did not meet MQOs, all samples in that batch for that particular analyte were flagged.

2.7. CONTAMINATION

Blank samples were analyzed for contamination, and results were compared to MQOs set by Appendix A of the RMC QAPP. For creek status monitoring, the RMC QAPP requires all blanks (laboratory and field) to be less than the analyte reporting limits. If a blank sample did not meet this MQO, all samples in that batch for that particular analyte were flagged.

3. RESULTS

3.1. OVERALL PROJECT REPRESENTATIVENESS

The SMCWPPP staff and field crew members were trained in SWAMP and RMC protocols, and received significant supervision from the local monitoring coordinator and QA officer. As a result, creek status monitoring data were considered to be representative of conditions in San Mateo County Creeks.

3.2. OVERALL PROJECT COMPARABILITY

SMCWPPP creek status monitoring data were considered to be comparable to both other agencies in the RMC and to SWAMP due to trainings, use of the same electronic data templates, and close communication.

3.3. BIOASSESSMENTS AND PHYSICAL HABITAT ASSESSMENTS

In addition to algae and BMI taxonomic samples, the SMCWPPP field crew collected chlorophyll a and ash free dry mass samples during bioassessments. The BMI taxonomic laboratory, BioAssessment Services, confirmed that the laboratory QA/QC procedures aligned with the procedures in Appendices B through D of the RMC QAPP and met the BMI MQOs in Appendix B.

3.3.1. Completeness

SMCWPPP completed bioassessments and physical habitat assessments for 10 of 10 planned/required sites for a 100% sampling completion rate. However, physical habitat assessments could not be taken at several transects due to inaccessibility.

3.3.2. Sensitivity

The BMI taxonomic identification met sensitivity objectives; the taxonomy laboratory, BioAssessment Services, and QC laboratory, Jon Lee Consulting, confirmed that organisms were identified to SAFIT STE Level I, with the exception of Chironomidae which was analyzed to SAFIT level 1a.

The analytical RL for ash free dry mass analysis (8 mg/L) was much higher than the RMC QAPP target RL of 2 mg/L due to high concentrations requiring large dilutions. The results were several orders of magnitude higher than the actual and target reporting limit and were not affected by the higher RL. While the chlorophyll a analyses also required large dilutions due to high concentrations within the samples, the chlorophyll a analytical RL was below that of the RMC QAPP target RL.

Note that the target RLs in the RMC QAPP are set by the SWAMP, but there are currently no appropriate SWAMP targets for either ash free dry mass or chlorophyll a. Limits in the RMC QAPP are meant to reflect current laboratory capabilities. At lower analyte concentrations where a dilution would not be necessary, the analytical RLs would have met the target RLs.

3.3.3. Accuracy

The BMI sample that was submitted to an independent QC taxonomic laboratory had no taxonomic or counting errors. The QC laboratory calculated sorting and taxonomic identification metrics, which were compared to the measurement quality objectives in Table 27-1 in Appendix B of the RMC QAPP. All MQOs were met. A comparison of the metrics with the MQOs is shown in Table 1. A copy of the QC laboratory report is available upon request.

There is currently no protocol for evaluating the accuracy of algae taxonomic identification.

Table 1. Quality control metrics for taxonomic identification of benthic macroinvertebrates collected in San Mateo County in WY 2018 compared to measurement quality objectives.

Quality Control Metric	MQO	Error Rate	Exceeds MQO?
Recount Accuracy	> 95%	100%	No
Taxa ID	≤ 10%	0%	No
Individual ID	≤ 10%	0%	No
Low Taxonomic Resolution Individual	≤ 10%	0%	No
Low Taxonomic Resolution Count	≤ 10%	0%	No
High Taxonomic Resolution Individual	≤ 10%	0%	No
High Taxonomic Resolution Count	≤ 10%	0%	No

3.3.4. Precision

Field blind duplicate chlorophyll a and ash free dry mass samples were collected at one site in WY 2018 and were sent to the laboratory for analysis.

Duplicate field samples do not provide a valid estimate of precision in the sampling and are of little use to assessing precision, because there is no reasonable expectation that duplicates will produce identical data. Nonetheless, the RPD of the chlorophyll a and ash free dry mass duplicate results were calculated and compared to the MQO (< 25%) for conventional analytes in water (Table 26-1 in Appendix B of the RMC QAPP). Due to the nature of chlorophyll a and ash free dry mass collection, the RPDs for both parameters are expected to exceed the MQO. However, it was found that neither of the RPDs exceeded the MQO this year. The field duplicate results and their RPDs are shown in Table 2.

Again, discrepancies were to be expected due to the potential natural variability in algae production within the reach and the collection of field duplicates at different locations along each transect (as specified in the protocol). As a result, both parameters have frequently exceeded the field duplicate RPD MQOs during past years' monitoring efforts.

Table 2. Field duplicate water chemistry results for sites 202R00614, collected on May 14, 2018

Analyte	Units	202R00614 May 14, 2018			
		Original Result	Duplicate Result	RPD	Exceeds MQO (>25%)[a]
Chlorophyll a	mg/m^2	30.0	32.4	8%	No
Ash Free Dry Mass	g/m^2	48.4	53.9	11%	No

[a] In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable

Laboratory duplicates were also collected for chlorophyll a and ash free dry mass samples. The RPDs for both chlorophyll a and ash free dry mass were below the MQO limit, and therefore no flagging of samples was required.

3.3.5. Contamination

All field collection equipment was decontaminated between sites in accordance with the RMC SOP FS-8 and CDFW Aquatic Invasive Species Decontamination protocols. As a result, it is assumed that samples were free of biological contamination.

3.4. FIELD MEASUREMENTS

Field measurements of temperature, dissolved oxygen, pH, specific conductivity, and chlorine residual were collected concurrently with bioassessments and water chemistry samples. Chlorine residual was measured using a HACH Pocket Colorimeter^{TM} II, which uses the DPD method. All other parameters were measured with a YSI Professional Plus or YSI 600XLM-V2-S multi-parameter instrument. All data collection was performed according to RMC SOP FS-3 (Performing Manual Field Measurements).

3.4.1. Completeness

Temperature, dissolved oxygen, pH, and specific conductivity were collected at all 10 bioassessment sites for a 100% completeness rate. Free chlorine residual was collected at 9 bioassessment sites for a 90% completeness rate, and total chlorine residual was collected at 8 bioassessment sites for an 80% completeness rate. The lack of chlorine sample collection at two bioassessment sites was due to battery failure in the HACH Pocket Colorimeter used as the sampling device. These circumstances will be avoided in the future by the addition of a back-up battery supply to field supplies.

3.4.2. Sensitivity

Free and total chlorine residual were measured using a HACH Pocket Colorimeter^{TM} II, which uses the DPD method. For this method, the estimated detection limit for the low range measurements (0.02-2.00 mg/L) was 0.02 mg/L. There is, however, no established method reporting limit. Based on industry standards and best professional judgment, the method reporting limit is assumed to be 0.13 mg/L, which is much lower than the 0.5 mg/L target reporting limit listed in the RMC QAPP for free and total chlorine residual.

There are also no method reporting limits for temperature, dissolved oxygen, pH, and conductivity measurements, but the actual measurements are much higher than target reporting limits in the RMC QAPP, so it is assumed that target reporting limits are met for all field measurements.

3.4.3. Accuracy

Data collection occurred Monday through Thursday, and the multi-parameter instrument was calibrated at most 12 hours prior to the first sample on Monday, with the dissolved oxygen sensor calibrated every morning to ensure accurate measurements. Calibration solutions are certified standards, whose expiration dates were noted prior to use. The chlorine kit is factory-calibrated and is sent into the manufacturer every other year to be calibrated.

Free chlorine was measured to be higher than total chlorine at one of the nine sites sampled in WY 2018. In past years, free chlorine has also occasionally been measured as higher than total chlorine. Theoretically, the free chlorine measurement should always be less than or equal to the total chlorine measurement, as the total chlorine concentration in water encompasses the free chlorine concentration in addition to any other chlorine species. The reason for free chlorine concentrations exceeding total chlorine concentrations at a sample site has not been definitively established. However, it is suspected that this could be due to inaccuracy of the chlorine meter at concentrations below 0.13 mg/L or varying chlorine concentrations between the water sample used for the total chlorine measurement and the water sample used for the free chlorine measurement. When free chlorine was observed to be higher than total chlorine at a sample site, the free chlorine measurement was retaken with a new water sample and recorded on the field form. It was deemed unnecessary to flag free chlorine measurements that were higher than total chlorine measurements.

3.4.4. Precision

Precision could not be measured as no duplicate field measurements are required or were collected.

3.5. WATER CHEMISTRY

Water chemistry samples were collected by SMCWPPP staff concurrently with bioassessment samples and analyzed by Caltest Analytical Laboratory (Caltest) within their respective holding times. Caltest performed all internal QA/QC requirements as specified in the QAPP and reported their findings to the RMC. Key water chemistry MQOs are listed in RMC QAPP Table 26-2.

3.5.1. Completeness

SMCWPPP collected 100% of planned/required water chemistry samples at the 10 bioassessment sites including one field duplicate sample. Samples were analyzed for all requested analytes, and 100% of results were reported. Water chemistry data were flagged when necessary, but none were rejected.

3.5.2. Sensitivity

Laboratory reporting limits met or were lower than target reporting limits for all nutrients except chloride and nitrate. The reporting limit for all chloride samples exceeded the target reporting limit, but concentrations were much higher than reporting limits, and the elevated reporting limits do not decrease confidence in the measurements.

The reporting limit (0.05 mg/L) and method detection limit (0.02 mg/L) for nitrate samples were higher than the target reporting limit (0.01 mg/L). As a result, the nitrate concentration at one site was measured to be below the method detection limit. SMCWPPP has discussed the reporting limits with Caltest, and there is the possibility for a lower reporting limit for future analysis. Target and actual reporting limits are shown in Table 3.

Table 3. Target and actual reporting limits for nutrients analyzed in SMCWPPP creek status monitoring. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte	Target RL mg/L	Actual RL mg/L
Ammonia	0.02	0.02
Chloride	0.25	1-10
Total Kjeldahl Nitrogen	0.5	0.1
Nitrate	0.01	0.05
Nitrite	0.01	0.005
Orthophosphate	0.01	0.01
Silica	1	1
Phosphorus	0.01	0.01

3.5.3. Accuracy

Recoveries on all LCS were within the MQO target range of 80-120% recovery, and most MS and MSD PRs were within the target range. Three MS/MSD PRs exceeded the MQO range listed in the RMC QAPP for conventional analytes, including ammonia and silica. The QA samples affected five sites, whose results have been assigned the appropriate SWAMP flag. Though the data were flagged, none of the analytical data were rejected by the local QA officer due to accuracy.

The PR ranges on laboratory reports were 70-130%, 85-115% or 90-110% for some conventional analytes (nutrients) while the RMC QAPP lists the PR as 80-120% for all conventional analytes in water. As a result, some QA samples that exceeded RMC MQOs were flagged by the local QA officer, but not by the laboratory and vice versa.

3.5.4. Precision

The RPD for all laboratory control sample and MS/MSD pairs were consistently below the MQO target of < 25%.

Water chemistry field duplicates were collected at one site in San Mateo County and were compared against the original samples. For WY 2018, the total Kjeldahl nitrogen and ammonia duplicate samples exceeded the RPD MQO. In past years of sampling, total Kjeldahl nitrogen has been common among the analytes that exceed the field duplicate RPD MQOs. Field crews will continue to make an effort in subsequent years to collect the original and duplicate samples in an identical fashion.

The field duplicate water chemistry results and their RPDs are shown in Table 4. Because of the variability in reporting limits, values less than the RL were not evaluated for RPD. For those analytes whose RPDs could be calculated and did not meet the RMC MQO, they were assigned the appropriate SWAMP flag.

Table 4. Field duplicate water chemistry results for site 202R00614, collected on May 14, 2018. Data in highlighted rows exceed measurement quality objectives in RMC QAPP.

Analyte Name	Fraction Name	Unit	Original Result	Duplicate Result	RPD	Exceeds MQO (>25%)[a]
Ammonia as N	Total	mg/L	0.048	0.033	37%	Yes
Chloride	None	mg/L	38	38	0%	No
Nitrate as N	None	mg/L	0.06	ND	N/A	N/A
Nitrite as N	None	mg/L	J 0.001	J 0.001	N/A	N/A
Nitrogen, Total Kjeldahl	None	mg/L	0.44	0.31	35%	Yes
Orthophosphate as P	Dissolved	mg/L	0.1	0.1	0%	No
Phosphorus as P	Total	mg/L	0.12	0.11	9%	No
Silica as SiO2	Total	mg/L	23	22	4%	No

[a] In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable

3.5.5. Contamination

None of the target analytes were detected in any of the laboratory blanks at levels above their reporting limit. All analytes were non-detect in the laboratory blanks. The RMC QAPP does not require field blanks to be collected, and possible contamination from sample collection was not assessed. However, the SMCWPPP field crew takes appropriate precautions to avoid contamination, including wearing gloves during sample collection and rinsing sample containers with stream water when preservatives are not needed.

3.6. PATHOGEN INDICATORS

Pathogen indicator samples were collected by SMCWPPP staff and were analyzed by Alpha Analytical Laboratories, Inc for *E. coli* and enterococcus. Samples were collected on July 27, 2018.

3.6.1. Completeness

All five required/planned pathogen indicator samples were collected for a 100% completeness rate. However, the samples taken at site 202PES150 and 202PES154 were not analyzed within the eight-hour hold time specified by the RMC QAPPP. The sample from site 202PES150 was analyzed 55 minutes after the eight-hour hold time limit, and the sample from site 202PES154 was analyzed 50 minutes after the limit. These hold time limit exceedances are not expected to have affected the integrity of the sample results. As a result, these were flagged but not rejected.

3.6.2. Sensitivity

The reporting limits for *E. coli* and enterococcus (1 MPN/100mL and 2 MPN/100mL, respectively) met the target RL of 2 MPN/100mL listed in the project QAPP.

3.6.3. Accuracy

Negative and positive laboratory controls were run for microbial media. A negative response was observed in the negative control and a positive response was observed in the positive control required by the project QAPP Table 26-4.

3.6.4. Precision

The RMC QAPP requires one laboratory duplicate to be run per 10 samples or per analytical batch, whichever is more frequent. However, determining precision for pathogen indicators requires 15 duplicate sets. Due to the small number of samples collected for this project, there were not enough laboratory duplicates to determine precision. In WY 2018, only one laboratory duplicate was run and is not sufficient in determining precision.

The RMC QAPP does not require a field duplicate to be collected for pathogen indicators. However, one field duplicate was collected in WY 2018 by the field crew for a different project. The RPD for *E. coli* was 75% and 17% for enterococcus. Since there is no requirement for pathogen field duplicates, there is no corresponding MQO, and the precision could not be assessed. See Table 5 for the field duplicate results.

Table 5. Lab and field duplicate pathogen results collected on July 27, 2018.

Duplicate Type	Analyte	Original Result (MPN/100mL)	Duplicate Result (MPN/100mL)	RPD
Lab Duplicate	E. coli	> 2419.6	> 2419.6	NA
Lab Duplicate	Enterococcus	> 2419.6	> 2419.6	NA
Field Duplicate	E. coli	260.3	275.5	6%
Field Duplicate	Enterococcus	547.5	410.6	29%

3.6.5. Contamination

One method blank (sterility check) was run in the batch for *E. coli* and enterococcus. No growth was observed in the blank.

3.7. CONTINUOUS WATER QUALITY

Continuous water quality measurements were recorded at two sites during the spring (May 2018), concurrent with bioassessments, and again in the summer (August 2018) in compliance with the MRP. Temperature, pH, dissolved oxygen, and specific conductivity were recorded once every 15 minutes for approximately two-weeks using a multi-parameter water quality sonde (YSI 6600-V2).

3.7.1. Completeness

The MRP requires one to two-week deployments, and both deployments exceeded the one week minimum. The first deployment lasted 13 days, while the second deployment lasted 11 days at site 202SPE040 and 9 days at 202SPE070. Due to an internal malfunction in the sonde deployed at site 202SPE070 during the second deployment, the sonde did not record the first two days of its deployment.

As a result, that sonde collected 81% of the planned deployment. The other sondes collected data for 100% of the planned deployments, and no data were rejected.

3.7.2. Sensitivity

There are no method reporting limits for temperature, dissolved oxygen, pH, and conductivity measurements, but the actual measurements are much higher than target reporting limits in the RMC QAPP, so it is assumed that target reporting limits are met for all field measurements.

3.7.3. Accuracy

The SMCWPPP staff conduct pre- and post-deployment sonde calibrations for the two sondes used during monitoring events and calculate the drift during the deployments. A summary of the drift measurements is shown in Table 6. During the second monitoring event, the sonde deployed at 202SPE040 exceeded the drift MQO for dissolved oxygen. Oxygen results at this site were subsequently flagged for this deployment, but not rejected.

Table 6. Drift measurements for two continuous water quality monitoring events in San Mateo County urban creeks during WY 2018. Bold and highlighted values exceeded measurement quality objectives.

Parameter	Measurement Quality Objectives	202SPE040		202SPE070	
		Event 1	Event 2	Event 1	Event 2
Dissolved Oxygen (mg/l)	± 0.5 mg/L or 10%	0.16	0.11	-0.19	0.07
pH 7.0	± 0.2	0.11	0.01	0.02	0.12
pH 10.0	± 0.2	0.12	-0.04	-0.01	0.07
Specific Conductance (uS/cm)	± 10%	0.8%	-0.6%	0.8%	-9.1%

3.7.4. Precision

There is no protocol listed in the RMC QAPP for measuring the precision of continuous water quality measurements.

3.8. CONTINUOUS TEMPERATURE MONITORING

Continuous temperature monitoring was conducted from April through September 2018 at five sites in San Mateo County. Onset HOBO Water Temperature data loggers recorded one measurement per hour.

3.8.1. Completeness

The MRP requires SMCWPPP to monitor four stream reaches for temperature each year, but anticipating the potential for a HOBO temperature logger to be lost during such a long deployment, SMCWPPP deployed one extra temperature logger for a total of five loggers. In the middle of the deployment, SMCWPPP staff checked the loggers to ensure that they were still present and recording. One logger was missing during the mid-deployment field check and was replaced with another logger. During the field check, staff also downloaded the existing data and redeployed the other loggers. Since the other four loggers recorded 100% of the deployment period, SMCWPPP was still able to achieve a completion rate of over 100%.

3.8.2. Sensitivity

There is no target reporting limit for temperature listed in the RMC QAPP, thus sensitivity could not be evaluated for continuous temperature measurements.

3.8.3. Accuracy

A pre-deployment accuracy check was run on the temperature loggers in March 2018. None of the loggers exceeded the 0.2 °C mean difference threshold for either the room temperature bath or the 0.2 °C mean difference for the ice bath. The loggers were subsequently deployed, and no flagging of the data was necessary.

3.8.4. Precision

There are no precision protocols for continuous temperature monitoring.

3.9. SEDIMENT CHEMISTRY

The dry season sediment chemistry sample was collected by Kinnetic Laboratories, Inc (KLI) concurrently with the dry season toxicity sample on July 17, 2018. Inorganic and synthetic organic compounds were analyzed by Caltest and grain size distribution was analyzed by Soil Control Laboratories, a subcontractor laboratory. Caltest conducted all QA/QC requirements as specified in the RMC QAPP and reported their findings to the RMC. Key sediment chemistry MQOs are listed in RMC QAPP Tables 26-9 through 26-11. Sediment chemistry data were flagged when necessary, but none were rejected

3.9.1. Completeness

The MRP requires a sediment chemistry sample to be collected at one location each year. In WY 2018, SMCWPPP collected the sediment chemistry sample at 204COR010. The laboratories analyzed samples within the one year holding time for analytes in sediment, set by the RMC SOP, and reported 100% of the required analytes.

3.9.2. Sensitivity

A comparison of target and actual reporting limits for those parameters is shown in Table 7. For sediment chemistry analysis conducted in WY 2018, laboratory reporting limits were higher than RMC QAPP target reporting limits for all 20 analytes. Since reporting limits for a sample are dependent on the percent solids of that sample, it is likely that the amount of solids in the sample resulted in these exceedances.

Table 7. Comparison of target and actual reporting limits for sediment analytes where reporting limits exceeded target limits. Sediment samples were collected in San Mateo County creeks in WY 2018.

Analyte	Target RL	Actual RL	Unit
Arsenic	0.3	1.0	mg/Kg
Cadmium	0.01	0.08	mg/Kg
Chromium	0.1	1	mg/Kg
Copper	0.01	0.41	mg/Kg
Lead	0.01	0.08	mg/Kg
Nickel	0.02	0.08	mg/Kg
Zinc	0.1	0.8	mg/Kg
Bifenthrin	0.33	1.3	ng/g
Cyfluthrin	0.33	1.3	ng/g
Total Lambda-cyhalothrin	0.33	1.3	ng/g
Total Cypermethrin	0.33	1.3	ng/g
Total Deltamethrin	0.33	1.3	ng/g
Total Esfenvalerate/Fenvalerate	0.33	1.3	ng/g
Permethrin	0.33	1.3	ng/g
Carbaryl	30	31	ng/g
Fipronil	0.33	1.3	ng/g
Fipronil Desulfinyl	0.33	1.3	ng/g
Fipronil Sulfide	0.33	1.3	ng/g
Fipronil Sulfone	0.33	1.3	ng/g
Total Organic Carbon	0.01	0.05	% dw

3.9.3. Accuracy

Inorganic Analytes

No QA samples exceeded the QAPP MQO for LCS percent recovery (PR) for metals (75-125%), but theMSD sample for lead exceeded the PR MQO. This sample was flagged but not rejected.

Synthetic Organic Compounds

The percent recovery MQO for pyrethroids and other synthetic organic compounds in sediment is 50-150% in the RMC QAPP. However, the PR MQOs listed in the laboratory reports for synthetic organic compounds varied by analyte and were much larger than PR ranges listed in the QAPP. The MQOs ranged from 1 to 275% in certain cases. As a result, several analytes were flagged by the local QA officers, but not by the laboratory.

None of the LCS PRs exceeded the RMC MQO range. However, the MS/MSD PRs exceeded the RMC MQO range for 10 PAHs, one pyrethroid (bifenthrin), and fipronil. The PAH MS/MSD samples that exceeded the PR MQO include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(e)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, perylene, and pyrene.

3.9.4. Precision

Inorganic Analytes

The RMC QAPP lists the maximum RPD for inorganic analytes (metals) as 25%. All MS/MSD sets for metals were well below the RMC RPD MQO of 25%.

Synthetic Organic Compounds

The maximum RPD for synthetic organics listed in the sediment laboratory report lists ranges from 30 to 50% for most analytes. However, the RMC QAPP lists the MQO as < 25% RPD for most synthetic organics, < 35% for pyrethroids and fipronil, and < 40% for carbaryl. None of the MS/MSD pairs or LCS duplicates exceeded the RPD MQO.

Field Duplicates

A sediment sample field duplicate was collected in San Mateo County on July 17, 2018 and evaluated for precision. The field duplicate sample and corresponding RPDs are shown in Table 8. Because of the variability in reporting limits, values less than the RL were not evaluated for RPD. The measured concentrations of a majority of analytes from the original and duplicate samples were below the method detection limit and therefore reported as “ND”. As a result, the RPDs were non-calculable. All calculable RPDs were below the MQO limits. Analytes that exceeded the MQO of RPD < 25% were cadmium; chromium; lead; anthracene; benz(a)anthracene; chrysene; dimethylnaphthalene, 2,6-; fluoranthene; methylnaphthalene, 1-; methylnaphthalene, 2-; naphthalene; phenanthrene; and pyrene.

Table 8. Sediment chemistry duplicate field results for site 204COR010, collected on July 17, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte		Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
Grain Size Distribution	Clay: <0.0039 mm	%	3.35	3.36	0%	No
	Silt: 0.0039 to <0.0625 mm	%	7.38	7.22	2%	No
	Sand: V. Fine 0.0625 to <0.125 mm	%	4.72	4.78	1%	No
	Sand: Fine 0.125 to <0.25 mm	%	13.39	13.79	3%	No
	Sand: Medium 0.25 to <0.5 mm	%	26.74	27.12	1%	No
	Sand: Coarse 0.5 to <1.0 mm	%	27.42	27.14	1%	No
	Sand: V. Coarse 1.0 to <2.0 mm	%	17.01	16.59	2.5%	No
	Granule: 2.0 to <4.0 mm	%	10.56	9.24	13%	No
	Pebble: Small 4 to <8 mm	%	13.14	12.64	4%	No
	Pebble: Medium 8 to <16 mm	%	ND	6.09	N/A	N/A
	Pebble: Large 16 to <32 mm	%	ND	ND	N/A	N/A
	Pebble: V. Large 32 to <64 mm	%	ND	ND	N/A	N/A
Metals	Arsenic	mg/Kg dw	4.1	4.1	0%	No
	Cadmium	mg/Kg dw	0.12	0.09	29%	Yes
	Chromium	mg/Kg dw	91	55	49%	Yes
	Copper	mg/Kg dw	25	23	8%	No
	Lead	mg/Kg dw	15	38	87%	Yes
	Nickel	mg/Kg dw	92	74	22%	No
	Zinc	mg/Kg dw	78	75	4%	No
Pyrethroids (MQO <35%)	Bifenthrin	ng/g dw	1.2	1.1	9%	No
	Cyfluthrin, total	ng/g dw	ND	0.6	N/A	N/A
	Cyhalothrin, Total lambda-	ng/g dw	ND	ND	N/A	N/A
	Cypermethrin, total	ng/g dw	ND	ND	N/A	N/A
	Deltamethrin/Tralomethrin	ng/g dw	0.69	ND	N/A	N/A
	Esfenvalerate/Fenvalerate, total	ng/g dw	ND	ND	N/A	N/A
	Permethrin, Total	ng/g dw	0.81	0.81	0%	No
	Total Organic Carbon	%	0.92	0.93	1%	No
	Carbaryl	mg/Kg dw	ND	ND	N/A	N/A
Fipronil	Fipronil	ng/g dw	ND	ND	N/A	N/A
	Fipronil Desulfinyl	ng/g dw	ND	ND	N/A	N/A

Table 8. Sediment chemistry duplicate field results for site 204COR010, collected on July 17, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte		Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
	Fipronil Sulfide	ng/g dw	ND	ND	N/A	N/A
	Fipronil Sulfone	ng/g dw	ND	ND	N/A	N/A
Polycyclic Aromatic Hydrocarbons	Acenaphthene	ng/g dw	ND	ND	N/A	N/A
	Acenaphthylene	ng/g dw	ND	ND	N/A	N/A
	Anthracene	ng/g dw	3.1	4.1	28%	Yes
	Benz(a)anthracene	ng/g dw	4.1	6.1	39%	Yes
	Benzo(a)pyrene	ng/g dw	ND	ND	N/A	N/A
	Benzo(b)fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Benzo(e)pyrene	ng/g dw	ND	ND	N/A	N/A
	Benzo(g,h,i)perylene	ng/g dw	ND	ND	N/A	N/A
	Benzo(k)fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Biphenyl	ng/g dw	8.2	10	20%	No
	Chrysene	ng/g dw	21	31	38%	Yes
	Dibenz(a,h)anthracene	ng/g dw	ND	ND	N/A	N/A
	Dibenzothiophene	ng/g dw	ND	ND	N/A	N/A
	Dimethylnaphthalene, 2,6-	ng/g dw	7.2	20	94%	Yes
	Fluoranthene	ng/g dw	21	31	38%	Yes
	Fluorene	ng/g dw	ND	ND	N/A	N/A
	Indeno(1,2,3-c,d)pyrene	ng/g dw	ND	ND	N/A	N/A
	Methylnaphthalene, 1-	ng/g dw	7.2	10	33%	Yes
	Methylnaphthalene, 2-	ng/g dw	10	20	67%	Yes
	Methylphenanthrene, 1-	ng/g dw	ND	ND	N/A	N/A
	Naphthalene	ng/g dw	6.2	10	47%	Yes
	Perylene	ng/g dw	ND	ND	N/A	N/A
	Phenanthrene	ng/g dw	21	51	83%	Yes
	Pyrene	ng/g dw	21	31	38%	Yes

[a] MQO for pyrethroids is <35%. In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable

Laboratory Duplicates

Laboratory duplicates were collected and analyzed for grain sizes and total organic carbon. All RPDs were below the MQO limits except for small (4 to <8 mm) and medium (8 to <16 mm) pebbles in addition to coarse (0.5 to <1.0 mm) and very coarse (1.0 to <2.0 mm) sand.

3.9.5. Contamination

Nickel was detected in an instrument (lab) blank at a concentration above the reporting limit. As a result, nickel samples were flagged. None of the other target analytes were detected in any of the blanks.

3.10. WET SEASON PESTICIDES

Wet season pesticide samples were collected by KLI concurrently with the wet season toxicity sample on January 8, 2018. Samples were analyzed by Physis Environmental Laboratories, Inc. within their respective hold times for pesticides, including pyrethroids, fipronil, fipronil degredates, and imidacloprid. Physis conducted all QA/QC requirements as specified in the RMC QAPP and reported their findings to the RMC. Key water chemistry MQOs are listed in RMC QAPP Tables 26-9 through 26-11. Water chemistry data were flagged when necessary, but none were rejected.

3.10.1. Completeness

The MRP requires the RMC to collect ten water column pesticides samples over the permit term if sampling is conducted by the RMC on behalf of all Permittees. Permittees have decided to collaborate, and in WY 2018, two samples were collected in San Mateo County at 202SPE005 and 204COR010. A total of ten samples were collected by the RMC on behalf of Permittees in WY 2018. The laboratories analyzed and reported 100% of the planned/required analytes.

3.10.2. Sensitivity

The reporting limits for analytes collected in WY 2018 were all below the target reporting limits specified in the RMC QAPP.

3.10.3. Accuracy

The percent recovery MQO for pyrethroids and other synthetic organic compounds in sediment is 50-150% in the RMC QAPP. None of the LCS percent recoveries exceeded the RMC MQO range. However, the MS/MSD percent recoveries exceeded the RMC MQO range for three compounds including fipronil, fipronil desulfinyl, and fipronil sulfide.

3.10.4. Precision

The RPD listed in the laboratory report for water column pesticides is listed as 30%. However, the RMC QAPP lists the MQO as < 25% RPD for most synthetic organics and < 35% for pyrethroids and fipronil. None of the MS/MSD pairs or LCS duplicates exceeded the RPD MQOs.

<u>Field Duplicates</u>
A field duplicate was collected in Contra Costa County on January 8, 2018 and evaluated for precision. The field duplicate sample and corresponding RPDs are shown in Table 9. Because of the variability in reporting limits, values less than the Reporting Limit (RL) were not evaluated for RPD. The measured concentrations of a majority of analytes from the original and duplicate samples were below the method detection limit and therefore reported as ND, meaning that the RPDs were non-calculable. All calculable RPDs were below the MQO limits.

Table 9. Water column pesticides duplicate field results for site 204R01412, collected on January 8, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte		Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
Pyrethroids (MQO <35%)	Bifenthrin	ug/L	0.017	0.019	8%	No
	Cyfluthrin, total	ug/L	ND	ND	N/A	N/A
	Cyhalothrin, Total Lambda-	ug/L	ND	ND	N/A	N/A
	Cypermethrin, total	ug/L	ND	ND	N/A	N/A
	Deltamethrin/Tralomethrin	ug/L	ND	ND	N/A	N/A
	Esfenvalerate	ug/L	ND	ND	N/A	N/A
	Fenvalerate	ug/L	ND	ND	N/A	N/A
	Permethrin, cis-	ug/L	ND	ND	N/A	N/A
	Permethrin, trans-	ug/L	ND	ND	N/A	N/A
	Imidacloprid	ug/L	0.050	0.059	16%	No
Fipronil	Fipronil	ug/L	0.024	0.022	8%	No
	Fipronil Desulfinyl	ug/L	0.009	0.009	1%	N/A[b]
	Fipronil Sulfide	ug/L	0.002	0.002	9%	N/A[b]
	Fipronil Sulfone	ug/L	0.016	0.015	9%	N/A[b]

[a] MQO for pyrethroids is <35%. In accordance with the RMC QAPP, if the native concentration of either sample is less than the reporting limit, the RPD is not applicable.

[b] No MQO is listed in the RMC QAPP for Fipronil Desulfinyl, Sulfide, or Sulfone.

Laboratory Duplicates

Laboratory duplicates were collected and analyzed for all wet weather pesticides analytes in addition to total organic carbon. All RPDs were below the MQO limits except for imidacloprid. As a result, the imidacloprid samples were flagged.

3.10.5. Contamination

No target analytes were detected in corresponding instrument (lab) blanks at a concentration above their reporting limits. As a result, no samples were flagged.

3.11. TOXICITY TESTING

Dry season water and sediment toxicity samples were collected by KLI concurrently with dry season sediment chemistry samples at one San Mateo County site on July 17, 2018. All toxicity tests were performed by Pacific EcoRisk. The water samples were analyzed for toxicity to five organisms (*Selenastrum capricornutum, Ceriodaphnia dubia, Pimephales promelas, Hyalella azteca, and Chironomus dilutus*) and the sediment samples were analyzed for toxicity to *Hyalella azteca* and *Chironomus dilutus.*

Wet season water toxicity samples were collected by KLI concurrently with wet season water column pesticides samples at two San Mateo County sites on January 8, 2018. All wet season water toxicity tests were also performed by Pacific EcoRisk. The samples were analyzed for toxicity to five organisms (*Selenastrum capricornutum, Ceriodaphnia dubia, Pimephales promelas, Hyalella azteca, and Chironomus dilutus*).

3.11.1. Completeness

The MRP requires the collection of dry season water and sediment toxicity samples at one site per year in San Mateo County. Additionally, the MRP requires ten wet season water toxicity samples to be collected by the RMC participants over the permit term. SMCWPPP staff collected a wet season water toxicity sample in WY 2018. Pacific EcoRisk tested the required organisms for toxicity, and 100% of results were reported.

3.11.2. Sensitivity and Accuracy

Internal laboratory procedures that align with the RMC QAPP, including water and sediment quality testing and reference toxicant testing, were performed and submitted to SMCWPPP. The laboratory data QC checks found that all conditions and responses were acceptable. A copy of the laboratory QC report is available upon request.

3.11.3. Precision

One field duplicate was collected in San Mateo County on behalf of the RMC and tested for toxicity by Pacific EcoRisk. The mean toxicity endpoints of test organisms (mean survival, mean cell count, mean biomass, and mean young per female) for the field duplicates were compared, and the RPD for each toxicity test was calculated. These RPDs are compared to the RMC QAPP MQO of <20% for acute and chronic freshwater toxicity testing (Appendix A, Table 26-12 and 26-13) in Table 10. There is no MQO for sediment toxicity field duplicates listed in the RMC QAPP, so the recommended MQO listed in the RMC QAPP for the water toxicity field duplicates (< 20%) was used as an MQO for the sediment toxicity field duplicates. Samples met the MQO for toxicity testing for all species and endpoints.

Table 10. Water and sediment toxicity duplicate results for site 204COR010, collected on July 17, 2018 in San Mateo County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Matrix	Organism	Endpoint	Original Sample Mean	Duplicate Sample Mean	RPD	Exceeds Recommended MQO (<20%)?
Water	Pimephales promelas	% Survival	95	97.5	3%	No
Water	Pimephales promelas	Biomass (mg/individual)	0.905	0.959	6%	No
Water	Ceriodaphnia dubia	% Survival	100	100	0%	No
Water	Ceriodaphnia dubia	Young per female	33	32	3%	Yes
Water	Selenastrum capricornutum	Total Cell Count (cells/mL)	8680000	8960000	3%	No
Water	Hyalella azteca	% Survival	98	100	2%	No
Water	Chironomus dilutus	% Survival	85	85	0%	No
Sediment	Hyalella azteca	% Survival	95	91.3	4%	No
Sediment	Chironomus dilutus	% Survival	88.8	81.2	9%	No

3.11.4. Contamination

There are no QA/QC procedures for contamination of toxicity samples, but staff followed applicable RMC SOPs to limit possible contamination of samples.

4. CONCLUSIONS

Sample collection and analysis followed MRP and RMC QAPP requirements and data that exceeded measurement quality objectives were flagged. However, no data were rejected.

5. REFERENCES

Bay Area Stormwater Management Agency Association (BASMAA). 2012. Regional Monitoring Coalition Final Creek Status and Long-Term Trends Monitoring Plan. Prepared By EOA, Inc. Oakland, CA. 23 pp.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition. 2016a. Creek Status Monitoring Program Quality Assurance Project Plan, Final Draft Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program, and Armand Ruby Consulting on behalf of the Contra Costa Clean Water Program. 128 pp.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition. 2016b. Creek Status Monitoring Program Standard Operating Procedures Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program, and Armand Ruby Consulting on behalf of the Contra Costa Clean Water Program. 192 pp.

Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Team. 2008. SWAMP Quality Assurance Program Plan, Version 1.0. Prepared for the California State Water Quality Control Board by Moss Landing Marine Laboratories and San Jose State University Research Foundation. 1 September. 108 pp.

Attachment 2

RMC 5-Year Report

BASMAA Regional Monitoring Coalition Five-Year Bioassessment Report

Water Years 2012 - 2016

Prepared for:

Bay Area
Stormwater Management
Agencies Association

Prepared by:

EOA inc.

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March 2019

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Executive Summary

Biological assessment (bioassessment) is an evaluation of the biological condition of a water body based on the organisms living within it. In 2009, the Bay Area Stormwater Management Agencies Association's (BASMAA) Regional Monitoring Coalition (RMC) developed a bioassessment monitoring program to answer management questions identified in the Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit (referred to as the Municipal Regional Permit or MRP):

- *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 or likely to be supportive of beneficial uses?*

Bioassessment data collected over the first five years of RMC monitoring (2012-2016) are included in this report. The RMC's monitoring design addresses these management questions on a regional (Bay Area) scale to monitoring results across the five participating Bay Area counties (Alameda, Contra Costa, San Mateo, Santa Clara and Solano). Three study questions, developed to assist with addressing the management questions described above, including:

1) What is the biological condition of perennial and non-perennial streams in the region?
2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of this study are intended to help stormwater programs better understand the current condition of these water bodies and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area. The report evaluates the existing RMC monitoring design and identifies a range of potential options for revising the design (if desired) to better address the questions posed. These options are intended to provide considerations for discussion during the planning for reissuance of the Municipal Regional Permit, which is likely to be adopted in 2020 or 2021.

KEY FINDINGS

- **Most streams in the region are in poor biological condition.** The biological conditions of streams in the RMC area are assessed using two ecological indicators: benthic macroinvertebrates (BMIs) and algae. Results from 2012 through 2016 study period indicate that streams in the RMC area are generally in poor biological condition. Based on BMIs, over half (58%) of stream length was ranked in the lowest condition category of the California Stream Condition Index (CSCI). For algae indices (D18 and S2), stream conditions appear slightly less degraded, with approximately 40% of the streams ranked in lowest condition category. These findings should be interpreted with the understanding that the survey focused on urban stream conditions, and that these data represent current (baseline) conditions.
- **Poor biological conditions are strongly associated with physical habitat and landscape stressors.** The associations between biological indicators (CSCI and D18) and stressor data were evaluated using random forest and relative risk analyses. The study results showed that different biological indicators responded to different types of stressors. CSCI scores were strongly influenced by

physical habitat variables (e.g., level of human disturbance at a site) and land use factors (e.g., level of impervious surfaces near the site), while D18 scores were moderately influenced by water quality variables (e.g., dissolved oxygen and conductivity). Together, BMI and algae indices can be used to assess the overall biological condition of water bodies and potentially identify the causes of poor (or good) conditions. In general, CSCI scores at urban sites were consistently low, indicating that degraded physical habitat conditions common in urban settings are impacting biological conditions in streams. In contrast, D18 scores at urban sites were more variable, indicating that healthy diatom (algae) assemblages can occur at sites with poor physical habitat, which may provide valuable information about the overall water quality conditions in urban streams.

- **No changes in biological conditions are evident over the 5-year survey.** The short time frame of the survey (five years) limited the ability to detect trends. The variability in biological condition observed over the five years of the current analysis may have been associated with annual variation in precipitation, which included drought conditions during the first four years of the survey. A longer time period may be needed to detect trends in biological condition at a regional scale.
- **Baseline biological assessment data can assist Bay Area stormwater managers in evaluating the long-term effectiveness of ongoing or planned management actions.** Baseline bioassessment monitoring data collected by the RMC provides valuable information about the current status of aquatic life uses in the Bay Area and how RMC streams compare to other regions in the State of California. The baseline dataset provides context for potential future biological integrity policies being developed by the State Water Resources Control Board (State Water Board) and serves as a foundation for evaluating on-going and future watershed management actions that attempt to reduce the impacts of urbanization on creeks and channels. Future creek status monitoring may provide additional insight into the potential positive impacts of actions, such as green stormwater infrastructure and creek restoration, that improve water quality and address other needs of aquatic life uses in urban creeks.
- **The RMC monitoring design provides estimates for overall stream conditions in RMC area and urban stream conditions for each county.** Because participating municipalities are primarily concerned with stormwater runoff from urban areas, the RMC focused sampling efforts on urban sites (approximately 80%) over non-urban sites (approximately 20%). As a result, non-urban sites are under-represented in the dataset, resulting in lower overall biological condition scores than would be expected for a spatially balanced dataset. Depending on the goals for the RMC moving forward, consideration should be given to developing a new sample draw that establishes a new list of assessment sites that are weighted for specific land uses categories and Program areas of interest. Based on evaluation of data collected during the first five years of the survey, several options to revise the RMC Monitoring Design are presented in the report.

1 INTRODUCTION

1.1 BACKGROUND

The Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) is a consortium of six San Francisco Bay Area municipal stormwater programs that joined together in 2010 to coordinate and oversee water quality monitoring required by the Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit (referred to as the Municipal Regional Permit or "MRP"). The MRP was first adopted in 2009 (Order R2-2009-0074) by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). The MRP was reissued in 2015 through Order R2-2015-1049. The 2009 and 2015 versions of the MRP are referred to as MRP 1.0 and MRP 2.0, respectively. Both versions of the MRP require bioassessment monitoring in accordance with Standard Operating Procedures (SOPs) established by the California Surface Water Ambient Monitoring Program (SWAMP), including sampling of benthic macroinvertebrates (BMIs), benthic algae (i.e., diatoms and soft algae), and water chemistry, and the characterization of physical habitat.

The MRP identifies two broad management questions that required bioassessment monitoring (and other creek status monitoring requirements) is intended to address:

- *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 or likely to be supportive of beneficial uses?*

Consistent with the requirements of the MRP, the RMC developed a probabilistic monitoring design to address the management questions on a regional scale and compare monitoring results across stormwater programs. The probabilistic design is based on the Generalized Random Tessellation Stratified (GRTS) approach (Stevens and Olson 2004) for evaluating and selecting sampling stations in perennial and nonperennial streams. A power analysis estimated a minimum sample size of 30 sites to evaluate the condition of aquatic life within a confidence interval of approximately 12%. This was considered sufficient for decision-making in the RMC area. Under the MRP, each municipal Stormwater Program is required to assess a minimum number of stream/channel sites based on their relative population. As a result, the number of sites required each year varies by county: 20 sites for Santa Clara and Alameda counties and 10 sites for San Mateo and Contra Costa counties. Fairfield-Suisun and Vallejo are required to sample 8 and 4 sites, respectively, during each five-year period. In addition, the San Francisco Bay Regional Water Quality Control Board (SF Bay Water Board) collaborated with the RMC by monitoring additional sites in non-urban areas in each of the counties.

1.2 PROJECT GOAL

This goal of this project was to compile and evaluate bioassessment data collected over the first 5-years of bioassessment monitoring conducted by the RMC (2012 – 2016). The evaluation was designed to address three main questions, consistent with the overarching questions in the MRP:

1) What is the biological condition of perennial and non-perennial streams in the region?

2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The findings of this report are intended to help stormwater programs better understand the current condition of these water bodies, prioritize stream reaches in need of protection or restoration, and identify stressors that are likely to pose the greatest risk to the health of streams in the Bay Area.

This report also provides an evaluation of the existing RMC monitoring design and identifies a range of potential options for revising the design (if desired) in anticipation of the next version of the MRP, which is likely to be adopted in 2020 or 2021. These options can inform the monitoring re-design process as part of a future BASMAA Regional Project.

This project was implemented by a Project Team comprised of EOA, Inc. and Applied Marine Sciences, Inc. (AMS) with technical review provided by the Southern California Coastal Water Research Project (SCCWRP). A BASMAA Project Management Team (PMT) consisting of representatives from BASMAA stormwater programs and municipalities provided oversight and guidance to the Project Team.

Sections of this report are organized according to the following topics:

- **Section 1.0** – Introduction including summary of other Regional Monitoring Programs using biological assessments, development of State policies that are relevant to bioassessment data collection, and description of the goals for this report;
- **Section 2.0** – Methods including monitoring survey design, site evaluation procedures, field sampling and data analyses;
- **Section 3.0** – Results summarizing biological conditions, stressor association with conditions, and trends;
- **Section 4.0** – Discussion organized by the management questions and goals; and
- **Section 5.0** – Conclusions and recommendations.

1.3 BIOASSESSMENTS PROGRAMS IN CALIFORNIA

Bioassessment programs are currently implemented on a statewide and regional basis in California. The RMC's monitoring design is consistent with the design used by the statewide Perennial Streams Assessment (PSA) program and is specifically intended to allow for future integration of data between the two monitoring programs. The RMC has also integrated lessons learned from the Stormwater Monitoring Coalition (SMC), which spearheads a similar collaborative monitoring effort in Southern California, in the development of alternatives for potential re-design of the RMC monitoring survey described at the end of this report.

Since 2000, the State of California has conducted probability surveys of its perennial streams and rivers with a focus on biological endpoints. These surveys are managed collectively by the Surface Water Ambient Monitoring Program (SWAMP) under its PSA program. The PSA collects samples for biological indicators (BMIs and algae), chemical constituents (nutrients, major ions, etc.), and physical habitat assessments for both in-stream and riparian corridor conditions. As of 2012, over 1300 unique perennial stream sites have been monitored by PSA and its partner programs.[1] In 2015, the PSA developed a management memorandum summarizing biological conditions (based on California Stream Condition Index score) and associated stressor data collected at probabilistic sites over a 13-year time period (2000 – 2012) (SWRCB 2015).

The SMC, a coalition of multiple state, federal, and local agencies, initiated a regional monitoring program in 2009. The SMC uses multiple biological indicators to assess ecological health of streams, including BMIs, benthic algae (diatoms and soft algae) and riparian wetland condition. The SMC also collects water chemistry, water column toxicity, and physical habitat data to evaluate potential stressors to biological health. During the first five years of the program (2009 to 2013), the SMC monitored more than 500 probabilistic sites in 15 major watersheds in California's South Coast region, with a focus on perennial streams (Mazor 2015). Evolution of those data suggested that few perennial, wadeable streams in the SMC study area are in good biological condition (Mazor 2015a). Recognizing that perennial streams account for only 25% of stream-miles in the region, in 2015, the SMC expanded its monitoring program to include nonperennial streams, which account for approximately 59% of stream-miles (Mazor 2015b). The SMC program also focused about 30% of the monitoring effort towards revisiting probabilistic sites to provide an estimate of change in condition (Mazor 2015b). The next iteration of the SMC monitoring program will likely include a larger focus on trends monitoring (Rafael Mazor, SCCWRP, personal communication, 2018).

1.4 BIOSTIMULATORY/BIOINTEGRITY POLICY DEVELOPMENT

Bioassessment monitoring conducted by the RMC not only provides information about the condition of aquatic life uses in Bay Area streams and how they compare to other regions (i.e., SMC), it also generates a significant baseline dataset that provides context for potential future biological integrity and biostimulatory policies that are currently under development by the State Water Resources Control Board (State Water Board). The biostimulatory policy will likely develop water quality objectives for biostimulatory substances (e.g., nutrients) along with an implementation program as an amendment to the Water Quality Control Plan for Inland Surface Water, Enclosed Bays and Estuaries of California (ISWEBE Plan).[2] The biostimulatory substances policy may include a numeric and/or narrative objective(s) that will be applicable to streams in California. The State Water Board plans is expected to establish the implementation plan for the biostimulatory substances policy in three phases, with each phase including a plan that would be unique for each of the three different water body types. The first phase of the Biostimulatory Amendment would be applicable to wadeable streams.

The biostimulatory policy will also include a water quality control policy (i.e., Biointegrity Policy) to establish and implement biological condition assessment methods, scoring tools, and targets aimed at protecting the biological integrity in wadeable streams. The policy will utilize a multi-indicator approach that includes the California Stream Condition Index (CSCI) for benthic macroinvertebrates and statewide

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[1] The Stormwater Monitoring Coalition has collected a majority of samples at probabilistic sites in Coastal Southern California watersheds and the US Forest Service has collected PSA-comparable data from sites in National Forests of the Sierra Nevada.

[2] Information obtained from: https://www.waterboards.ca.gov/water_issues/programs/biostimulatory_substances_biointegrity

algal stream condition index (ACSI), which is currently under development. The State Water Board's plan is to establish "assessment endpoints" as primary lines of evidence to assess beneficial use support in wadeable streams. These endpoints may be used to establish default nutrient objectives or thresholds for California streams, with potential option to refine the thresholds under a "watershed approach."

The State Water Board's biostimulatory/biointegrity project has been delayed due to several unresolved policy issues that need to be addressed prior to development of the policy, including[3]:

1) Consideration of channels in highly developed landscapes (i.e., where assessment endpoints may not be achieved);
2) Identify Beneficial Uses;
3) Relationship between established biological assessment endpoints and nutrient endpoints; and
4) Define process for coordinated watershed approach.

The State Water Board is currently planning to develop draft policy options to present to Stakeholder Advisory and Regulatory Groups in 2019.

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[3] Information obtained from presentation by Jessie Maxfield, California State Water Board, given at the 2017 California Aquatic Bioassessment Workgroup conference in Davis, California.

2 METHODS

2.1 STUDY AREA

The study area for RMC creek status monitoring consists of the perennial and non-perennial streams, channels and rivers within the portions of the five participating counties (San Mateo, Santa Clara, Alameda, Contra Costa, Solano) that overlap with the San Francisco Bay Regional Water Quality Control Board (Region 2) boundary, and the eastern portion of Contra Costa County that drains to the Central Valley region (Region 5). The RMC creek status sample frame consists of the urban and non-urban portions of the stream network flowing through the RMC area. The source dataset used to create the sample frame was the 1:100,000 National Hydrography Dataset (NHD).

2.2 SURVEY DESIGN AND SAMPLING SITES

Creek status monitoring sites were selected based on a probabilistic survey design consisting of a master draw of 5,740 sites (approximately one site for every stream kilometer in the sample frame). The selection procedure employed the U.S. EPA's Generalized Random Tessellation Stratified (GRTS) survey design methodology (Stevens and Olson, 2004). The GRTS approach generated a spatially-balanced distribution of sites covering the majority of the San Francisco Bay Area. It should be noted that the sample draw of 5,740 sites did not account for land use designations or other emphases (i.e., County) and therefore, the master draw of sample sites was weighted towards commonly occurring conditions (i.e., non-urban sites), with less common conditions (i.e., reference and urban sites) being less represented due to their lower relative abundance in the sample frame.

The RMC sampling design targeted the population of accessible streams with flow conditions suitable for sampling (i.e., adequate flow during spring index period). A random set of potential monitoring sites (i.e., the master draw) was established, with each site having an equal, non-zero weight, proportional to the inverse of its selection probability. Thus, all sites were assumed to have an equal probability of selection throughout the sample frame. The weights represent the amount of stream length encompassed by each site in the overall target population.

Once the master draw was established, the list of monitoring sites was separated into 19 categories to facilitate site evaluations and implement creek status monitoring, including bioassessment (Table 1). The following attributes were used to generate the categories:

- County (n=5): San Mateo, Santa Clara, Alameda, Contra Costa, Solano (source: California Department of Forestry and Fire, 2009);
- Water Quality Control Board Region (n=2): Region 2, Region 5 (source: San Francisco Regional Water Quality Control Board, undated);
- Land use Category (n = 4): Urban or nonurban in all counties, except Solano ('urban_V' and 'urban_FS' in Solano County). Urban land use was defined as a combination of US Census (2000) areas classified as urban, and areas within Census City boundaries. This definition of urban land use results in some relatively undeveloped areas and parks along the fringes of cities to be

classified as urban. Urban sites therefore represent a broad range of developed (i.e., impervious surface) conditions. Non-urban area was defined as all remaining area in the RMC boundary not classified as urban.

Table 1. Number of sites and stream length from the master draw in each post-stratification category.

County	Urban		Non-Urban		Total	
	Sites	Stream Length (km)	Sites	Stream Length (km)	Sites	Stream Length (km)
San Mateo	222	233.8	528	556.0	750	789.8
Santa Clara	542	570.8	1376	1449.1	1918	2019.8
Alameda	454	478.1	842	886.7	1296	1364.8
Contra Costa (Region 2)	587	618.2	363	382.3	845	889.9
Contra Costa (Region 5)			349	367.5	454	478.1
Solano (Vallejo)	12	12.6	386	406.5	477	502.3
Solano (Fairfield-Suisun)	79	83.2				
Overall Total					5740	6,044.7

To maintain a spatially-balanced pool of monitoring sites, sites were evaluated in the order that they appeared in the master draw list (with a few exceptions). Sites were evaluated for sampling using both desktop and field reconnaissance. Field crews attempted to locate a reach suitable for sampling within 300 m of the target coordinates. Sites without a suitable reach were rejected for sampling. Reasons for rejection included physical barriers, lack of flowing water, refusal or lack of response from landowners, unwadeable (i.e., >1 m deep for at least 50% of the reach) and inappropriate waterbody types (e.g., tidally influenced). Sites with temporary inaccessibility, unsafe/hazardous or permission issues (e.g., construction, lack of response from landowners) were re-evaluated for sampling in subsequent years. All program participants were instructed to use a standard set of codes to identify the reason behind exclusion of sites.

In contrast to the PSA and SMC regional monitoring designs, which targeted perennial streams, the RMC sampled both perennial and non-perennial streams. Additionally, at the outset, each countywide Program agreed they would attempt to assess up to 20% of their required sites in non-urban areas.

2.3 SAMPLING PROTOCOLS/DATA COLLECTION

Biological sample collection and processing was consistent with the BASMAA RMC Quality Assurance Project Plan (QAPP)[4] (BASMAA 2016a) and Standard Operating Protocols (SOPs) (BASMAA 2016b) which

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[4] The RMC QAPP and SOP documents were initially developed in 2012 (Version 1.0), revised in 2013 (Version 2.0) and 2016 (Version 3.0)

were developed to be consistent with the current SWAMP Quality Assurance Program Plan (QAPrP) and SOPs. Bioassessments were conducted during the spring index period (approximately April 15 – June 30) with the goal to sample a minimum of 30 days after any significant storm (defined as at least 0.5-inch of rainfall within a 24-hour period). A 30-day grace period allows diatom and soft algae communities to recover from peak flows that may scour benthic algae from the bottom of the stream channel.

2.3.1 Biological Indicators

Each monitoring site consisted of an approximately 150-meter stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. Benthic macroinvertebrate (BMI) and algae (i.e., diatom and soft algae) samples were collected at each transect using the Reach-wide Benthos (RWB) method described in Ode et al. (2016). The algae composite sample was also used to collect chlorophyll a and ash free dry mass (AFDM) samples following methods described in Ode et al. (2016).

Biological samples were sent to laboratories for analysis. The laboratory analytical methods used for BMIs followed Woodward et al. (2012), using the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) Level 1a Standard Taxonomic Level of Effort, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family (Chironomidae). Soft algae and diatom samples were analyzed following SWAMP protocols (Stancheva et al. 2015). The taxonomic resolution for all data was standardized to the SWAMP master taxonomic list.

2.3.2 Physical Habitat

Both quantitative and qualitative measurements of physical habitat structure were taken at each of the 11 transects and 10 inter-transects at each monitoring site. At the outset of the monitoring program in 2012, Physical habitat measurements followed procedures defined in the "BASIC" level of effort (Ode 2007), with the following exceptions as defined in the "FULL level of effort: stream depth and pebble count + coarse particulate organic matter (CPOM), cobble embeddedness, and discharge measurements. In 2016, the entire "FULL" level of effort for the characterization of physical habitat described in Ode et al. (2016) was adopted, consistent with the reissued MRP 2.0 (SFBRWQCB 2015). Physical habitat measurements include channel morphology (e.g., channel width and depth), habitat features (e.g., substrate size, algal cover, flow types, and in-stream habitat diversity) and human disturbance in the riparian zone (e.g., presence of buildings, roads, vegetation management). In addition, a qualitative Physical Habitat Assessment (PHAB) score was assessed for the entire bioassessment reach. The PHAB score is composed of three characteristics for the reach, including channel alteration, epifaunal substrate, and sediment deposition. Each attribute is individually scored on a scale of 0 to 20, with a score of 20 representing good condition.

2.3.3 Water Quality

Immediately prior to biological and physical habitat data collection, general water quality parameters (dissolved oxygen, pH, specific conductance and temperature) were measured at each site, at or near the centroid of the stream flow using pre-calibrated multi-parameter probes. In addition, water samples were collected for nutrients and conventional analytes analysis using the Standard Grab Sample Collection Method as described in SOP FS-2 (BASMAA 2016b).

2.3.4 Stressor Variables

Physical habitat, land-use, and water quality data were compiled and evaluated as potential stressor variables for biological condition. Land-use variables were calculated in GIS by overlaying the drainage area for sample locations with land use and road data. The variables included percent urbanization, percent impervious, total number of road crossings and road density at three different spatial scales (1 km, 5 km, and entire watershed).

Physical habitat metrics were calculated using the SWAMP Bioassessment Reporting Module (SWAMP RM). The SWAMP RM output includes calculations based on parameters that are measured using EPA's Environmental Monitoring and Assessment Program (EMAP) for freshwater wadeable streams (Kaufmann et al. 1999), as well as parameters collected under the SWAMP protocol (Marco Sigala, personal communication, 2017). The RM produces a total of 176 different metrics based on data collected using the SWAMP "FULL" habitat protocol. Ten of the best performing metrics (Andy Rehn, CDFW, personal communication) were selected based on best professional judgment from the SWAMP RM output to analyze physical habitat data collected by the RMC.

General water quality (e.g., DO, SpCond) and chemistry (e.g., nitrate and phosphorus) data collected at the bioassessment sites were also included. Some of the water chemistry variables were calculated from the analytes that were measured. These include Total Nitrogen (sum of Nitrate, Nitrite and Total Kjeldahl Nitrogen) and Unionized Ammonia (calculated using pH and temperature).

2.3.5 Rainfall Data

For evaluation of trends, a representative rainfall dataset was collated for San Mateo, Santa Clara, Contra Costa, and Alameda counties. The total accumulated rainfall in each water year during the period of 2012-2016 was calculated. The rainfall dataset assembled was derived from: San Jose Airport (Santa Clara), San Francisco Airport (San Mateo), Oakland Airport (Alameda), and Walnut Creek (Contra Costa).

2.4 DATA ANALYSES

All statistical, tabular, and graphical analyses were conducted in R Studio, running R version 3.4.3 (R Core Team 2016). For analyses involving water quality data, censored results (i.e., below the method detection limit) were substituted with 50% of the method detection limit (MDL). Generally, analytical sensitivity was good, with only three variables having > 30% non-detects (Suspended Sediment Concentration, Nitrite, Ammonia). To facilitate use of the data for random forest and relative risk analyses, missing values were subject to an imputation method to fill in data gaps. Seven variables were found to have missing values. Three of these, Suspended Sediment Concentration (SSC), Dissolved Organic Carbon (DOC), and Alkalinity[5], consisted of more than 50 missing values, and were excluded from further analysis. The remaining four variables (Silica, Ash Free Dry Mass, Chlorophyll a, Nitrate) were subject to imputation using the R-package *mice* (van Buuren and Groothuis-Oudshoorn, 2011). In this method, replacement values were randomly selected from the distribution of observed data. Overall, fewer than 25 values were

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[5] Suspended Sediment Concentration (SSC), Dissolved Organic Carbon (DOC) and alkalinity were not monitored in 2016, due to the removal of these parameters in Provision C.8.c of the reissued MRP.

imputed for any variable (Silica, n = 24; AFDM, n = 4; Nitrate, n = 1; Chl a, n = 1), and thus their influence on the analysis is assumed to be minor.

2.4.1 Biological Condition Indices

The California Stream Condition Index (CSCI) was developed by the State Water Board as a standardized measure of benthic macroinvertebrate assemblage condition in perennial wadeable rivers and streams. The CSCI was developed using a large reference data set representing the range of natural conditions in California (Ode et al. 2016). The CSCI tool (Mazor et al. 2016) translates BMI data into an overall measure of stream health by combining two types of indices: 1) ratio of observed-to-expected taxa (O/E) (used as a measure of taxonomic completeness), and 2) a predictive multi-metric index (pMMI) for reference conditions (used as a measure of ecological structure and function). The CSCI score is computed as the average of the sum of O/E and pMMI.

The CSCI scoring tool was used to assess BMI data collected at both perennial and non-perennial sites in the RMC area. The CSCI scores for RMC sites should be interpreted with caution, as the CSCI tool has not been fully validated at non-perennial sites. Preliminary analyses suggest that the CSCI is valid in certain types of nonperennial streams in southern California, but its validity in nonperennial streams in other regions, such as the Bay Area, remains unknown.

The algae data were analyzed using algal indices of biological integrity (IBIs) that were developed for streams in Southern California (Fetscher 2014). These include a soft algae index (S2), diatom index (D18) and soft algae-diatom hybrid index (H20). The algal indices were calculated using the SWAMP Algae Reporting Module (Algae RM). The interpretation of algae data collected in San Francisco Bay area using IBIs developed in Southern California (SoCal) should be considered preliminary. The State Board and SCCWRP are currently developing and testing a statewide index using benthic algae data as a measure of biological condition for streams in California. The statewide Algae Stream Condition Indices (ASCIs) were not available at the time this project was conducted, but are expected to be available in late 2018 (personal communication, Jessie Maxfield, SWRCB).

2.4.2 Biological Indicator Thresholds

Existing thresholds for biological indicator scores (CSCI, D18, S2) defined in Mazor (2015) were used to evaluate bioassessment data compiled and analyzed in this report (Table 2, Figure 1). The thresholds for each index were based on the distribution of scores for data collected at reference calibration sites in California (BMI) or in Southern California (algae). Four condition categories are defined by these thresholds: “likely intact” (greater than 30th percentile of calibration reference site scores); “possibly altered” (between the 10th and the 30th percentiles); “likely altered” (between the 1st and 10th percentiles; and “very likely altered” (less than the 1st percentile). The probability-based approach to develop the threshold classes was consistent across indices, allowing comparison for all indicators across sites.

The performance of CSCI on a statewide basis is the subject of ongoing review by the State Water Board. In the current MRP, the SF Bay Water Board defined a CSCI score of 0.795 as a threshold for identifying sites with degraded biological condition that should be considered candidates for Stressor Source Identification (SSID) projects. No MRP threshold has been established for any of the algae indices.

Table 2. Biological condition indices, categories and thresholds.

Index	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Benthic Macroinvertebrates (BMI)				
CSCI Score	≥ 0.92	≥ 0.79 to < 0.92	≥ 0.63 to < 0.79	< 0.63
Benthic Algae				
S2 Score	≥ 60	≥ 47 to < 60	≥ 29 to < 47	< 29
D18 Score	≥ 72	≥ 62 to < 72	≥ 49 to < 62	< 49

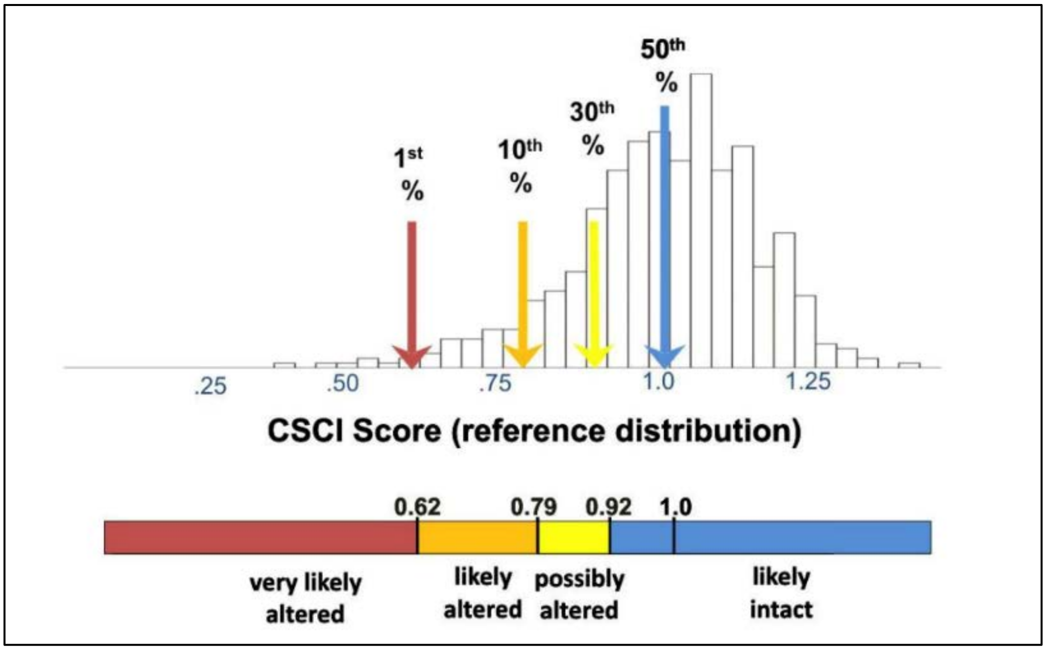

Figure 1. Distribution of CSCI scores at reference sites with thresholds and condition categories used to evaluate CSCI scores (from Rehn et al. 2015). Note: colors in this figure differ from other figures in this report.

2.4.3 Estimating Extent of Healthy Streams in SF Bay Area

To estimate overall extent of biological conditions in streams within the RMC area, cumulative distribution functions (CDFs) of biological condition scores were generated. Because the survey focused significantly more effort in urban areas compared to non-urban areas, sample weights were re-calculated as the total stream length in the sample frame, and divided by the stream length evaluated in each land use category. Therefore, sites contribute a proportional amount of stream length to the extent estimates, based on the number of sites assessed in each land use category. Sites without evaluations (6%), primarily non-urban sites, were excluded from the analysis. The adjusted sample weights were used to estimate the proportion of stream length represented by CSCI, D18, and S2 scores both regionwide and for urban sites only. Estimates for non-urban streams were not calculated separately due to the lower number of monitoring events at non-urban sites and greater width of confidence intervals. Condition estimates and 95% confidence intervals were calculated for all sampled sites in the RMC sample frame and for urban sites only. Post-stratification of the urban sites by County was also performed. However, Solano County was excluded from this assessment, due to the relatively low sample size compared to the other areas. All calculations were conducted using the R-package *spsurvey* (Kincaid and Olsen 2016). See Section 4.4 for further discussion of the RMC sample design.

2.4.4 Evaluating the Importance of Stressors

2.4.4.1 Random Forest Analyses

Stressor association with biological condition scores was evaluated using random forest statistical analyses. Random forest analysis is a non-parametric classification and regression tree (CART) method commonly applied to large datasets of multiple explanatory variables. Recent papers describe their use for stressor identification in stream bioassessment studies (e.g., Maloney et al. 2009, Waite et al. 2012, Mazor et al. 2016). Random forest models use bootstrap averaging to determine splits of numerous trees (Elith et al. 2008) for reducing error and optimizing model predictions. Model outputs provide an ordered list of importance of the explanatory variables that can be applied to a new or validation dataset for prediction.

Random forest models were developed using the R-package *randomForest* to determine a list of explanatory variables related to biological condition scores (CSCI or D18 score). The stressor data consisted of 49 variables, related to (1) water quality; (2) habitat; and (3) land use factors that could potentially influence condition scores (Appendix 1, Table A). Subsequently, the data were partitioned into training (80%) and validation (20%) sets for model testing. A random selection of samples was generated by sub-sampling from within each RMC County to maintain a regional balance of samples within the partitioned datasets. The training dataset had 278 sites, while the validation data encompassed 76 sites across all counties.

First, several iterations of the model procedure were performed with the training data set to optimize the random forests, including tuning the model to the maximum number of predictors per branch, the number of trees to build, and validation of the predictions. Appendix 1 presents the results of initial steps to optimize the random forest model outputs. The final set of models evaluated a maximum of 6 predictor interactions, and 1000 trees. Two variable importance statistics were used to estimate the relative influence of predictor variables: (1) % Increase in MSE = percent increase in mean-square-error of predictions as a result of variable values being permuted; (2) Increase in Node Purity = difference between the residual sum-of-squares before and after a split in the tree. More important variables achieve larger changes in MSE and node purity. K-fold cross validation of the selected models was performed to assess prediction error, by evaluating residual error and R-squared differences.

Random forest models were developed in two steps: (1) random forest models were run with all variables included (N = 49), retaining the top 10 variables in the variable relative importance list ranked by % increase in MSE, and (2) random forest models were re-run with just the top 10 variables from step 1. Subsequently, the variable list was further trimmed by evaluating the corresponding variable importance scores, partial dependency plots, and the change in R^2 once the variable was excluded. Partial dependency plots show the predicted biological response based on an individual explanatory variable with all other variables removed. No variable with less than 10% influence on CSCI or D18 predictions was retained in the final models. Finally, random forest models were used to predict biological condition scores for the validation data set. Appendix 1, Figure B presents the observed and predicted values for the validation models with CSCI and D18 in Steps 1 and 2 of the model development.

2.4.4.2 Stressor Thresholds and Relative Risk Assessment

Relative risk analyses were also conducted to evaluate associations between stressors with biological condition scores. From the list of potential stressors discussed in Section 2.3.4, eight variables were selected to conduct a relative risk analyses (Table 3). Six of the stressor thresholds were derived from statewide data collected for the Perennial Streams Assessment (SWAMP 2015). The thresholds were based on the 90th percentile of data collected at bioassessment sites that exhibited good biological condition (i.e., CSCI scores > 0.92, likely intact). The 90th percentile of stressor values at these sites was used to define the most-disturbed thresholds for variables where higher values indicate more disturbance (SWRCB 2015). Similarly, the chlorophyll a threshold (100 mg/m2) used for this report (Table 3) was based on 90th percentile of data that was collected at all RMC sites that had CSCI scores > 0.92 (Figure 2). The threshold for Dissolved Oxygen (7.0 mg/l) was based on Water Quality Objectives (WQOs) for COLD Freshwater Habitat Beneficial Use in the Water Quality Control Plan for the San Francisco Basin (SFBRWQCB 2017).

Table 3. Biological condition and stressor variable thresholds used for relative risk assessment.

Variables	Thresholds		Units	Reference	Criteria
Biological Condition	*Poor*	*Good*			
CSCI Score	< 0.625	≥ 0.925		Mazor et al. 2016	
Stressor Condition	*High*	*Low*			
Dissolved Oxygen (DO)	<7.0	≥ 7.0	mg/L	SF Bay Water Quality Control Plan	WQO
Specific Conductivity (SpCon)	> 1460	≤ 1460	us/cm	SWAMP 2015	90th Percentile of sites with CSCI score > 0.925
Chloride	> 122	≤ 122	mg/L		
Total Nitrogen (TotN)	> 2.3	≤ 2.3	mg/L		
Total Phosphorus (TotP)	> 0.122	≤ 0.122	mg/L		
Chlorophyll a (Chla)	> 100	≤ 100	mg/m^2	RMC data	
Sand and Fines (SaFn)	> 69	≤ 69	%	SWAMP 2015	
Human Disturbance Index (HDI)	> 1.3	≤ 1.3			

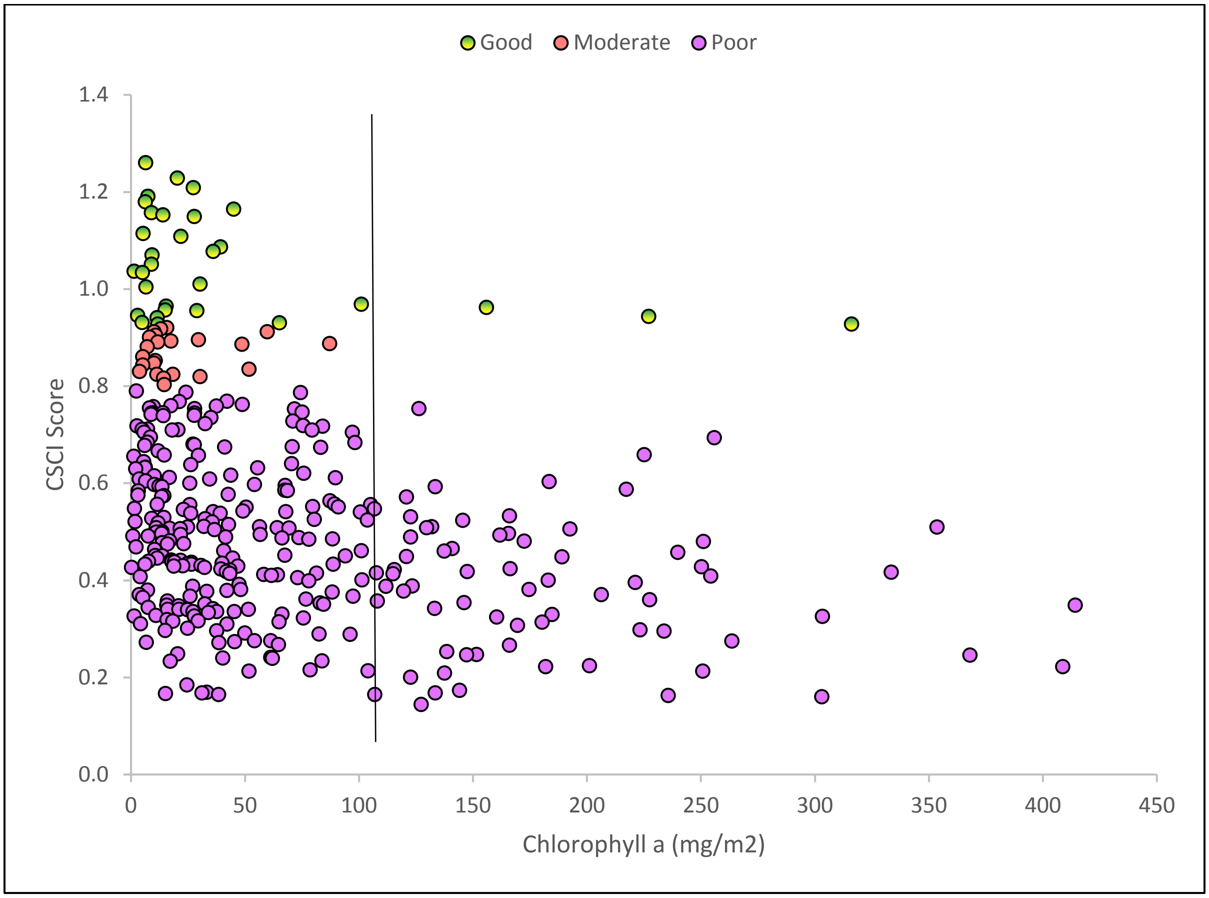

Figure 2. Plot of CSCI score and *chlorophyll a* concentration at RMC sites. Threshold for *chlorophyll a* used for relative risk assessment is shown. Sites classified as "good" include the two highest CSCI condition categories.

The relative risk approach was used to evaluate the association between stressors and biological condition (Van Sickle et al., 2008). The relative risk is a conditional probability representing the likelihood that poor biological condition is associated with high stressor levels and is calculated as follows:

$$\text{Relative Risk} = \frac{\Pr\,(CSCI_p)/S_h}{\Pr\,(CSCI_p)/S_l}$$

The numerator is the probability of finding poor biological condition ($CSCI_p$) given high stressor scores (S_h) and denominator is the probability of finding poor biological condition given low stressor scores (S_l). Poor biological conditions were defined as CSCI scores < 0.625. High and low stressor levels are defined in Table 3. In cases where RR is equal to 1, there is no association between stressor and biological indicator score. Where RR > 1, the higher the value, the more likely poor biological condition would occur given high stressor levels.

3 RESULTS

3.1 SITE EVALUATION RESULTS

A total of 354 monitoring sites were sampled in the RMC region between 2012 and 2016. These are identified as “target” sites in Figure 3 and Table 4. Samples were collected at 284 urban sites (80%) and 70 non-urban sites (20%) (Table 4). The greatest number of non-urban sampling locations were in Santa Clara (n=25) and San Mateo Counties (n=19). Samples were collected at 8 or 9 non-urban sites for each of the other counties.

The population of 354 monitored sites was obtained through the evaluation of 1,455 unique sites, which equate to a rejection rate of 76% for entire RMC area over the 5-year period. Solano County had the highest rejection rate (90%) and San Mateo County had the lowest (65%). The most common reason for site rejection (55% of all evaluated sites) was that a site did not present the physical requirements to support monitoring within a 300-meter radius of target coordinates. These “non-target sites” were rejected for several reasons, including lack of flowing water, site was not a stream (e.g., aqueduct or pipeline), tidally influenced, or non-wadeable. The lack of flow was the most common reason for rejection. The extended drought period between 2012 and 2014 may have resulted in an unusually high number of sites with no or low flow conditions during the target index period.

Another reason for site rejection was the inability to obtain access to conduct the sampling (e.g., physical access or obtain private land/permission). These “target non-sampleable” sites comprised 21% of sites that were rejected. These sites were often located on private land in non-urban areas where permissions were not granted and/or where steep, highly-vegetated conditions prevented access. Obtaining access to sites in urban areas was variable by county. For example, most of the streams in the urban area of San Mateo County are privately owned, while most of the urban sites in Santa Clara County are owned by municipal jurisdictions and water district agencies, making permissions more easily obtained.

Table 4. Number of sites per county in each site evaluation class.

County	Target Not-Sampleable		Non-Target		Target		Total by County
	Non-Urban	Urban	Non- Urban	Urban	Non- Urban	Urban	
Alameda	12	74	162	91	9	96	444
Contra Costa	12	34	32	89	9	48	224
San Mateo	21	42	9	37	19	41	169
Santa Clara	37	24	74	161	25	87	408
Solano	44	3	109	34	8	12	210
Total RMC	126	177	386	412	70	284	1,455
% of Total RMC	9%	12%	27%	28%	5%	20%	-

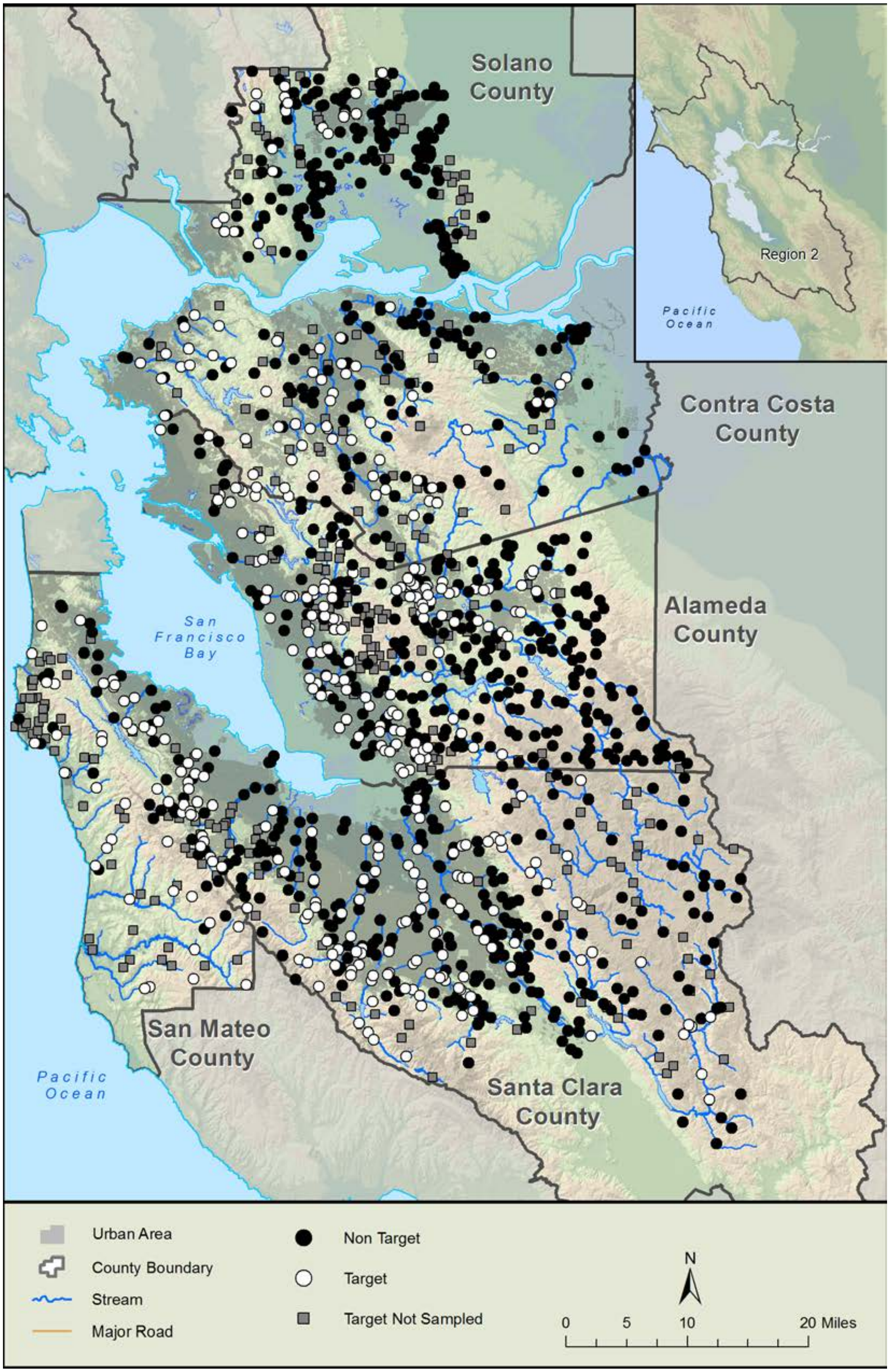

Figure 3. RMC sites evaluated by evaluation class.

Figure 4 presents rainfall for the 2000-2017 time period at the San Francisco Airport. Rainfall was generally below average during the 2012-2016 period, especially in 2014, and therefore, the RMC monitoring occurred in a drier-than-normal period. Because biological condition index scores can vary natural due to multi-year climatic patterns, it is important to note that the 5-year period of monitoring may not be representative of the long-term condition.

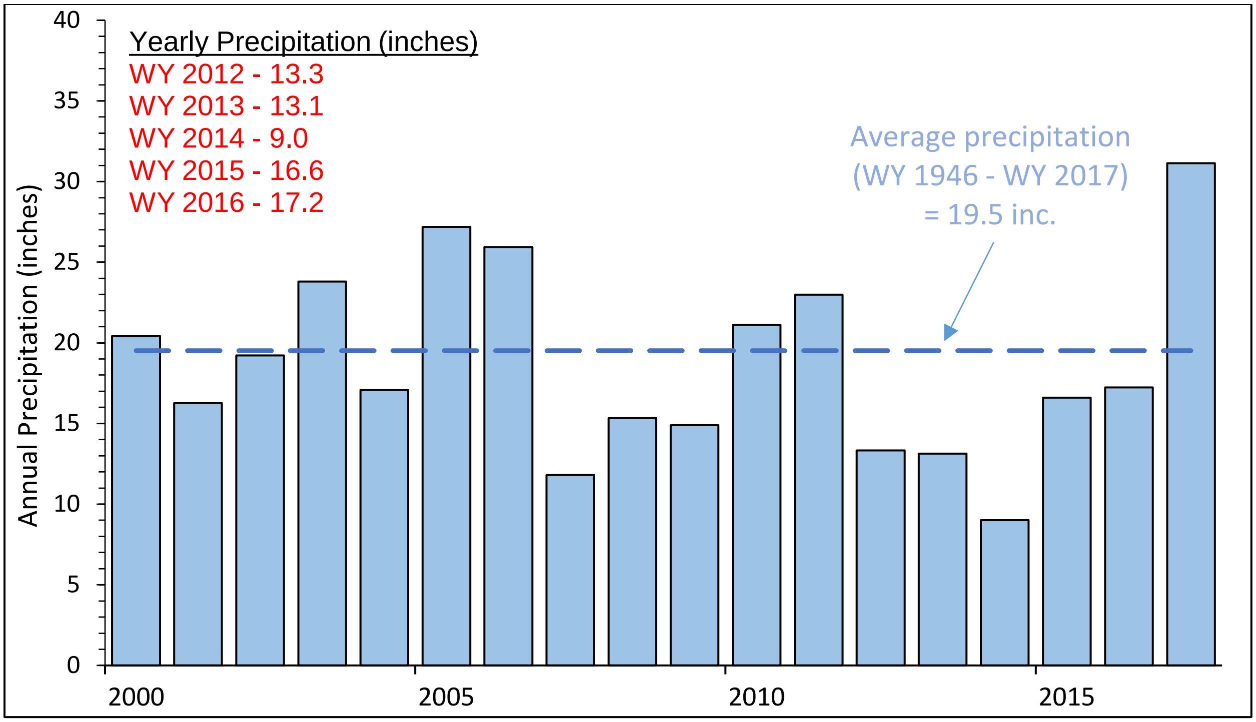

Figure 4. Annual precipitation at San Francisco Airport (2000-2017)

3.2 BIOLOGICAL CONDITION OF BAY AREA STREAMS

3.2.1 Regional Assessment

The distribution of BMI and algae index scores observed during 2012-2016 suggests that the majority of streams in the RMC sample area do not exhibit healthy biological conditions. Figures 5, 6 and 7 show cumulative distribution functions of the biological index scores for the entire regional dataset (i.e., urban and non-urban sites) and the urban dataset. Across all sites, over half (58%) of the stream-length was in the lowest condition class for CSCI (Very Likely Altered) and 15% of the stream-length was in the highest condition class (Likely Intact) (Figure 5).

Both of the algae index scores (D18 and S2) exhibited higher condition scores than CSCI regionally. For D18 (diatoms), 41% of the stream-length in the Bay Area was in the Very Likely Altered condition class and 19% of the stream-length was in the Likely Intact condition class (Figure 6). Similar distribution of scores was evident with S2 (soft-algae), where less than half (44%) of the stream-length was in the Very Likely Altered condition class and 21% of the stream-length was in the Likely Intact condition class (Figure 7). The higher proportion of sites in the Likely Intact condition for algae indices compared to CSCI suggest that the algae communities in streams may be less degraded than BMI assemblages.

Bay Area wide, urban sites were responsible for the majority of poor CSCI scores. Seventy-nine percent (79%) of the stream length in urban areas was in the Very Likely Altered condition category for CSCI, while only 3.5% was in the Likely Intact class (Figure 5). Additionally, over 80% of the sampled stream length in urban areas was below the MRP trigger for CSCI scores (0.795), where potential follow-up source/stressor identification studies should be considered.

The influence of urban sites on the stream condition of all sites was also apparent for algae scores, although to a lesser degree than for CSCI. For D18, just over half (53%) of the stream length in urban areas was in the Very Likely Altered condition class, compared to 9% in the Likely Intact class (Figure 6). For S2 scores, 65% of stream length in urban areas was in the Very Likely Altered class, and only 7% in the Likely Intact class (Figure 7). These patterns suggest that stressors in the urban landscape may still exert influence on algae condition. Section 4.0 provides additional discussion about the results presented here.

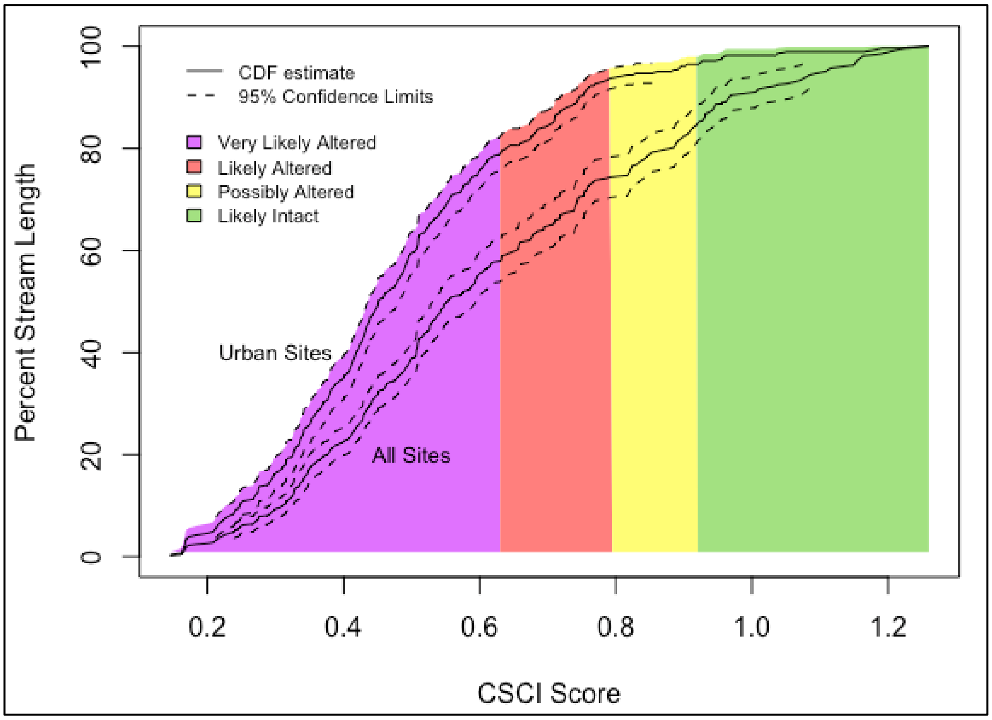

Figure 5. Cumulative distribution function (CDF) of CSCI scores at all RMC sites and urban sites.

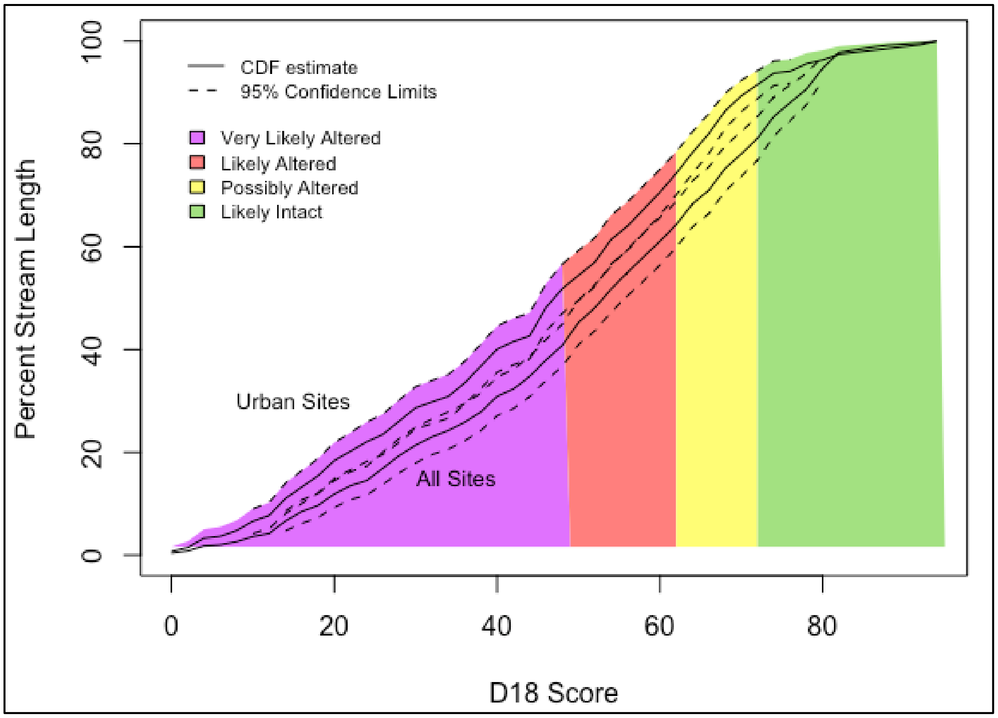

Figure 6. Cumulative distribution function (CDF) of D18 scores at all RMC sites and urban sites.

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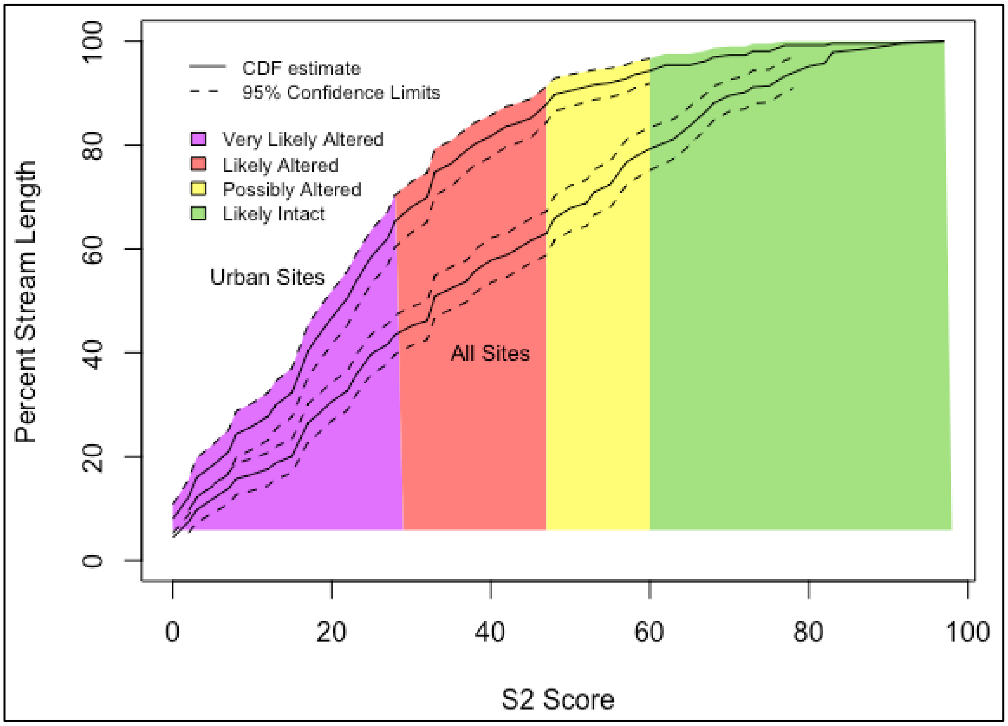

Figure 7. Cumulative distribution function (CDF) of S2 scores at all RMC sites and urban sites.

3.2.2 County Assessment

In addition to Bay Area wide biological condition estimates of streams, post-stratification of the CSCI condition estimates for urban sites in each County (excluding Solano County due to low sample size) suggests that poor condition scores are widespread in each Bay Area county. The proportion of urban stream length in the Very Likely Altered condition class was highest for Contra Costa (96%), followed by Alameda County (83%), San Mateo County (73%), and Santa Clara County (64%) (Figure 8). Less than 10% of the urban stream length in each of the counties was in the Likely Intact condition class. The highest proportion of Likely Intact BMI communities occurred in San Mateo and Santa Clara counties (7% each), followed by Alameda (1%) and Contra Costa (0%) counties. In comparison to the MRP threshold of 0.795, the vast majority of urban streams in each county fall below this threshold.

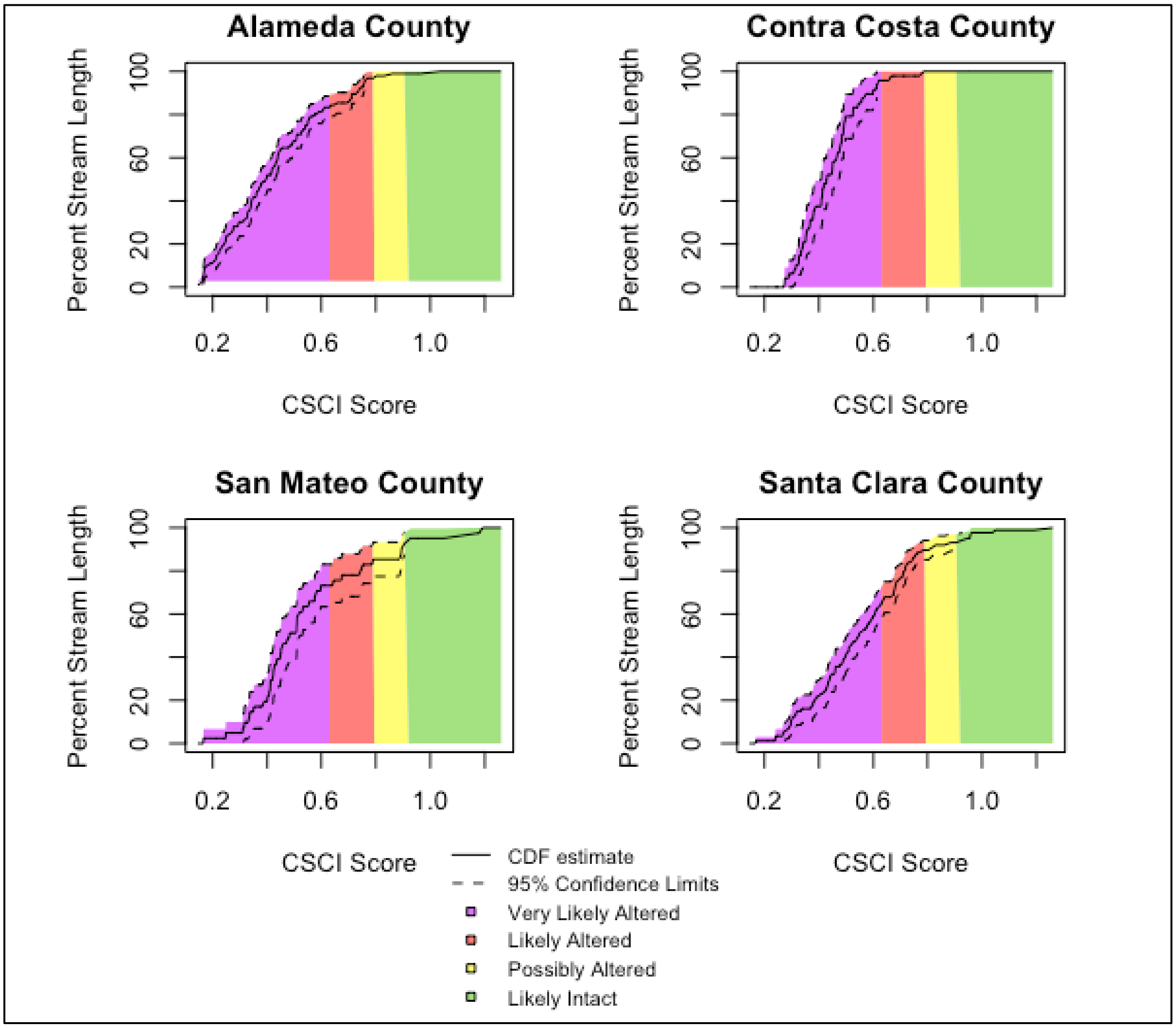

Figure 8. Cumulative distribution functions of CSCI scores at RMC urban sites in each participating Bay Area County.

3.2.3 Biological Condition of Urban and Non-Urban Streams

Figure 9 illustrates CSCI scores (by condition category) for the region and includes county boundaries and urban areas for reference. Maps illustrating the biological condition of stream in each county based on CSCI and D18 scores are included in Appendix 4.

Figure 9. Biological condition of streams in the RMC area based on CSCI scores.

CSCI scores grouped by land use class (urban vs. non-urban) showed that all counties, with the exception of Solano, exhibit higher scores in non-urban areas (Figure 10), which generally span a narrower scoring range than urban sites. Santa Clara and San Mateo counties had the highest median CSCI scores compared to other counties, with several sites in both counties receiving scores greater than 1.0, which typically represent reference conditions. However, non-urban sites for all five counties had CSCI scores below the MRP trigger (0.795), indicating that some sites non-urban areas have degraded biological condition.

Stratification of D18 and S2 scores by land use (urban vs non-urban; Figures 11 and 12) suggests that biological condition scores based on algae metrics generally mirror CSCI scores, which are based on BMIs. Generally, algae scores in the non-urban area were higher than scores for sites in urban areas within each county. The low sample sizes of the non-urban population preclude making any definitive comparisons, however, it was noteworthy that sites in the urban areas may receive similar or higher algae index scores than sites non-urban areas.

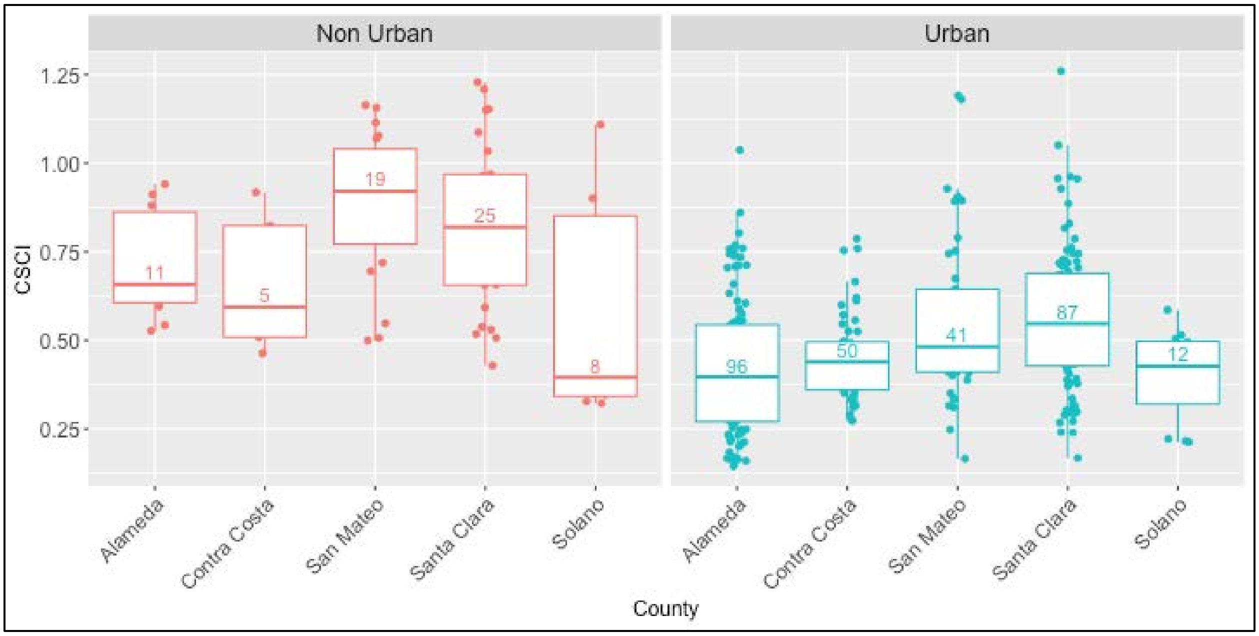

Figure 10. CSCI scores for urban and non-urban sites in each County. Sample sizes for each county are included in each boxplot.

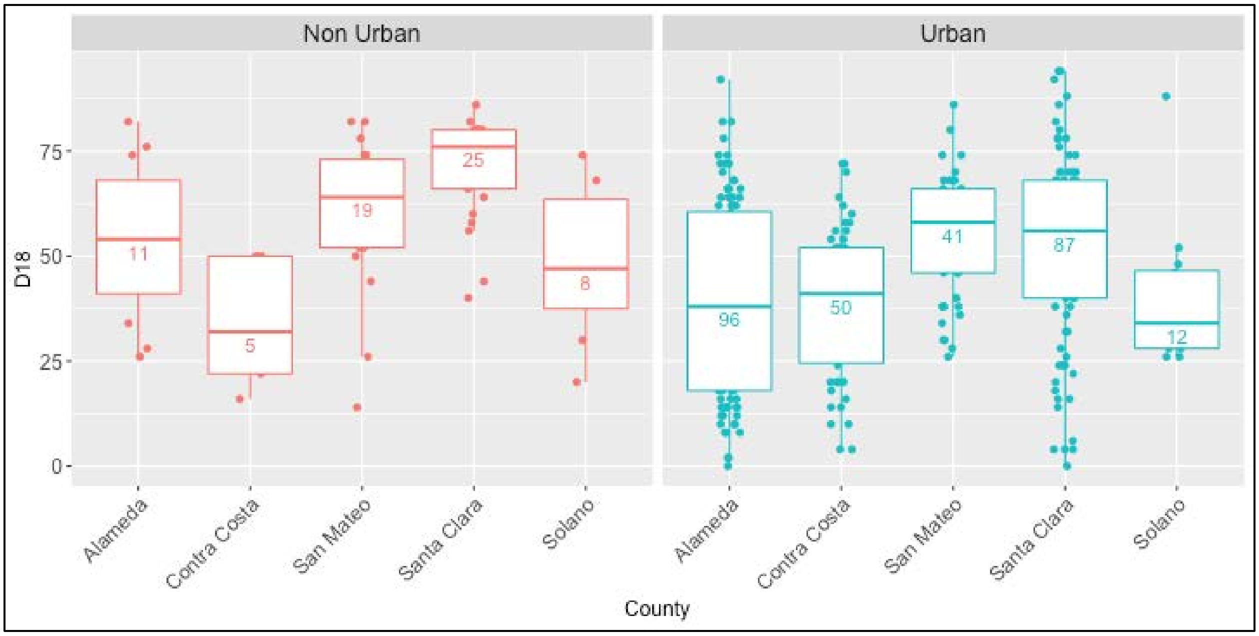

Figure 11. D18 scores for urban and non-urban sites in each County. Sample sizes for each county are included in each boxplot.

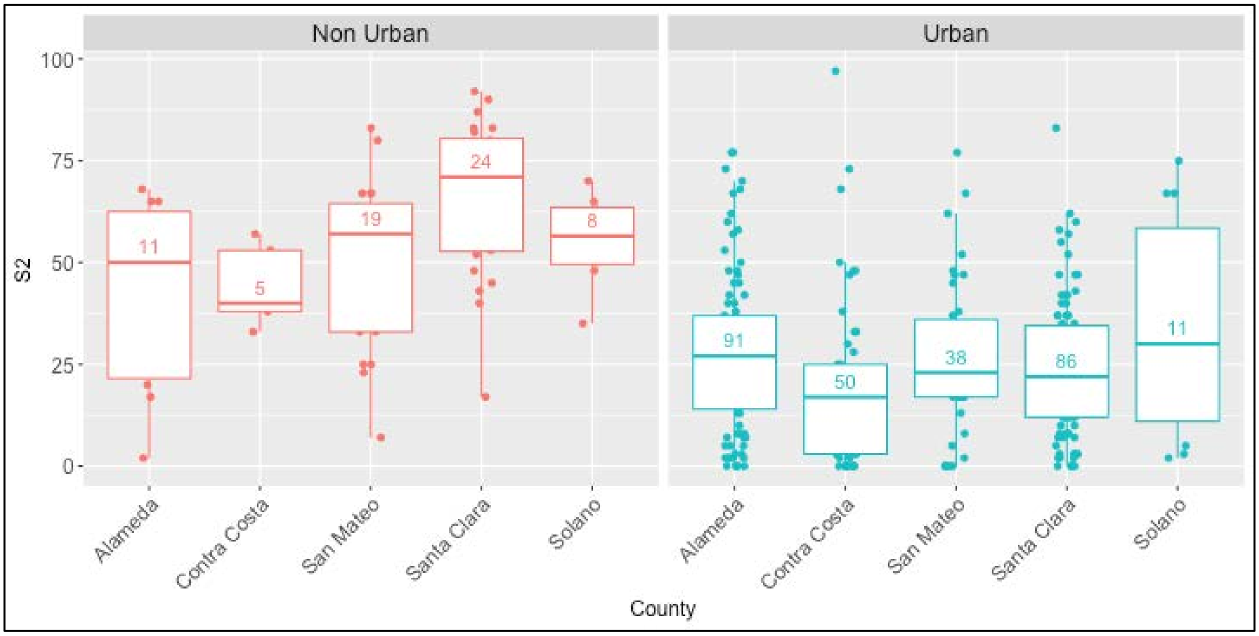

Figure 12. S2 scores for urban and non-urban sites in each County. Sample sizes for each county are included in each boxplot.

3.3 STRESSORS ASSOCIATED WITH BIOLOGICAL CONDITION

3.3.1 Random Forest Model Outputs

To evaluate stressors associated with biological condition within the RMC area, random forest models were developed using the CSCI and D18 index results. A parallel analysis was not performed for the S2 indicator due to the lack of soft algae at many of the assessment sites. Stressor data consisted of 49 variables grouped into three types: (1) water quality; (2) habitat; and (3) land use (Appendix 1, Table A). Model results clearly indicated better relationships between stressors and the CSCI, versus the D18 index. Validation of the final random forest models showed that the CSCI model explained 61% of the variance using eight predictor (stressor) variables, while the D18 model only explained 34% of the variance using six predictors.

The CSCI random forest model indicated that land use and physical habitat variables were most influential to most biological condition (Table 5). Of the eight variables in the final CSCI model, four were landscape-based (HDI, PctImp_5K, PctImp_1K, PctImp), three were habitat associated (PctFines, PctGra, PctFstH20), and one was a water quality variable (Dissolved Oxygen, DO). There was general consistency amongst the individual variables within each of the landscape and habitat groups. The landscape variables that were most influential to CSCI scores were associated with the degree of human impact/imperviousness and the habitat variables were associated with the characteristics of the sediment substrate and water flow. Overall, the largest influence on the CSCI random forest model was percent impervious area within a 5 km radius (35.2%) of the site. The other seven variables in the final model exerted a lesser, but similar degree of influence (18.8 – 25.3%) on CSCI scores. It was notable that none of the nutrient variables were identified as indicators of biological condition scores using the CSCI model (Appendix 3 Figure A). The same may be true for DO, where the apparent relationship was driven by a few high values (Appendix 3 Figure B).

Table 5. Summary statistics for the CSCI random forest model. Rank of importance of selected stressor variables are colored according to categories: physical habitat (green), land use (brown), and water quality (blue). The correlation coefficient (rho) for each stressor variable is also presented.

Stressor Variable	% Increase MSE	Increase Node Purity	Rank Correlation Coefficient (Rho)
Percent Impervious Area in 5km (PctImp_5K)	35.21	4.74	-0.62
Percent Impervious Areas of Reach (PctImp)	25.37	1.03	-0.59
Dissolved Oxygen (DO)	24.43	1.60	0.24
Percent Fast Water of Reach (PctFstH20)	22.52	1.62	0.51
Percent Fines (PctFin)	20.73	1.13	-0.36
Percent Substrate Smaller than Sand (PctSmalSnd)	20.64	1.36	-0.46
Percent Impervious Area in 1km (PctImp_1K)	20.64	2.26	-0.61
Human disturbance Index (HDI)	18.81	1.45	-0.62

The results of the random forest model for D18 indicated that different variables explained biological condition than the CSCI model. Water quality variables exerted greater influence in the D18 model (Table 6). Of the six variables in the final D18 model, four were water quality variables (SpCond, Chloride, AFDM, Phosphorus), one was a habitat variable (PctSmalSnd), and one was a landscape variable (RdDen_1k). Overall, the variable with the largest influence on the random forest model was specific conductivity (29.5%). The remaining five variables exerted a lesser, but similar influence (12.5% – 22.0%) on the model. The importance of water quality variables in the model suggests that general water quality conditions (e.g., conductivity) likely influence algae condition scores. Specific types of water quality stress, such as from nutrients, however, appear to be less important to algal community condition on a regionwide scale.

Table 6. Summary statistics for the D18 random forest model. Rank of importance of selected stressor variables are colored according to categories: physical habitat (green), land use (brown), and water quality (blue). The correlation coefficient (rho) for each stressor variable is also presented.

Stressor Variable	% Increase MSE	Increase Node Purity	Rank Correlation Coefficient (Rho)
Specific Conductivity (SpCond)	29.55	35357.81	-0.49
Percent Substrate Smaller than Sand (PctSmalSnd)	21.99	24671.80	-0.46
Phosphorus	21.93	17465.87	-0.33
Chloride	18.53	18873.52	-0.51
Ash Free Dry Mass (AFDM)	15.09	21937.23	-0.44
Road Density in 1km (RdDen_1k)	12.51	16383.17	-0.33

Using the random forest model outputs, plots of individual stressor variables versus observed response values (i.e., CSCI and D18 scores) were developed to illustrate relationships between stressors and biological condition (Figures 13 to 18 and Appendix 2). For the CSCI model output, the plots of habitat and landscape variables indicate patterns of dose-response. For example, the Human Disturbance Index (HDI) stressor variable indicated that poor condition scores are observed when HDI exceeds a value of 2. This pattern was also evident in the regressions of observed CSCI values, relative to HDI and separating out HDI scores by their condition class (Figure 13). It is worth noting that Ode et al. (2016) identified a cutoff of HDI = 1.5 for reference sites (Ode et al. 2016). Based on the analysis conducted on this five-year Bay Area dataset, the range between 1.5 and 2.0 appeared to separate out the urban and non-urban sites, supporting the previous authors' assertion that sites with HDI values below this range exhibit reference conditions.

Similar to HDI, the stressor variables related to imperviousness indicated a threshold-style response with CSCI scores. For the variable 'percent imperviousness in 5km', a value above 10% appeared to correspond to poor CSCI condition scores (Figure 14). All sites that had less than 10% impervious area within 5km were classed as either Possibly Intact or Likely Intact condition. In the case of the habitat variables included in the final model, response patterns were less pronounced than for the landscape variables (Figure 15). For example, the variable 'percent reach habitat smaller than sand', indicated that poor sites spanned a wide-range in stressor values, while sites in the top three condition classes had a much narrower range in this metric. Biological condition at sites where more than 50% of the stream reach had substrate smaller than sand appeared to be a line of demarcation between the bottom two and top three condition categories.

The results of the D18 model indicated dose-response relationships between biological condition and all four water quality variables (i.e. SpCond, Chloride, AFDM, Phosphorus), however there were less obvious patterns delineating biological condition. For example, the partial dependency plots for D18 scores indicated that poor condition (i.e., bottom two condition categories) was evident when chloride was above 200 mg/L (Figure 16) and specific conductivity was above 1200 µS/cm[6] (Figure 17). However, the plots of observed D18 values relative to these variables suggested that only some of the lowest scoring sites could be delineated using these threshold values. Similarly, response patterns of the habitat variables were inconclusive for delineating biological condition. A value of approximately 60% or greater of the stream habitat 'smaller than sand' corresponded to lower D18 scores (Figure 18), but there was considerable variability to this signal.

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[6] This corresponds well with the MRP threshold of 2000 uS/cm^2 for evaluating continuous monitoring data. Sites with 20% or more of instantaneous specific conductance results greater than 2000 uS/cm^2 are considered as candidates for SSID projects.

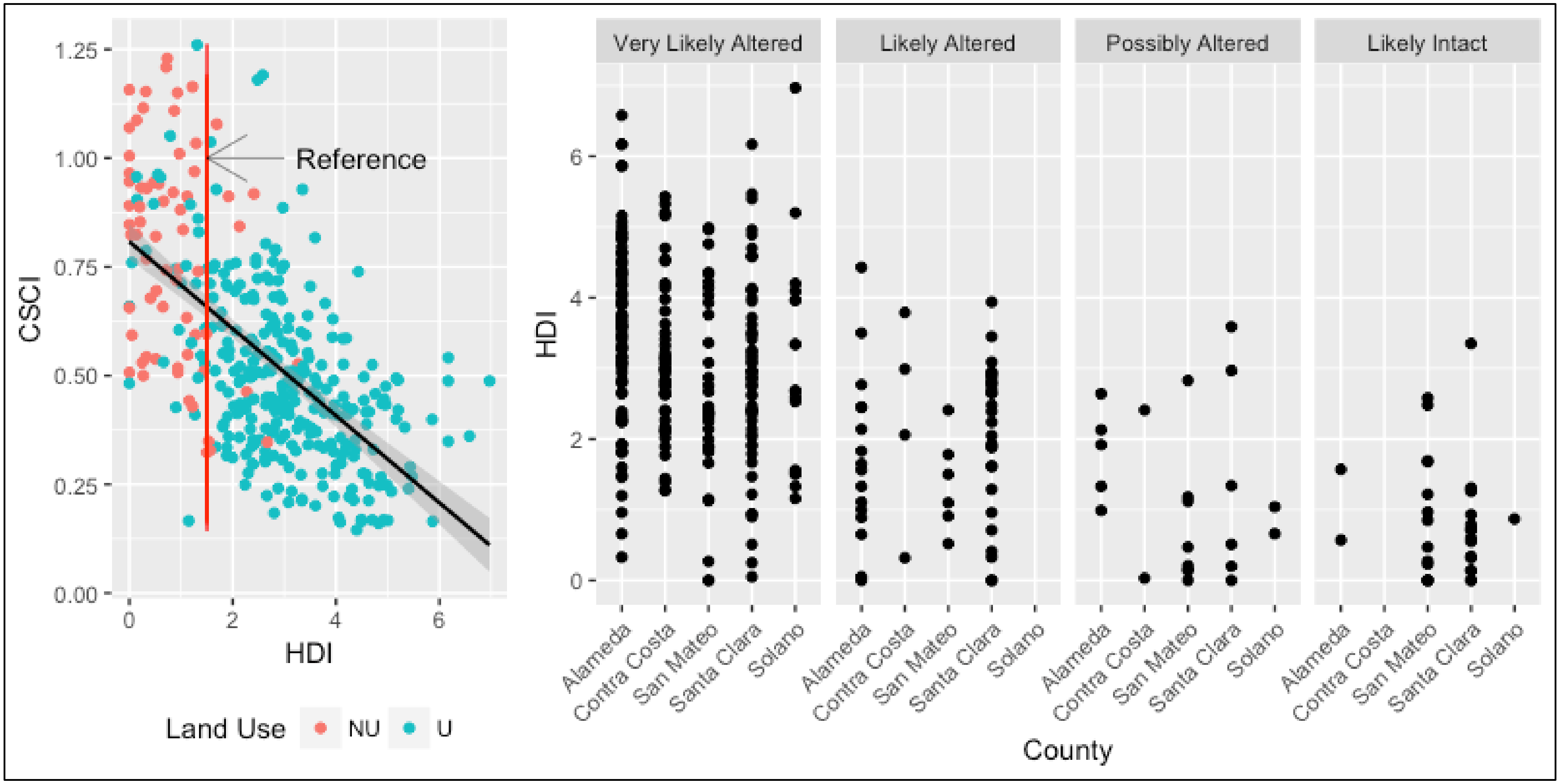

Figure 13. Relationship of CSCI scores to the Human Disturbance Index (HDI) stressor indicator. Red line indicates a reference condition cutoff of 1.5 (Ode et al. 2016).

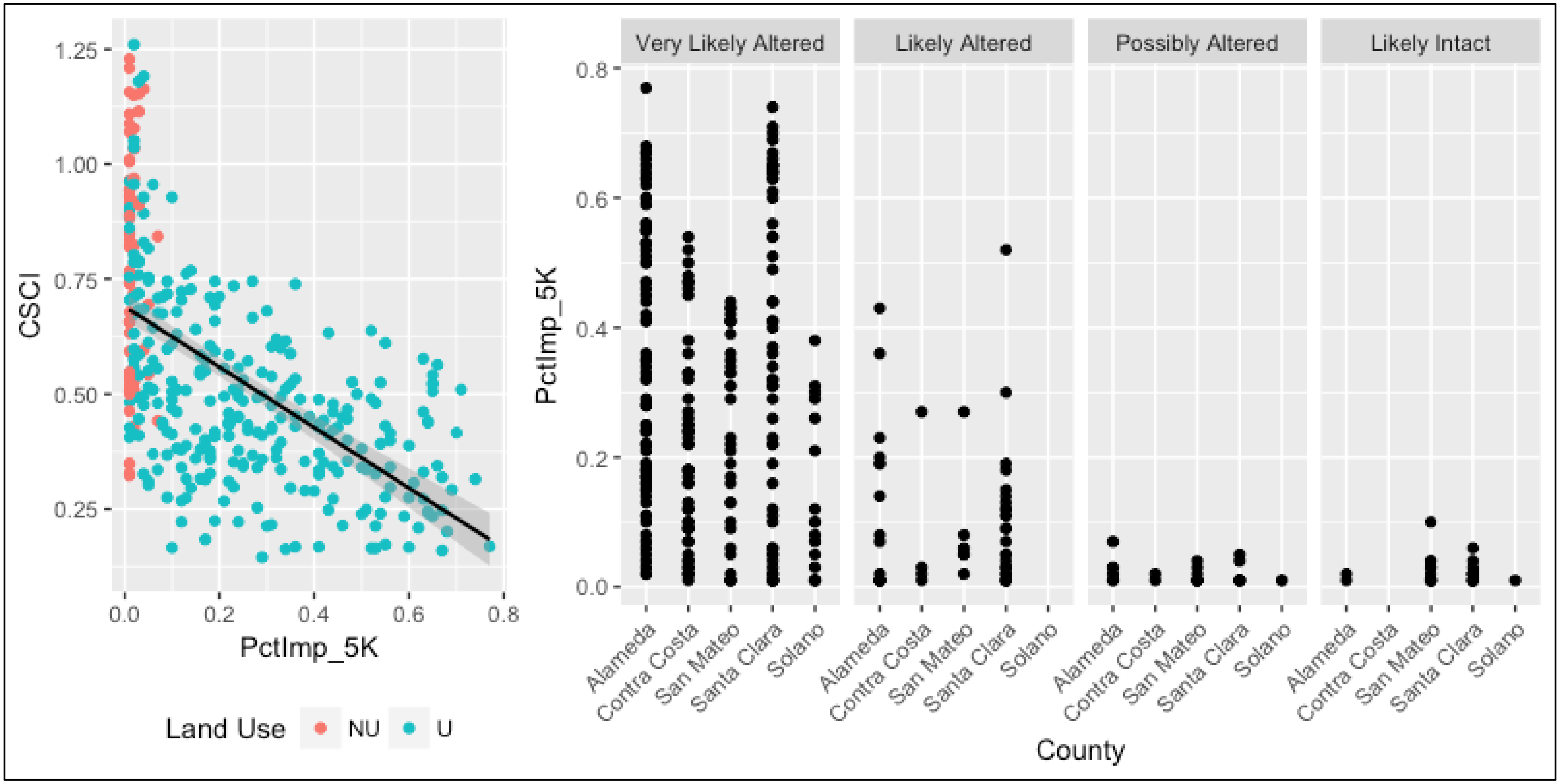

Figure 14. Relationship of CSCI scores to the percentage of land area in a 5 km radius (km^2) around the site that is impervious.

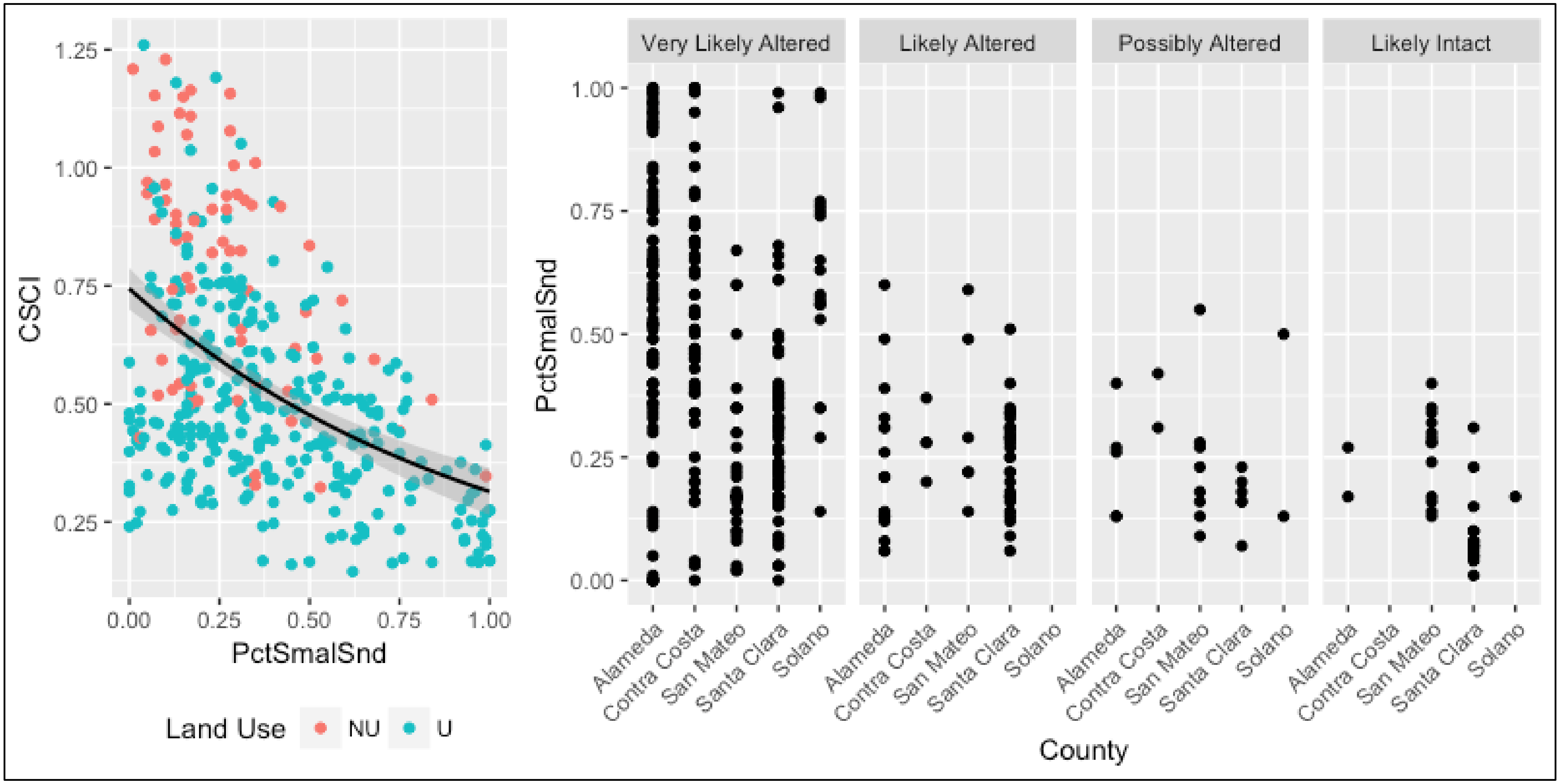

Figure 15. Relationship of CSCI score to the percent of substrate in the stream reach that was smaller than sand.

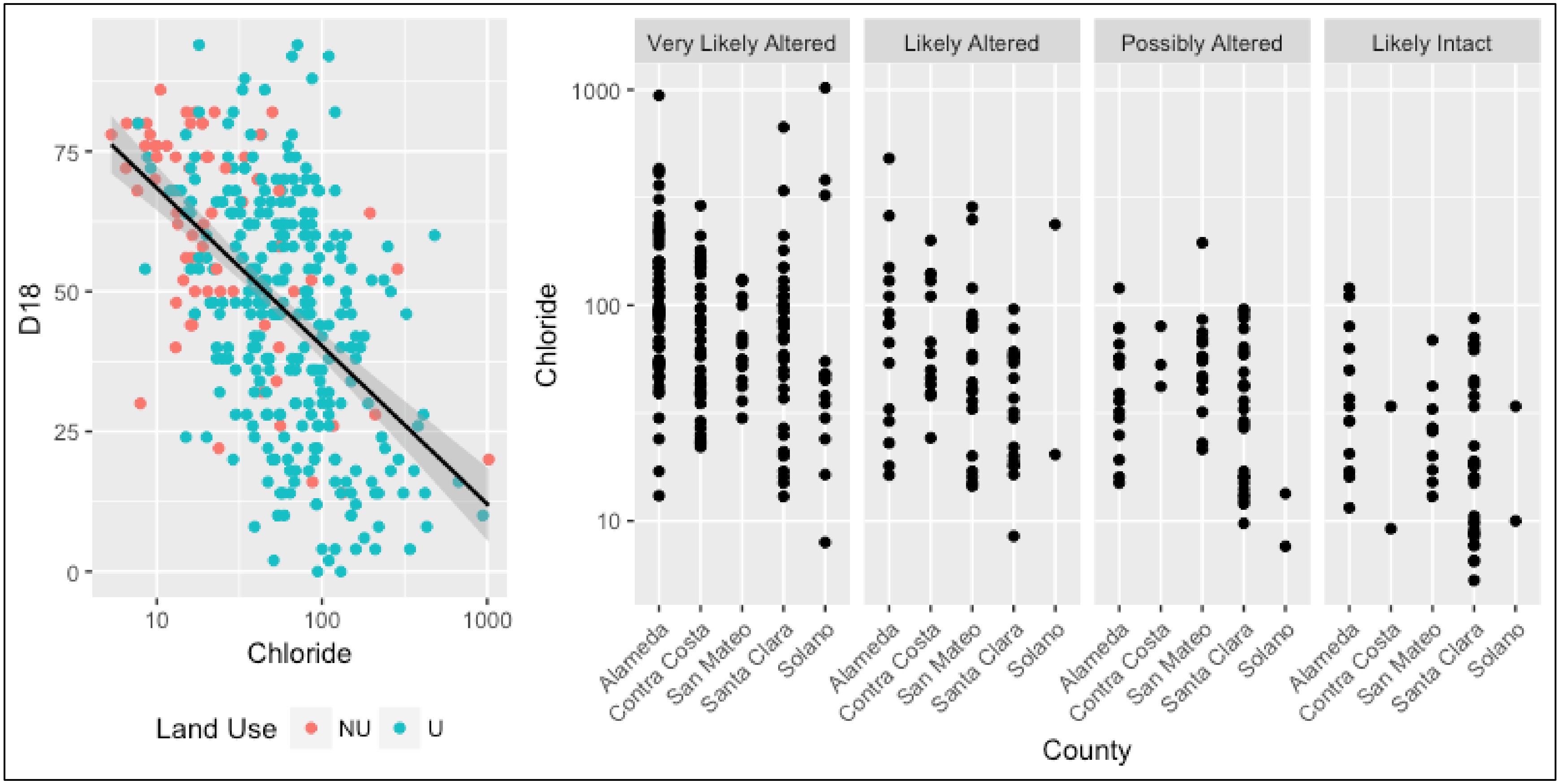

Figure 16. Relationship of D18 score to chloride concentration (mg/L). Note the chloride concentration scale is displayed in log units.

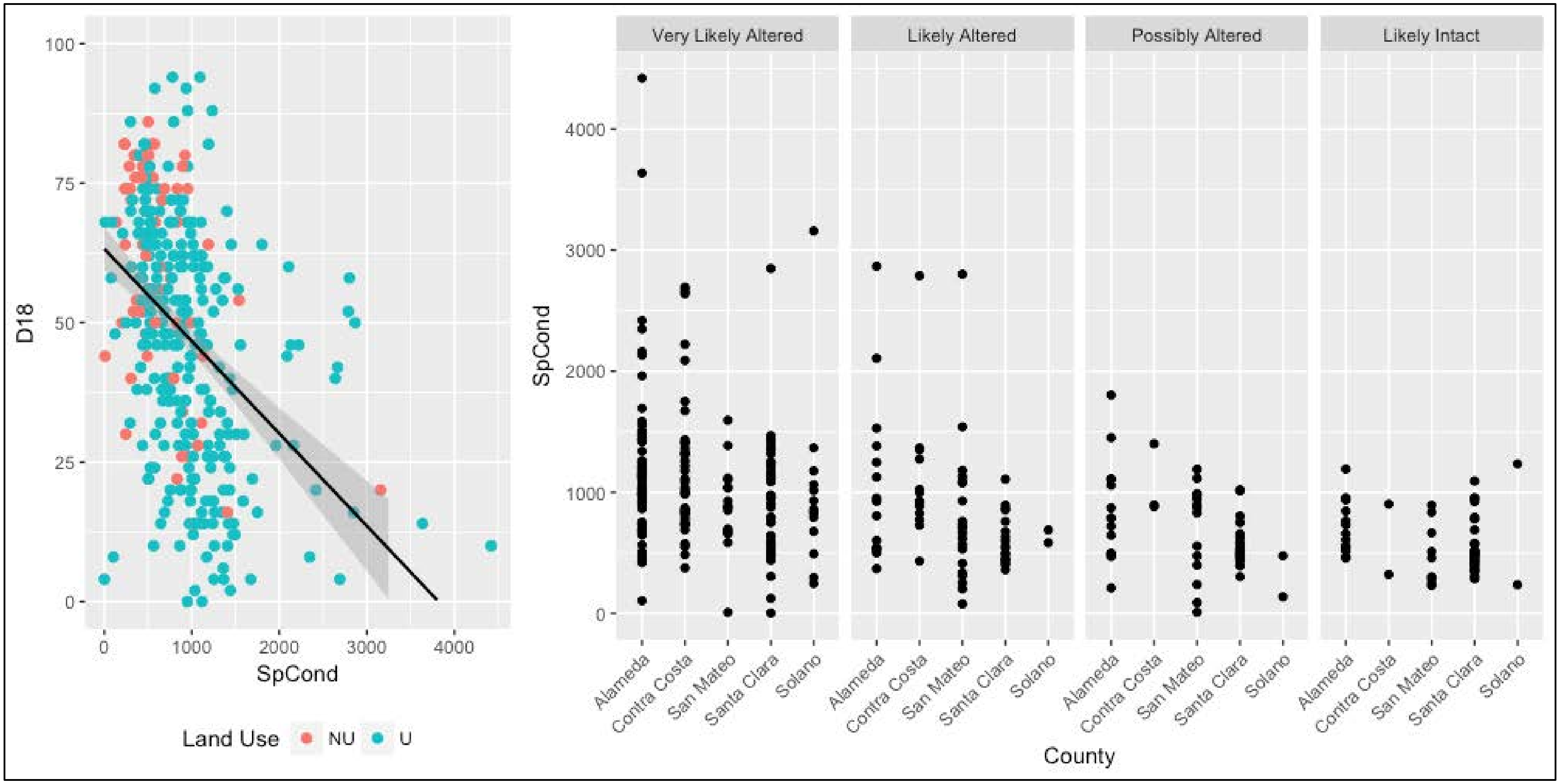

Figure 17. Relationship of D18 score to specific conductivity (µS/cm).

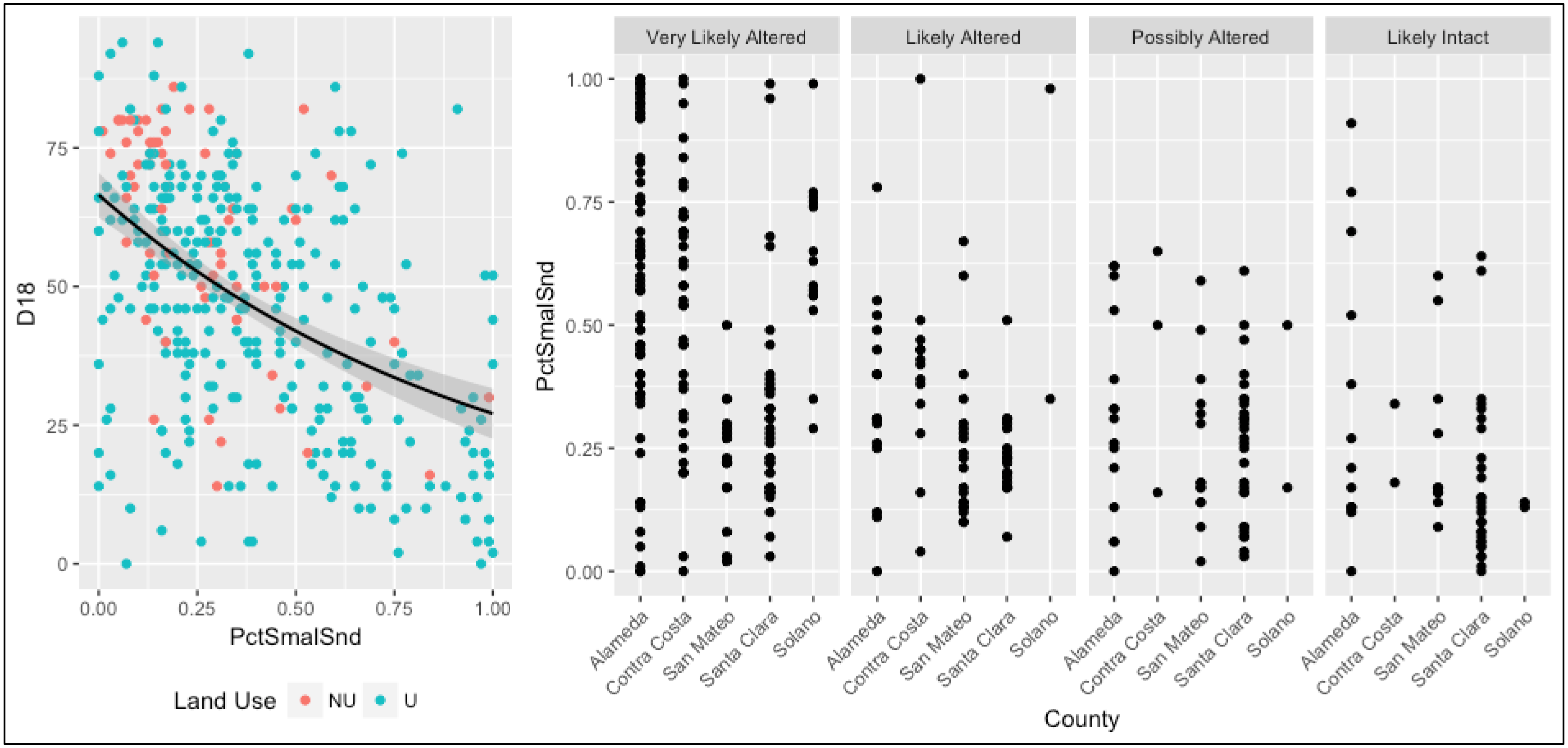

Figure 18. Relationship of D18 score to the percent of substrate in the stream reach that was smaller than sand.

3.3.2 Relative Risk Outputs

The relative risk of several stressors that may impact biological condition (based on CSCI scores) is shown in Figure 19. Definitions of abbreviations and threshold values for relative risk are described in Section 2.4.5. The Human Disturbance Index (HDI) stressor had the strongest relationship (> 3.0) with poor biological condition observed in the RMC dataset. Of the remaining physical habitat stressor variables, percent substrate smaller than sand (SmalSnd) had the strongest relationship (1.56) with poor biological condition. The remaining six stressors evaluated were associated with water quality and water chemistry and had Relative Risk values ranging between 1.26 and 1.51. These results are consistent with the random forest model results presented in the previous section, suggesting that physical habitat variables are more strongly associated with biological condition (based on CSCI scores) in the Bay Area, compared to water quality variables.

The relative risk for the eight stressors evaluated for RMC study were consistent with the results of the relative risk analysis of the same stressors that was conducted by the SMC (Mazor 2015a), with the exception of nutrients. The SMC study showed that relative risk for both Total Nitrogen and Phosphorus slightly under 3.0, while the RMC analysis indicated a much lower relative risk for each of these water quality parameters. The differences in relative risk of nutrients in Northern and Southern California suggest that there may be regional differences in the effects of these water quality parameters on biological condition (based on CSCI). However, it is important to note that the threshold values used by the SMC for Total Nitrogen and Phosphorus were lower than those used in the RMC data analyses.

Please note that the relative risk estimates for the eight stressors illustrated in Figure 19 could not be compared among RMC counties due to the insufficient number of sites with biological conditions above and below stressor thresholds in some counties.

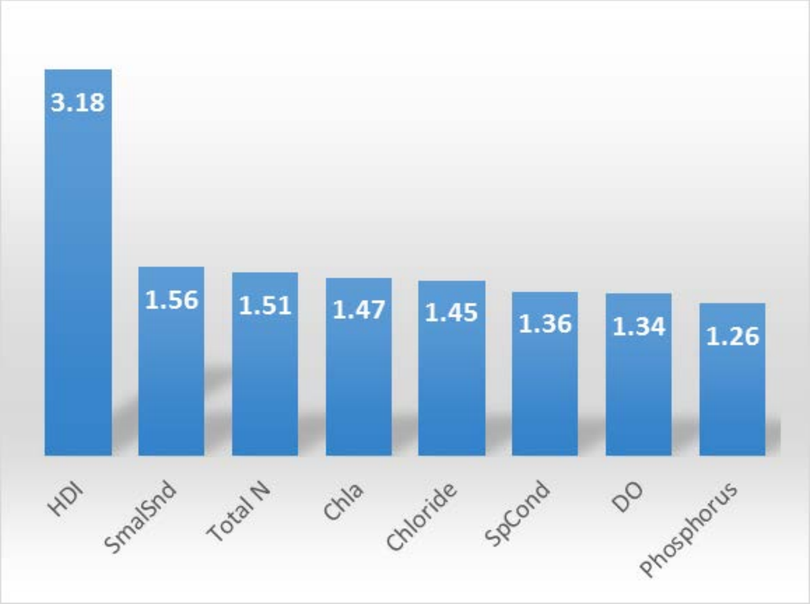

Figure 19. Relative risk of poor biological condition (i.e., scores in the lowest two CSCI condition categories) for sites that exceed stressor disturbance thresholds.

3.4 TRENDS

During the 2012-2016 monitoring period, there was no obvious temporal trend in biological condition, using either the CSCI, D18 or S2 indices. The median annual CSCI score for non-urban sites fluctuated between 0.518 and 0.931, but estimates in three of five years (2012, 2015, 2016) were only based on data collected at ten sites or less. Estimates were particularly imprecise for 2016, where only five non-urban sites were sampled. In urban areas, the median scores for CSCI had a much smaller range (0.408 to 0.510) than scores at non-urban sites. For urban sites, there was a clear lack of temporal trend, with 2016 exhibiting the highest median of the five years monitored (Figure 20).

D18 and S2 scores in each of the water years followed a similar pattern to CSCI scores. Scores in non-urban areas tended to vary widely depending on the water year and number of sites assessed (Figures 21 and 22). However, the urban sites tended to be relatively consistent, with scores generally being within a similar range each year. One observation to note was that S2 scores at urban sites were generally lower in 2016, compared to the preceding years of the survey, while CSCI scores were higher in 2016.

A comparison of median scores for CSCI each year and accumulated rainfall in each County did not reveal clear patterns on a county-by-county basis (Figure 23). Annual rainfall, as measured at San Francisco International Airport, during the five-year survey period was generally below the long-term average (Figure 5). Regional differences in accumulated rainfall additionally contribute to the lack of discernible changes in condition over time at a regional scale.

Contra Costa exhibited the highest range in accumulated rainfall during the monitoring period (10-20 inches) and generally had consistently low median CSCI scores. Alameda and Santa Clara counties, however, experienced a similar range in accumulated rainfall (5-16 inches), but had very different median CSCI scores in each water year. Given the variations in CSCI scores during different water years in some counties, future analyses to evaluate temporal trends in biological conditions will likely need to consider the influence of climatic variation at the county and regional-scales.

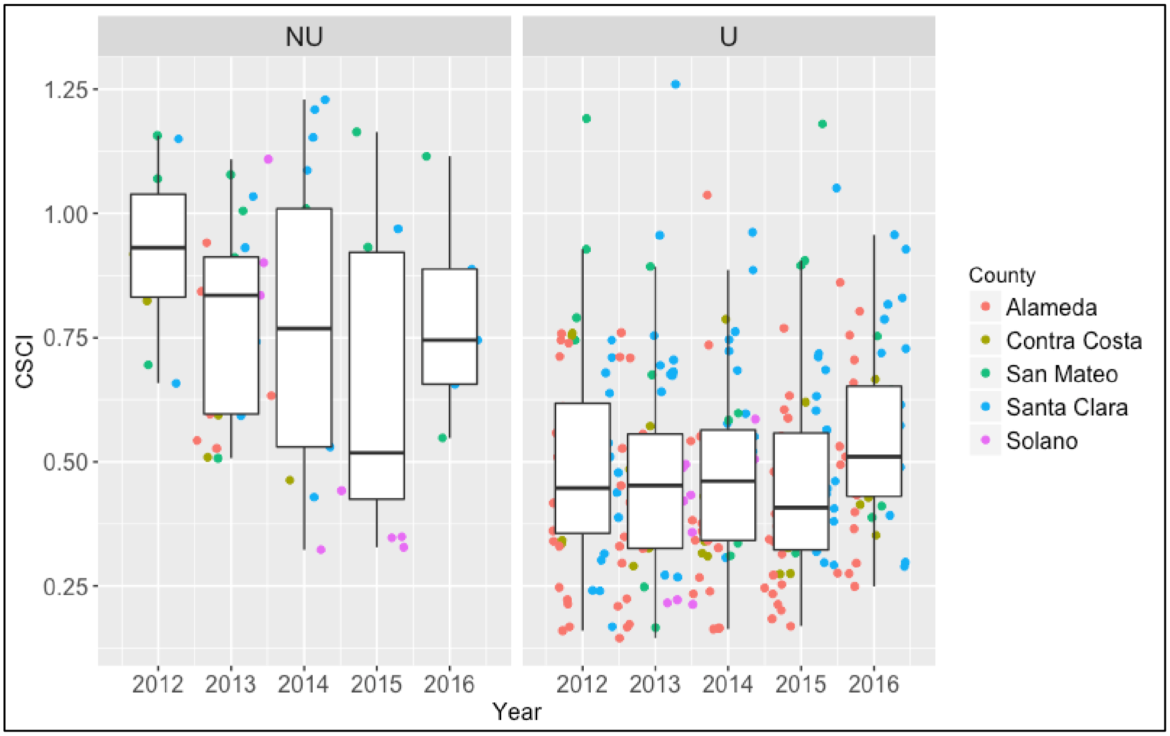

Figure 20. Distribution of CSCI scores during water years 2012-2016. NU = non-urban, U= urban.

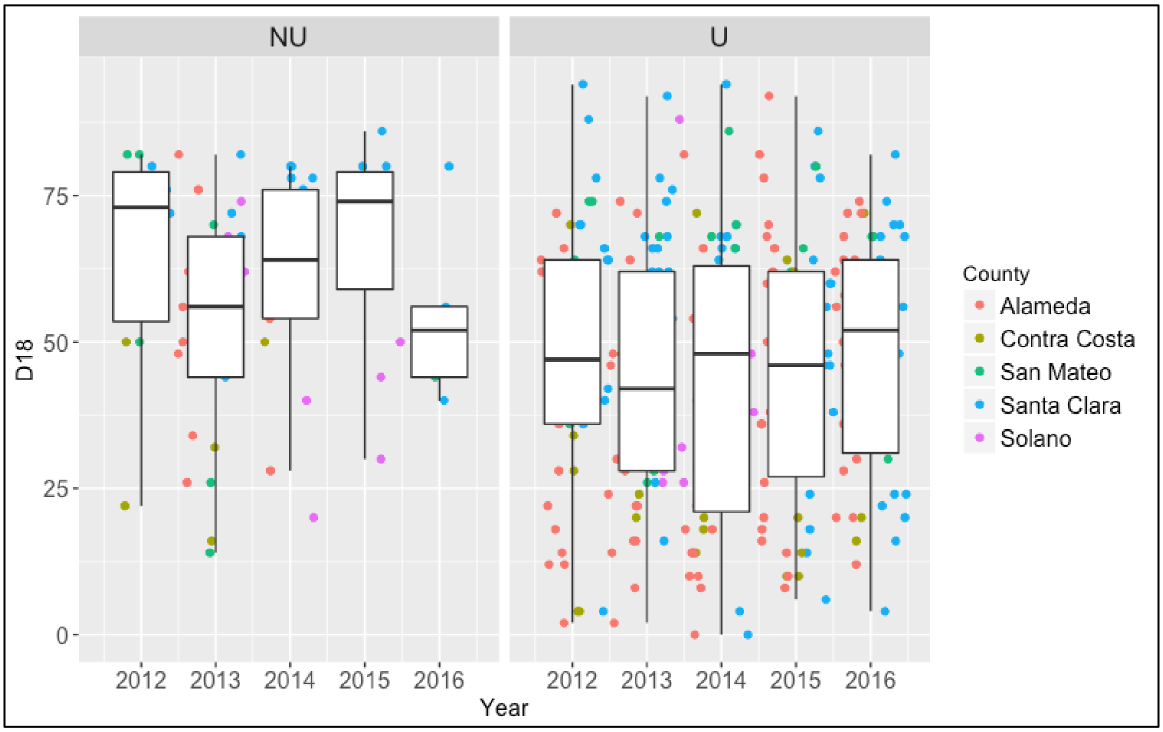

Figure 21. Distribution of D18 scores during water years 2012-2016. NU = non-urban, U= urban.

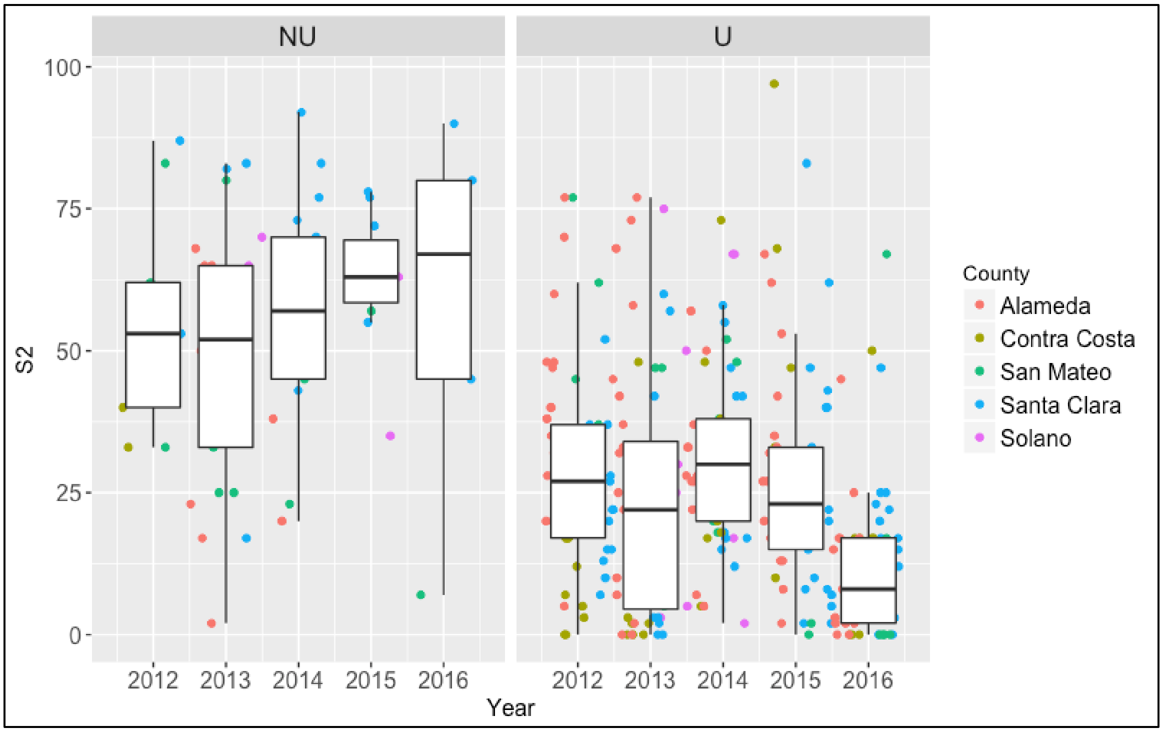

Figure 22. Distribution of S2 scores during water years 2012-2016. NU = non-urban, U= urban.

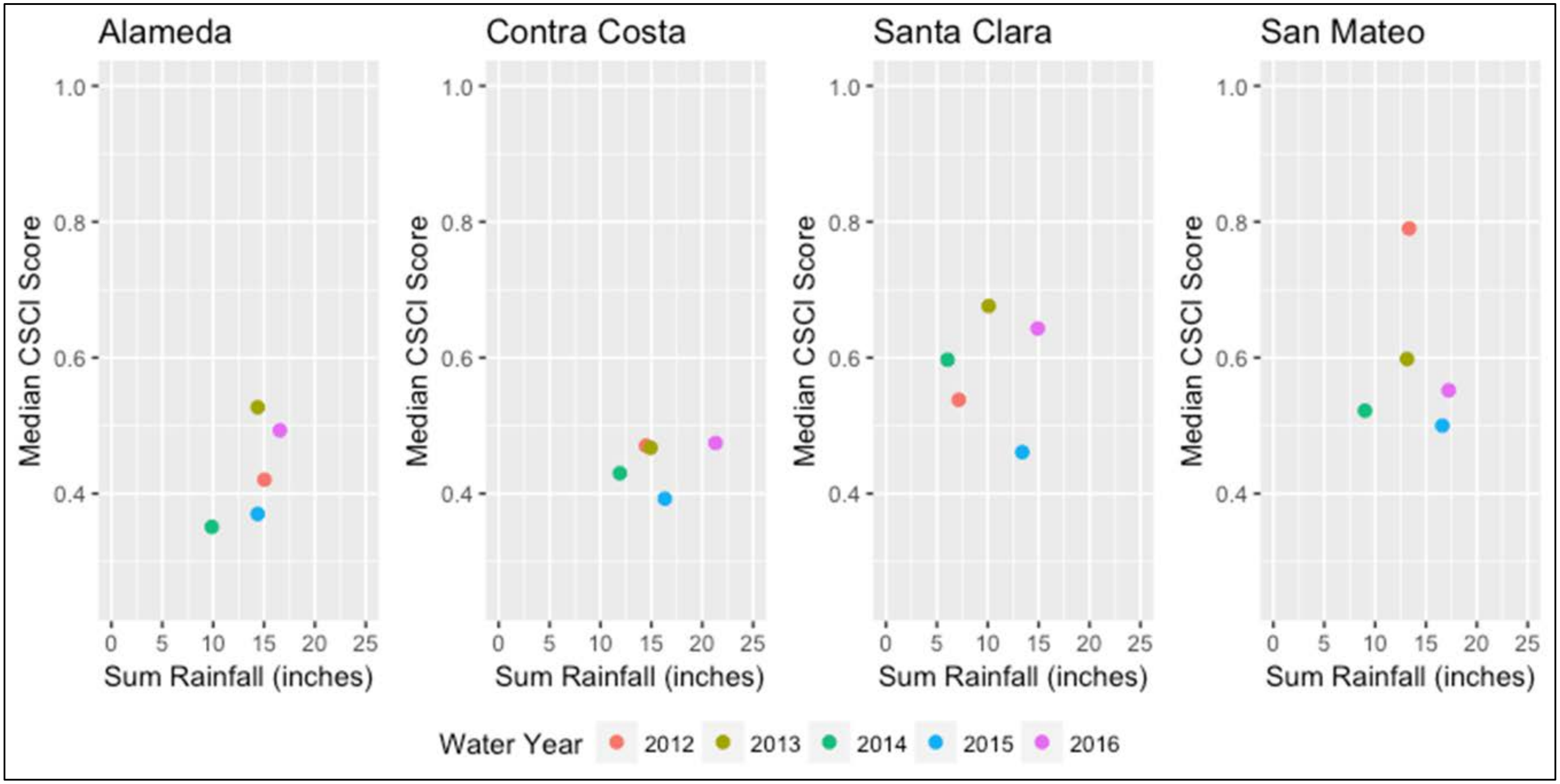

Figure 23. Relationship between median CSCI scores and accumulated annual rainfall in each County during water years 2012-2016. Includes urban and non-urban sites.

4 FINDINGS AND NEXT STEPS

The results and conclusions of the RMC's five-year bioassessment data evaluation are discussed below as they relate to the management questions and goals identified for the project.

4.1 *WHAT ARE THE BIOLOGICAL CONDITIONS OF STREAMS IN THE RMC AREA?*

Regional Conditions

The biological conditions of streams in the RMC area were assessed using two ecological indicators: BMIs and algae. The probabilistic survey design was developed to provide an objective estimate of biological condition of sampleable streams (i.e., accessible streams with suitable flow conditions) at both the RMC area and countywide scale.[7] Results of the survey indicate that streams in the RMC area are generally in poor biological condition:

- The CSCI for benthic macroinvertebrates (BMIs) indicates that 58% of stream length in the region are in the lowest CSCI condition category (Very Likely Altered); 74% of the of the sampled stream length exhibited CSCI scores below 0.795, the MRP trigger for potential follow-on activity.
- Using both algae indices (D18 and S2), stream conditions regionwide appear slightly less degraded than when using CSI, with approximately 40% of the streams ranked in the lowest algae condition category (Very Likely Altered). The algal indices also indicate that greater stream lengths (19-21%) are in the highest condition category (Likely Intact) compared to lengths in this category when the CSCI is used (15%).

These findings should be interpreted with the understanding that the survey focused on urban stream conditions. Approximately 80% of the samples (284 of 354) were collected at urban sites. As a result, the overall condition assessment represents the range of conditions found in the urban area, which is defined in the sample frame as areas classified as "urban" in the US Census (2000), plus all areas within city boundaries. Although the low non-urban sample size precludes making any definitive comparisons, bioassessment scores in the non-urban area were higher than scores in the urban area for each of the RMC counties. In general, the biological condition assessment for the RMC area (with a focus on urban sites) was consistent with the statewide assessment of biological conditions at sites located within urban land uses (PSA 2015), which resulted in more than 90% of urban streams rated in the two lowest biological condition categories using CSCI.

Differences Across Counties

One of the goals for the RMC monitoring design was to compare biological conditions of streams between counties. In general, biological conditions, based on CSCI and D18 scores, appeared better in streams located in Santa Clara and San Mateo counties, compared others. However, Santa Clara and San Mateo counties had proportionally more non-urban sites (with higher CSCI and D18 scores) compared to other

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[7] More samples are needed to estimate condition for non-urban land use areas and finer spatial scales (i.e., watersheds).

counties. All counties exhibit higher biological condition scores in the non-urban area compared to the urban area. The difference between urban and non-urban median scores is lower for the D18 index, suggesting that diatoms may respond less to the habitat degradation commonly found at urban sites and may therefore provide better response to changes in water quality conditions.

Higher overall scores in Santa Clara and San Mateo may also be associated with regional differences in rainfall and flow duration. For example, San Mateo County and western Santa Clara County watersheds drain the Santa Cruz mountains, which typically receive higher rainfall, in contrast to Alameda and Contra Costa counties, which primarily contain watersheds that drain the western slopes of the drier Diablo range.

Indicator Tools

The use of multiple indicators provides a broad assessment of ecosystem functions. Streams that show degraded conditions for a single indicator may provide opportunities to identify the stressor and potentially implement management controls to reduce impacts. Alternatively, streams with poor conditions for both indicators (BMI and algae) may have multiple stressors that might be more challenging to address. Watershed managers may also choose to prioritize streams that are in good biological condition, based on both biological indicators, for protection of beneficial uses.

The RMC used existing tools to assess biological condition (CSCI and SoCal Algal IBIs). Although these tools were also used in the regional assessments conducted by the SMC, uncertainty remains as to how well these indices perform for streams within the San Francisco Bay Region:

- The CSCI is a statewide index that was developed for perennial streams. For the RMC project, however, the CSCI was used to evaluate BMI data collected in both perennial and non-perennial streams (note: the RMC assessed flow status by conducting site visits at all sampled sites during the dry season). In addition, CSCI scores appear highly sensitive to physical habitat degradation, which occurs frequently in the many highly modified urban streams monitored by the RMC. It is not clear how well the CSCI tool can show response to stressors associated with water quality, when physical habitat is the primary factor affecting the BMI community.

- For this report, the RMC evaluated algae data using SoCal Algae IBIs for diatoms (D18) and soft algae (S2). The D18 was more responsive to stressor gradients associated with water quality, however, high scores were often found in urban sites with highly degraded physical habitat. The soft algae index (S2) was not a reliable indicator of condition due to overall low taxa richness observed at both disturbed and undisturbed sites throughout the RMC area. In many cases, there was insufficient number of soft algae taxa to calculate S2, resulting in data gaps and lack of utility of the S2 index. Additional testing of soft algae indices is needed to assess the utility of this indicator in the RMC area.

  The State Water Board and Southern California Coastal Water Research Project are currently developing and testing a set of statewide indices using benthic algae data as a measure of biological condition for streams in California. The statewide Algae Stream Condition Indices (ASCIs) are expected to be finalized in 2019. It is anticipated that the RMC will apply the ASCIs to analyze algae data when they become available.

4.2 *WHAT STRESSORS ARE ASSOCIATED WITH BIOLOGICAL CONDITIONS?*

This question was addressed by evaluating the relationships between biological indicators (CSCI and D18) and stressor data through random forest and relative risk analyses. The study results indicate that each of the biological indicators responded to different types of stressors and therefore the two may be best used in combination to assess potential causes of poor (or good) biological conditions in streams:

- Biological condition, based on CSCI scores, is strongly influenced by physical habitat variables and land use within the vicinity of the site. The percent of the land area within a 5 km radius of a site that is impervious appears to have the largest influence on CSCI scores based on the random forest model results. Based on the relative risk analysis, the degree of human disturbance near a site, as observed via the Human Disturbance Index (HDI), appears to have the greatest relationship with poor biological condition of streams.
- Biological condition, based on D18 scores, is moderately correlated with water quality variables and less associated with physical or landscape variables, such as imperviousness or HDI.

In general, CSCI scores at urban sites were consistently low in all RMC counties, indicating that degraded physical habitat conditions in and around streams do not support healthy in-stream biological communities. D18 scores at urban sites were more variable, indicating that healthy diatom assemblages can occur at sites with poor physical habitat and may be important water quality indicator these sites.

No nutrient variables (e.g., nitrate, total nitrogen, orthophosphate, phosphorus) correlated strongly with CSCI scores in the Bay Area, nor were nutrients ranked as important variables explaining CSCI scores via the random forest model. Phosphorus and ash-free dry mass, which increase in response to biostimulation, were important in predicting algae (D18) index scores, although no statistically significant relationships were observed. This finding suggests that nutrient targets currently under development by the State Water Board as part of their Biostimulatory/Biointegrity Project, should be applied in the context of observed biological conditions, not uniformly based solely on broad relationships that may not apply to the Bay Area streams.

Although results show associations between some stressors and biological condition, they do not establish causation. There are several factors that may affect the strength of the correlation between stressors and biological condition:

- Stressors are not independent of one another and may have synergistic or mediating effects on condition. For example, elevated temperatures reduce the amount of oxygen that can be dissolved in the water column and both stressors may result in adverse effects to aquatic biota.
- Potential variability of stressor concentrations over time may not be represented in a single grab sample. For example, dissolved oxygen can have a wide range of concentrations over a 24-hour period. Drops in DO concentrations typically occur in early morning hours, potentially well prior to the timing of measurements during bioassessment events.
- Many of the physical habitat variables can be highly variable throughout the sample reach. For example, a wide range of substrate grain sizes can occur within a single transect. Thus, degraded habitat conditions that may exist at selected transect(s) of the assessment reach may not be well represented in reach-wide averages used as endpoints for the stressor analysis.

- Stressor impacts may be dependent on other factors (possibly not measured) for negative effects to occur. For example, elevated nutrient concentrations do not necessarily result in eutrophication (i.e., excessive plant and algal growth, reduced oxygen levels). Stream locations that have minimal exposure to sunlight, cooler water and higher flow rates may not develop eutrophic conditions, despite presence of elevated concentrations of nutrients.
- Stressors may have natural sources; prevalence and magnitude may vary by watershed or regionally. For example, naturally occurring nitrogen or phosphorus concentrations may be present in minimally disturbed upper watershed areas.

4.3 *ARE BIOLOGICAL CONDITIONS CHANGING OVER TIME?*

The short timeframe of the survey (five years) limited the ability to detect temporal trends in bioassessment data. Since new sites are surveyed each year, it is expected that a much longer time period is needed to detect trends at a regional scale over time. The variability in biological condition observed over the five years of the current analysis may have been associated with annual variation in precipitation or other factors. Drought conditions were present during the first four years of the survey. Trends in biological condition are more likely to occur on the decadal timescale. That said, the PSA evaluated trends for unique probabilistic sites sampled over a 13-year period and observed no trends (i.e., consistent directional change over time) (PSA 2015).

It is also important to consider these results within the broader context of the progress made over the past decade to reduce the effects of urbanization on creeks and channels through the mandatory treatment of stormwater and reduction of impervious areas via applicable new and redevelopment projects, and the numerous stream restoration projects that have been put into place. The implementation of mandatory stormwater treatment via green stormwater infrastructure (GSI) and low impact development (LID) began prior to the adoption of the MRP in 2005. These requirements reduce the effects of stormwater from impervious surfaces created via new and redevelopment and likely have positive effects on biological condition in streams, although the responses may be delayed. Bay Area municipalities are currently developing GSI Plans, which will result in the strategic and widespread integration of GSI into Capital Improvement Projects and other co-benefit projects like regional stormwater capture projects, creek restoration and flood control and resiliency projects. These efforts are anticipated to further reduce the impacts of stormwater on local streams. Future creek status monitoring may provide additional insight into the potential positive impacts of GSI and creek restoration on water quality and beneficial uses in urban creeks.

The ability to detect trends would be increased if the sample design included re-visiting sites over multiple years. Multiple surveys at individual sites would provide more site-specific detection of changing biological conditions over time. Should RMC participants intend to use BMIs and algae as long-term indicators, analyses should be conducted to identify the minimum number of samples needed over a specified timeframe to detect trends at a site or within a watershed or county, with a specified level of confidence. The analysis could also be used to optimize the monitoring program by evaluating appropriate sample sizes for detecting trends when considering expected variability in condition for different groups of sites, land use types, or areas where management actions are being implemented.

4.4 EVALUATION OF MONITORING DESIGN

The information presented below is intended to provide recommendations on potential revisions RMC monitoring procedures that should be considered for future implementation of bioassessment programs in the Bay Area.

4.4.1 Site Evaluations

Over the first five years of monitoring, the RMC evaluated about 25% (1455 out of 5740) of the sites in the sample frame to assess 354 sites. Approximately 46% (873 out of 1896) of the total number of urban sites in the sample frame were evaluated during that time. Additional sites have subsequently been selected from the sample frame and evaluated for sampling in 2017 and 2018. The number of remaining sites for evaluation in the RMC Sample Frame for each county is presented in Table 7.

Table 7. Sites remaining in RMC sample frame before site evaluation in water year 2019.

County	Urban	Non-urban
Alameda	124	797
Contra Costa (R2)	348	307
Contra Costa (R5)		331
Santa Clara	143	1189
San Mateo	67	469
Fairfield-Suisun	37	208
Vallejo	4	

Based on rejection rates from previous years, the sample frame is anticipated to only last two to three years at which time the urban sites in the frame will be exhausted. Revision of the RMC monitoring design could seek to reduce the future rejection rate through re-evaluation of the sample frame to exclude areas of low management interest or regions that would not be candidates for sampling (such as due to lack of permissions or physical barriers to access). This would improve the spatial balance of samples that more closely represents the proportion of the sample frame that can be reliably assessed.

Each countywide stormwater program managed their site evaluation information independently using a standardized database. The site evaluation data were then compiled to conduct the spatial analysis needed to calculate the regional biological condition estimates presented in this report. During the compilation process, inconsistencies in procedures used to conduct site evaluation (BASMAA 2016a) were identified that affect the statistical certainty of the regional estimates. Some sites in the sample draw were skipped over (e.g., challenges in obtaining permissions from private land owners, lack of flow during period of drought) with the intention to re-evaluate the sites at a future date. The skipped sites created sampling bias that affects the spatial balance of the draw and reduces certainty in the condition estimates.

Another issue was the disproportionate sampling of non-urban sites among the counties. The RMC intended to sample twenty percent of the targeted sites each year. Some Programs had difficulty getting access to non-urban sites, or decided to focus on urban sites, resulting in a wide range in number of samples collected at non-urban sites across the counties. As a result, biological condition scores at the county-scale tended to be higher in counties that sampled more non-urban sites.

4.4.2 RMC Sample Frame

Consistent with the PSA, the RMC sample design was created to probabilistically sample all streams within the RMC area, which resulted in a master list of 33% urban sites and 67% non-urban sites. However, because participating municipalities are primarily concerned with runoff from urban areas, the RMC focused sampling efforts on urban sites (80%) over non-urban sites (20%). As a result, non-urban samples are under-represented in the dataset resulting in much lower overall biological condition scores than would be expected for a spatially balanced dataset. In addition, the limited number of non-urban samples (2% sample frame assessed thru-2016) prevented statistical confidence in estimates of biological condition for non-urban land use at the regional scale.

Depending on the goals for the RMC moving forward, the RMC may want to consider developing a new sample draw that establishes a new list of sites that is weighted for specific land uses categories and Program areas of interest. Development of a revised sample frame would result in a new list of sites, associated with different length weights for each land use category. The sample draw could also include a list of sites for oversampling (replacements for sites not sampled) to maintain the spatial balance throughout any timeframe of the draw and allow for a much longer time frame before the list is exhausted.

Re-design of the RMC sample frame could also include new strata based on developed channel classifications created by SCCWRP. The classifications are created using a statistical model that predicts likely ranges of CSCI scores based on landscape characteristics (Mazor et al. 2018). These channel classifications could be integrated as strata into the RMC sample frame to allow varying sampling efforts for urbanized streams.

4.5 POSSIBLE NEXT STEPS FOR THE RMC BIOASSESSMENT MONITORING

Based on evaluation of data collected during the five years of the survey, several options to revise the RMC Monitoring Design are presented below:

1) Continue to sample new probabilistic sites until the draw is exhausted;
2) Re-visit probabilistic sites in support of assessing temporal trends;
3) Monitor targeted sites for special studies; or
4) Combination of two or more of the above.

Each of these options is discussed in more detail below.

Continue Sampling New Probabilistic Sites

The RMC could continue to sample new probabilistic sites from the current sample frame with the goal to establish baseline conditions over smaller spatial scales. Eventually, statistically significant datasets would be obtained to estimate biological condition for all strata previously considered (i.e., non-urban and countywide), as well as finer scales (e.g., watersheds). Smaller geographic scales of assessments may provide stronger associations between biological conditions and stressor levels. Watershed-level assessments may provide managers more opportunities to evaluate spatial patterns and temporal trends for specific watersheds.

Exclusively sampling new sites would exhaust sites in the current sample draw. It is anticipated that at the current rate of sampling (at same proportion of urban/non-urban sites), some of the Programs would run out of urban sites in two to three years. Solano County has already depleted urban sites from their sample frame. Sampling effort at new non-urban sites should be also be evaluated. Resources to conduct site evaluations (e.g., permission to access private property) are typically much higher at non-urban sites. In addition, the access to non-urban sites appears to be highly variable by county.

If this option is desired, the RMC could develop a new probabilistic sample draw with a list of oversample sites.

Re-visit Probabilistic Sites to Assess Temporal Trends

Re-visiting probabilistic sites previously sampled may provide trend estimates and more refined information to potentially explain causes of observed trends. The most robust trends scenario would involve sampling the same sites each year; however, given the current level-of-effort, this would only be possible at a relatively small number of sites in each county. Thus, the resulting trends assessment could only answer regional questions. Some sites could be sampled for multiple years to evaluate potential variability related to changes in precipitation; non-urban sites may be particularly sensitive to annual variation in precipitation. Integrating site re-visits into the sample design would have the advantage of extending the life of the sample frame (i.e., reduce number of new sites each year).

Targeted Studies

There are several potential objectives for conducting biological assessments at targeted sites, including:

1) Evaluate effectiveness of stream restoration/BMP implementation projects;
2) Determine source/stressor at impaired site (i.e., causal assessment);
3) Evaluate conditions in selected watersheds;
4) Study trends at minimally disturbed sites (e.g., climate change);
5) Assess validity of CSCI in nonperennial streams in the Bay Area;
6) Investigate variability in biological indicator scores within sampling index period.

Targeted studies could be coordinated among RMC participants to evaluate similar objectives at regional scale or could be done independently by each Program. It is anticipated that targeted studies may require more resources with regards to site selection, data needs, detailed analyses, and reporting. However, targeted monitoring could also leverage requirements that Permittees have for other projects.

Combined Approaches

The RMC may consider implementing a combination of all the approaches described above for the future monitoring design.

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APPENDICES

1. Random Forest Analysis
2. Partial Dependency Plots
3. CSCI-Stressor Plots
4. Additional Figures

APPENDIX 1 RANDOM FOREST ANALYSIS

Table 1-A. Variable group, variable code, and description of response variables (condition indices) and explanatory environmental variables (landscape, habitat, and water quality) used for random forest model development.

Variable Group	Variable Code	Description
Response	CSCI	California Stream Condition Index
Response	D18	Soft algae condition score
Habitat	AvAlgCov	Mean Filamentous Algae Cover
Habitat	AvBold	Mean Boulders cover
Habitat	AvWetWd	Mean Wetted Width/Depth Ratio
Habitat	AvWoodD	Mean Woody Debris <0.3m cover
Habitat	ChanAlt	Channel Alteration Score
Habitat	EpiSub	Epifaunal Substrate Score
Habitat	FlowHab	Evenness of Flow Habitat Types
Habitat	NatShelt	Natural Shelter cover - SWAMP
Habitat	NatSub	Evenness of Natural Substrate Types
Habitat	PctBold_L	Percent Boulders - large
Habitat	PctBold_LS	Percent Boulders - large & small
Habitat	PctBold_S	Percent Boulders - small
Habitat	PctFin	Percent Fines
Habitat	PctFstH20	Percent Fast Water of Reach
Habitat	PctGra	Percent Gravel - coarse
Habitat	PctSlwH20	Percent Slow Water of Reach
Habitat	PctSmalSnd	Percent Substrate Smaller than Sand (<2 mm)
Habitat	PctSnd	Percent Sand
Habitat	ShD.AqHab	Shannon Diversity (H) of Aquatic Habitat Types
Habitat	ShD.NatSub	Shannon Diversity (H) of Natural Substrate Types

Variable Group	Variable Code	Description
Land Use	HDI	Combined Riparian Human Disturbance Index - SWAMP
Land use	PctImp	Percent Impervious Area of Reach
Land use	PctImp_1K	Percent Impervious Area in 1km
Land use	PctImp_5K	Percent Impervious Area in 5km
Land use	PctUrb	Percent Urban Area of Reach
Land use	PctUrb_1K	Percent Urban Area in 1km
Land use	PctUrb_5K	Percent Urban Area in 5km
Land use	RdCrs_5K	Number Road Crossings in 5km
Land use	RdCrs_W	Number Road Crossings in watershed
Land use	RdDen_1K	Road Density in 1km
Land use	RdDen_5K	Road Density in 5km
Land use	RdDen_W	Road Density in watershed
Land use	RoadCrs_1K	Number Road Crossings in 1km
Water Quality	AFDM.sub	Ash Free Dry Mass
Water Quality	Ammonia.sub	Ammonia
Water Quality	Chla.sub	Chlorophyll a
Water Quality	Chloride	Chloride
Water Quality	DO	Dissolved oxygen
Water Quality	Nitrate.sub	Nitrate
Water Quality	Nitrite.sub	Nitrite
Water Quality	OP.sub	Orthophosphate
Water Quality	pH	pH
Water Quality	Phosphorus.sub	Phosphorus
Water Quality	Silica	Silica
Water Quality	SpCond	Specific conductivity
Water Quality	Temp	Temperature
Water Quality	TKN.sub	Total Kjeldahl Nitrogen

Variable Group	**Variable Code**	**Description**
Water Quality	Total N	Total Nitrogen
Water Quality	UIA.sub	Unionized Ammonia

Table 1-B. Model and cross-validation statistics for random forest models with CSCI and D18 scores using the final set of model variables (Table 2, Table 3)

Index	Model Dataset	Model Statistic	
CSCI	Training	R^2	0.95
	Validation	R^2	0.61
CSCI	Training	CV R^2	0.66
	Validation	CV R^2	0.52
D18	Training	R^2	0.92
	Validation	R^2	0.34
D18	Training	CV R^2	0.35
	Validation	CV R^2	0.33

Training and validation models run with the same variables, *R^2 = adjusted R-squared, CV R^2 = Cross validation R^2

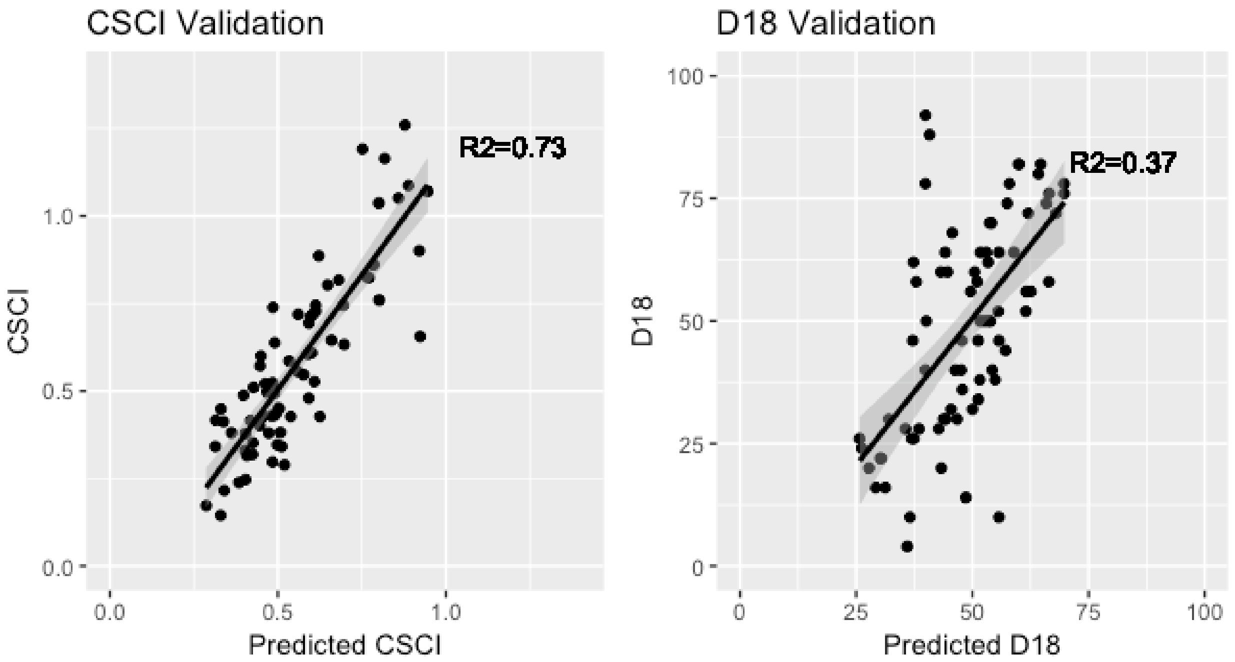

Figure 1-A. Relationship of observed to predicted CSCI and D18 scores in the validation dataset using all 49 explanatory variables in Step 1 of the random forest trial

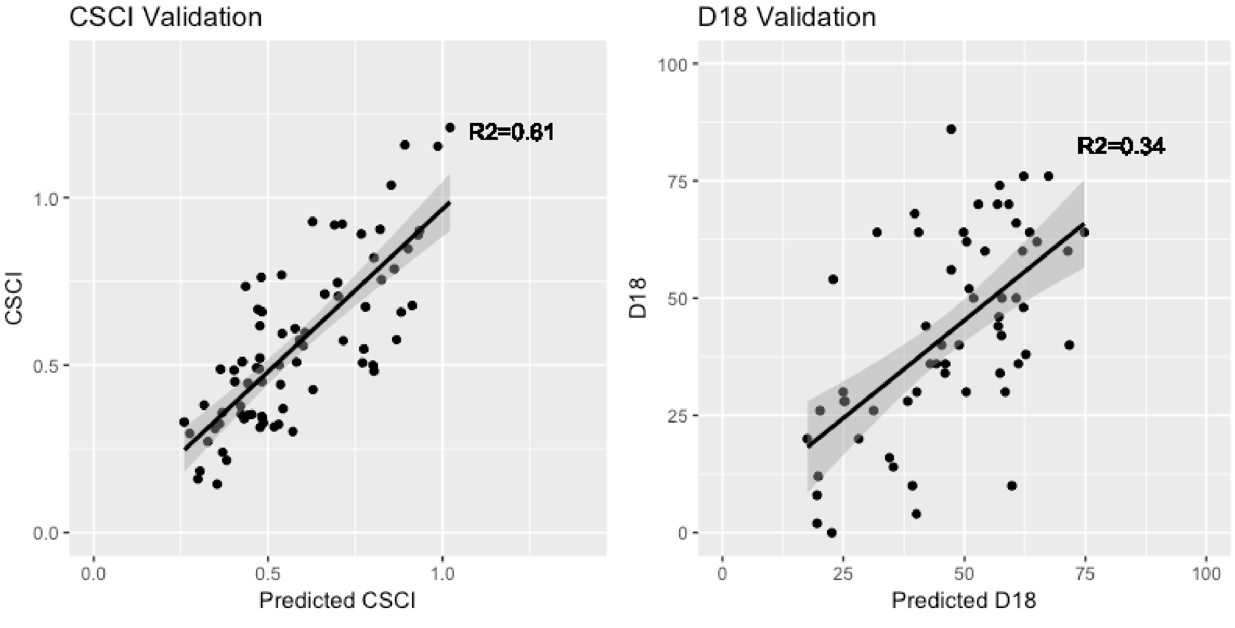

Figure 1-B. Relationship of observed to predicted CSCI and D18 scores in the validation dataset using the final, selected list of explanatory variables in Step 2 of the random forest trial

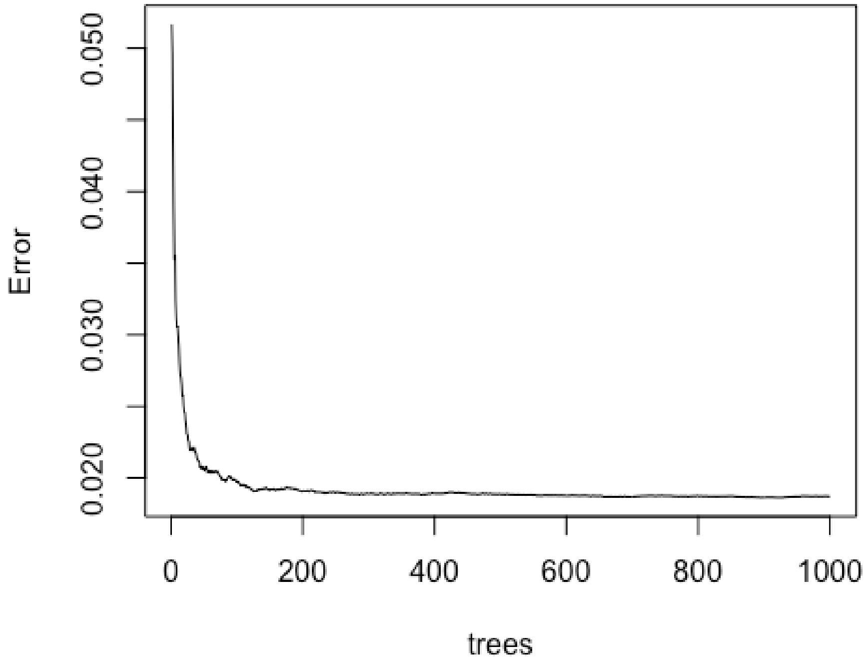

Figure 1-C. Prediction error vs. number of trees in the CSCI model with 49 stressor variables

APPENDIX 2 PARTIAL DEPENDENCY PLOTS

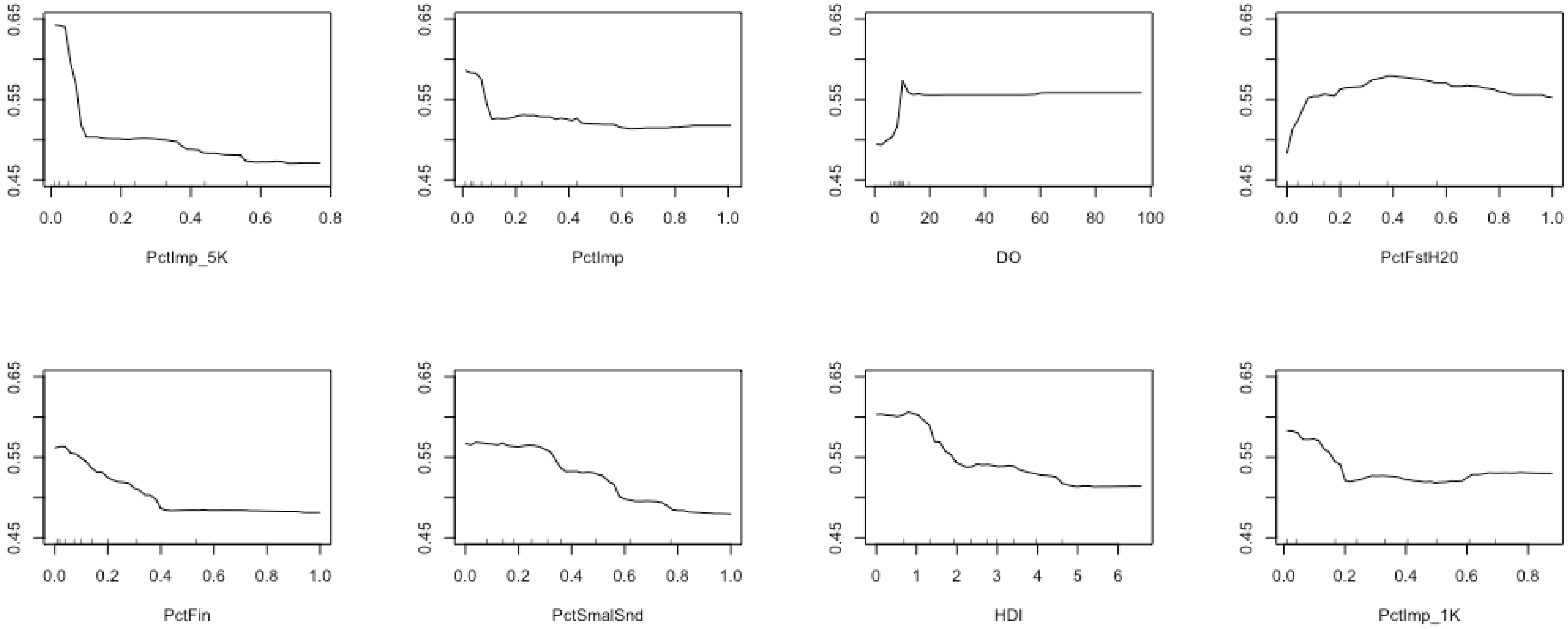

Figure 2-A. Partial dependency plots for stressor variables in random forest model of CSCI condition. Plots show the predicted response of CSCI (y-axis) based on the effect of individual explanatory variables (x-axis) with the response of all other variables removed in the training data set.

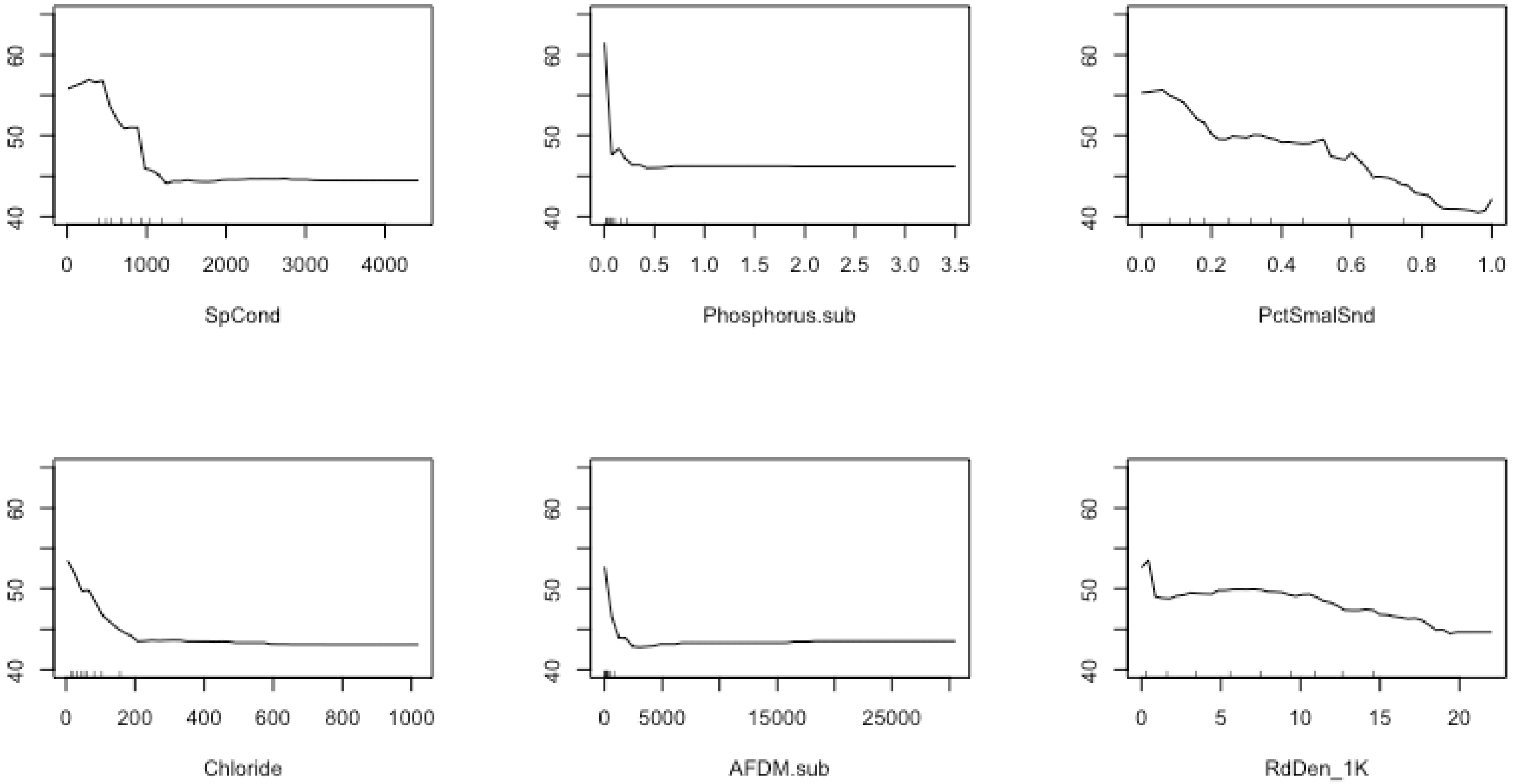

Figure 2-B. Partial dependency plots for stressor variables in random forest model of D18 condition. Plots show the predicted response of D18 (y-axis) based on the effect of individual explanatory variables (x-axis) with the response of all other variables removed in the training data set.

APPENDIX 3 CSCI-STRESSOR PLOTS

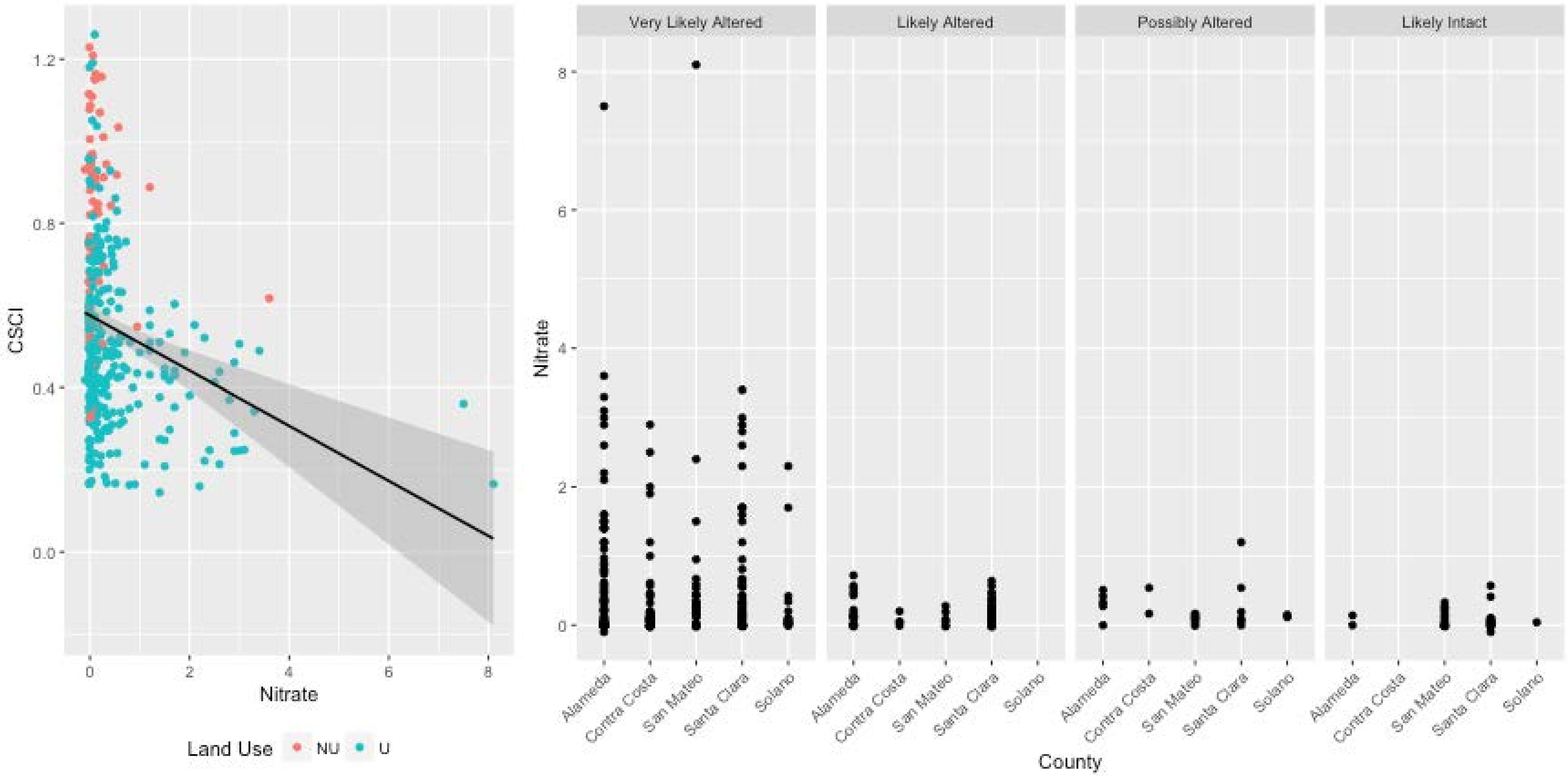

Figure 3-A. Relationship of Nitrate concentration to CSCI scores

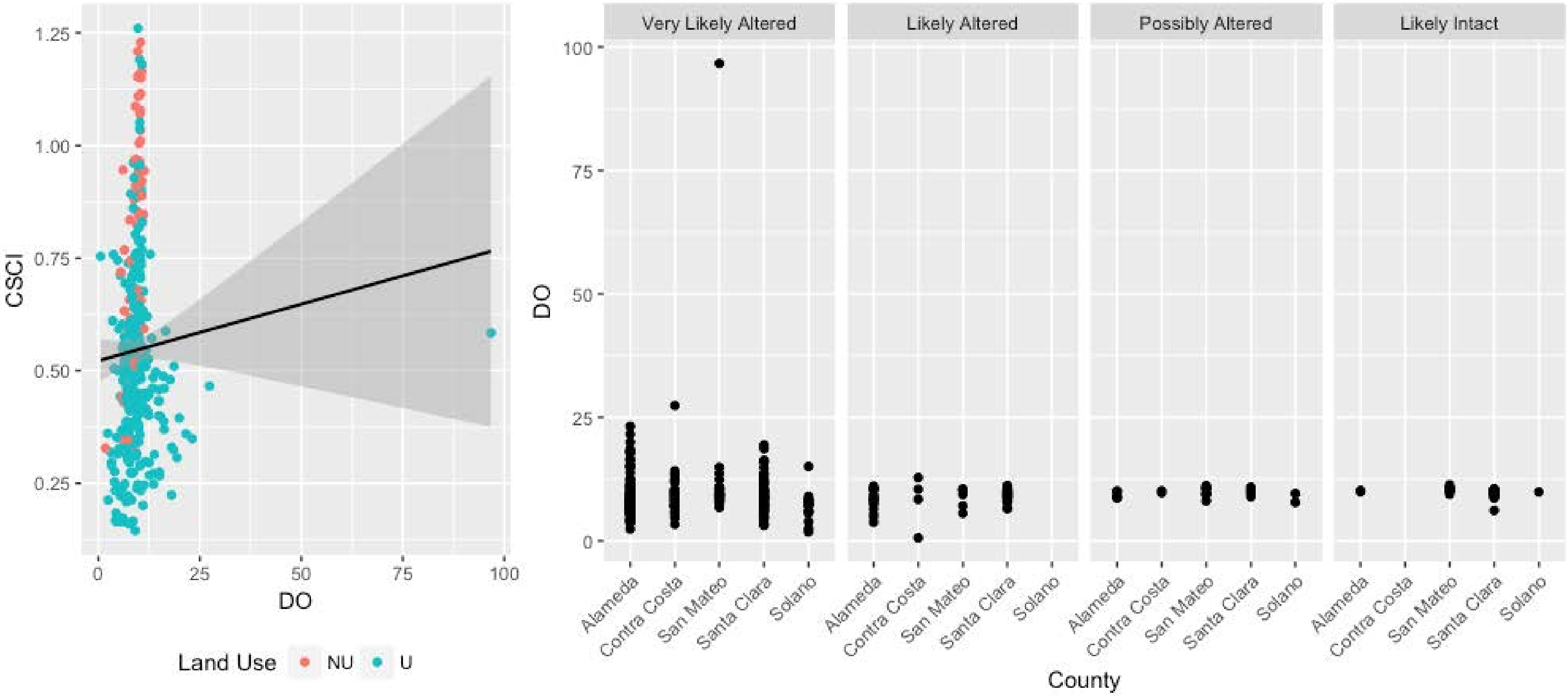

Figure 3-B. Relationship of Dissolved Oxygen values to CSCI scores

APPENDIX 4 ADDITIONAL FIGURES

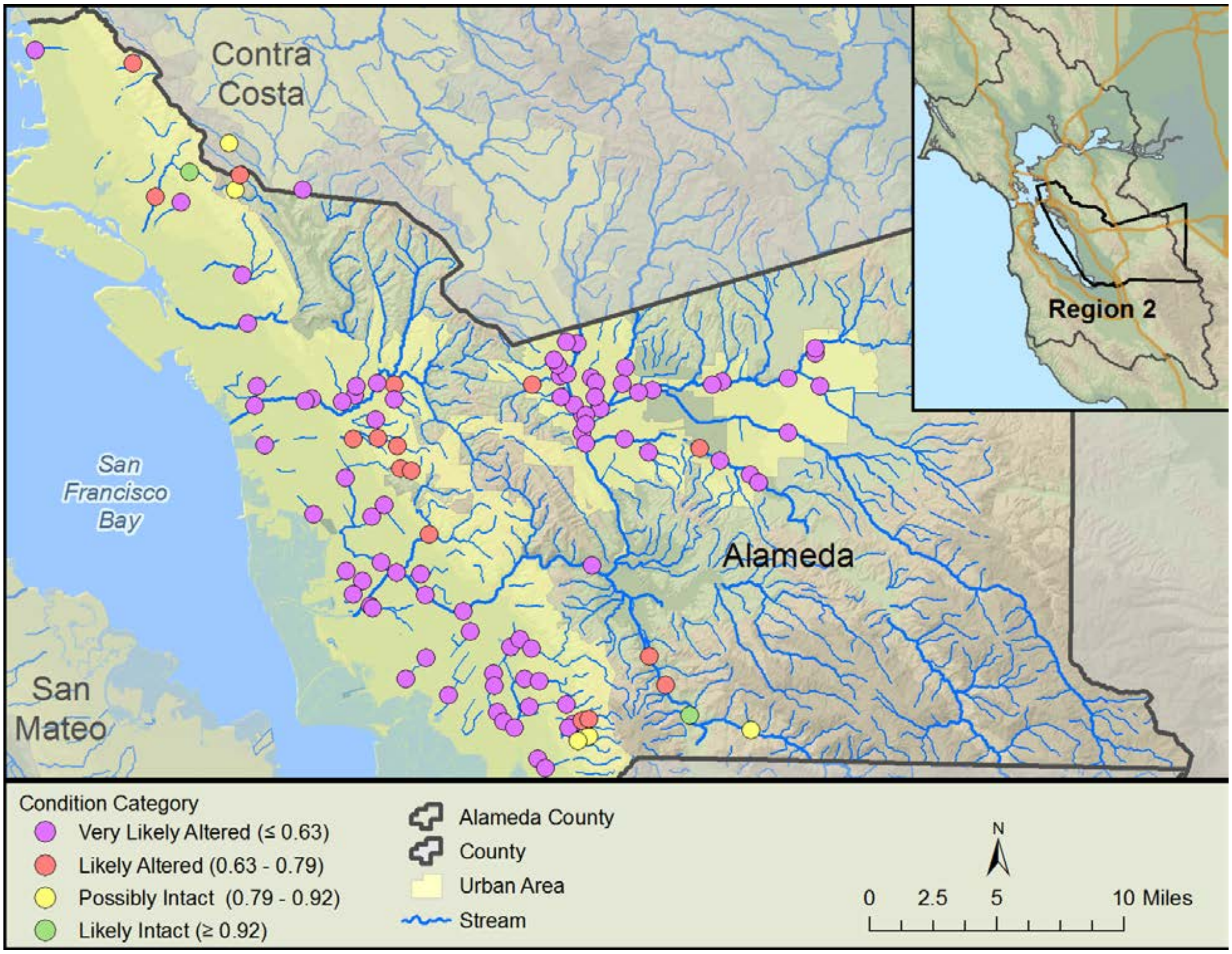

Figure 4-A. Biological condition based on CSCI scores in Alameda County.

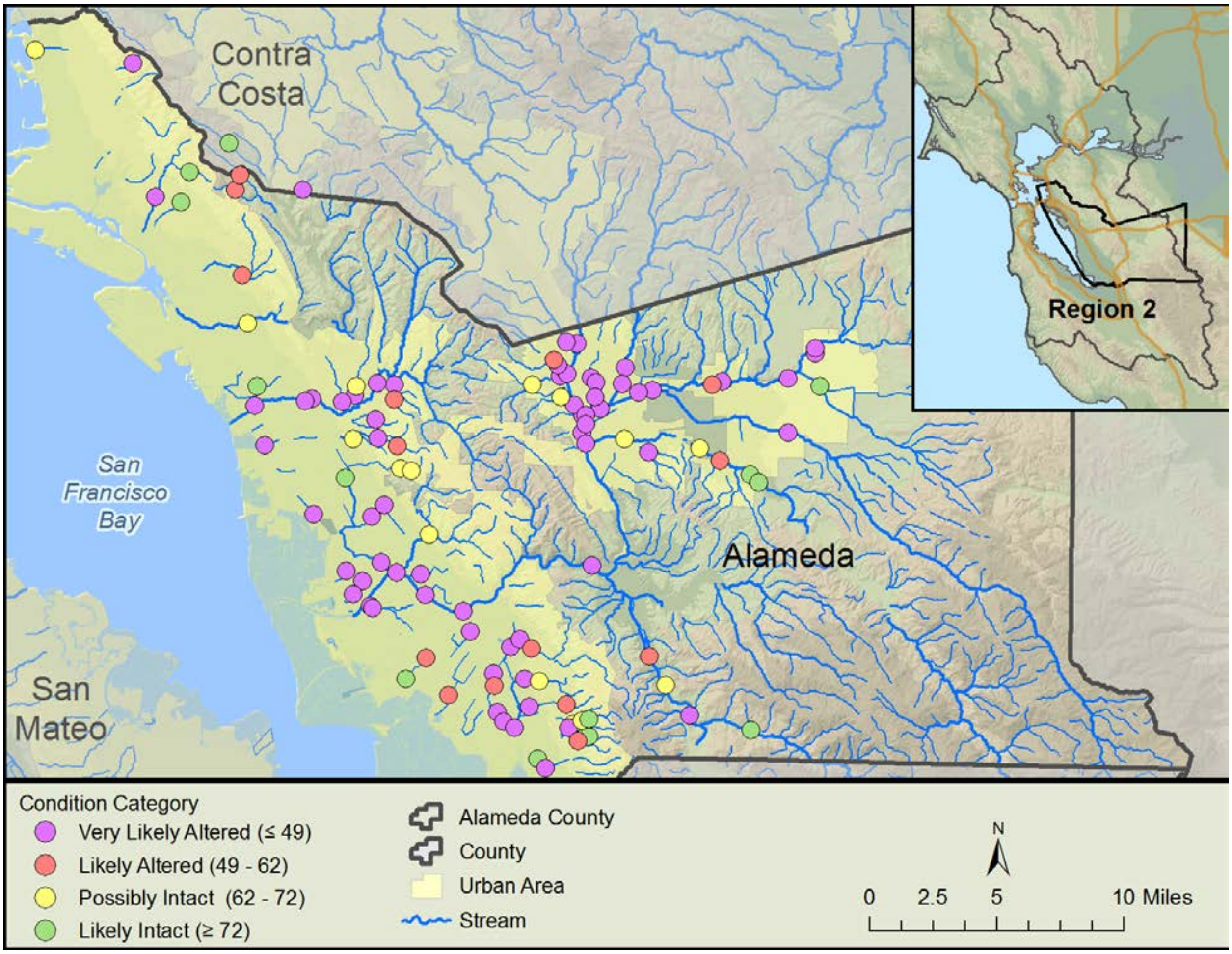

Figure4-B. Biological condition based on D18 scores in Alameda County.

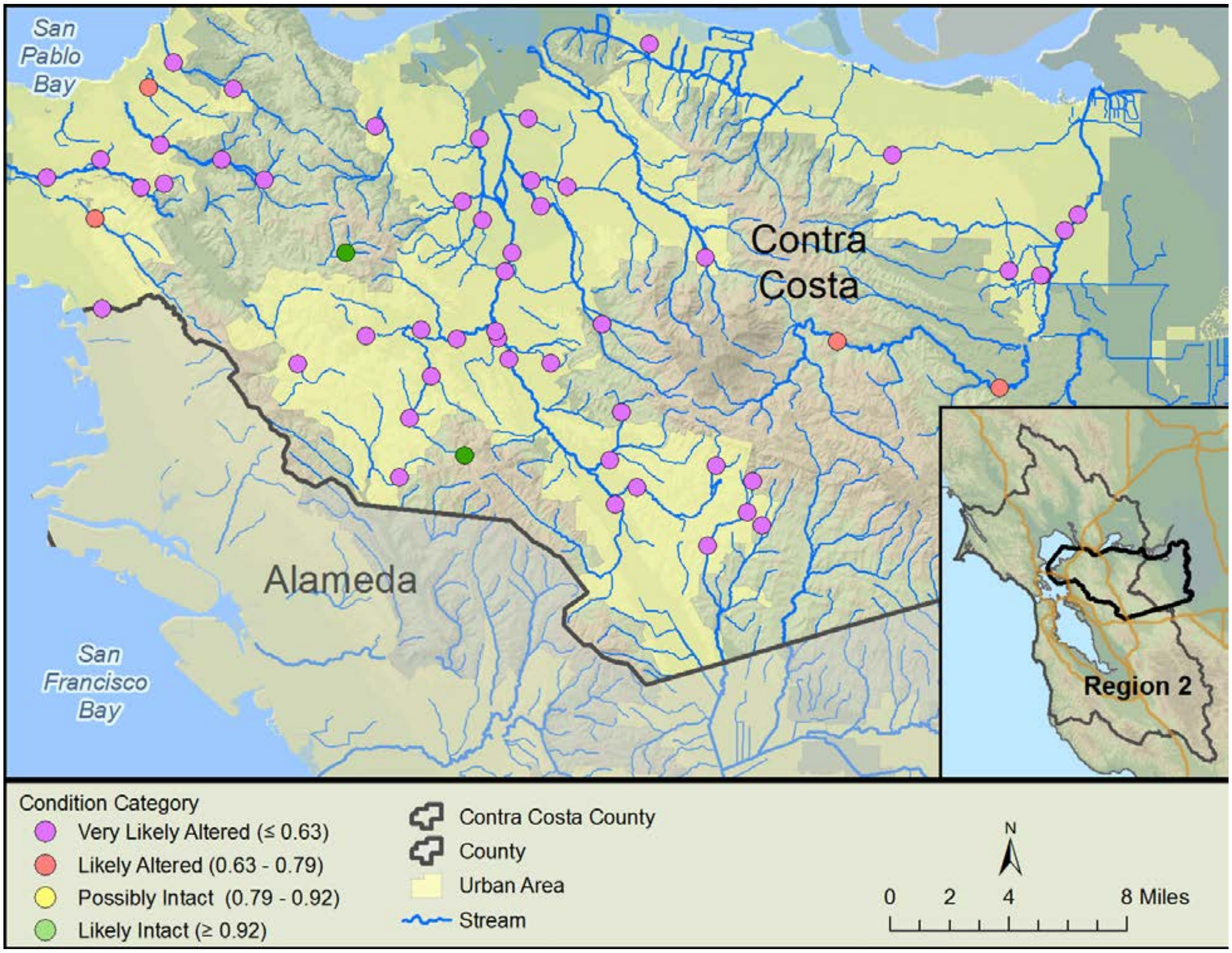

Figure 4-C. Biological condition based on CSCI scores in Contra Costa County.

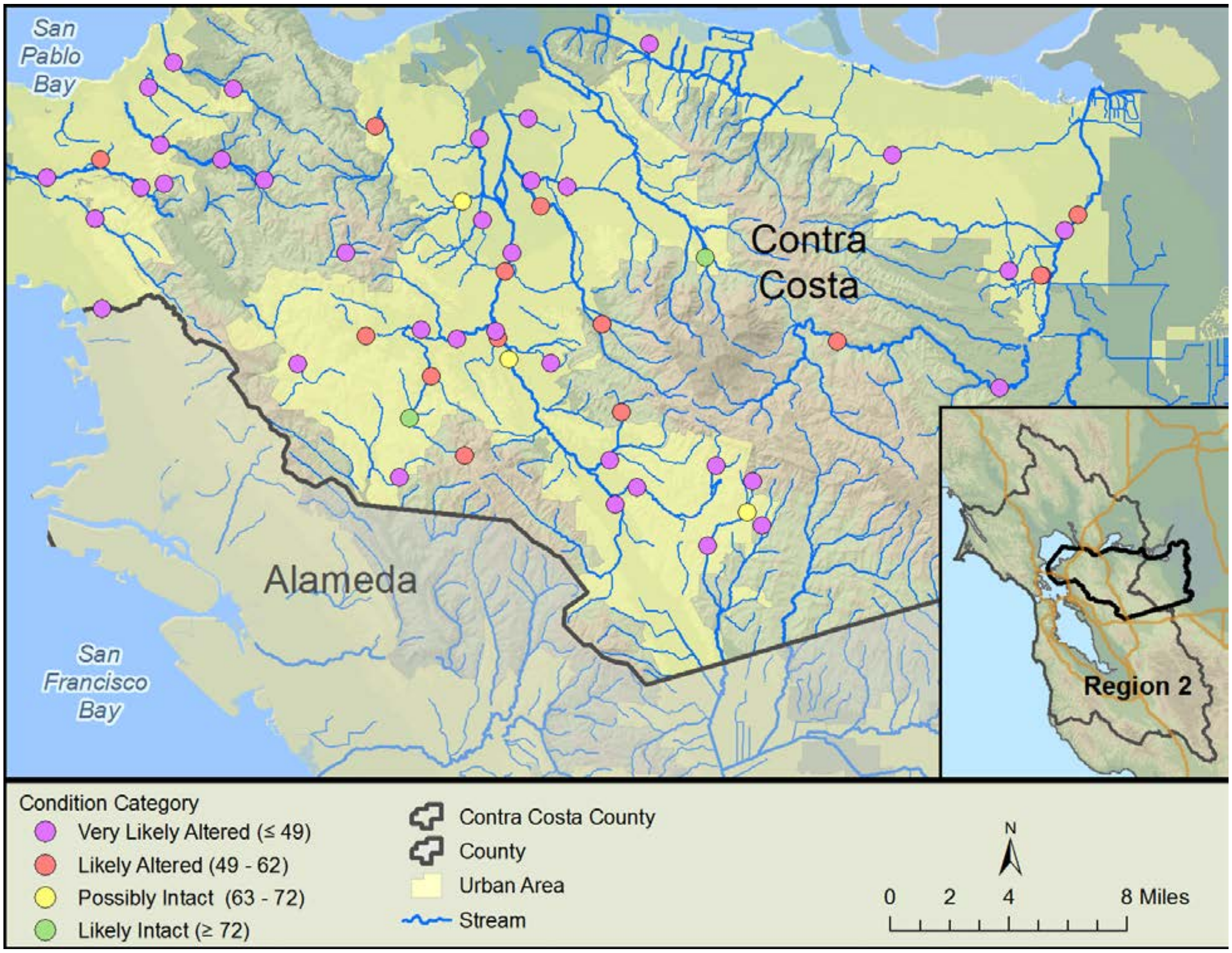

Figure 4-D. Biological condition based on D18 scores in Contra Costa County.

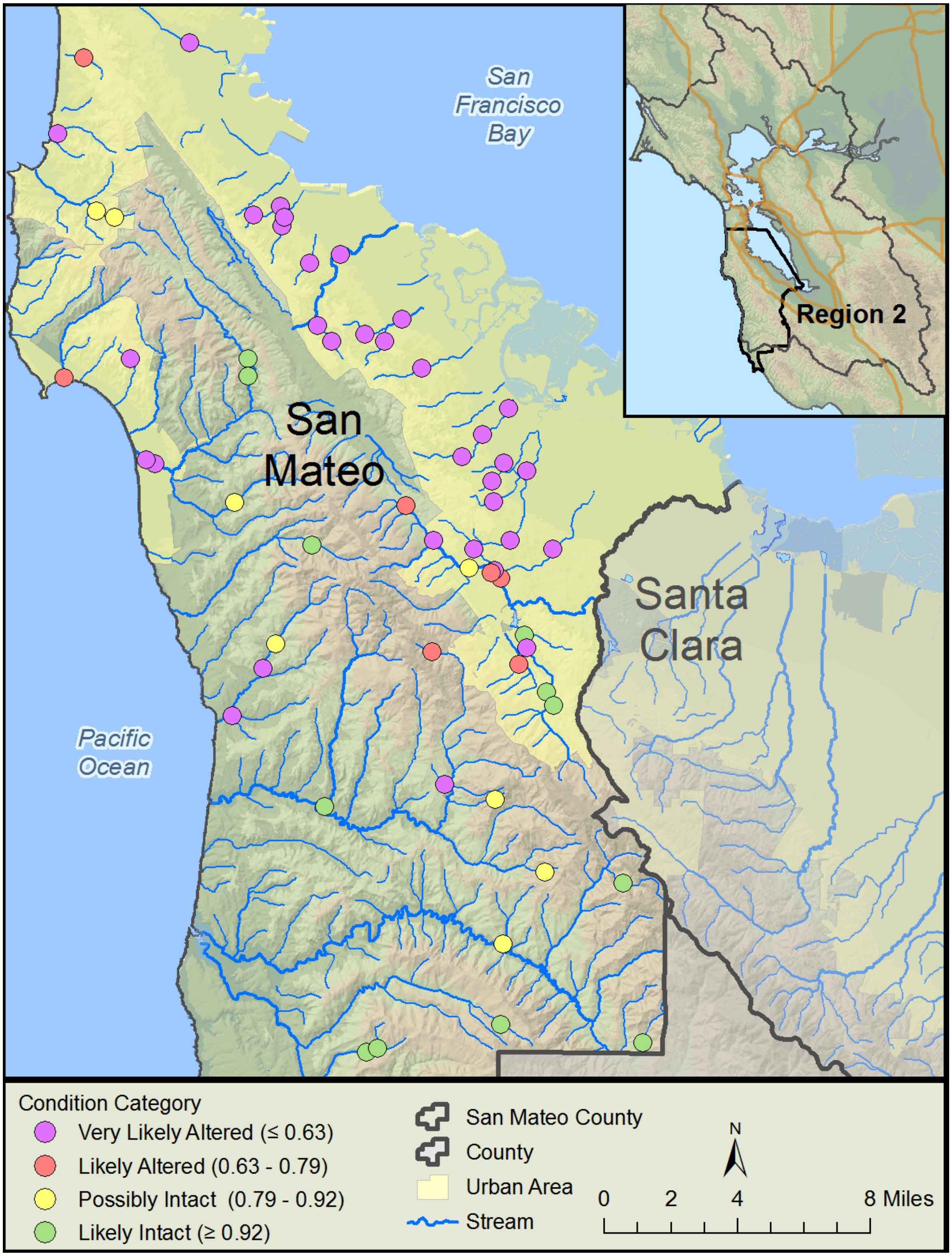

Figure 4-E. Biological condition based on CSCI scores in San Mateo County.

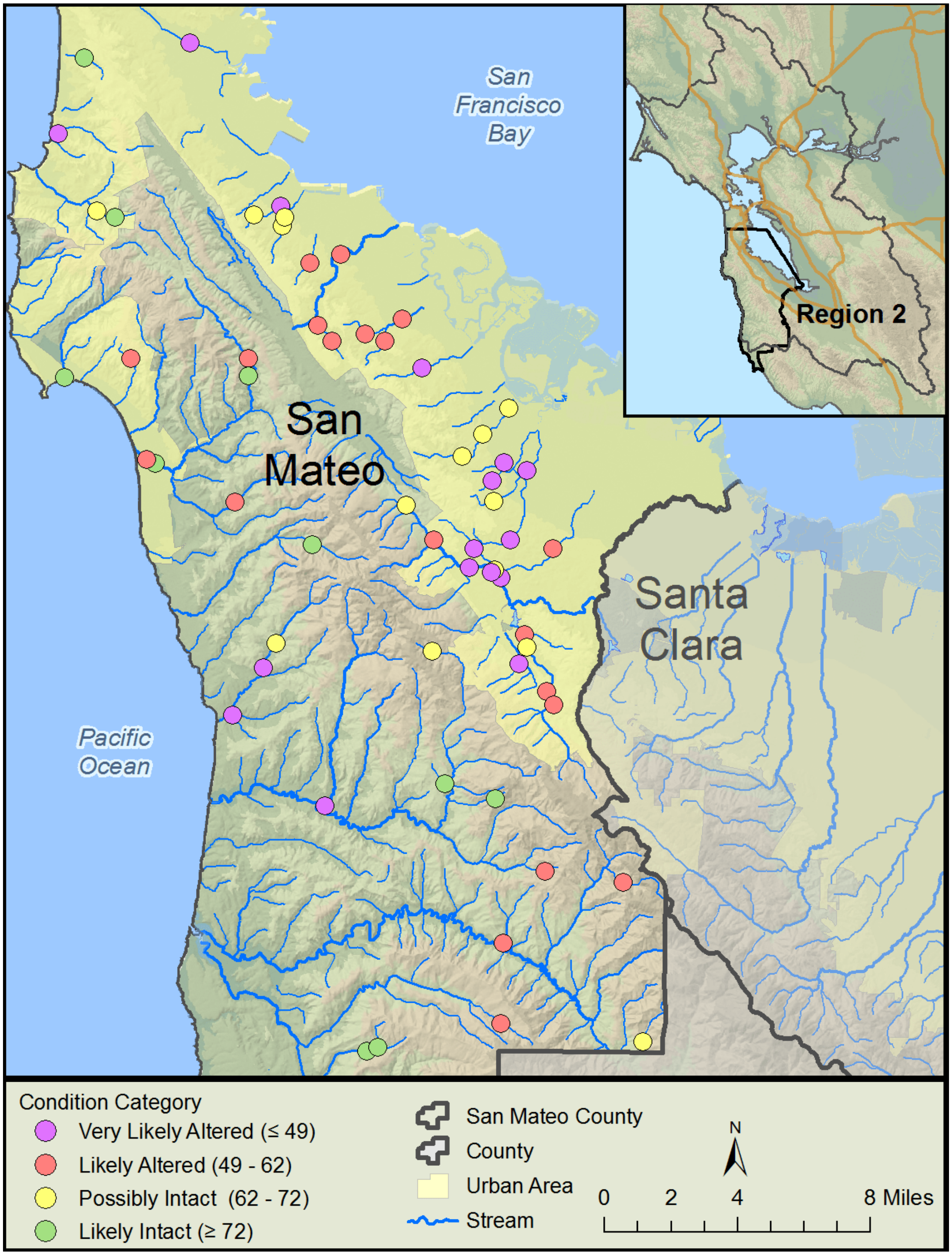

Figure 4-F. Biological condition based on D18 scores in San Mateo County.

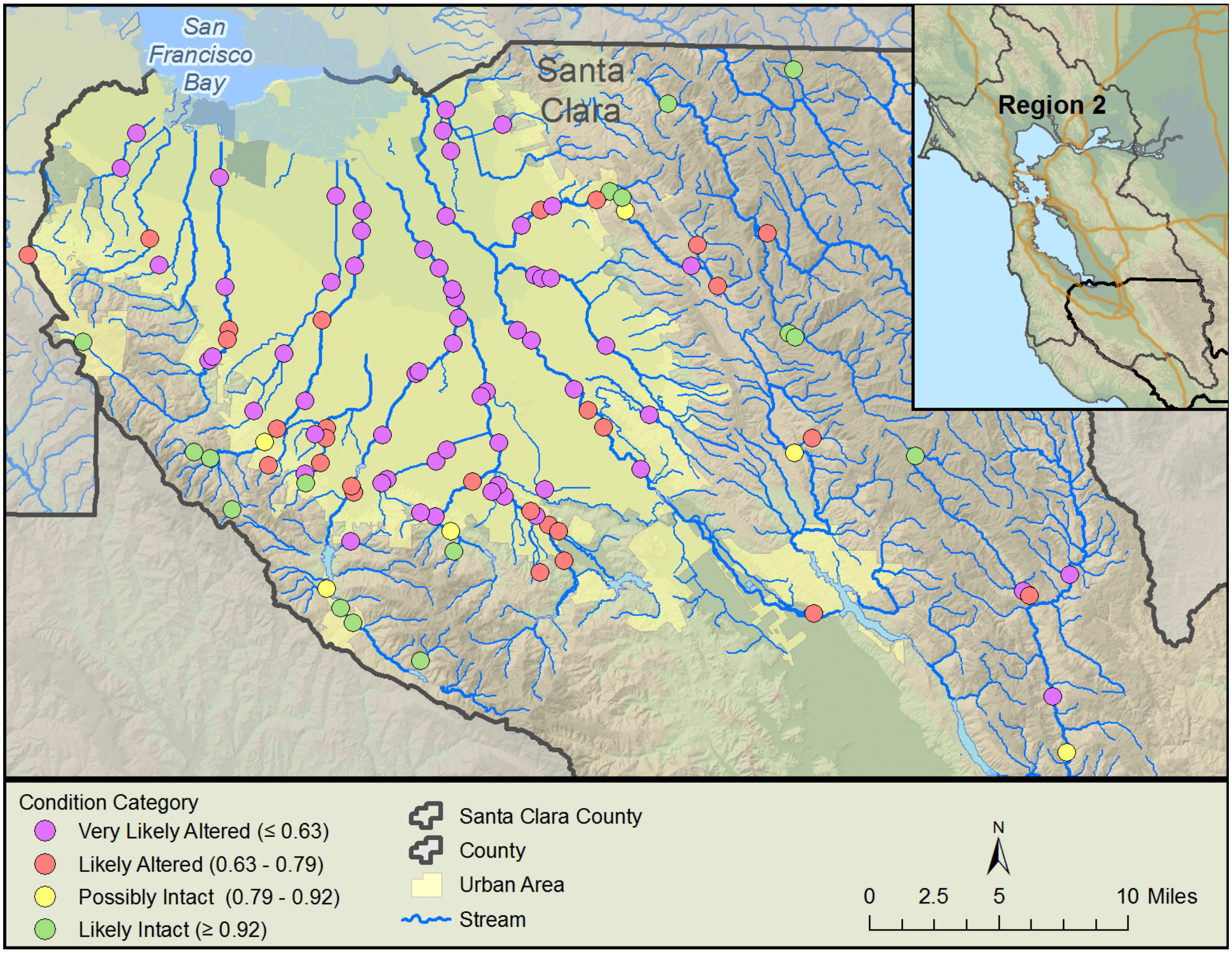

Figure 4-G. Biological condition based on CSCI scores in Santa Clara County.

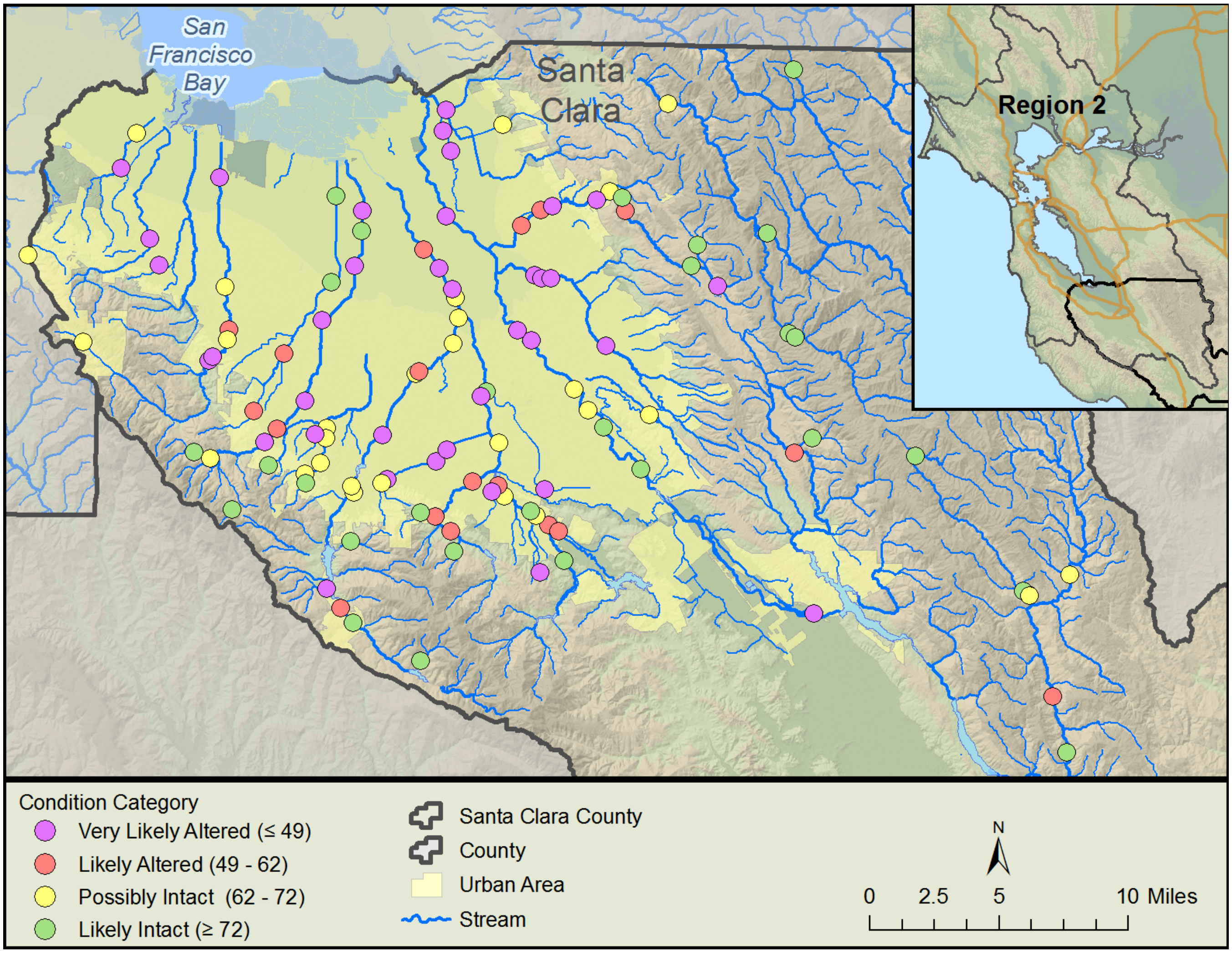

Figure 4-H. Biological condition based on D18 scores in Santa Clara County.

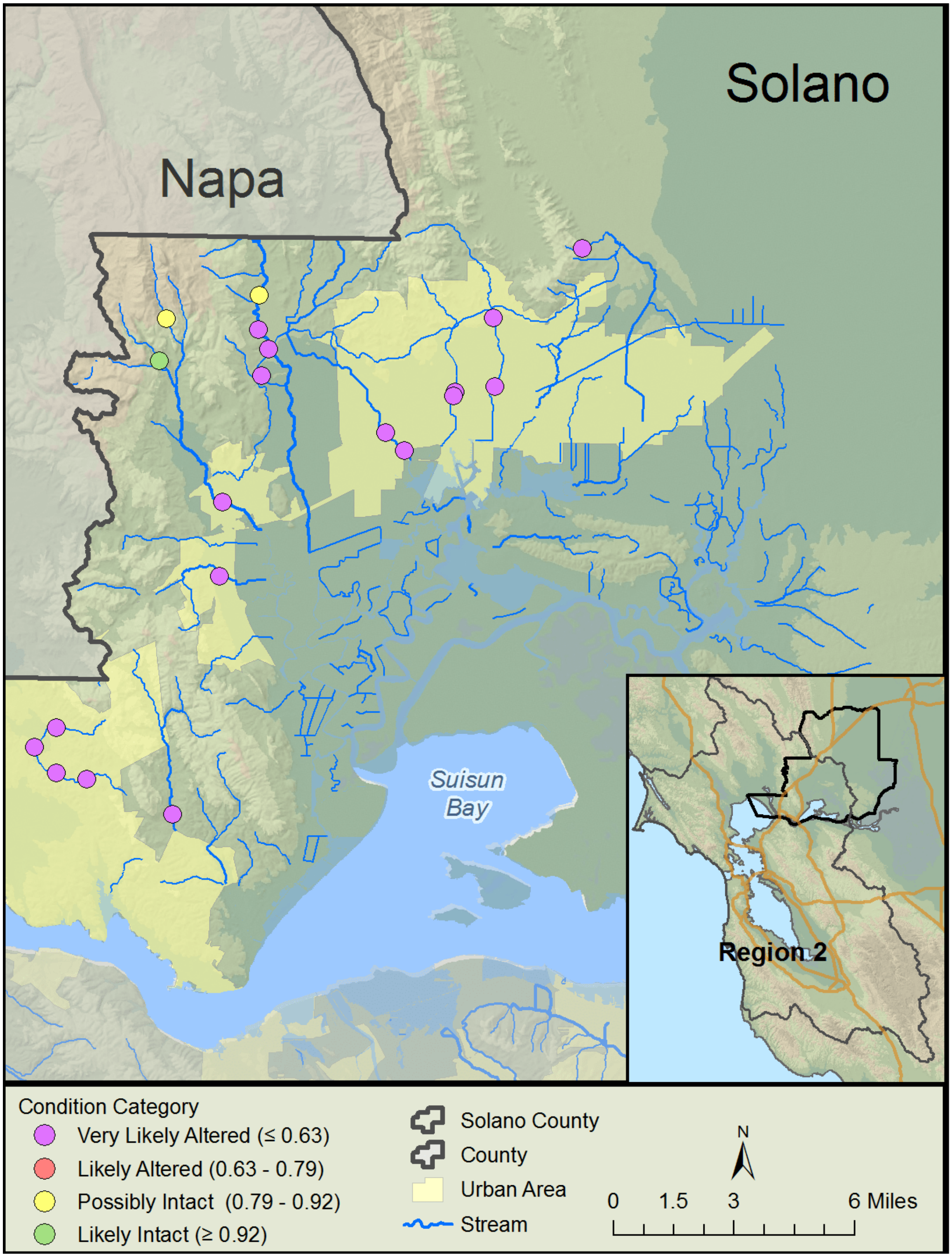

Figure 4-I. Biological condition based on CSCI scores in Solano County.

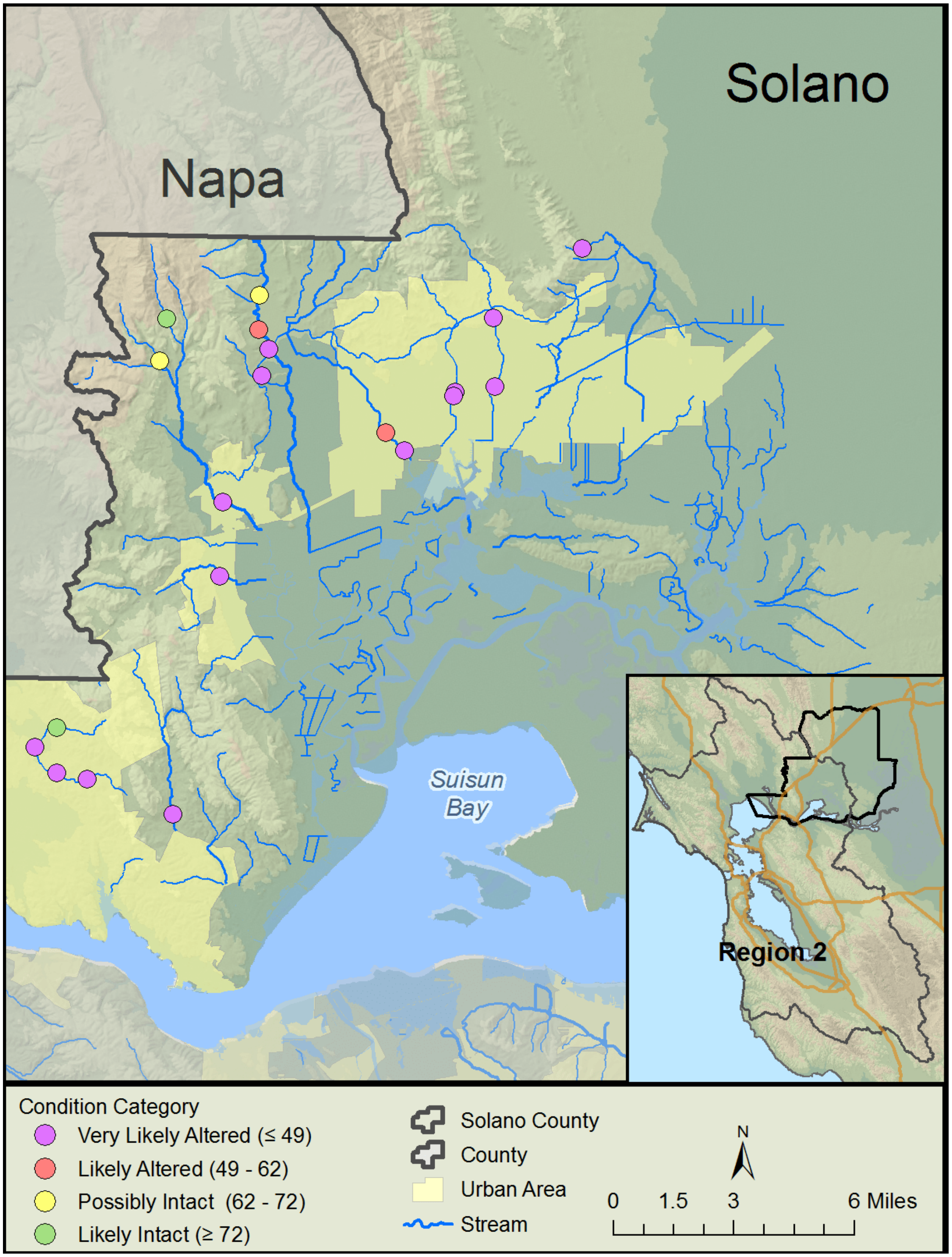

Figure 4-J. Biological condition based on D18 scores in Solano County.

Appendix B

Regional Stressor/Source Identification (SSID) Report

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 2019

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	1/14/19	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 was submitted in August 2018. WY 2018 sampling and monitoring took place April – September and the data are currently being processed.	
AL-2	3/5/19	ACCWP	Arroyo Las Positas		Arroyo las Positas Stressor Source Identification Project	X									CSCI scores below the threshold were recorded on Arroyo Las Positas in WYs 2016 and 2017. In 2017, one site exceeded the Basin Plan threshold for chloride. The creek is also listed on the 303(d) list for eutrophication and has an approved TMDL for Diazinon.	ACCWP is exploring a potential SSID project on Arroyo las Positas. The Water Board is conducting sampling in the watershed as part of their TMDL development efforts and an SSID project may combine well with those efforts and generate a better overall picture of stressors impacting the waterbody.	The SSID project is under development. The Final SSID project may end up focusing on a different waterbody depending on the outcome of communications with Water Board staff and analysis of WY 2018 triggers.	
CC-1	1/2/19	CCCWP	Lower Marsh Creek		Marsh Creek Stressor Source Identification Study									X	9 fish kills have been documented in Marsh Creek between September 2005 and October 2017. A conclusive cause has not been identified.	This SSID study addresses the root causes of fish kills in Marsh Creek. Monitoring data collected by CCCWP and other parties are being used to investigate multiple potential causes, including low dissolved oxygen, warm temperatures, daily pH swings, fluctuating flows, physical stranding, and pesticide exposure.	The CCCWP SSID work plan was submitted in 2018 and is currently being implemented. The Year 1 Status Report is included in this WY 2018 UCMR.	
SC-1	1/12/19	SCVURPPP	Coyote Creek	NA	Coyote Creek Toxicity SSID Project						X				The SWRCB recently added Coyote Creek to the 303(d) list for toxicity.	This SSID study is investigating sources of toxicity to sediments in Coyote Creek. Results of sediment toxicity and chemistry monitoring conducted during the WY 2018 dry season were inconclusive. Sediment chemistry results were inconclusive and toxicity results too inconsistent to proceed with a TIE study. The WY 2018 results support earlier	The work plan was submitted with SCVURPPP's WY 2017 UCMR. A project report describing the results of the WY 2018 and WY 2019 monitoring will be	

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				
																findings from SCVURPPP and SPoT that toxicity and pesticide concentrations in Coyote Creek are sporadic. Additional monitoring will be conducted in WY 2019 to confirm the findings.	submitted with the WY 2019 UCMR.	
SC-2	2/19/19	SCVURPPP	TBD	TBD	TBD										TBD	TBD	Project options currently under discussion by Monitoring Ad Hoc Task Group	
SM-1	1/12/19	SMCWPPP	Pillar Point / Deer Creek / Denniston Creek	NA	Pillar Point Harbor Bacteria SSID Project								X		FIB samples from 2008, 2011-2012 exceeded WQOs.	A grant-funded Pillar Point Harbor MST study conducted by the RCD and UC Davis in 2008, 2011-2012 pointed to urban runoff as a primary contributor to bacteria at Capistrano Beach and Pillar Point Harbor. The study, however, did not identify the specific urban locations or types of bacteria. This SSID project is investigating bacteria contributions from the urban areas within the watershed. In WY 2018, Pathogen indicator and MST monitoring was conducted at 14 freshwater sites during 2 wet and 2 dry events. Very few samples contained "controllable" source markers (i.e., human and dog). Additional field studies are being conducted in WY 2019 to understand hydrology and specific source areas.	The work plan was submitted with SMCWPPP's WY 2017 UCMR. A project report describing the results of the WY 2018 and WY 2019 investigations will be submitted with the WY 2019 UCMR.	
FSV-1	2/4/2019	City of Vallejo in assoc. with FSURMP	Rindler Creek	207R03504	Rindler Creek Bacteria and Nitrogen Study								X		E. coli result of 2800 MPN/100mL in Sept., 2017.	A source identification study is warranted in Rindler Creek due to the elevated FIB result, other (non-RMC) monitoring indicating elevated ammonia levels, and the presence of a suspected pollutant source upstream of the data collection point. Rindler Creek is a highly urbanized and modified creek that originates in open space northeast of the City of Vallejo. Monitoring is conducted just downstream of the creek crossing under Columbus Parkway; upstream of this site there is City-owned land that is grazed by cattle roughly from December-June.	Project planning is proceeding in FY 2018-19. Follow-up monitoring is being performed during early 2019 to verify the spatial and temporal extent of the water quality issues during the grazing period.	

MRP 2.0 SSID Project Locations, Rationales, Status

Updated March 2019

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				
RMC-1	1/12/19	RMC/ Regional	NA (entire RMC area)	NA	Regional SSID Project: Electrical Utilities as a Potential PCBs Source to Stormwater in the San Francisco Bay Area									X	Fish tissue monitoring in San Francisco Bay led to the Bay being designated as impaired on the CWA 303(d) list and the adoption of a TMDL for PCBs in 2008. POC monitoring suggests diffuse PCBs sources throughout region.	PCBs were historically used in electrical utility equipment, some of which still contain PCBs. Although much of the equipment has been removed from services, ongoing releases and spills may be occurring at levels approaching the TMDL waste load allocation. This regional SSID project will investigate opportunities for BASMAA RMC partners to work with RWQCB staff to: 1) improve knowledge about the extent and magnitude of PCB releases and spills, 2) improve the flow of information from utility companies, and 3) compel cooperation from utility companies to implement improved control measures.	A work plan is currently under development and is anticipated for submittal with the WY 2018 UCMRs.	

Appendix C

SMCWPPP Pollutants of Concern Data Report, Water Year 2018

POLLUTANTS OF CONCERN MONITORING DATA REPORT

Water Year 2018

Submitted in Compliance with
NPDES Permit No. CAS612008 (Order No. R2-2015-0049)
Provision C.8.h.iii

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

A Program of the City/County Association of Governments

March 31, 2019

CREDITS

This report is submitted by the participating agencies in the

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program
Clean Water. Healthy Community.
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City of Belmont
City of Brisbane
City of Burlingame
Town of Colma
City of Daly City
City of East Palo Alto
City of Foster City
City of Half Moon Bay
Town of Hillsborough
City of Menlo Park
City of Millbrae
City of Pacifica
Town of Portola Valley
City of Redwood City
City of San Bruno
City of San Carlos
City of San Mateo
City of South San Francisco
Town of Woodside
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Prepared for:
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A Program of the City/County Association of Governments (C/CAG)

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LIST OF ABBREVIATIONS

BASMAA	Bay Area Stormwater Management Agency Association
BMP	Best Management Practice
CEC	Contaminants of Emerging Concern
CEDEN	California Environmental Data Exchange Network
CSCI	California Stream Condition Index
CW4CB	Clean Watersheds for Clean Bay
DTSC	California Department of Toxic Substances Control
ECWG	Emerging Contaminants Work Group of the RMP
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollution Discharge Elimination System
PBDEs	Polybrominated Diphenyl Ethers
PCBs	Polychlorinated Biphenyls
PFAS	Perfluoroalkyl Sulfonates
PFOS	Perfluorooctane Sulfonates
POC	Pollutant of Concern
RMC	Regional Monitoring Coalition
RMP	San Francisco Bay Regional Monitoring Program
RWSM	Regional Watershed Spreadsheet Model
SAP	Sampling and Analysis Plan
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program (Countywide Program)
SFEI	San Francisco Estuary Institute
SPoT	Statewide Stream Pollutant Trend Monitoring
SSC	Suspended Sediment Concentration
STLS	Small Tributary Loading Strategy
TOC	Total Organic Carbon
UCMR	Urban Creeks Monitoring Report
USEPA	US Environmental Protection Agency
WQO	Water Quality Objective
WY	Water Year

1.0 INTRODUCTION

This Pollutants of Concern (POC) Monitoring Data Report (POC Data Report) was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP or Countywide Program), a program of the San Mateo County City/County Association of Governments (C/CAG). SMCWPPP prepared this report on behalf of San Mateo County local agencies subject to the National Pollutant Discharge Elimination System (NPDES) regional stormwater permit for Bay Area municipalities, referred to as the Municipal Regional Permit (MRP). The MRP was reissued by the San Francisco Regional Water Quality Control Board (Regional Water Board) on November 19, 2015 (Regional Water Board 2015). This report fulfills the requirements of MRP Provision C.8.h.iii for reporting a summary of Provision C.8.f POC Monitoring conducted during Water Year (WY) 2018[1].

This POC Data Report builds on SMCWPPP's POC Monitoring Report dated October 15, 2018 (SMCWPPP 2018c). In accordance with MRP Provision C.8.h.iv, the POC Monitoring Report included POC monitoring locations, number and types of samples collected, purpose of sampling (i.e., Management Questions addressed), and analytes measured. The October 15, 2018 POC Monitoring Report also described the POC monitoring allocation of sampling effort planned for WY 2019.

This POC Data Report is included as an appendix to the Countywide Program's WY 2018 Urban Creeks Monitoring Report (UCMR). In addition, consistent with MRP Provision C.8.h.ii, POC monitoring data generated from sampling of receiving waters (e.g., creeks) were submitted to the San Francisco Bay Area Regional Data Center for upload to the California Environmental Data Exchange Network (CEDEN)[2].

1.1. POC Monitoring Requirements

Provision C.8.f of the MRP requires monitoring of several POCs including polychlorinated biphenyls (PCBs), mercury, copper, emerging contaminants[3], and nutrients. Provision C.8.f specifies yearly (i.e., WY) and total (i.e., permit term) minimum numbers of samples for each POC. In addition, POC monitoring must address the five priority management information needs (i.e., Management Questions) identified in C.8.f:

1. **Source Identification** – identifying which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff;
2. **Contributions to Bay Impairment** – identifying which watershed source areas contribute most to the impairment of San Francisco Bay beneficial uses (due to source intensity and sensitivity of discharge location);

---

[1] The water quality monitoring described in this report was conducted on a Water Year basis. A Water Year begins on October 1 and ends on September 30 of the named year. For example, Water Year 2018 (WY 2018) began on October 1, 2017 and concluded on September 30, 2018.

[2] CEDEN has historically only accepted and shared data collected in streams, lakes, rivers, and the ocean (i.e., receiving waters). In late-2016, we were notified that there were changes to the types of data that CEDEN would accept and share. However, pending further clarification, SMCWPPP will continue to submit only receiving water data to CEDEN.

[3] Emerging contaminant monitoring requirements will be met through participation in the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) special studies. The special studies will account for relevant contaminants of emerging concern (CECs) in stormwater and will address at least PFOS, PFAS, and alternative flame retardants being used to replace PBDEs.

3. **Management Action Effectiveness** – providing support for planning future management actions or evaluating the effectiveness or impacts of existing management actions;
4. **Loads and Status** – providing information on POC loads, concentrations or presence in local tributaries or urban stormwater discharges; and
5. **Trends** – providing information on trends in POC loading to the Bay and POC concentrations in urban stormwater discharges or local tributaries over time.

The MRP specifies the minimum number of samples for each POC that must address each Management Question. For example, over the first five years of the permit, a minimum total of 80 PCBs samples must be collected and analyzed. At least eight PCB samples must be collected each year. By the end of year four[4] of the permit term, each of the five Management Questions must be addressed with at least eight PCB samples. It is possible that a single sample can address more than one information need. The MRP's POC Monitoring requirements are summarized in Table 1.

SMCWPPP participated in a Bay Area Stormwater Management Agencies Association (BASMAA) regional project that was developed to satisfy provision C.8.f requirements for SMCWPPP and other Bay Area stormwater programs to each collect at least eight PCBs and mercury samples that address Management Question No. 3 (Management Action Effectiveness). The study investigated the effectiveness of hydrodynamic separator (HDS) units and various types of biochar-amended bioretention soil media (BSM) at removing PCBs and mercury from stormwater runoff. The study is summarized in the main body of the Countywide Program's WY 2018 UCMR and further details are provided in the project reports (BASMAA 2019a and b).

Data gathering needed to comply with MRP provisions C.11 (Mercury Controls) and C.12 (PCBs controls) is partly addressed through Provision C.8.f (i.e., POC Monitoring). Similarly, certain samples collected per C.11 and C.12 count towards C.8.f POC monitoring requirements. The specific provisions and their associated timelines are:

- Provisions C.11.a.iii and C.12.a.iii require that Permittees provide a list of management areas in which new PCBs and mercury control measures will be implemented during the permit term. These management areas are designated "Watershed Management Areas" (WMAs). Progress toward developing the list was initially submitted in a report dated April 1, 2016 (SMCWPPP 2016a). Beginning with a report submitted with the Countywide Program's September 2016 Annual Report, the initial list was expanded upon by designating all catchments with high interest parcels (i.e., with land uses associated with PCBs such as old industrial, electrical and recycling) and/or with existing or planned PCBs and mercury controls as WMAs (SMCWPPP 2016b). The WMA list was further updated in reports (SMCWPPP 2017b and 2018b) submitted with the Countywide Program's September 2017 and September 2018 Annual Reports and will continue to be updated with each subsequent Annual Report, per MRP Provision C.11.a.iii(3). MRP Provision C.8.f (POC Monitoring) supports C.11/12.a requirements by requiring monitoring directed toward source identification (i.e., identifying WMAs and source properties within WMAs that provide the greatest opportunities for implementing cost-effective controls that reduce loads of PCBs in urban stormwater runoff).

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[4] Note that the minimum sampling requirements addressing information needs must be completed by the end of year four of the permit (i.e., WY 2019); however, the minimum number of total samples does not need to be met until the end of year five of the permit (i.e., WY 2020).

- Provision C.12.e requires that Permittees collect at least 20 composite samples (region-wide) of caulks and sealants used in storm drains or roadway infrastructure in public rights-of-way. The Countywide Program participated in a BASMAA regional project to address this requirement. Results of the investigation were documented by BASMAA (2018), a report submitted with the Countywide Program's 2018 Annual Report.

1.2. Third-Party Data

The Countywide Program strives to work collaboratively with water quality monitoring partners to develop mutually beneficial monitoring approaches. Provision C.8.a.iii of the MRP allows Permittees to use data collected by third-party organizations to fulfill monitoring requirements, provided the data are demonstrated to meet the required data quality objectives. As such, samples collected in San Mateo County through two ongoing programs, (1) the Small Tributary Loading Strategy (STLS) of the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) and (2) the State's Stream Pollution Trends (SPoT) Monitoring Program, supplement the Countywide Program's efforts towards achieving Provision C.8.f monitoring requirements. In addition, Clean Watersheds for a Clean Bay (CW4CB), a BASMAA project that was funded by a grant from USEPA and ended in 2017, provided WY 2016 data. Third party monitoring conducted by the RMP, SPoT, and CW4CB also provides context for reviewing and interpreting Countywide Program monitoring results. As in past years, this POC Data Report evaluates PCBs and mercury data from third-party POC monitoring efforts, along with data collected by the Countywide Program.

1.2.1. RMP STLS

The RMP's Small Tributary Loading Strategy (STLS) Team typically conducts annual monitoring for POCs on a region-wide basis. SMCWPPP is an active participant in the STLS and works with other Bay Area municipal stormwater programs to identify opportunities to direct RMP funds and monitoring activities towards addressing both short- and long-term municipal stormwater permit management questions. POC monitoring activities conducted by the STLS in recent years focused on pollutant loading monitoring at six region-wide stations (WY 2012 – WY 2014), including the Pulgas Creek Pump Station drainage station in San Mateo County, and wet weather characterization monitoring in catchments of interest (WY 2015 – WY 2018). The wet weather characterization sampling uses a similar approach to the PCBs and mercury sampling that has been implemented by SMCWPPP, and Countywide Program staff has assisted the STLS to select all of its PCBs and mercury monitoring stations in San Mateo County.

RMP STLS monitoring in WY 2019 will continue to focus on wet weather characterization. The number of stations in San Mateo County that will be targeted by the STLS will likely be limited to two or less and, similar to WY 2018, the STLS will likely monitor stations that were previously sampled but had relatively low PCBs concentrations.

In future years, RMP STLS monitoring is expected to shift towards Management Question No. 5 (Trends). A STLS Trends Strategy Team was initiated in WY 2015, with SMCWPPP participation in the Team since it convened. The Team is currently developing a regional monitoring program to assess trends in POC loading to San Francisco Bay from small tributaries. The STLS Trends Strategy will initially focus on PCBs and mercury, but will not be limited to those POCs. Analysis of recent and historical data collected at region-wide loadings stations suggests that PCBs concentrations are highly variable. Therefore, a monitoring design to detect trends with statistical confidence may require more samples than is feasible given budget constraints. The STLS Trends Strategy Team is continuing to evaluate available data to help inform developing feasible monitoring strategies. The preliminary design concept included additional monitoring at one or two of the region-wide loadings stations to gain a better understanding of the variability in PCBs concentrations/loadings in the existing dataset. However, uncertainties about the utility of developing a trends monitoring program that targets just one or two watersheds coupled with unknowns about how to extrapolate findings to the region has prompted the Trends Strategy Team to delay monitoring and focus instead on identifying practical modeling approaches. The Team is considering modeling options that could be used in concert with monitoring to detect and predict trends in POC loadings. A Trends Strategy Road Map is currently being developed. STLS Trends monitoring is not anticipated to commence before WY 2020.

1.2.2. SPoT Monitoring Program

SPoT conducts annual dry season monitoring (subject to funding constraints) of sediments collected from a statewide network of selected rivers and streams throughout California. The goal of the SPoT monitoring program is to investigate long-term trends in sediment toxicity and sediment contaminant concentrations, and relate contaminant concentrations and toxicity to watershed land uses. Sites are targeted in bottom-of-the-watershed locations with slow water flow and appropriate micromorphology to allow deposition and accumulation of sediments, including a station (204SMA020) near the mouth of San Mateo Creek in the City of San Mateo.

SPoT monitoring staff reported that the San Mateo Creek station was monitored in June 2018. Sediment samples were analyzed for mercury, copper, pesticides, a variety of organic pollutants, and toxicity, but not PCBs. Results of this WY 2018 SPoT monitoring are not yet available (Siegler 2018, personal communication). The most recent technical report prepared by SPoT program staff was published in 2016 and describes seven-year trends from the initiation of the program in 2008 through 2014 (Phillips et al. 2016). An update to the report is anticipated in mid-2019.

Table 1. MRP Provision C.8.f Pollutants of Concern Monitoring Requirements.

Pollutant of Concern	Media	Total Samples by the End of Year Five[d]	Yearly Minimum	Minimum Number of Samples That Must Be Collected for Each Information Need by the End of Year Four				
				Source Identification	Contributions to Bay Impairment	Management Action Effectiveness	Loads and Status	Trends
PCBs	Water or sediment	80	8	8	8	8	8	8
Total Mercury	Water or sediment	80	8	8	8	8	8	8
Total & Dissolved Copper	Water	20	2	--	--	--	4	4
Nutrients[a]	Water	20	2	--	--	--	20	--
Emerging Contaminants[b]	--	--	--	--	--	--	--	--
Ancillary Parameters[c]	--	--	--	--	--	--	--	--

[a] Ammonium[5], nitrate, nitrite, total Kjeldahl nitrogen, orthophosphate, total phosphorus (analyzed concurrently in each nutrient sample).

[b] Must include perfluorooctane sulfonates (PFOS, in sediment), perfluoroalkyl sulfonates (PFAS, in sediment), alternative flame retardants. The Permittee shall conduct or cause to be conducted a special study that addresses relevant management information needs for emerging contaminants. The special study must account for relevant Contaminants of Emerging Concern (CECs) in stormwater and would address at least PFOS, PFAS, and alternative flame retardants being used to replace PBDEs.

[c] Total Organic Carbon (TOC) should be collected concurrently with PCBs data when normalization to TOC is deemed appropriate. Suspended sediment concentration (SSC) should be collected in water samples used to assess loads, loading trends, or BMP effectiveness. Hardness data are used in conjunction with copper concentrations collected in fresh water.

[d] Total samples that must be collected over the five-year Permit term.

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[5] There are several challenges to collecting samples for "ammonium" analysis. Therefore, samples are analyzed for total ammonia which is the sum of un-ionized ammonia (NH_3) and ionized ammonia (ammonium, NH_{4+}). Ammonium concentrations are calculated by subtracting the calculated concentration of un-ionized ammonia from the measured concentration of total ammonia. Un-ionized ammonia concentrations are calculated using a formula provided by the American Fisheries Society that includes field pH, field temperature, and specific conductance. This approach was approved by Regional Water Board staff in an email dated June 21, 2016.

2.0 POC MONITORING RESULTS

In compliance with Provision C.8.f of the MRP, the Countywide Program conducted POC monitoring for PCBs, mercury, copper, and nutrients in WY 2018. General methods employed for POC monitoring and quality assurance/quality control (QA/QC) procedures were similar to previous years (SMCWPPP 2015, 2017a, 2018a). The MRP-required yearly minimum number of samples was met or exceeded for all POCs. The total number of samples collected for each POC, the organization conducting the monitoring, and the Management Questions addressed are summarized in Tables 2 - 5. Specific monitoring stations are shown in Table 6 and mapped in Figure 1. The sections below describe the results of the WY 2018 monitoring. Compliance with applicable water quality objectives (WQOs) is discussed in Section 3.0.

2.1. Statement of Data Quality

A comprehensive QA/QC program was implemented by the Countywide Program covering all aspects of POC monitoring. The QA/QC protocols were similar to previous years and continued to be based upon the Quality Assurance Project Plan (QAPP) developed for the CW4CB project (AMS 2012) and the BASMAA Regional Monitoring Coalition (RMC) QAPP (BASMAA 2016).

Data were assessed for seven data quality attributes: (1) Representativeness, (2) Comparability, (3) Completeness, (4) Sensitivity, (5) Contamination, (6) Accuracy, and (7) Precision. Data Quality Objectives (DQOs) related to these categories were established to ensure that the data collected are of adequate quality for the intended uses. Overall, the results of the QA/QC review suggested that the POC monitoring data generated during WY 2018 were of sufficient quality. Although, some data were flagged in the project database, none was rejected based on comparison to the DOQs. Attachment 1 contains a report summarizing the results of the data validation.

Table 2. SMCWPPP and Third-Party POC Monitoring Accomplishments, PCBs, WYs 2016 - 2018.

Pollutant of Concern/ Organization	Number of PCBs Samples	Management Question Addressed[a]					Sample Type and Comments
		1. Source Identification	2. Contributions to Bay Impairment	3. Management Action Effectiveness	4. Loads and Status	5. Trends	
WY 2018							
SMCWPPP	13	13	13	--	13	1	Stormwater runoff samples to characterize WMAs
SMCWPPP	57	57	--	--	--	--	Upland sediment samples to identify source areas
BASMAA	5	5	--	--	--	--	Regional public infrastructure caulk/sealant samples (1/4 of project total)
BASMAA	8	--	--	8	--	--	Regional HDS unit & biochar effectiveness study (1/4 of project total)
RMP STLS	2	2	2	--	2	2	Stormwater runoff samples to characterize WMAs.
SPoT	--	--	--	--	--	--	Sediment sample to assess trends (mercury only, no PCBs)
WY 2017							
SMCWPPP	17	17	17	--	17	--	Stormwater runoff samples to characterize WMAs
SMCWPPP	67	67	--	--	--	--	Sediment samples to identify source areas
RMP STLS	4	4	4	--	4	--	Stormwater runoff samples to characterize WMAs
SPoT	1	--	--	--	--	1	Sediment sample to assess trends (PCBs only, no mercury)
WY 2016							
SMCWPPP	8	8	8	--	8	--	Stormwater runoff samples to characterize WMAs
RMP STLS	7	7	7	--	7	--	Stormwater runoff samples to characterize WMAs
CW4CB	--	--	--	3	--	--	BMP effectiveness samples at Bransten Road bioretention facilities
Total / MRP Minimum[b]	189 / 80	180 / 8	51 / 8	11 / 8	51 / 8	4 / 8	

NA = Not Applicable. For this pollutant, the MRP does not require sampling to address the management question.

[a] Individual samples can address more than one Management Question simultaneously.

[b] The MRP overall minimum number of samples must be met by the end of the five-year permit term. The MRP minimum number of samples for each Management Question must be met by the end of year four of the permit.

Table 3. SMCWPPP and Third-Party POC Monitoring Accomplishments, Mercury, WYs 2016 - 2018.

Pollutant of Concern/ Organization	Number of Mercury Samples	Management Question Addressed[a]					Sample Type and Comments
		1. Source Identification	2. Contributions to Bay Impairment	3. Management Action Effectiveness	4. Loads and Status	5. Trends	
WY 2018							
SMCWPPP	13	13	13	--	13	1	Stormwater runoff samples to characterize WMAs
SMCWPPP	57	57	--	--	--	--	Upland sediment samples to identify source areas
BASMAA	8	--	--	8	--	--	Regional HDS unit & biochar effectiveness study (1/4 of project total)
RMP STLS	2	2	2	--	2	2	Stormwater runoff samples to characterize WMAs
SPoT	1	--	--	--	--	1	Sediment sample to assess trends (mercury only, no PCBs)
WY 2017							
SMCWPPP	17	17	17	--	17	--	Stormwater runoff samples to characterize WMAs
SMCWPPP	67	67	--	--	--	--	Sediment samples to identify source areas
RMP STLS	4	4	4	--	4	--	Stormwater runoff samples to characterize WMAs
SPoT	--	--	--	--	--	--	Sediment sample to assess trends (PCBs only, no mercury)
WY 2016							
SMCWPPP	8	8	8	--	8	--	Stormwater runoff samples to characterize WMAs
RMP STLS	7	7	7	--	7	--	Stormwater runoff samples to characterize WMAs
CW4CB	--	--	--	3	--	--	BMP effectiveness samples at Bransten Road bioretention facilities
Total / MRP Minimum[b]	184 / 80	175 / 8	51 / 8	11 / 8	51 / 8	4 / 8	

NA = Not Applicable. For this pollutant, the MRP does not require sampling to address the management question.

[a] Individual samples can address more than one Management Question simultaneously.

[b] The MRP overall minimum number of samples must be met by the end of the five-year permit term. The MRP minimum number of samples for each Management Question must be met by the end of year four of the permit.

Table 4. SMCWPPP and Third-Party POC Monitoring Accomplishments, Copper, WYs 2016 - 2018.

Pollutant of Concern/ Organization	Number of Samples	Management Question Addressed[a]					Sample Type and Comments
		1. Source Identification	2. Contributions to Bay Impairment	3. Management Action Effectiveness	4. Loads and Status	5. Trends	
WY 2018							
SMCWPPP	4	--	--	--	4	4	Creek water samples collected during storm event and spring base flows
SPoT	1	--	--	--	--	1	Sediment sample to assess trends at long-term monitoring station
WY 2017							
SMCWPPP	1	--	--	--	1	--	Copper analyzed on a subset of PCBs/Hg stormwater runoff samples
SMCWPPP	5	--	--	--	5	2	Creek water samples collected during storm event and spring base flows[c]
SPoT	1	--	--	--	--	1	Sediment sample to assess trends at long-term monitoring station
WY 2016							
SMCWPPP	3	--	--	--	3	--	Copper analyzed on a subset of PCBs/Hg stormwater runoff samples
Total / MRP Minimum[b]	15 / 20	--	--	--	13 / 4	8 / 4	

NA = Not Applicable. For this pollutant, the MRP does not require sampling to address the management question.

[a] Individual samples can address more than one Management Question simultaneously.

[b] The MRP overall minimum number of samples must be met by the end of the five-year permit term. The MRP minimum number of samples for each Management Question must be met by the end of year four of the permit.

[c] One of these five samples was a PCBs/Hg stormwater runoff sample that was also analyzed for copper.

Table 5. SMCWPPP and Third-Party POC Monitoring Accomplishments, Nutrients, WYs 2016 - 2018.

Pollutant of Concern/ Organization	Number of Samples	Management Question Addressed[a]					Sample Type and Comments
		1. Source Identification	2. Contributions to Bay Impairment	3. Management Action Effectiveness	4. Loads and Status	5. Trends	
WY 2018							
SMCWPPP	4	--	--	--	4	NA	Creek water samples collected during storm event and spring base flows
WY 2017							
SMCWPPP	5	--	--	--	5	NA	Creek water samples collected during storm event and spring base flows
WY 2016							
SMCWPPP	2	--	--	--	2	NA	Creek water samples collected from bottom-of-the-watershed stations
Total / MRP Minimum[b]	11 / 20	--	--	--	11 / 20	NA	

NA = Not Applicable. For this pollutant, the MRP does not require sampling to address the management question.

[a] Individual samples can address more than one Management Question simultaneously.

[b] The MRP overall minimum number of samples must be met by the end of the five-year permit term. The MRP minimum number of samples for each Management Question must be met by the end of year four of the permit.

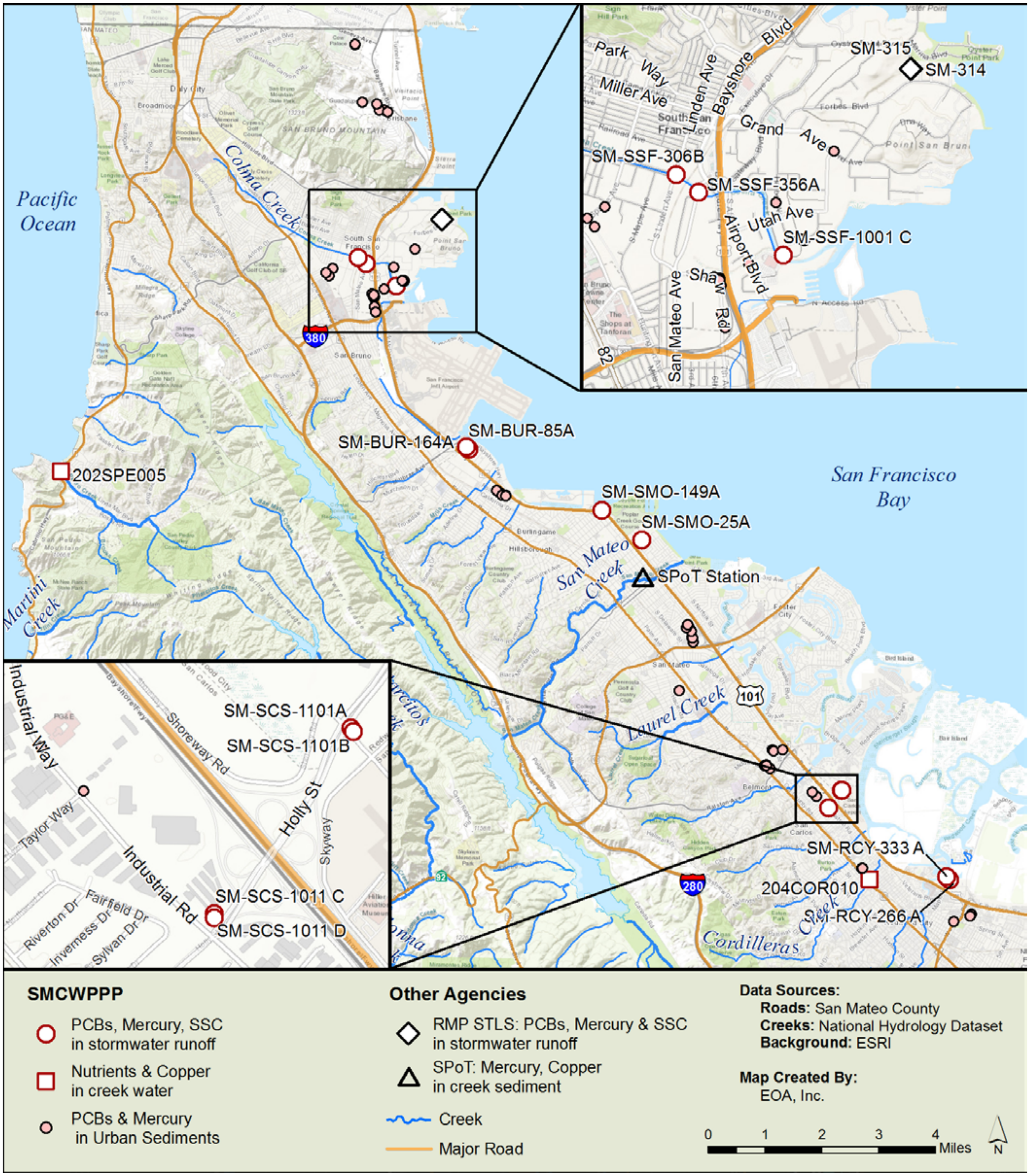

Figure 1. WY 2018 POC Monitoring Stations in San Mateo County (does not include BASMAA regional project sample locations).

Table 6. POC Monitoring Stations in San Mateo County, WY 2018.

Organization	Station Code	Sample Date	Latitude	Longitude	Matrix	PCBs	Mercury	Suspended Sediment	Total Copper	Dissolved Copper	Hardness as $CaCO_3$	Nutrients[a]
SMCWPPP												
SMCWPPP	SM-BUR-164A	1/8/2018	37.59960	-122.37526	SWR[b]	x	x	x				
SMCWPPP	SM-BUR-85A	1/8/2018	37.60194	-122.37499	SWR	x	x	x				
SMCWPPP	SM-SCS-1011A	1/8/2018	37.51701	-122.25379	SWR	x	x	x				
SMCWPPP	SM-SCS-1011B	1/8/2018	37.51692	-122.25373	SWR	x	x	x				
SMCWPPP	SM-SMO-149A	1/8/2018	37.58710	-122.33222	SWR	x	x	x				
SMCWPPP	SM-SMO-25A	1/8/2018	37.57970	-122.31911	SWR	x	x	x				
SMCWPPP	SM-SSF-366A	1/24/2018	37.64851	-122.40913	SWR	x	x	x				
SMCWPPP	SM-RCY-256A	3/1/2018	37.49483	-122.21869	SWR	x	x	x				
SMCWPPP	SM-RCY-333A	3/1/2018	37.49549	-122.21984	SWR	x	x	x				
SMCWPPP	SM-SCS-1011C	3/1/2018	37.51246	-122.25781	SWR	x	x	x				
SMCWPPP	SM-SCS-1011D	3/1/2018	37.51238	-122.25777	SWR	x	x	x				
SMCWPPP	SM-SSF-1001C	3/1/2018	37.64309	-122.39930	SWR	x	x	x				
SMCWPPP	SM-SSF-306B	4/6/2018	37.65024	-122.41170	SWR	x	x	x				
SMCWPPP	50 samples (see Appendix A)				sediment	x	x					
SMCWPPP	202SPE005	1/8/2018	37.59420	-122.50530	CW[c]				x	x	x	x
SMCWPPP	204COR010	1/8/2018	37.49450	-122.24430	CW				x	x	x	x
SMCWPPP	202SPE005	5/17/2018	37.59420	-122.50530	CW				x	x	x	x
SMCWPPP	204COR010	5/21/2018	37.49450	-122.24430	CW				x	x	x	x
Third Party Organizations												
RMP STLS	SM-SSF-314A	1/9/2018	37.66033	-122.38510	SWR	x	x	x				
RMP STLS	SM-SSF-315A	1/9/2018	37.66033	-122.38502	SWR	x	x	x				
SPoT	204SMA020	June 2018	37.5703	-122.3186	sediment		x		x			

[a] Ammonia (for ammonium), nitrate, nitrite, total Kjeldahl nitrogen, orthophosphate, and total phosphorus are analyzed concurrently in each nutrient sample.

[b] Stormwater Runoff – composite sample.

[c] Creek Water – grab sample.

2.2. PCBs and Mercury

The Countywide Program's PCBs and mercury monitoring focuses on San Mateo County WMAs (see Section 1.1) containing high interest parcels with land uses potentially associated with PCBs such as old industrial, electrical and recycling. During WY 2018, the Countywide Program collected 13 composite samples of stormwater runoff from outfalls at the bottom of WMAs and 50 grab embedded sediment samples within the WMAs. WY 2018 PCBs and mercury monitoring conducted by SMCWPPP primarily focused on addressing Management Question No. 1 (Source Identification), while contributing to the regional dataset being used to address Management Questions No. 2 (Contributions to Bay Impairment) and No. 3 (Loads and Status).

As part of continuing to develop strategies for reducing PCBs and mercury loads in stormwater runoff, the Countywide Program evaluated its WY 2018 PCBs and mercury stormwater runoff and sediment data, additional WY 2018 stormwater runoff sample data collected through the RMP STLS (see Section 1.2.1), and similar data from previous Water Years collected by the Countywide Program and through the STLS. Objectives include attempting to identify source areas and properties within WMAs, identifying which WMAs provide the greatest opportunities for implementing cost-effective PCBs controls, and prioritizing WMAs for potential future investigations.

2.2.1. Stormwater Runoff Monitoring in San Mateo County

During WY 2018, the Countywide Program collected 13 composite samples of stormwater runoff from outfalls at the bottom of WMAs that contain high interest parcels. An additional two stormwater runoff samples were collected in San Mateo County through the RMP's STLS, also from WMAs with high interest parcels. These combined 15 samples primarily help address Management Questions No. 1 (Source Identification). These data will also be used by the RMP STLS to improve calibration of the Regional Watershed Spreadsheet Model (RWSM), which is a land use based planning tool for estimation of overall POC loads from small tributaries to San Francisco Bay at a regional scale (i.e., Management Question No. 4 – Loads and Status).

SMCWPPP identified and prioritized WMAs for the WY 2018 stormwater runoff sampling by evaluating several types of data, including: land use, PCBs and mercury concentrations from prior sediment and stormwater runoff sampling efforts, municipal storm drain maps showing pipelines and access points (e.g., manholes, outfalls, pump stations), and logistical/safety considerations. Composite samples, consisting of four to eight aliquots collected during the rising limb and peak of the storm hydrograph (as determined through field observations), were analyzed for the 40 PCBs congeners used by the RMP for Bay samples[6] (method EPA 1668C), total mercury (method EPA 1631E), and suspended sediment concentration (SSC; method ASTM D3977-97).

Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. "Total PCBs" was calculated as the sum of the RMP 40 congeners. Particle ratio is calculated by dividing the total pollutant (PCBs or mercury) concentration by SSC. Assuming all of a pollutant is bound to suspended sediments in the water sample, particle ratios estimate the average concentration of pollutant on the suspended sediment and are sometimes referred to as particle concentration. Since PCBs and mercury are

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[6] PCBs congeners 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, l05, 110, 118, 128, 132, 138, 141, 149, l51, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, 203.

hypothesized to primarily be bound to sediment in aquatic environments, particle ratios are often used to normalize pollutant concentrations in samples with varying levels of suspended sediment.

For sites with more than one sample, total PCBs concentrations were averaged in Table 7. In addition, for sites with multiple samples, particle ratios in Table 7 were calculated by dividing the sum of PCBs concentrations by the sum of suspended sediment concentrations. This averaging is essentially equivalent to compositing all the individual samples that have been collected at a site. This is consistent with the RMP STLS approach to data evaluation (Gilbreath et al. 2019, in preparation).

Both of the WY 2018 RMP STLS catchments (WMAs 314 and 315, located in South San Francisco) had previously been sampled (in WY 2016) using similar methods. PCBs concentrations in the WY 2016 samples (stations SM-SSF-314A and SM-SSF-315A) were relatively low. PCBs concentrations (total PCBs and particle ratio) in samples from these stations were elevated (particle rations greater than 0.5 ppm) and roughly an order of magnitude higher in WY 2018, except that the PCBs particle ratio for sample SM-SSF-314A was at a similar elevated level for both events (Table 7). The PCBs monitoring data from WMAs 314 and 315 are described further in Section 2.2.4. In addition, STLS wet weather characterization data are described in greater detail by Gilbreath et al. (2019, in preparation).

One of the WY 2018 SMCWPPP stations (SM-SSF-306A/B[7]) had also previously been sampled (in WY 2015) by the RMP STLS using similar methods. The total PCBs concentration was about one-third of the concentration measured in WY 2015, but the PCBs particle ratio was not elevated (less than 0.2 ppm) and very similar to the previous sample (Table 7).

It should be noted that low PCBs concentrations in a composite stormwater runoff sample from the bottom of a catchment suggest that either PCBs sources are not prevalent in the catchment or the sample is a “false negative.” False negatives could be the result of low rainfall/runoff rates failing to mobilize sediments from source areas, or many other factors. The RMP is currently conducting an “Advanced Data Analysis” that will include attempting to develop a method to normalize results from this type of stormwater runoff composite PCBs sample based upon storm intensity.

2.2.2. Evaluation of Region-wide Water Sampling Data

This section evaluates data collected by the Countywide Program to-date on PCBs concentrations in stormwater runoff and natural waterways in the context of similar data collected throughout the Bay Area. The analysis included data from other countywide stormwater programs and the RMP STLS (Gilbreath et al. 2019, in preparation). The dataset includes stormwater runoff samples collected from 127 municipal separate storm sewer system (MS4) bottom of catchment stations and water samples from 28 natural waterways (usually creeks with generally natural channels) throughout the Bay Area. The MS4 catchment sites included storm drain manholes, outfalls, pump stations, and artificial channels.[8] Many of the sites have been sampled more than once and/or have multiple sample results reported for individual storm events. Twelve of the 127 MS4 sites have multiple sample results (sample counts of 2 to 80) and 15 of the 28 natural waterway sites have multiple sample results (sample counts of 3 to 126).

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[7] SM-SSF-306A/B are two nearby sampling locations in the MS4 at the bottom of the watershed that drain the same catchment (WMA 306). Thus for the purposes of this report they are essentially the same station.

[8] Stormwater runoff samples have also been collected from inlets and/or treatment systems (e.g., bioretention) during special studies. However, those are not included in this analysis.

PCBs concentrations in Bay Area stormwater runoff and natural waterway samples (n=155) are shown in Figure 2. PCBs particle ratios are shown in Figure 3. Figures 2 and 3 compare WY 2018 samples collected in San Mateo County to County samples collected in previous Water Years and samples collected outside of the County. In general, PCBs concentrations (total and particle ratio) in WY 2018 San Mateo County samples fell within a similar range compared to earlier County samples and samples collected outside of the County. Two of the three highest PCBs concentrations in the overall water sample dataset were for previous samples collected in San Mateo County, with Pulgas Creek Pump Station South having the highest PCBs concentration (average 448 ng/L) and SM-SCS-75A (Industrial Rd Ditch) having the third highest concentration (160 ng/L). The 33 samples collected at Pulgas Creek Pump Station South station had very elevated PCBs concentrations. The site has had the two highest PCBs concentrations (6,669 ng/L and 4,084 ng/L) measured out of 647 total individual samples and the four highest PCBs particle ratios (37,363 ng/g, 20,733 ng/g, 15,477 ng/g, and 14,744 ng/g).

Table 7. PCB, Mercury, and Suspended Sediment Concentrations in Stormwater Runoff Samples Collected in San Mateo County by SMCWPPP and the RMP STLS through WY 2018.

Station Code	Permittee	Sample Date	SSC (mg/L)	Total PCBs (ng/L)[a]	PCBs Particle Ratio (ng/g)[b]	Hg (ng/L)	Hg Particle Ratio (ng/g)
SMCWPPP Samples							
SM-BEL-60A	Belmont	2/9/2017	34	6.1	178	(c)	(c)
SM-BEL-60B	Belmont	2/9/2017	36	37.2	1,022	(c)	(c)
SM-BUR-1006A	Burlingame	12/15/2016	52	18.9	365	(c)	(c)
SM-BUR-141A	Burlingame	12/15/2016	51	8.5	165	(c)	(c)
SM-BUR-142A	Burlingame	12/15/2016	52	34.5	670	(c)	(c)
SM-BUR-164A	Burlingame	1/8/2018	9.9	4.4	447	5.3	532
SM-BUR-85A	Burlingame	1/8/2018	15	3.7	241	5.6	365
SM-MPK-238A	Menlo Park	3/5/2016	80	3.2	40	13	159
SM-MPK-238B	Menlo Park	3/5/2016	51	6.2	121	9	173
SM-MPK-66A	Menlo Park	3/24/2017	21	8.4	390	(c)	(c)
SM-MPK-71A	Menlo Park	2/17/2016	14	0.6	43	7	496
SM-RCY-254A	Redwood City	3/5/2016	14	1.6	113	10	712
SM-RCY-266A	Redwood City	3/1/2018	22	0.1	4.9	4.1	188
SM-RCY-323A	Redwood City	1/8/2017	8	1.6	191	(c)	(c)
SM-RCY-324A	Redwood City	1/8/2017	44	7.4	169	(c)	(c)
SM-RCY-327A	Redwood City	2/17/2016	44	5.7	130	15	341
SM-RCY-333A	Redwood City	3/1/2018	417	6.3	15	4.4	11
SM-RCY-379A	Redwood City	3/5/2016	123	13.0	106	18	149
SM-RCY-379B	Redwood City	3/5/2016	43	7.9	182	11	252
SM-RCY-388A	Redwood City	2/17/2016	50	2.5	50	15	311
SM-SCS-1011A	San Carlos	1/8/2018	60	10.8	181	3.9	66
SM-SCS-1011B	San Carlos	1/8/2018	15	2.5	167	6.1	408
SM-SCS-1011C	San Carlos	3/1/2018	28	5.8	204	0.7	25.3
SM-SCS-1011D	San Carlos	3/1/2018	25	5.8	230	0.7	26.1
SM-SMO-149A	San Mateo	1/8/2018	17	1.8	105	5.2	308
SM-SMO-156A	San Mateo	2/20/2017	91	18.5	204	(c)	(c)

Station Code	Permittee	Sample Date	SSC (mg/L)	Total PCBs (ng/L)[a]	PCBs Particle Ratio (ng/g)[b]	Hg (ng/L)	Hg Particle Ratio (ng/g)
SM-SMO-25A	San Mateo	1/8/2018	15	2.2	150	3.1	209
SM-SMO-408A	San Mateo	2/20/2017	29	55.3	1,900	(c)	(c)
SM-SMO-89A	San Mateo	1/10/2017	28	4.0	145	(c)	(c)
SM-SSF-1001B	South San Francisco	12/15/2016	32	55.2	1,714	(c)	(c)
SM-SSF-1001C	South San Francisco	3/1/2018	3.2	1.1	353	7.3	2,284
SM-SSF-292A	South San Francisco	12/15/2016	719	7.9	11	(c)	(c)
SM-SSF-294A	South San Francisco	12/15/2016	29	10.5	367	(c)	(c)
SM-SSF-306B	South San Francisco	4/6/2018	14	2.5	173	4.7	323
SM-SSF-316A	South San Francisco	12/10/2016	44	4.3	96	(c)	(c)
SM-SSF-317A	South San Francisco	12/10/2016	6	2.6	450	(c)	(c)
SM-SSF-318A	South San Francisco	12/10/2016	9	2.3	266	(c)	(c)
SM-SSF-356A	South San Francisco	1/24/2018	56	4.9	88	0.4	7.89
RMP Samples							
SM-SCS-210A (Pulgas South)	San Carlos[d]	33 samples[e]	54	448.0	8,222	N/A	N/A
SM-SCS-31A (Pulgas North)	San Carlos[d]	4 samples[e]	68	60.3	893	N/A	N/A
SM-BRI-1004A	Brisbane	3/5/2016	96	10.5	109	71	741
SM-BRI-17A	Brisbane	3/5/2016	96	10.4	109	27	276
SM-EPA-70A	East Palo Alto	2/6/2015	265	28.5	108	52	194
SM-EPA-72A	East Palo Alto	2/6/2015	82	6.5	79	35	427
SM-RCY-267A	Redwood City	12/2/2014	148	9.2	62	55	372
SM-RCY-337A	Redwood City	12/15/2014	29	3.5	121	14	469
SM-SCS-32A	San Carlos	3/11/2016	25	4.2	169	29	1,156
SM-SCS-75A	San Carlos	3/11/2016	26	159.6	6,139	14	535
SM-SSF-291A	South San Francisco	1/8/2017	16	11.8	736	12	775
SM-SSF-293A	South San Francisco	2/6/2015	45	5.2	117	20	436
SM-SSF-296A	South San Francisco	1/8/2017	111	3.4	30	39	350
SM-SSF-306A	South San Francisco	2/6/2015	43	7.8	182	29	679
SM-SSF-314A	South San Francisco	3/5/2016	10	8.6	859	6	562
SM-SSF-314A	South San Francisco	1/9/2018	75	71.0	946	5.1	68.0
SM-SSF-315A	South San Francisco	3/5/2016	33	5.8	175	10	315
SM-SSF-315A	South San Francisco	1/9/2018	91	93.2	1024	4.7	52.1
SM-SSF-319A	South San Francisco	3/5/2016	23	1.8	80	15	639
SM-SSF-359A	South San Francisco	2/7/2017	43	33.9	788	9	210

[a] Total PCBs calculated as sum of RMP 40 congeners.

[b] PCB and Hg Particle Ratios calculated by dividing Total PCBs and Hg concentrations by SSC.

[c] SMCWPPP WY 2017 mercury data were rejected by SMCWPPP's QA/QC Officer (see Section 2.1).

[d] Pulgas Pump Station watershed data were collected during Water Years 2011-2014.

[e] Results are averaged.

Note: stations that were resampled are indicated via shading. SM-SSF-306A/B are two nearby sampling locations in the MS4 at the bottom of the watershed that drain the same catchment (WMA 306). Thus for the purposes of this report they are essentially the same station.

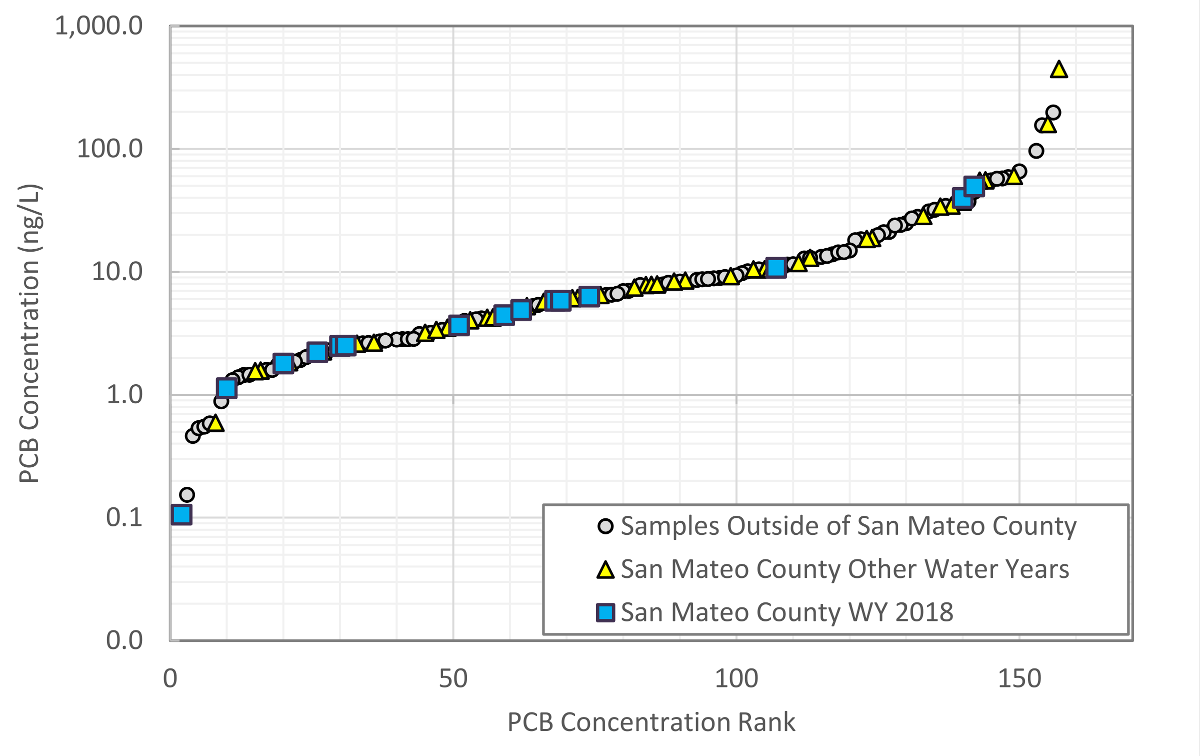

Figure 2. PCBs Concentrations in Stormwater Runoff Samples Collected in MS4s and Natural Waterways in the Bay Area.

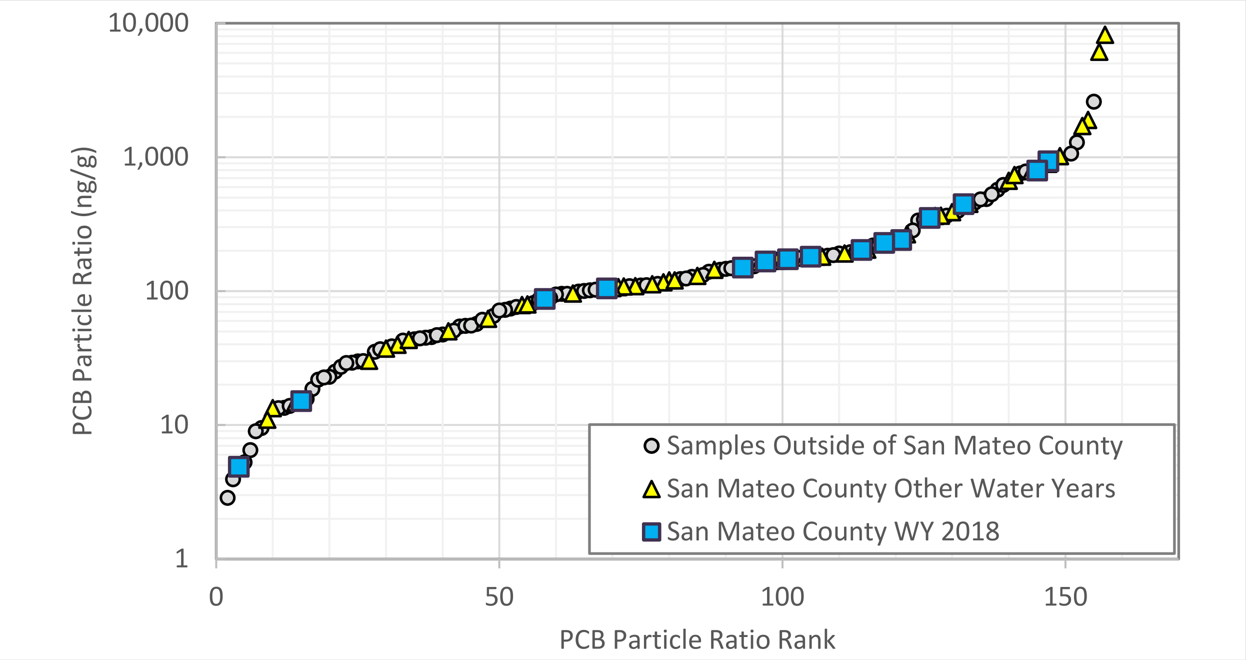

Figure 3. PCBs Particle Ratio in Stormwater Runoff Samples Collected in Large MS4s and Natural Waterways in the Bay Area.

Table 8 provides descriptive statistics for PCBs and mercury concentrations in the Bay Area stormwater runoff and natural waterway dataset (n=155). The median PCB concentration is 6.6 ng/L and the mean is 18.6 ng/L. The median PCB particle ratio is 114 ng/g and the mean is 323 ng/g. As can be seen in Figures 2 and 3, which are plotted on a log scale, there are a few catchments with highly elevated in PCBs (such as the Pulgas Creek Pump Station catchments) that greatly influence the mean concentration relative to the median (i.e., 50th percentile).

Table 8. Descriptive Statistics – PCBs and Mercury Concentrations in Bay Area Stormwater Runoff and Natural Waterway Water Samples through WY 2018[a]

	PCBs (ng/L)[b]	Hg (ng/L)	SSC (mg/L)	PCBs Particle Ratio (ng/g)[c]	Hg Particle Ratio (ng/mg)[c]
Min	ND[d]	0.4	3.2	ND	0.008
10th Percentile	1.56	4.10	16.0	15.5	0.11
25th Percentile	2.76	7.4	31.0	47.1	0.19
50th Percentile	6.6	15.4	55.8	114	0.33
75th Percentile	14.5	36.9	111	230	0.53
90th Percentile	41.7	70.7	266	745	0.77
Max	448	1,053	2,630	8,222	5.29
Mean	18.6	41.7	130	323	0.45

[a] Based upon 155 PCBs samples and 100 mercury samples.

[b] Total PCBs calculated as sum of RMP 40 congeners.

[c] PCBs and Hg Particle Ratios calculated by dividing Total PCBs and Hg concentrations by SSC, respectively.

[d] Not Detected.

2.2.3. Sediment Sampling in San Mateo County

During WY 2018, the Countywide Program collected 50 grab embedded sediment samples as part of the program to attempt to identify source properties within WMAs, potentially for referral to the Regional Water Board for further investigation and potential abatement. These samples were collected in the public right-of-way (ROW), including locations adjacent to high interest parcels with land uses associated with PCBs such as old industrial, electrical and recycling and/or other characteristics potentially associated with pollutant discharge (e.g., poor housekeeping, unpaved areas). Individual and composite sediment samples were collected from manholes, storm drain inlets, driveways, streets, and sidewalks.

Each sample was analyzed for the RMP 40 PCBs congeners and total mercury. Total PCBs was calculated as the sum of the 40 congeners. The laboratory passed all samples through a 2 mm sieve before analysis to remove gravel and cobbles. Table 9 compares the descriptive statistics for POC sediment samples that have been collected in San Mateo County to-date and WY 2018 samples. The mean and median PCBs concentrations were lower in WY 2018 than previous years. For the WY 2018 PCBs samples, one sample was above 1.0 mg/kg, four were between 0.2 and 0.5 mg/kg, and 45 were below 0.2 mg/kg. The median was 0.018 mg/kg and the mean was 0.077 mg/kg. For the WY2018 mercury samples, none was above 1.0 mg/kg, one was between 0.3 and 1.0 mg/kg, and 49 were below 0.3 mg/kg. The median was 0.074 mg/kg and the mean was 0.106 mg/kg.

Table 9. Descriptive Statistics – San Mateo County Embedded Sediment Sample PCBs & Mercury Concentrations

	All Samples To-date		WY 2018 Samples	
Number of Samples	**263**	**216**	**50**	**50**
	PCBs (mg/kg)[a]	**Hg (mg/kg)**	**PCBs (mg/kg)[a]**	**Hg (mg/kg)**
Min	0.001	0.006	0.002	0.019
10th Percentile	0.008	0.044	0.004	0.050
25th Percentile	0.017	0.060	0.009	0.060
50th Percentile	0.044	0.086	0.018	0.074
75th Percentile	0.116	0.158	0.043	0.119
90th Percentile	0.565	0.301	0.244	0.175
Max	193	3.93	1.02	0.831
Mean	1.25	0.208	0.077	0.106

[a] Total PCBs calculated as sum of RMP 40 congeners.

Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results. The results are discussed by WMA in the following section, along with sediment data from previous Water Years and the stormwater runoff data collected to-date.

2.2.4. Watershed Management Area Prioritization and Descriptions

The Countywide Program evaluated PCBs stormwater runoff and sediment monitoring data to help prioritize WMAs for further investigation and control measure implementation. Based upon the data collected in San Mateo County to-date by the Countywide Program and other parties (e.g., the RMP's STLS), WMAs with one or more sediment and/or stormwater runoff samples with PCBs concentrations (particle ratios for stormwater runoff) greater than 0.5 mg/kg (or 500 ng/g) were provisionally designated high priority. WMAs with samples in the 0.2 – 0.5 mg/kg (200 – 500 ng/g) range were provisionally designated medium priority. WMAs with stormwater runoff sample PCBs particle ratios less than 0.2 mg/kg (200 ng/g) were provisionally designated low priority. It is important to emphasize the provisional nature of these prioritizations, and especially designating a WMA as low priority due to a single stormwater runoff sample having a low PCBs particle ratio. As noted previously, low PCBs results in any single stormwater runoff sample could be a "false negative" in that they result from the storm not being large enough to mobilize sediments with associated PCBs, or other factors. In addition, embedded sediment sample results were not used to designate a WMA lower priority due to the high potential for false negatives. Figure 4 is a map illustrating the current status of WMAs in San Mateo County, based on this provisional prioritization scheme and sediment and stormwater runoff monitoring results to-date.[9] Only WMAs with high interest parcels were included in Figure 4.

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[9] Where sediment and stormwater runoff particle ratio analysis results conflict, the higher result was conservatively applied.

Attachment 3 provides a summary of PCBs and mercury monitoring results for San Mateo county WMAs. For each WMA, Attachment 3 includes:

- The WMA area, the area of high interest parcels in the WMA, and the percent of the total WMA area that is comprised of high interest parcels;
- A summary of the number of stormwater runoff and sediment samples collected to-date in the WMA; and
- The median and range of PCBs concentrations in the samples collected to-date in the WMA (median and range of PCBs particle ratio for stormwater runoff samples).

Of the 56 stormwater runoff samples collected in San Mateo County from WY 2015 - 2018 by the Countywide Program and the RMP, ten samples had PCBs particle ratios greater than 0.5 mg/kg, eleven were between 0.2 and 0.5 mg/kg, and the remainder were below 0.2 mg/kg.

Based on the available data to-date (e.g., sediment and stormwater runoff monitoring and land use research through WY 2018), WMAs with PCBs particle ratios over 0.2 mg/kg, elevated concentrations of PCBs in sediment samples, and/or other features relevant to PCBs investigations are described in more detail below.[10] All of the WMAs provisionally designated high or medium priority in Figure 4 are included in the below discussion.

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[10] The WMA IDs in San Mateo County are numerical (1 – 1017). Sample names consist of a prefix for the county (SM), followed by a three-letter prefix for the Permittee where the sample was collected (e.g., SSF for South San Francisco, SCS for San Carlos), followed by the WMA ID, and followed by a letter (e.g., A, B, C) to distinguish the sampling site from the WMA in which that sample was collected. Samples collected previously may have a different sample naming convention.

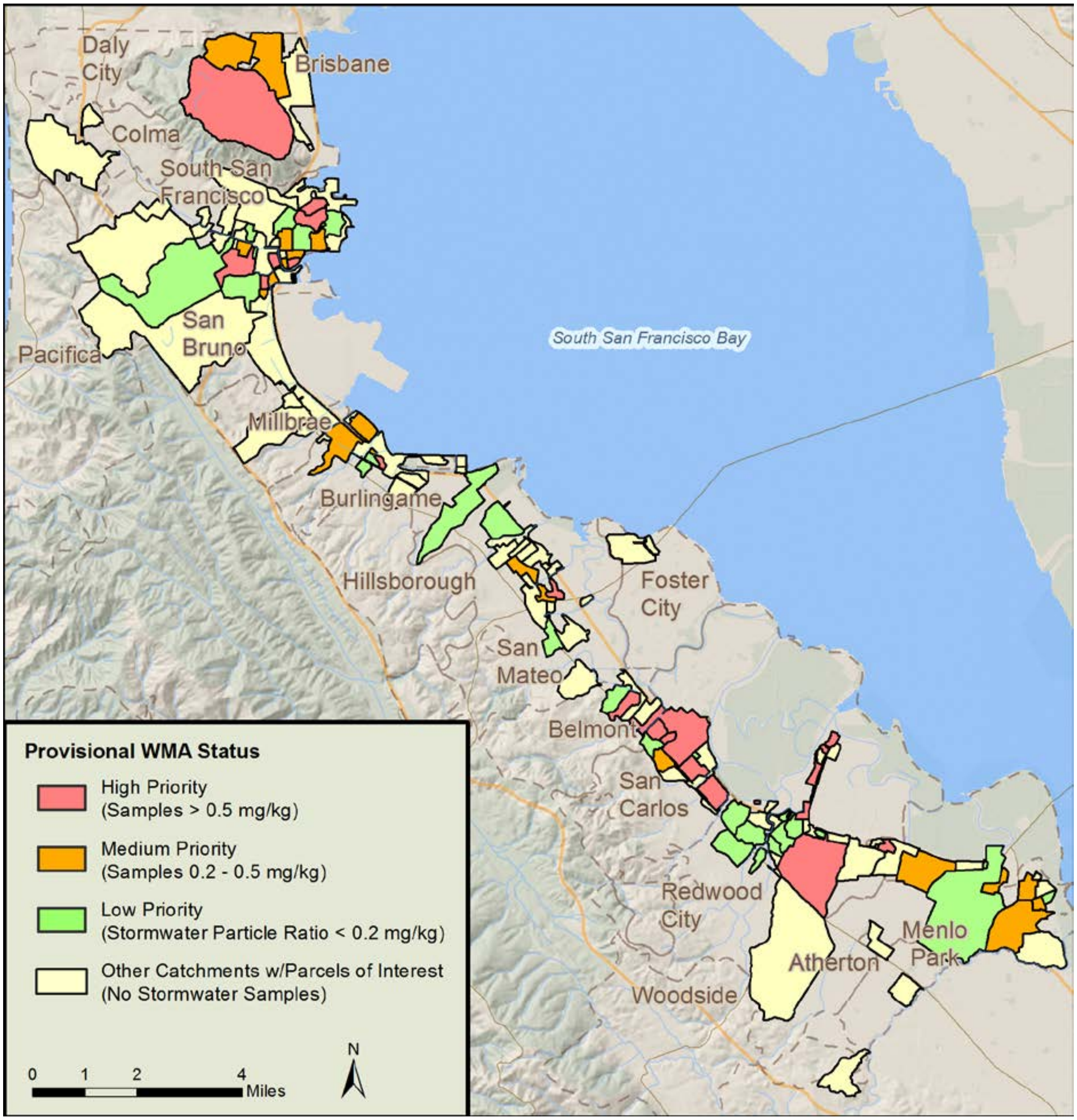


Figure 4. San Mateo County WMA Status Based upon Sediment and Stormwater Runoff Data Collected through WY 2018.

City of Brisbane

WMAs in the City of Brisbane with PCBs particle ratios over 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figure 5 and briefly described below. It should be noted that the industrial area in the northeast corner of Figure 5 drains to San Francisco's combined sewer and is therefore considered non-jurisdictional. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 17

WMA 17 is a large catchment that corresponds to the watershed of the now underground Guadalupe Creek. It contains a large industrial area developed mostly in the 1960s and buildings of the type that would be expected to potentially have PCBs in building materials. Several old railroad lines used to support the industries. A sediment sample collected during WY 2015 in one of the two main lines under Valley Drive had elevated levels of PCBs (1.22 mg/kg) despite potential dilution due to the large size of the watershed. Six additional samples were collected in WY 2018, with one of the samples being high (1.02 mg/kg), and the remaining samples all under 0.2 mg/kg. The high sample was collected from an inlet that drains a portion of one of the old railroad lines. A stormwater runoff sample collected by the RMP in WY 2016 (SM-BRI-17A or Valley Dr SD) had a relatively low PCBs particle ratio of 109 ng/g.

WMA 1004

WMA 1004 is located along Tunnel Avenue in the Brisbane Baylands area. Sample SM-BRI-1004A (Tunnel Avenue Ditch) was collected by the RMP in WY 2016 and (as with the above WMA 17 sample) had a relatively low PCBs particle ratio. The catchment contains all of the Brisbane Baylands old railyard and a large PG&E property on Geneva Avenue. The Baylands area is an active cleanup site (although not for PCBs) and will eventually be redeveloped. Several sediment samples collected in past years in the vicinity of the PG&E property and historical railroad lines had relatively low PCBs concentrations.

WMA 350

WMA 350 is upstream of WMA 1004, and contains a PCBs cleanup site (Bayshore Elementary) that was redeveloped in 2017. The PCBs were associated with the original building materials and it therefore appears unlikely that there is an ongoing source of PCBs to the MS4. One sample collected downstream of the school in WY 2018 had a relatively low concentration of PCBs.

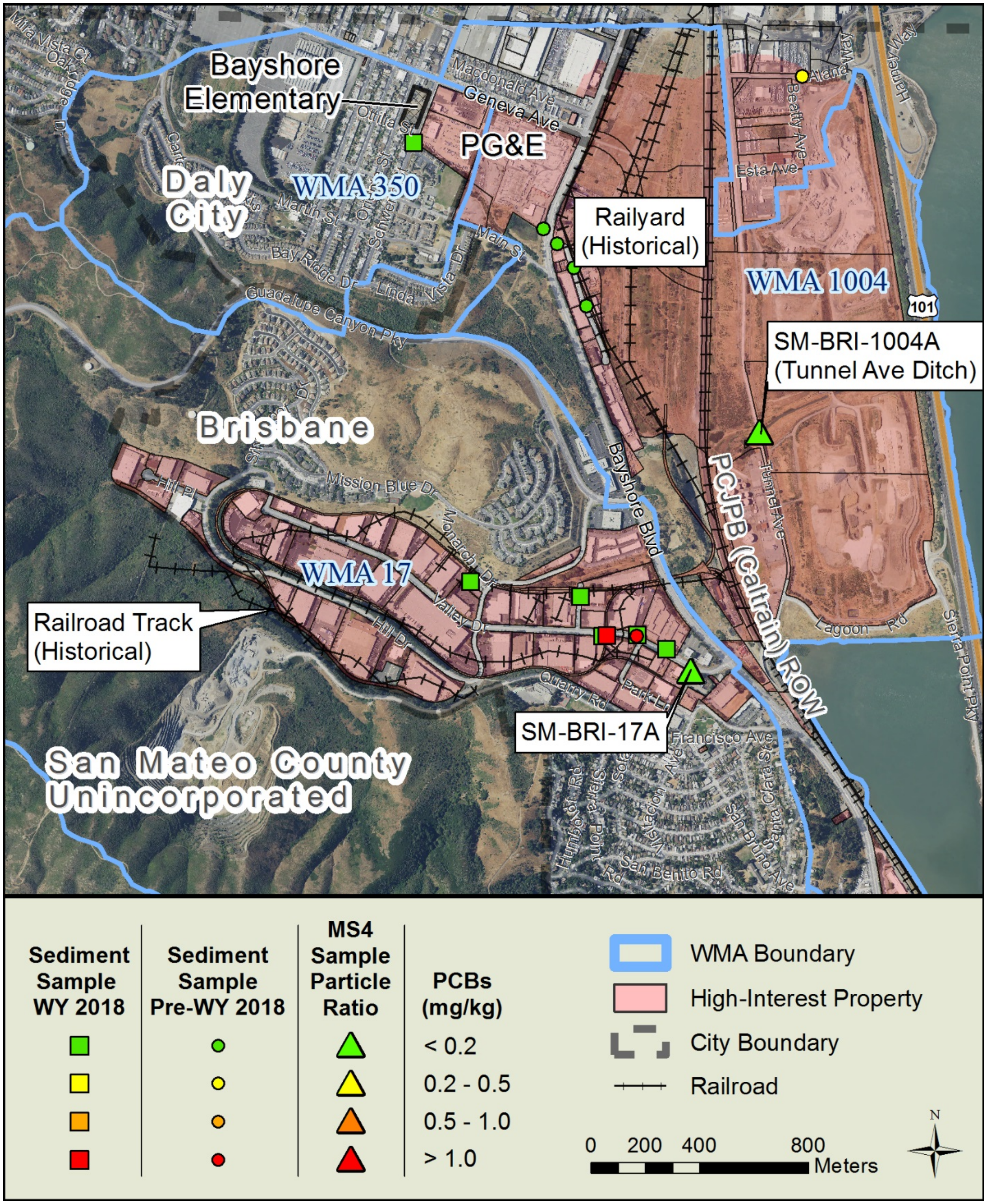


Figure 5. WMAs 17, 350, and 1004.

City of South San Francisco

WMAs in the City of South San Francisco with PCBs particle ratios over 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figures 6 through 10 and briefly described below. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 291

WMA 291 is a relatively large catchment that is comprised almost entirely of old industrial land uses. A stormwater runoff sample collected by the RMP in WY 2017 had an elevated PCB particle ratio (736 ng/g). A 2002 sediment sample at 245 S. Spruce Avenue had an elevated PCBs concentration of 2.72 mg/kg. Samples in WY 2015 and WY 2017 on Linden Avenue near Dollar Avenue were also moderately elevated for PCBs (0.48 and 0.44 mg/kg). Two sediment samples were collected near 245 S. Spruce Avenue in WY 2018, one of which was moderately elevated for PCBs (0.21 mg/kg). The moderately elevated sample was collected from the boundary of the property and a historical railroad, which now is part of the current BART right-of-way.

WMA 294

WMA 294 is a 67 acre catchment that drains into Colma Creek at Mitchell Avenue. Within the WMA is 166 Harbor Way, designated in the Department of Toxic Substances Control (DTSC) Envirostor database as “Caltrans/SSF Maintenance Station.” This property was purchased by Caltrans which tested the soil and found several contaminants including PCBs. The contaminated soil has been capped since at least 2005 and the property is currently mostly vacant with a small portion devoted to k-rail storage. A sediment sample was collected in the driveway of this property in WY 2017 had a moderate PCBs concentration of 0.28 mg/kg. A stormwater runoff sample collected in WY 2017 had a moderately elevated PCBs particle ratio (367 ng/g).

WMA 314

WMA 314 is a 66 acre catchment located near Oyster Point that is comprised of light industrial land uses along with an old railroad right-of-way. Site SM-SSF-314A (Gull Dr. SD) was sampled by the RMP STLS in WYs 2016 and resampled in 2018 and had an elevated PCBs particle ratio in both samples (943 and 946 ng/g). The WY 2018 sample had a total PCBs concentration (71 ng/L) that was about an order of magnitude higher than the WY 2016 sample (8.6 ng/L). Two sediment samples collected in WY 2017 both had relatively low (urban background) concentrations of PCBs, with the highest concentration being 0.15 mg/kg.

WMA 315

WMA 315 is a 108 acre catchment with an outfall very close to the outfall for WMA 314. WMA 315 is comprised almost entirely of light industrial land uses. The RMP STLS collected a stormwater runoff sample at the bottom of this catchment in WY 2016 and then resampled the same station in WY 2018. Total PCBs (5.8 ng/L) and PCBs particle ratio (175 ng/g) were relatively low in the WY 2016 sample, but roughly an order of magnitude higher in the WY 2018 sample (total PCBs = 93.2 ng/L and PCBs particle ratio = 1,024 ng/g). Sediment samples have not been collected in this catchment to-date.

WMA 319

WMA 319 is also located near Oyster Point. Sample SM-SSF-319A (Forbes Blvd Outfall) was collected by the RMP STLS in WY 2016 and had a relatively low PCBs particle ratio of 80 ng/g. Although the catchment was historically industrial, it is now mostly redeveloped and composed of biotechnology corporations. A sediment sample in WY 2017 also had a relatively low (urban background) PCBs concentration.

WMA 358

WMA 358 is a small 32 acre catchment that drains into Colma Creek at Utah Avenue. A sediment sample in WY 2015 had elevated concentrations of PCBs (1.46 mg/kg). Three followup sediment samples in WY 2017 all had relatively low (urban background) levels of PCBs, with the highest concentration being 0.09 mg/kg.

WMA 359

WMA 359 is a small 23 acre catchment that drains into Colma Creek behind 222 Littlefield Avenue. In WY 2017 the RMP STLS collected a storm sample elevated in PCBs that had an elevated PCBs particle ratio of 788 ng/g. The catchment is composed of all old industrial land uses including old railroad tracks. In WY 2018, three follow-up sediment samples collected in the catchment all had relatively low PCBs concentrations (less than 0.2 mg/kg).

WMA 1001

WMA 1001 is a large catchment that is composed of all the non-contiguous small catchments along Colma Creek that have outfall diameters of 18-inches and smaller. In WY 2017, a stormwater runoff sample collected on Shaw Road near the catchment outfall (SM-SSF-1001B) had an elevated PCBs particle ratio (1,710 ng/g). The catchment for this sample is very small and only drains about five light industrial properties along Shaw Road. Six samples were collected in this catchment in WY 2018, with one having a moderately elevated PCBs concentration of 0.35 mg/kg, and the other five all having relatively low concentrations. In WY 2018 a stormwater sample was collected from WMA 1001(c) and had a relatively low PCBs concentration of 1,100 ng/L, but a moderately elevated PCBs particle ratio of 353 ng/g.

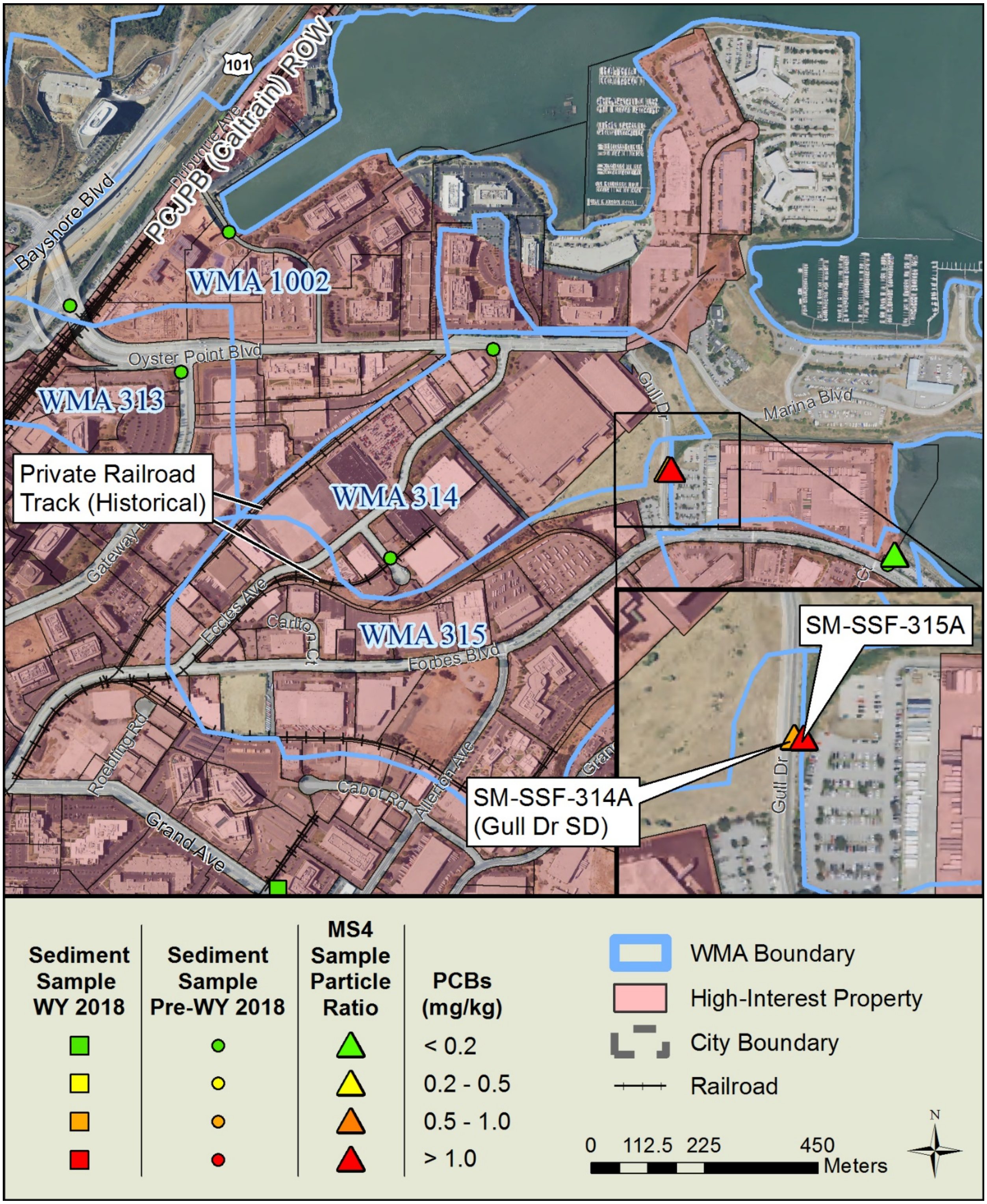


Figure 6. WMAs 313, 314, 315, and 1002

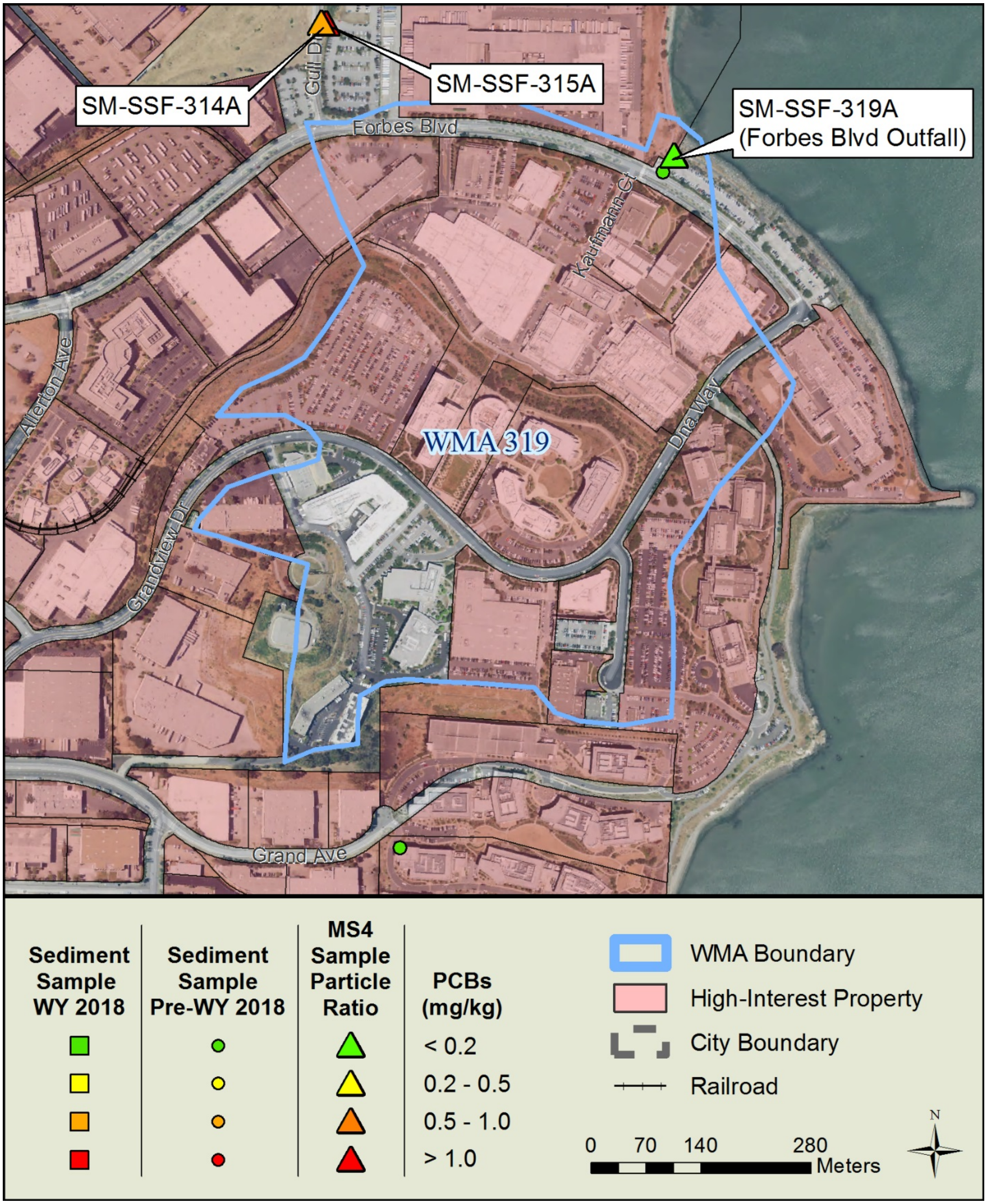


Figure 7. WMA 319

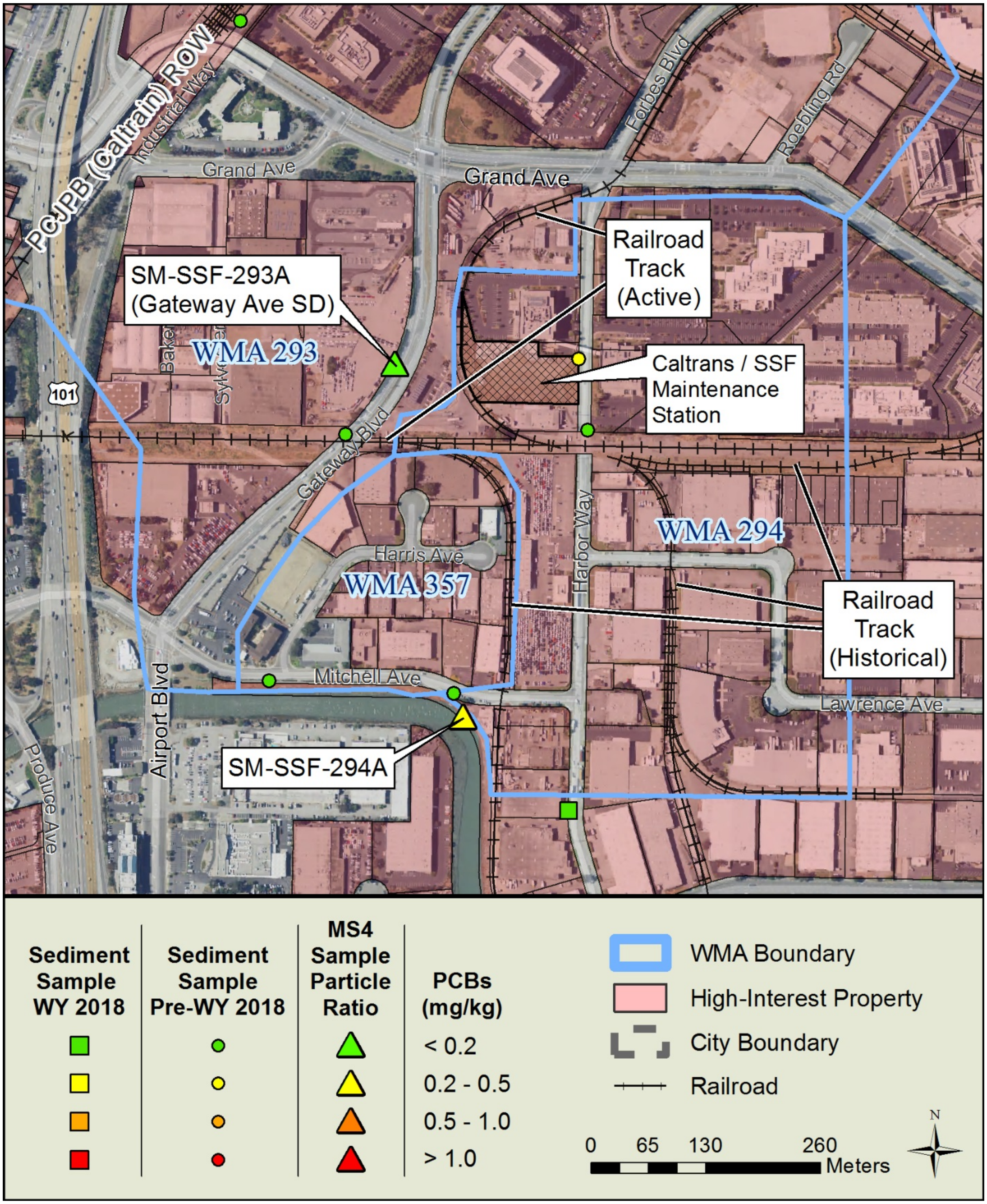


Figure 8. WMAs 293, 294, and 357

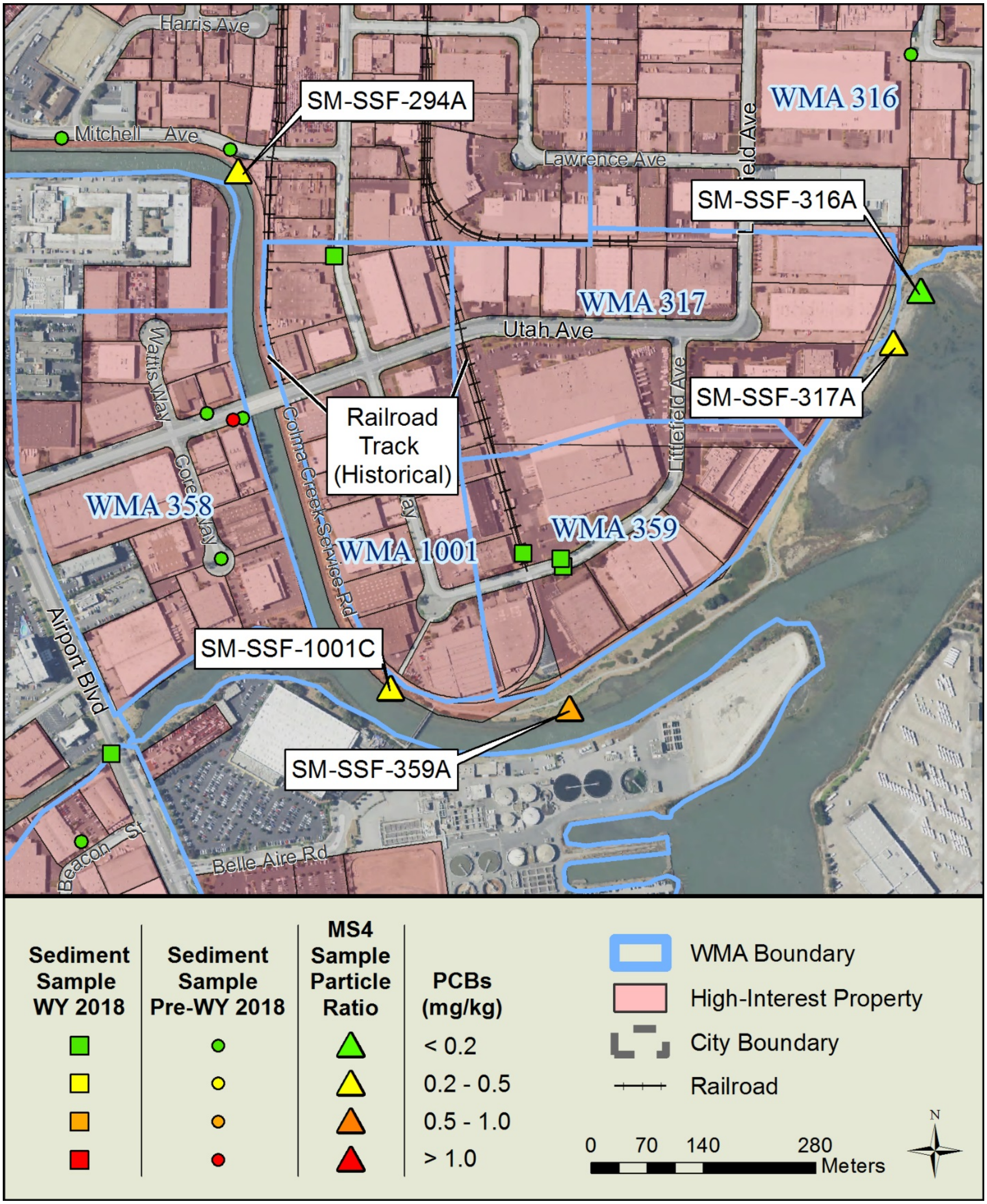


Figure 9. WMAs 316, 317, 358, 359, and 1001

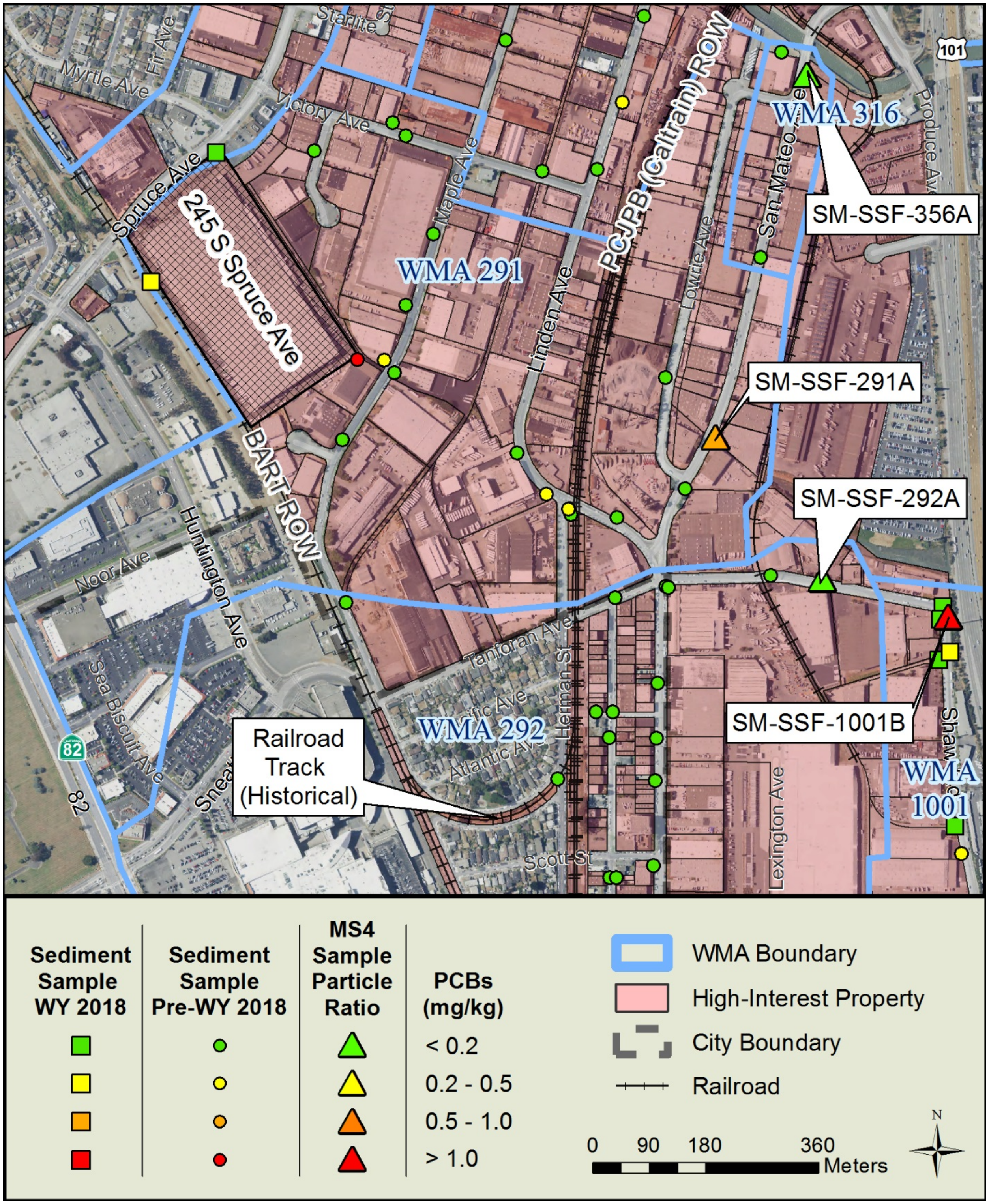


Figure 10. WMAs 291, 292, 316, and 1001

City of Burlingame

WMAs in the City of Burlingame with PCBs particle ratio over 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figures 11 and 12 and briefly described below. The PCBs concentrations in fourteen previous sediment samples in the industrial parts of Burlingame have all been relatively low. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 85

WMA 85 is a 121 acre catchment northwest of Highway 101 in Burlingame that is comprised mostly of light industrial land uses. A stormwater sample collected in WY 2018 had a slightly elevated PCBs particle ratio of 241 ng/g. Two previous sediment samples collected in this WMA had relatively low concentrations (less than 0.2 mg/kg), including one at the pump station.

WMA 142

WMA 142 is a small 20 acre catchment that is comprised mostly of industrial land uses. Sample SM-BUR-142A was part of a trio of stormwater runoff samples collected at the forebay of the Marsten Road pump station. It had a relatively high PCBs particle ratio (670 ng/g). SM-BUR-1006A, which was collected at the same location but drains adjacent WMA 1006, had a moderately elevated PCBs particle ratio (365 ng/g). Seven sediment samples collected in or very close to WMA 142 in WY 2018 all had a low PCBs concentration (less than 0.2 mg/kg).

WMA 164

WMA 164 is a 241 acre catchment. The lower half of this catchment has mostly light industrial land uses and the upper half has mostly residential and commercial land uses. A stormwater runoff sample collected in WY 2018 had a moderately elevated PCBs particle ratio of 447 ng/g. This site is downstream of a pump station where sediments may settle out of the stormwater runoff flows. Four embedded sediment samples collected in this catchment in WYs 2002 and 2015 had relatively low PCBs concentrations (less than 0.2 mg/kg).

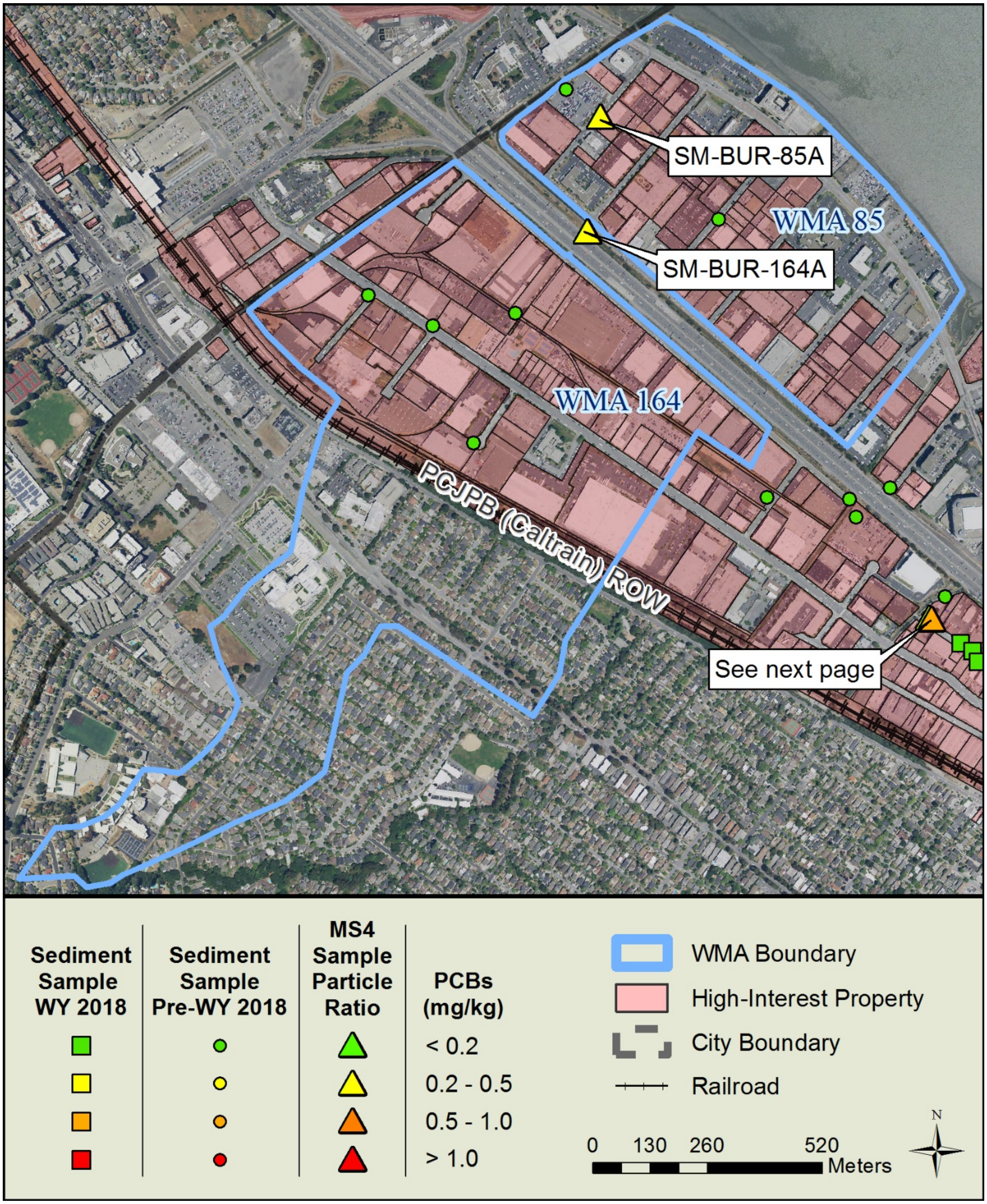
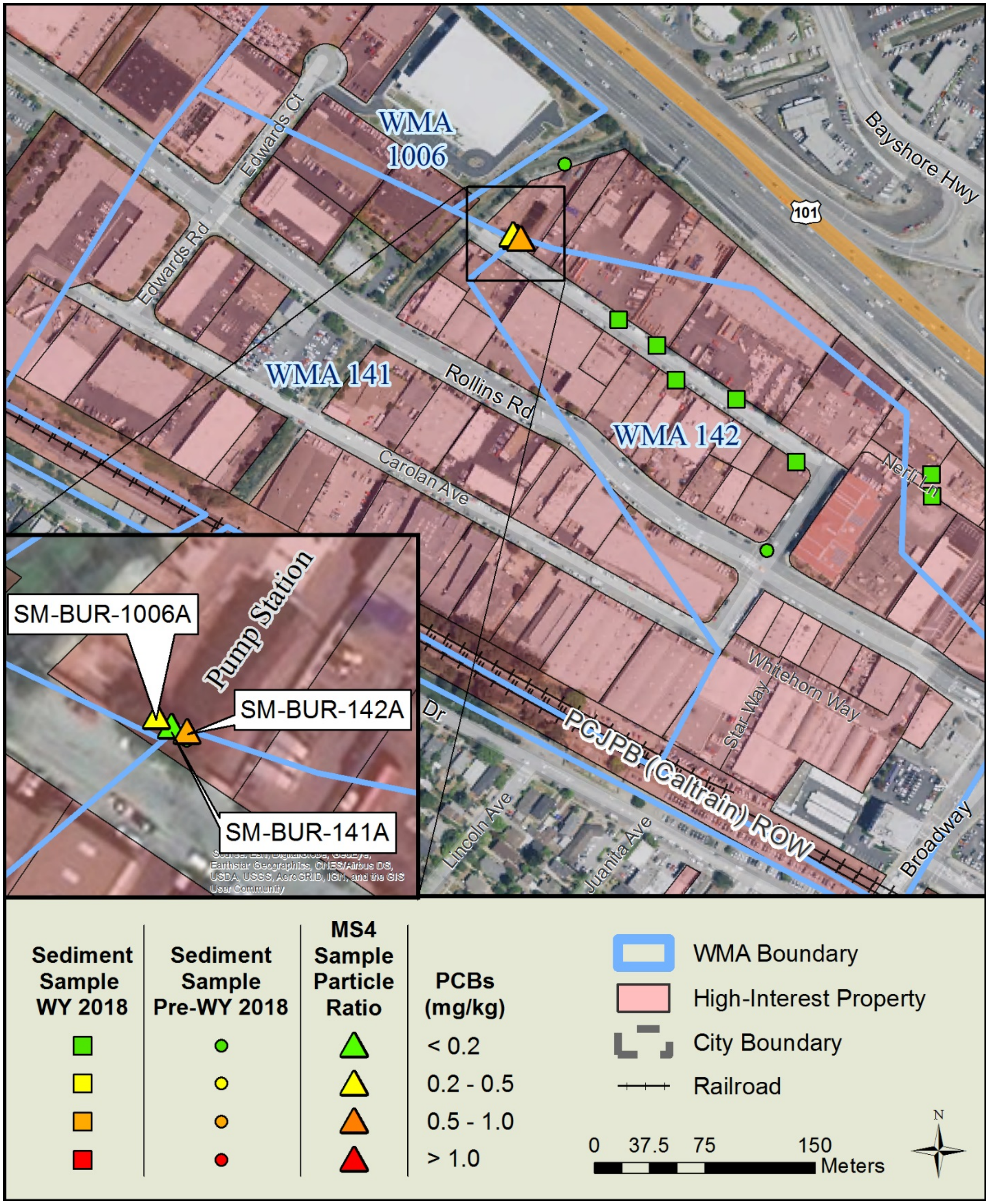


Figure 11. WMAs 85 and 164



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 12. WMAs 141, 142, and 1006

City of San Mateo

WMAs in the City of San Mateo with PCBs particle ratio greater than 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figure 13 and briefly described below. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 156

WMA 156 is a 40 acre catchment that flows north into the 16th Street Channel at Delaware Street. Historically it contained old industrial land uses. It drains Caltrain property including the Hayward Park Station. There is a major retail redevelopment project currently underway in this WMA. A stormwater runoff sample collected in WY 2017 near the catchment outfall had a slightly elevated PCB particle ratio (204 ng/g) but a sediment sample collected upstream did not have an elevated PCBs concentration.

WMA 408

WMA 408 is a 43 acre catchment next to WMA 156. It is comprised of a mix of retail, commercial and residential land uses, with a relatively low proportion (16%) of high interest parcels (see Attachment 3). A stormwater runoff sample collected in WY 2017 had a relatively high PCBs particle ratio (1,900 ng/g). This result is notable given the lack of industrial land uses and low percentage of high interest parcels. Seven embedded sediment samples collected from this WMA in WY 2018 all had relatively low PCBs concentrations (less than 0.2 mg/kg). Given the high previous result and low concentrations in the embedded sediment samples, it may be advisable to resample the stormwater runoff station.

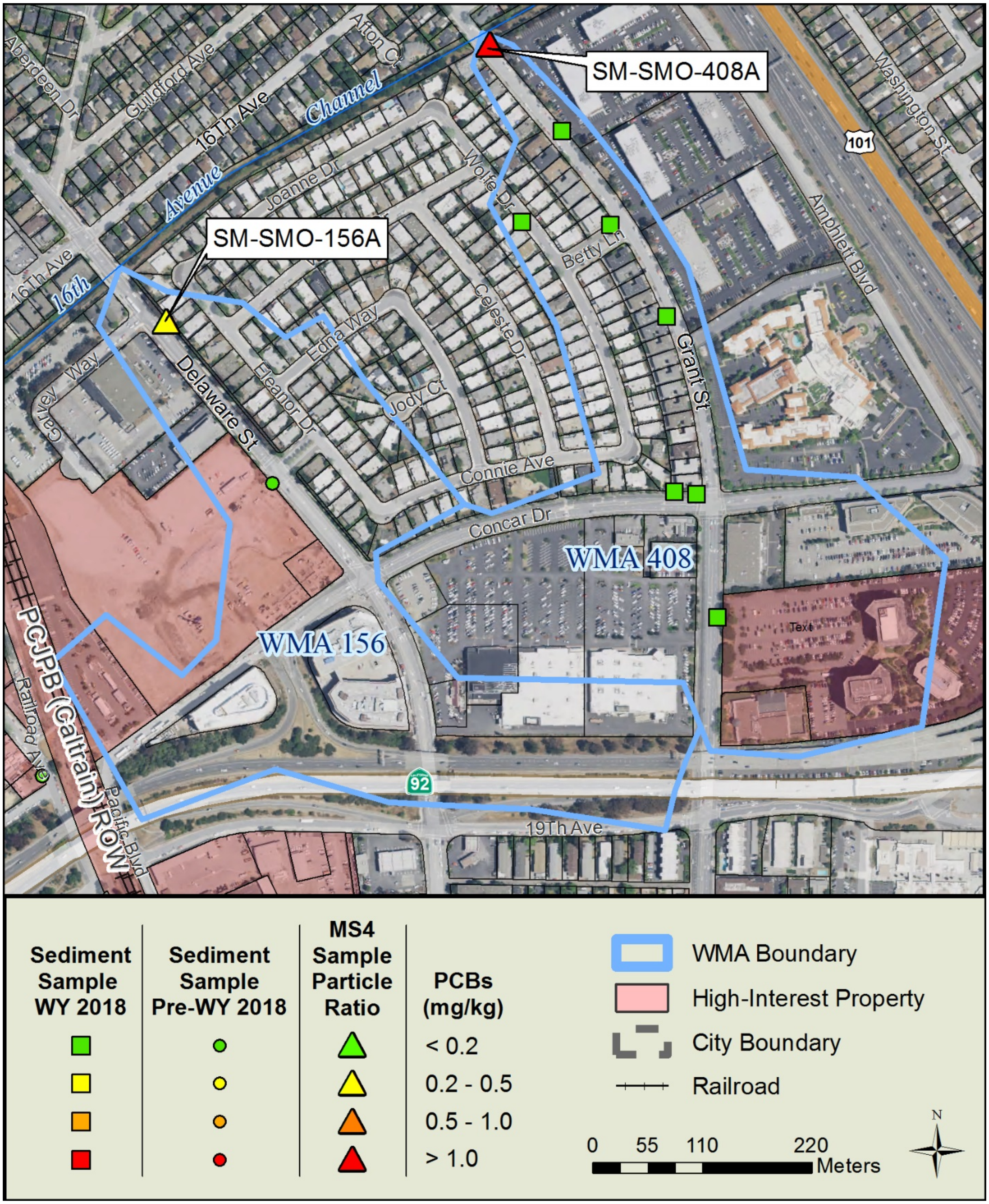


Figure 13. WMAs 156 and 408

City of Belmont

WMAs in the City of Belmont with PCBs particle ratio greater than 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figure 14 and briefly described below. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 60

WMA 60 is a 298 acre catchment that drains north into Laurel Creek. Two stormwater runoff samples were collected in the catchment in WY 2017 (SM-BEL-60A and SM-BEL-60B). Sample SM-BEL-60A was not elevated but SM-BEL-60B had a relatively high PCBs particle ratio (1,022 ng/g). This result was notable since the sample catchment is mostly residential with few high interest parcels. In WY 2018, seven embedded sediment samples were collected in the WMA, all of which had relatively low PCBs concentrations (less than 0.2 mg/kg). Given the high previous result and low concentrations in the embedded sediment samples, it may be advisable to resample the stormwater runoff station.

Figure 14. WMA 60

City of San Carlos

WMAs in the City of San Carlos with PCBs particle ratios greater than 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figure 15 – 18 and briefly described below. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 75

WMA 75 is a 66 acre catchment comprised entirely of old industrial land uses. Sample SM-SCS-75A (Industrial Rd Ditch) was collected by the RMP in WY 2016 and had a PCBs particle ratio of 6,140 ng/g, which is among the highest levels found in Bay Area stormwater samples collected to-date. The sample station is located where the MS4 daylights into a ditch on the east side of Industrial Road downstream of the adjacent Delta Star and Tiegel Manufacturing properties. The Countywide Program collected seven sediment samples in WY 2017 in the area. Two of these samples were collected near the Delta Star and Tiegel properties. One was collected in the storm drain line directly downstream of both properties and had a very elevated PCBs concentration (49.4 mg/kg). The other was also elevated, with a PCBs concentration of 1.20 mg/kg, and was collected from surface sediments at the location where the Tiegel property drains into the public right-of-way. In WY 2018, SMCWPPP collected a sample across the street from Delta Star in front of the PG&E property. The sample had a PCBs concentration of 0.76 mg/kg. It is not believed that the PCBs in this sample originated from the PG&E property given that the sample only drained a portion of the front parking lot, PCBs tend to create a halo effect around polluted areas, and that the entire MS4 in this area consistently contains groundwater and PCBs potentially could have been conveyed up the pipe. The remainder of the PG&E property drains toward the east. The remaining samples were not elevated, suggesting that there are no other sources of PCBs in this WMA other than these two properties (Figure 15).

Delta Star manufactures transformers, including transformers with PCBs historically (from 1961 to 1974). This is a cleanup site with elevated PCBs found in on-site soil and groundwater samples. PCBs migrated to the adjacent Tiegel property at 495 Bragato Road, a roughly three acre site that is largely unpaved. A “Removal Action” under DTSC oversight was implemented between June 1989 and January 1991 to remove soil impacted with PCBs exceeding 25 ppm. The Delta Star and Tiegel properties are currently determined to be in compliance with public health, safety, and the environmental cleanup goals based on exposure at the site. However, based on the PCBs concentrations in the sediment and stormwater runoff samples, the site appears to be a source of PCBs to the MS4 and San Francisco Bay at levels that are a concern from the standpoint of the Bay PCBs TMDL (i.e., contribute to bioaccumulation in Bay fish and other wildlife). The Countywide Program recently worked with the City of San Carlos to refer this property to the Regional Water Board for potential additional investigation and abatement.

WMA 31 (Pulgas Creek Pump Station North)

WMA 31 is a 99 acre catchment that drains to the Pulgas Creek pump station from the north. The RMP collected four stormwater runoff samples from this catchment during two storms in WY 2011. The samples were all elevated, with an average PCBs particle ratio of 893 ng/g. In addition, street dirt and sediment samples with elevated PCBs have been collected in front of and in the vicinity of 977 Bransten Road, a property within WMA 31 (Figure 16). The current occupant of this property is GC Lubricants. 977 Bransten Road is a DTSC cleanup site due to soil and groundwater contamination with PCBs and other pollutants associated with activities at GC Lubricants and California Oil Recyclers, Inc., a previous tenant at the site. 1007/1011 Bransten Road is the property located adjacent to and immediately north of 977 Bransten Road and designated the "Estate of Robert E. Frank." A DTSC "Site Screening Form" describes PCBs in the subsurface on both sides of border between the two properties and states there may have been a historic source on both sides of the property line. Abatement measures have been implemented to reduce movement of contaminated soils from the properties, including a concrete cap over contaminated areas. However, the available information suggest that soils/sediments with PCBs are migrating from these properties into the public ROW, including the street and the MS4. The Countywide Program recently worked with the City of San Carlos to refer this property to the Regional Water Board for potential additional investigation and abatement.

WMA 210 (Pulgas Creek Pump Station South)

WMA 210 drains to the Pulgas Creek pump station from the south (Figures 17 and 18). The RMP has collected 33 storm samples from this catchment with an average PCBs particle ratio of 8,220 ng/g, the highest of any stormwater runoff sampling location in the Bay Area. There appear to be several sources of PCBs within this WMA.

The best documented of these sites is the property at 1411 Industrial Road. A sediment sample with a very elevated PCBs concentration (193 mg/kg) was previously collected from a storm drain inlet located in the parking lot of this about 1.3 acre property. The property drains to the MS4 at a sidewalk manhole where other elevated sediment samples have been collected. Since 2012 the occupant of this property has been a Habitat for Humanity Re-Store. Before that the property was occupied by an auto body shop and an automotive paint company. Between 1958 and 1994, Adhesive Engineering / Master Builders, Inc. was the occupant and conducted manufacturing, research and development of construction grade epoxy resin and products. Adhesive Engineering / Master Builders, Inc. had a history of violations for leaky wastewater drums and improper storage of hazardous wastes in the late 1980s and early 1990s, and PCBs were reportedly used on the site in the past. An environmental assessment report conducted as part of a business closure in 1994 revealed that 93 mg/kg PCBs was found in a soil sample collected in 1987. The soil sample was collected beneath an aboveground tank that was heated by oil-containing PCBs circulating in coils around the tank. The report also described the removal in 1987 of 44 cubic yards of contaminated soil from the area where the tank was located. As part of the 1994 environmental assessment, a soil sample was collected from the same area and PCBs were not detected at that time, but soil samples from other areas on the property were not collected and tested for PCBs. The above information suggests that the 1411 Industrial Road property is a source of PCBs to the MS4. The Countywide Program is currently working with the City of San Carlos to prepare the documentation to refer this property to the Regional Water Board for potential additional abatement.

In WY 2017, the Countywide Program collected ten sediment samples from the WMA 210 to better delineate the sources of PCBs in this catchment. Three samples were collected in the vicinity of 1411 Industrial Road to help rule out that neighboring properties are PCBs sources. All three of these samples had relatively low PCBs concentrations, with the highest having a PCBs concentration of 0.07 mg/kg, which helps to verify that the properties to the east and south are not also sources. Multiple sediment samples previously collected around the PG&E substation across the street also had relatively low levels of PCBs, suggesting that this property is not a source. PCBs from unknown sources were previously found in inlets and manholes in the vicinity of Center, Washington and Varian Streets and Bayport Avenue (Figure 18). The PCBs in these samples could have originated from any of about 20 small industries on these streets. During WY 2017, seven additional samples were collected in this area. The results suggest that three small properties may be PCBs sources. Two samples collected from the driveways of 1030 Washington Street, a construction business, had elevated PCBs (1.29 and 3.73 mg/kg). A sample from the driveway of 1029 Washington Street was also elevated with a concentration of 5.64 mg/kg. In addition, samples from the driveway of 1030 Varian Street, an unpaved lot used for storage, had an elevated PCBs concentration of 1.84 mg/kg. It should be noted that all of the buildings in this area appear to be of the type and age that may have PCBs in building materials.

In WY 2018, the Countywide Program collected two sediment samples along Washington Street. The first sample was from the gutter upstream of 1030 Washington Street and had a PCBs concentration of 0.25 mg/kg. The second sample was from the gutter upstream of 1029 Washington Street and had a PCBs concentration of 0.06 mg/kg. These relatively low concentrations suggest that the sources of PCBs are not upstream of the two properties of interest along Washington Street. The Countywide Program is currently working with the City of San Carlos to determine next steps for these properties.

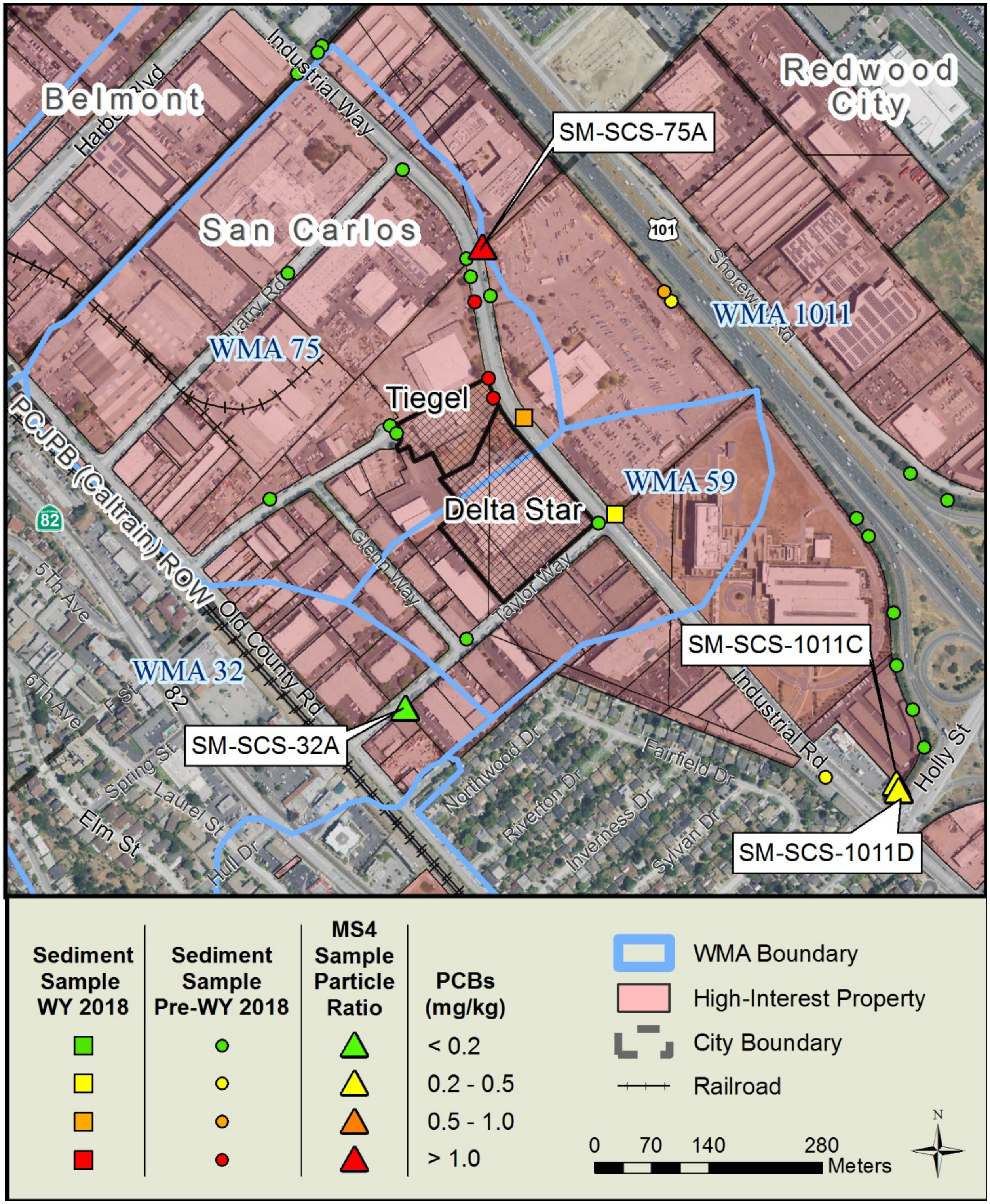


Figure 15. WMAs 59, 75, and 1011

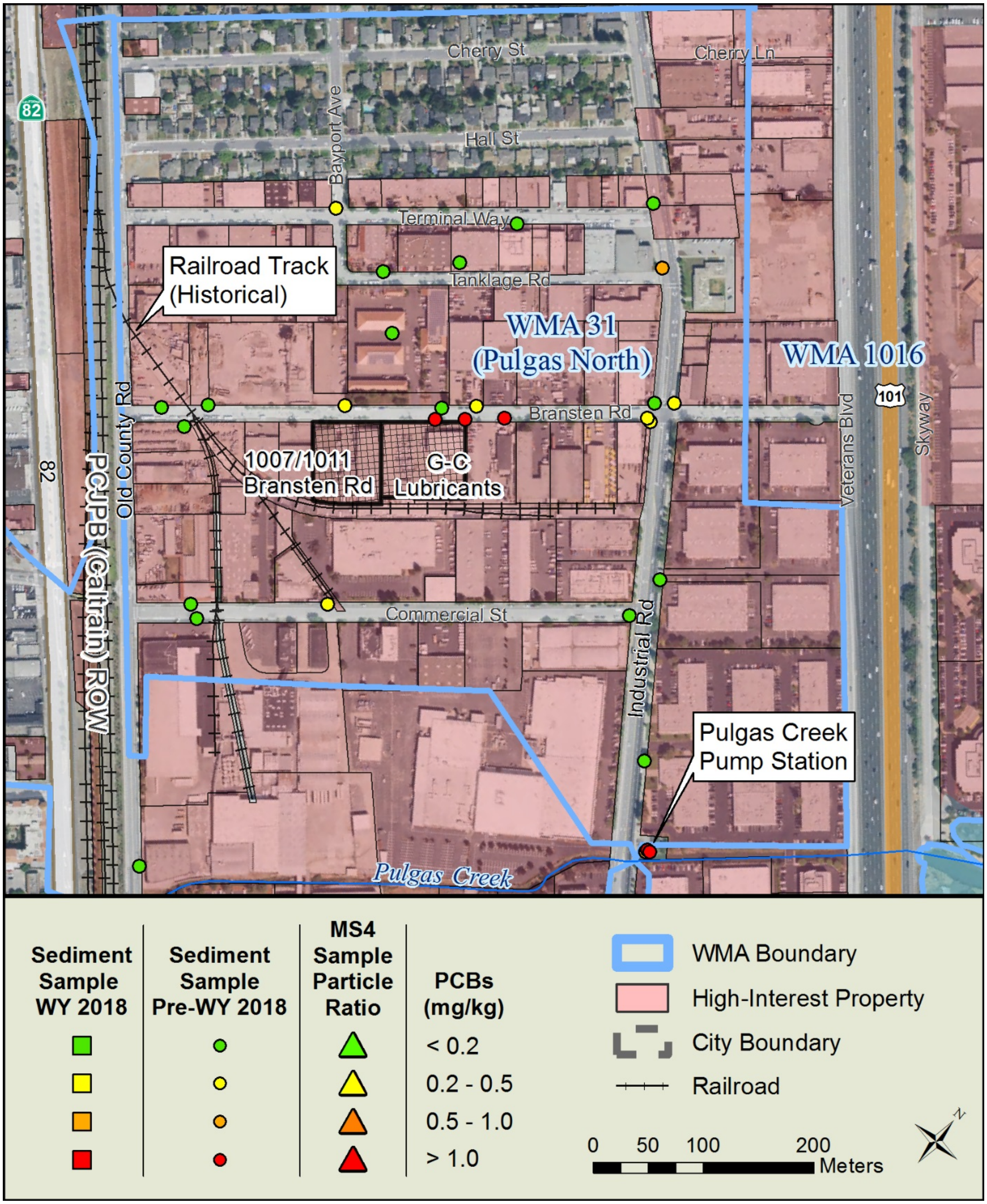


Figure 16. WMA 31

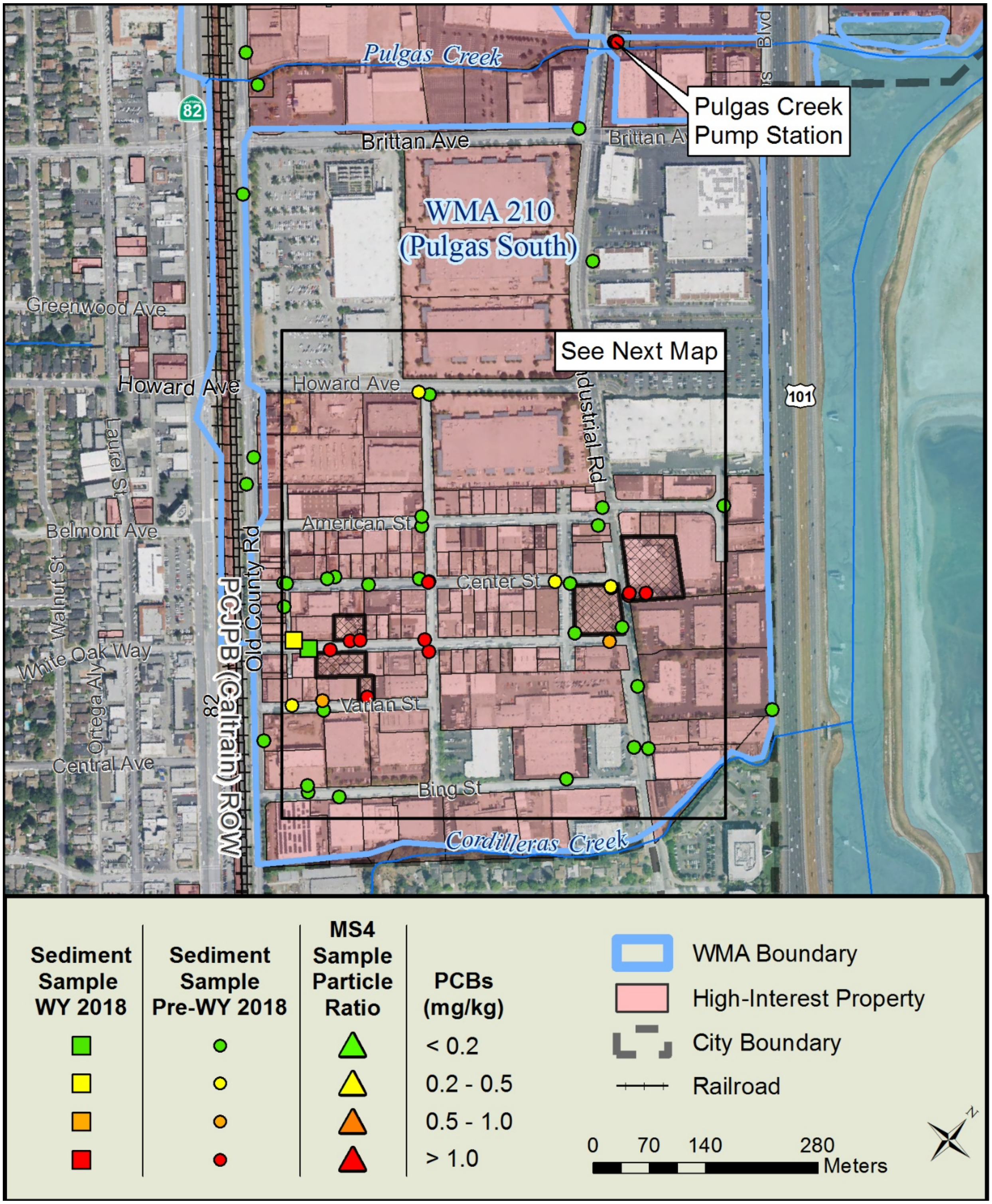


Figure 17. WMA 210

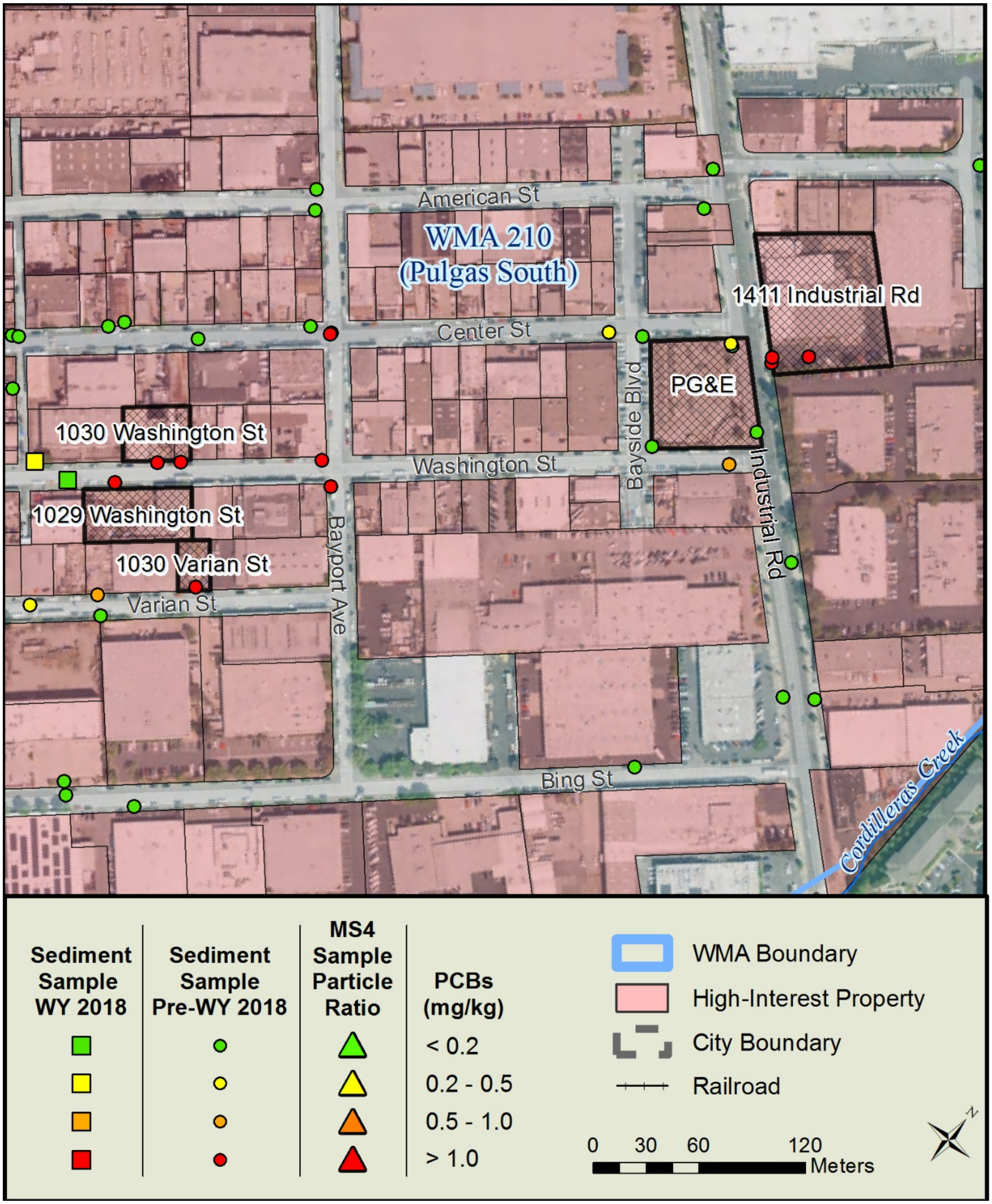


Figure 18. WMA 210 – Enlargement of Sampled Area

City of Redwood City

WMAs in the City of Redwood City with PCBs particle ratio greater than 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figure 19 – 22 and briefly described below. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 239

WMA 239 (Figure 22) is a 36 acre mostly industrial catchment that is half in Redwood City and half in Menlo Park. In WY 2015, SMCWPPP collected a sediment sample in this catchment that had an elevated PCBs concentration of 0.57 mg/kg. Four additional sediment samples were collected in WY 2017, all of which had relatively low (urban background) PCBs concentrations, with the highest concentration being 0.16 mg/kg. Currently in this WMA there is a large housing redevelopment that is almost complete. One of the industries that was redeveloped (Haven Avenue Industrial Condominiums) at 3633 Haven Ave was remediated for PCBs contamination in 2006. Stormwater runoff sampling has not been conducted in this catchment due to a lack of public access to the catchment outfall (which discharges to the Bay).

WMA 379

WMA 379 (Figures 19 and 20) is an 802 acre catchment located in Redwood City and the unincorporated North Fair Oaks census-designated place (CDP). The catchment is divided into a northerly half (A) and a southerly half (B), each with a distinct MS4 outfall. Both were sampled by the Countywide Program in WY 2016. Sample SM-RCY-379A had a relatively low PCBs particle ratio (105 ng/g). Sample SM-RCY-379B also had a relatively low PCBs particle ratio (182 ng/g). In WY 2017, the Countywide Program collected fifteen samples in WMA 379 in an attempt to identify PCBs source along Bay Road and Spring Street, in follow-up to elevated sediment samples collected during previous years. None of nine samples collected in the Bay Road near Hurlingame Avenue area was elevated, with the highest PCBs concentration being 0.14 mg/kg. A single sample collected from an inlet at the back of the sidewalk in front of 2201 Bay Road had a PCBs concentration of 1.97 mg/kg. This site is the location of two properties listed for PCBs on GeoTracker[11]: Tyco Engineering Products and the railroad spur next to the property. The Tyco site was remediated and redeveloped (MRP Provision C.3 compliant) and is currently a parking lot for Stanford Hospital. Four sediment samples were collected on Spring Street in WY 2017. None was elevated, with the highest PCBs concentration being 0.08 mg/kg. In WY 2018, two additional samples were collected to further verify the lower results along Spring Street, and to test for the presence of any PCBs sources along Charter Street on the south side of the old Tyco property. Both samples had low concentrations of PCBs (less than 0.2 mg/kg).

WMA 405

WMA 405 (Figure 21) consists almost entirely of SIMS Metal Management at the Port of Redwood City. Samples from the driveway of SIMS and nearby in WYs 2015 and 2017 had elevated PCBs concentrations of 0.57 and 0.75 mg/kg, respectively. The site has recently made efforts to prevent metal fluff potentially containing a variety of contaminants (including PCBs) from entering the Bay.

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[11] GeoTracker is the State Water Resources Control Board's Internet-accessible database system used to track and archive compliance data from authorized or unauthorized discharges of waste to land, or unauthorized releases of hazardous substances from underground storage tanks.

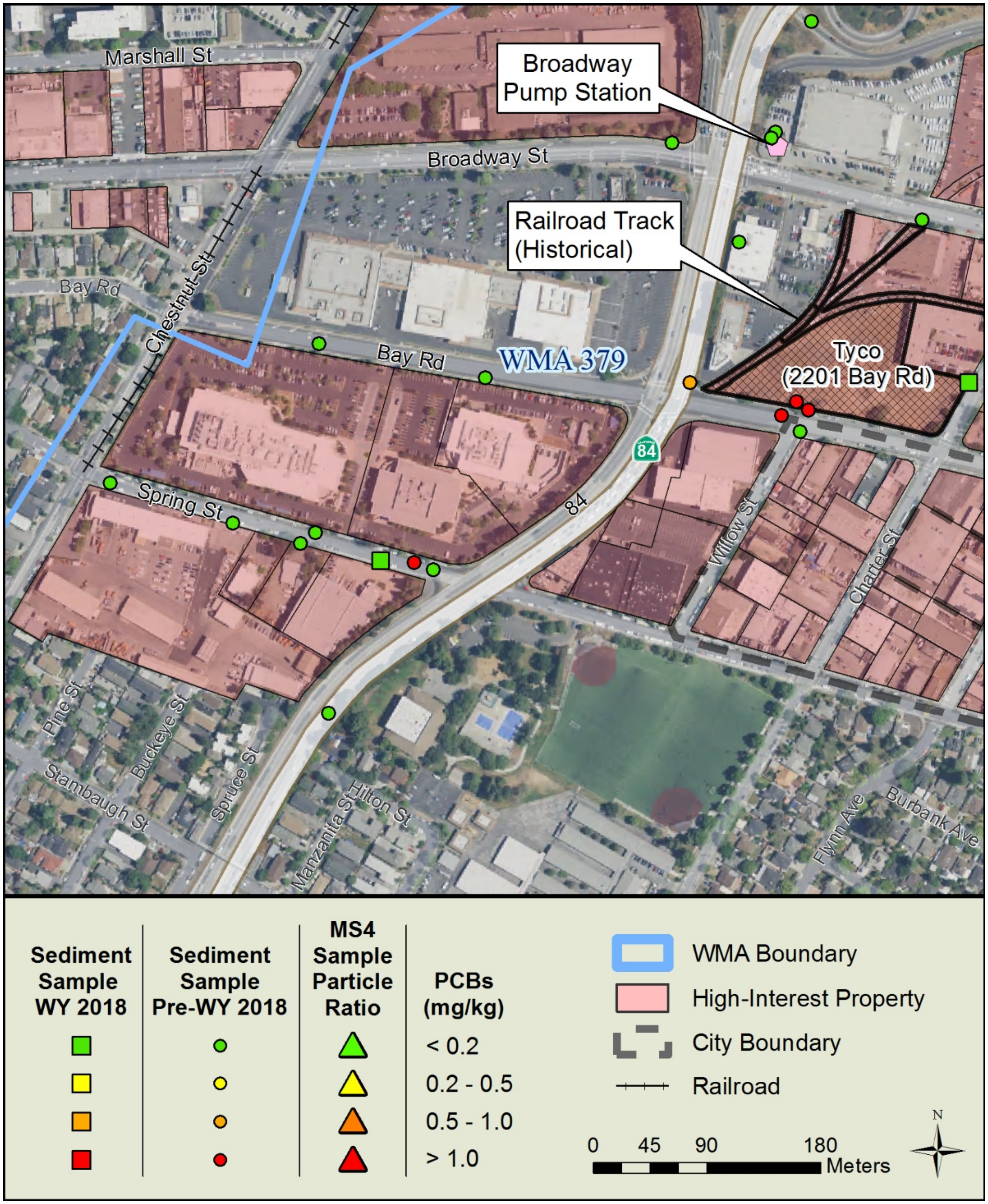

Figure 19. WMA 379 (northwest portion)

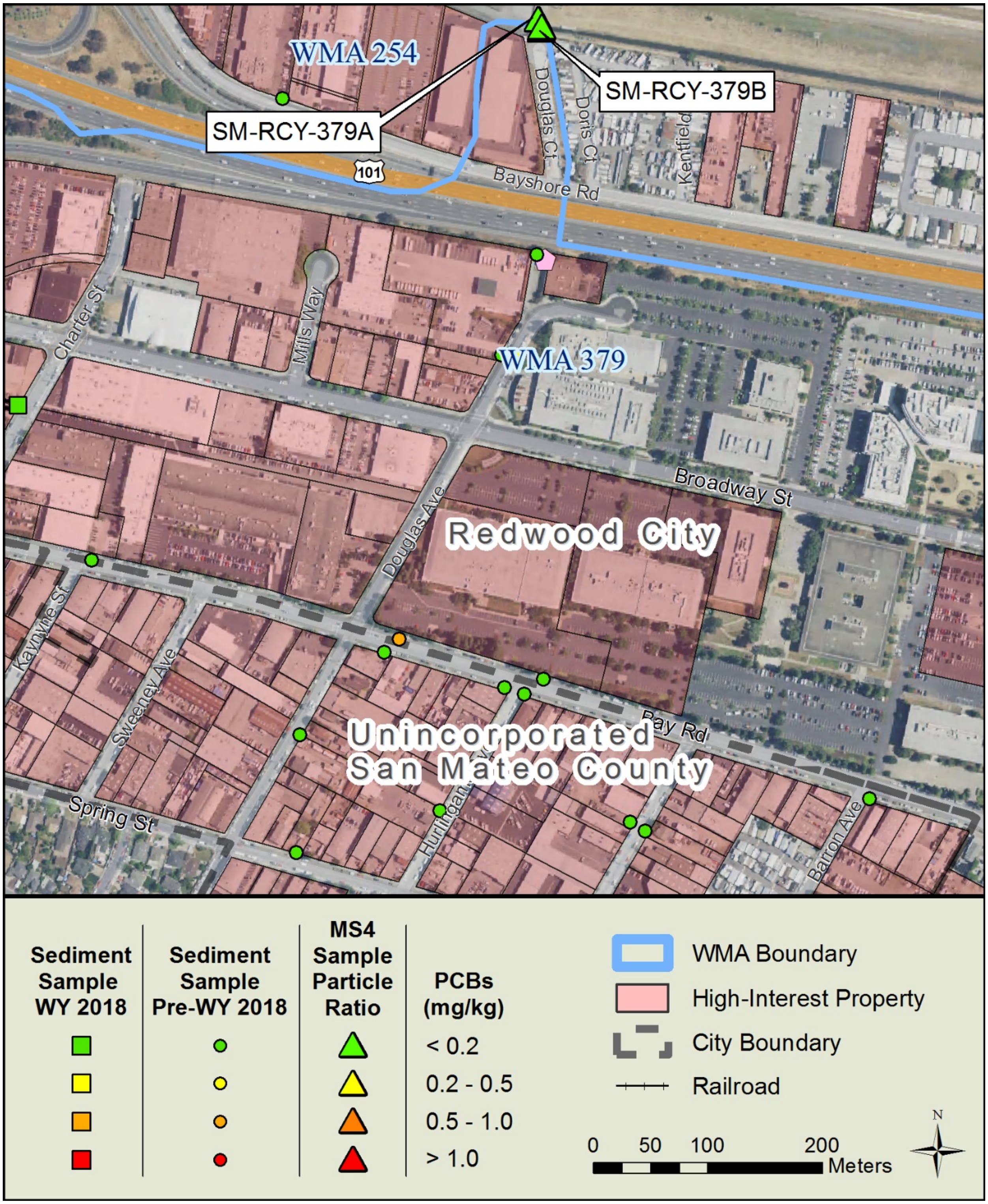

Figure 20. WMAs 254 and 379 (southeast portion)

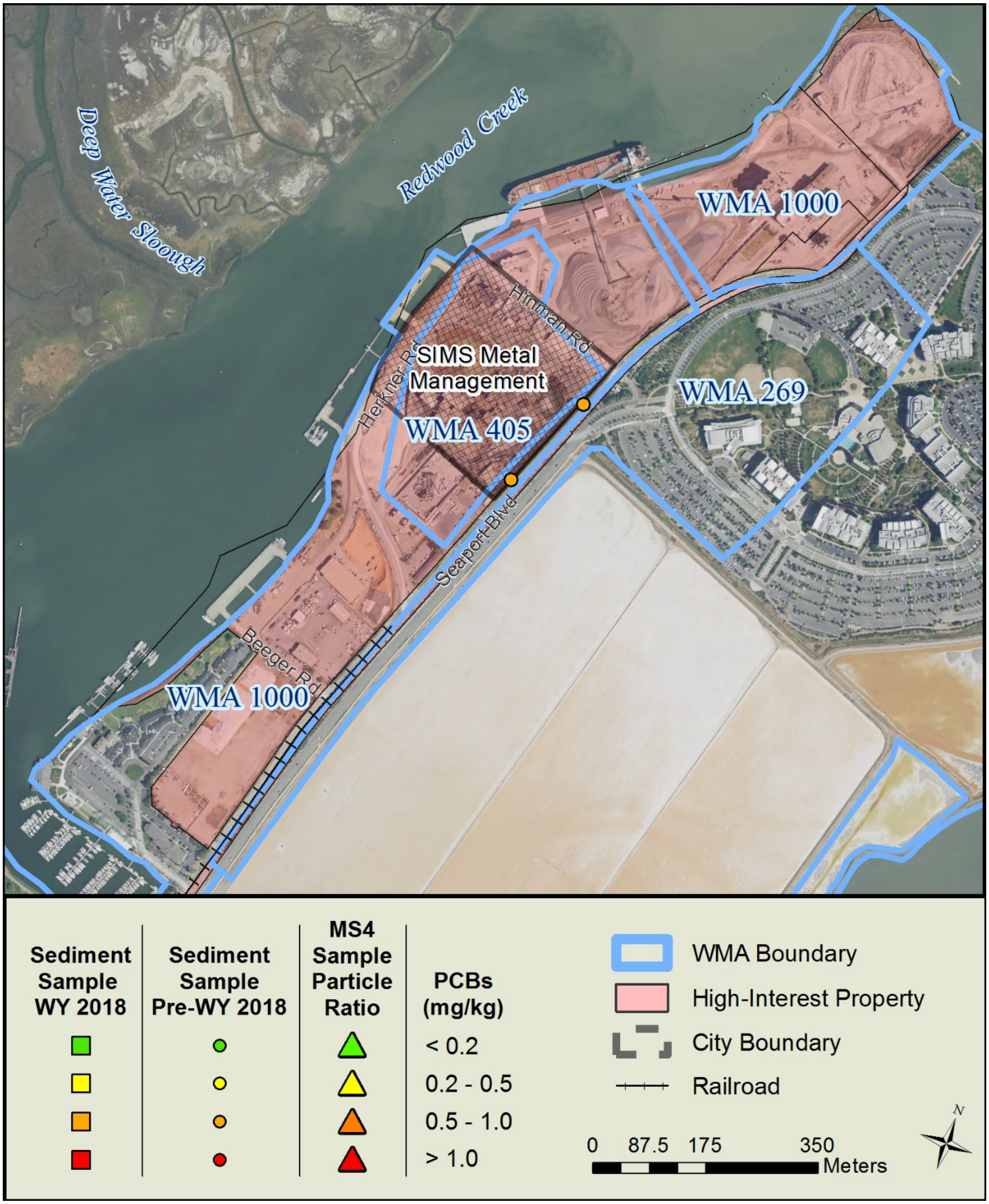

Figure 21. WMAs 269, 405, 1000

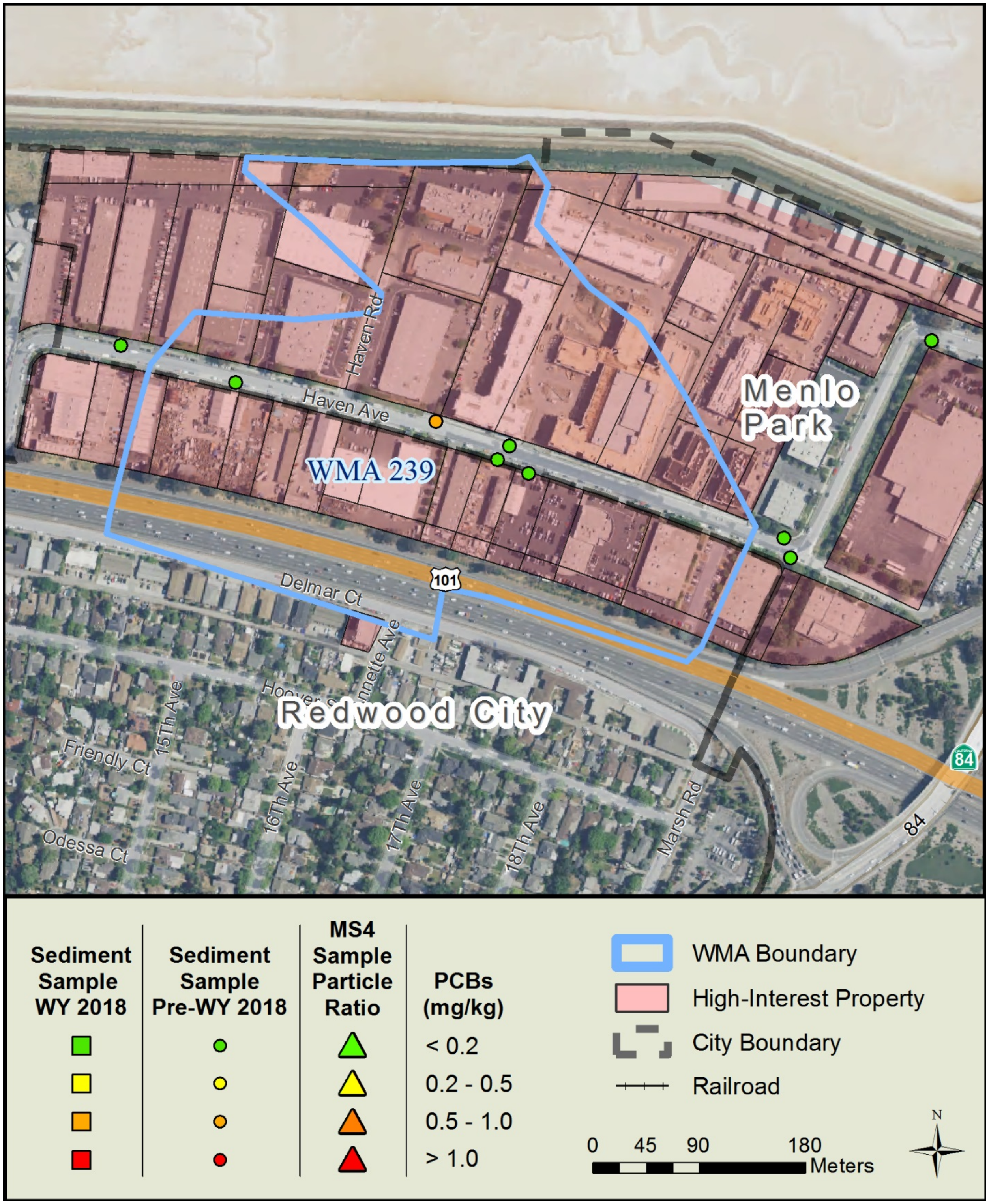

Figure 22. WMA 239

City of East Palo Alto

WMAs in the City of East Palo Alto with PCBs particle ratios greater than 0.2 mg/kg in stormwater runoff samples, elevated concentrations of PCBs in sediment samples, and/or other features relevant to investigating sources of PCBs are shown in Figure 23 and briefly described below. Table 7 summarizes PCBs, mercury, and SSC monitoring results for stormwater runoff samples collected in San Mateo County by the Countywide Program and RMP STLS through WY 2018. Attachment 2 summarizes WY 2018 embedded sediment monitoring locations and analytical results.

WMA 70

WMA 70 is a 490 acre catchment. A stormwater runoff sample collected by the RMP in WY 2015 had an elevated total PCBs concentration (28.5 ng/L) but a relatively low PCBs particle ratio (108 ng/g). Three sediment samples collected by SMCWPPP in the area in WY 2017 had relatively low PCBs concentrations, with the highest having a concentration of 0.03 mg/kg.

WMA 1015

WMA 1015 consists of multiple catchments in the City of East Palo Alto. This WMA contains Romic Environmental Technologies Corporation, a property that is known to be contaminated with PCBs and has been vacant for many years. A stormwater runoff sample and two sediment samples near the driveway to Romic all had relatively low concentrations of PCBs. However, the property drains directly to the Bay and the outfall is inaccessible. The WMA also contains 391 Demeter, a property that formerly was used to stockpile soils with PCBs that were removed from a separate remediation site. The site is expected to be redeveloped in the future. This property also drains directly to the Bay and is not possible to sample since it is all private property and inaccessible. A sediment sample from an inlet at the north end of Demeter Street was moderately elevated in PCBs with a concentration of 0.21 mg/kg.

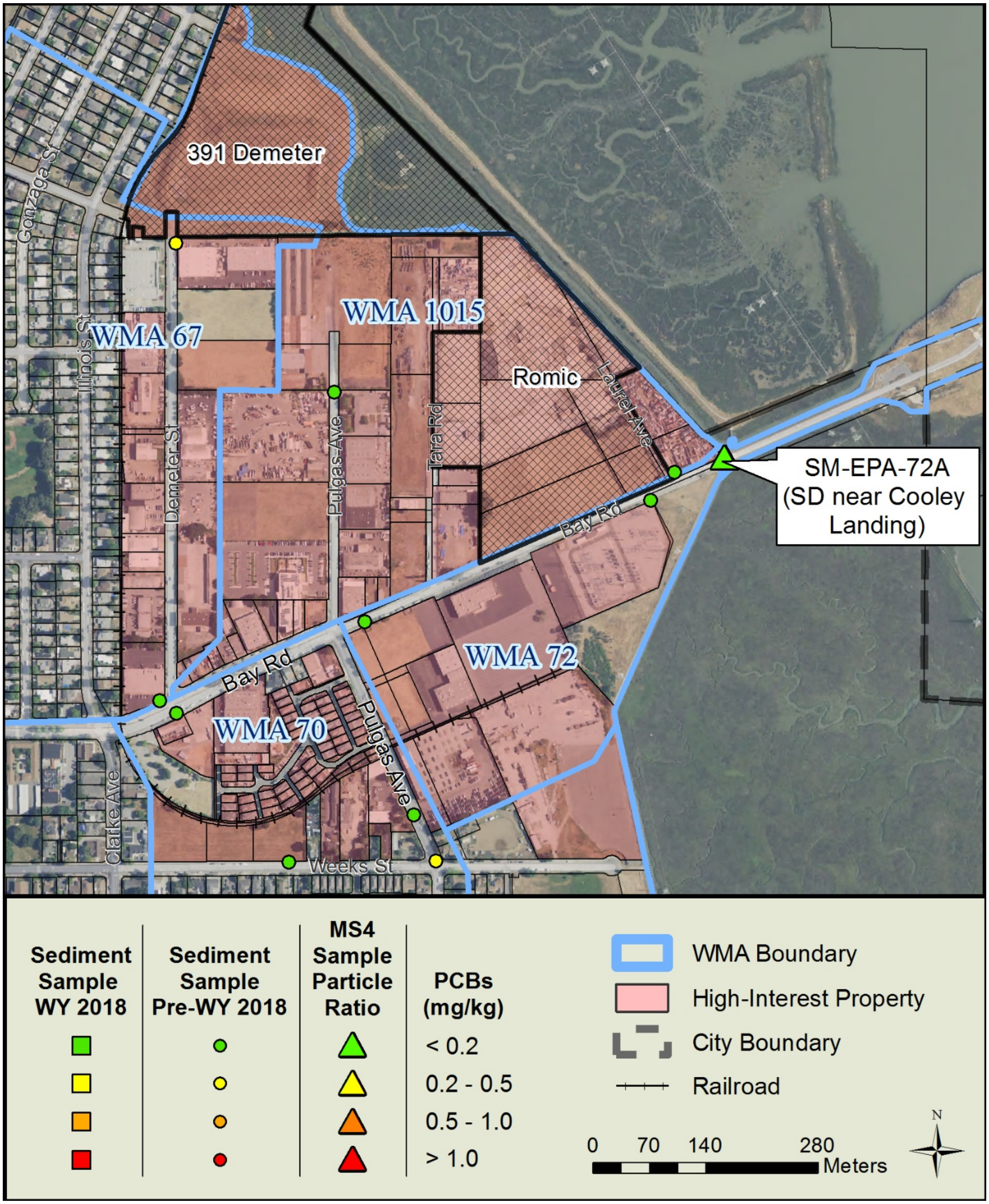

Figure 23. WMAs 70, 72, 1015

2.3. Copper

In WY 2018, the Countywide Program collected a total of four grab creek water samples for copper analysis. Bottom-of-the-watershed stations on San Pedro Creek and Cordilleras Creek were sampled during a storm event on January 8, 2018 (i.e., while stormwater runoff was being discharged to the creeks from the MS4), concurrent with nutrient POC monitoring and MRP Provision C.8.g.iii Wet Weather Pesticides and Toxicity Monitoring. The same two stations were sampled again in May 2018 during dry season base flows. The goal of this approach was to address Management Question No. 5 (Trends) by evaluating seasonal trends in copper concentrations. Management Question No. 4 (Loads and Status) is also addressed by characterizing copper concentrations in mixed-use watersheds. These data are supplemented by the SPoT sample collected in San Mateo Creek and analyzed for copper and other pollutants to assess long-term trends (Management Question No. 5).

All SMCWPPP samples were analyzed for total and dissolved copper[12] (method EPA 200.8) and hardness (method SM 2340C). The results are summarized in Table 10. Comparisons to freshwater WQOs are described in Section 3.0.

Table 10. Total and Dissolved Copper Concentrations in SMCWPPP Water Samples, WY 2018.

Sample Date	Total Copper (µg/L)	Dissolved Copper (µg/L)	Hardness as $CaCO_3$ (mg/L)
San Pedro Creek (202SPE005)			
1/8/2018	9.5	2.7	50
5/17/2018	0.84	0.41 J	190
Cordilleras Creek (204COR010)			
1/8/2018	8.4	4.3	76
5/21/2018	1.7	1.2	380

J-flagged data are above the detection limit but less than the reporting limit and are therefore considered estimated.

Based on the laboratory results, the following findings were noted:

- As expected, dissolved copper concentrations are lower than total copper concentrations. The dissolved portion of the total copper concentration was higher in the spring base flow samples compared to the storm samples. This finding is consistent with copper's affinity to suspended sediment. Suspended sediment concentration is generally higher during storm events.
- Copper concentrations at both stations were higher during the January storm event compared to the spring base flow event, suggesting an influence by stormwater runoff.
- Copper concentrations were similar (i.e., within the same order of magnitude) in both creeks. This finding is consistent with a lack of local sources of copper.

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[12] In order to simplify the field effort and reduce the risk of sample contamination, SMCWPPP requested that the analytical laboratory conduct the sample filtration required for dissolved copper analysis.

2.4. Nutrients

Nutrients were included in the POC monitoring requirements to support Regional Water Board efforts to develop nutrient numeric endpoints (NNE) for the San Francisco Bay Estuary. The "San Francisco Bay Nutrient Management Strategy" (NMS) is part of a statewide initiative to address nutrient over-enrichment in State waters (Regional Water Board 2012). Its goal is to lay out a well-reasoned and cost-effective program to generate the scientific understanding needed to fully support major management decisions such as establishing/revising WQOs for nutrients and dissolved oxygen, developing/implementing a nutrient monitoring program, and specifying nutrient limits in NPDES permits. The NMS monitoring program currently focuses on stations located within San Francisco Bay rather than freshwater tributaries.

MRP Provision C.8.f requires monitoring for a suite of nutrients (i.e., ammonium, nitrate, nitrite, total Kjeldahl nitrogen (TKN), orthophosphate, and total phosphorus). This list is similar to the list of analytes measured by the RMP and BASMAA partners at the six regional loading stations (including a San Mateo County station at the Pulgas Creek Pump Station in the City of San Carlos) monitored in WY 2012 - WY 2014. The prior data collected in freshwater tributaries to San Francisco Bay were used by the Nutrient Strategy Technical Team to develop and calibrate nutrient loading models.

In WY 2018, the Countywide Program collected a total of four samples for nutrient analysis. The analytes and chemical analysis methods were ammonia (SM 4500 C), nitrate (EPA 300.0), nitrite (SM 4500 B), TKN (SM 4500 C), orthophosphate (SM 4500 E), and total phosphorus (SM 4500 E).

Bottom-of-the-watershed stations on San Pedro Creek and Cordilleras Creek were sampled during a storm event on January 8, 2018, concurrent with copper POC monitoring and Provision C.8.g.iii Wet Weather Pesticides and Toxicity Monitoring. The two sites were sampled again in May 2018 during dry season base flows. Nutrient POC monitoring addresses Management Question No. 4 (Loads and Status). Management Question No. 5 (Trends) is also addressed by comparing nutrient concentrations during different flow events. Results are summarized in Table 11. Comparisons to applicable freshwater WQOs are described in Section 3.0.

Based on the laboratory results, the following findings were noted:

- Concentrations of all nutrients at both stations were higher during the January storm event compared to the spring base flow event, suggesting an influence by stormwater runoff. This finding is consistent with the draft conceptual model developed by the NMS which suggests that nutrient loads to San Francisco Bay from creeks are highest during the wet season, but still considerably less than loads from publicly owned wastewater treatment works (POTWs) (Senn and Novick 2014).
- Organic nitrogen (TKN) made up a greater proportion of the total nitrogen concentration during the January storm event compared to the May event. It is likely that organically-bound nitrogen that washed off surfaces during the January storm had not yet had time to cycle through the ammonification and nitrification processes before samples were collected.

Table 11. Nutrient Concentrations in WY 2018 POC Creek Water Samples Collected by SMCWPPP.

Date	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen (TKN)	Ammonia as N	Un-ionized Ammonia as N[1]	Ammonium[2]	Total Nitrogen[3]	Dissolved Orthophosphate as P	Phosphorus as P
San Pedro Creek (202SPE005)									
1/8/2018	0.81	0.009	0.88	0.077 J	0.0008	0.076	1.70	0.062	0.22
5/17/2018	0.47	0.004 J	0.18	0.05	0.0013	0.049	0.65	0.033	0.025
Cordilleras Creek (204COR010)									
1/8/2018	0.54	0.012	0.88	0.077 J	0.001	0.076	1.43	0.13	0.21
5/21/2018	0.11 J	<0.001	0.70	0.055	0.0008	0.054	0.81	0.089	0.11

Notes:

All constituents reported as mg/L.

J-flagged data are above the detection limit but less than the reporting limit and are therefore considered estimated.

[1] Un-ionized ammonia calculated using formula provided by the American Fisheries Society Online Resources. Formula requires field measurements of temperature, pH, and specific conductance, which were not recorded for the January 8, 2018 event. Specific conductance and pH values for Jan. 8 samples were estimated based on laboratory intake measurements reported for the concurrent toxicity samples. Temperature was estimated to be 12°C.

[2] Ammonium = ammonia – un-ionized ammonia.

[3] Total nitrogen = TKN + nitrate + nitrite. Non-detects valued at ½ method detection limit in calculation.

2.5. Emerging Contaminants

Emerging contaminant monitoring is being addressed through the Countywide Program's participation in the RMP. The RMP began investigating Contaminants of Emerging Concern (CECs) in 2001 and established the RMP Emerging Contaminants Work Group (ECWG) in 2006. The purpose of the ECWG is to identify CECs that might impact beneficial uses in the Bay and to develop cost-effective strategies to identify, monitor, and minimize impacts. The RMP published a CEC Strategy "living" document in 2013, completed a full revision in 2017 (Sutton et al. 2013, Sutton and Sedlak 2015, Sutton et al. 2017), and made minor updates in 2018 (Lin et al. 2018). The CEC Strategy document guides RMP special studies on CECs using a tiered risk and management action framework.

Provision C.8.f of the MRP identifies three emerging contaminants that must be addressed through POC monitoring: Perflourooctane Sulfonate Substances (PFOS), Perfluoroalkyl and Polyfluoroalkyl Sulfonate Substances (PFAS), and Alternative Flame Retardants (AFRs). PFAS is a broad class of chemicals used in industrial applications and consumer goods primarily for their ability to repel oil and water. PFOS are a subgroup within the PFAS umbrella and are identified in the CEC Strategy as "moderate" concern due to

Bay occurrence data suggesting a high probability of a low-level effect on Bay wildlife. Other PFAS and AFRs are identified as “possible” concerns due to uncertainties in measured or predicted Bay concentrations or in toxicity thresholds. RMP staff recently published reports summarizing PFOS and PFAS monitoring results (Houtz et al. 2016, Sedlak et al. 2017, Sedlak et al. 2018).[13]

AFRs came into use following state bans and nationwide phase-outs of polybrominated diphenyl ether (PBDE) flame retardants in the early 2000s. There are many categories of these compounds, including organophosphate esters. In 2018 the RMP STLS and ECWG worked together to conduct a special study to inform ECWG’s planning activities related to AFRs. The special study compiled and reviewed available data and previously developed conceptual models for PBDEs to support development by the ECWG of a stormwater-related AFR conceptual model. Organophosphate esters were prioritized for further investigation due to their increasing use, persistent character, and ubiquitous detections at concentrations exceeding PBDE concentrations in the Bay. Limited stormwater data from two watersheds in Richmond and Sunnyvale suggest that urban runoff may be an important source of these compounds. Additional monitoring and modeling was recommended. Results of the AFR special study were published in a Technical Report in 2018 (Lin and Sutton 2018).

In 2018, the RMP’s ECWG also developed a special study proposal to analyze stormwater samples collected from urban watersheds for a large suite of CECs. The list of CECs to be analyzed is based on recent work conducted in Puget Sound streams and is intended to target urban runoff constituents rather than those found in wastewater (e.g., pharmaceuticals). The list includes PFOSs, PFASs, and AFRs. Pilot sampling will begin in WY 2019 in close coordination with the STLS.

The above RMP special studies satisfy the POC monitoring requirement for CECs in MRP Provision C.8.f.

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[13] The Emerging Contaminants Workgroup is also monitoring a number of other emerging contaminants that are not identified in the MRP. These include microplastics, ethoxylated surfactants, and fipronil.

3.0 COMPLIANCE WITH APPLICABLE WATER QUALITY OBJECTIVES

MRP Provision C.8.h.i requires RMC participants to assess all data collected pursuant to Provision C.8 for compliance with applicable water quality objectives (WQOs). In compliance with this requirement, POC monitoring water sampling data collected in WY 2018 by the Countywide Program were compared to applicable numeric WQOs. There were no exceedances of applicable WQOs.

The comparison to applicable WQOs to into account the following considerations:

- **Discharge vs. Receiving Water** – WQOs apply to receiving waters, not discharges such as stormwater runoff. A WQO generally represents the maximum concentration of a pollutant that can be present in the water column without adversely effecting organisms using the aquatic system as habitat, people consuming those organisms or water, and/or other current or potential beneficial uses. During WY 2018, only nutrient and copper data were collected in receiving waters by SMCWPPP. PCBs and mercury samples were collected within the engineered storm drain network. Dilution is likely to occur when the MS4 discharges urban stormwater (and non-stormwater) runoff into local receiving waters. Therefore, it is unknown whether discharges that exceed WQOs result in exceedances in the receiving water itself, the location where there is the potential for aquatic life to be exposed to a pollutant.
- **Freshwater vs. Saltwater** - POC monitoring samples were collected from freshwater (i.e., above tidal influence in creeks) and therefore comparisons were made to freshwater WQOs.
- **Aquatic Life vs. Human Health** - Comparisons were primarily made to WQOs for the protection of aquatic life, not WQOs for the protection of human health to support the consumption of water or organisms. The rationale is that water and organisms are not likely consumed by humans at the locations of the monitoring stations.
- **Acute vs. Chronic Objectives/Criteria** – All monitoring of stormwater runoff for PCBs and mercury and one of the two copper/nutrient creek sampling events were conducted during episodic storm events. Storm episode monitoring results likely do not represent long-term concentrations of the monitored constituents in receiving waters. Storm monitoring data was compared to acute WQOs for aquatic life that represent the highest concentrations of a pollutant to which an aquatic community can be exposed for a short period of time (e.g., one hour) without resulting in an unacceptable effect. Spring baseflow creek monitoring data were compared to chronic WQOs developed to assess longer-term exposure.

Of the WY 2018 POC monitoring analytes, promulgated WQOs for the protection of aquatic life only exist for total mercury, dissolved copper, and unionized ammonia.

- **Total Mercury**. All water samples collected in San Mateo County watersheds by SMCWPPP and the STLS and analyzed for mercury were stormwater runoff (Table 7). Stormwater runoff results are not directly comparable to WQOs, as described above. However, all of the WY 2018 and previous Water Year mercury concentrations (Table 7) were well below the freshwater acute objective for mercury of 2.4 µg/L (2,400 ng/L).
- **Dissolved Copper.** Acute (1-hour average) and chronic (4-day average) WQOs for copper are expressed in terms of the dissolved fraction of the metal in the water column and are hardness

dependent[14]. The copper WQOs were calculated using the base e exponential functions described in the California Toxics Rule (40 CFR 131.38) which apply hardness values measured at the sample station. Dissolved copper concentrations were compared to the calculated WQOs. Per the above discussion, storm monitoring data was compared to acute WQOs and spring baseflow creek monitoring data were compared to chronic WQOs. All dissolved copper concentrations were below calculated acute and chronic WQOs (Table 12).

- **Nutrients**. The un-ionized ammonia concentrations calculated based on measured concentrations of ammonia in Countywide Program samples (Table 11) were well below the annual median WQO for un-ionized ammonia of 0.025 mg/L.

Table 12. Comparison of WY 2018 Copper Monitoring Data to WQOs.

Station Code	Sample Date	Measured Dissolved Copper (µg/L)	Measured Hardness as $CaCO_3$ (mg/L)	Acute WQO for Dissolved Copper at Measured Hardness (µg/L)	Chronic WQO for Dissolved Copper at Measured Hardness (µg/L)
202SPE005	1/8/2018	2.7	50	7.0	5.0 (NA)
202SPE005	5/17/2018	0.41 J	190	24.6	15.5
204COR010	1/8/2018	4.3	76	10.4	7.1 (NA)
204COR010	5/21/2018	1.2	380	47.3	28.0

J-flagged data are above the detection limit but less than the reporting limit and are therefore considered estimated.
NA = Not applicable. Chronic WQOs are not applicable to storm event grab samples.

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[14] The current copper standards for freshwater in California do not account for the effects of pH or natural organic matter and can be overly stringent or under-protective (or both, at different times). Therefore, the California Stormwater Quality Association (CASQA) has asked the USEPA to considering updating the California Toxics Rule standards for copper using the Biotic Ligand Model (BLM) which accounts for the effect of water chemistry in addition to hardness (i.e., temperature, pH, dissolved organic carbon, major cations and anions).

4.0 SUMMARY AND DISCUSSION

In WY 2018, the Countywide Program continued to collect and analyze POC samples in compliance with Provision C.8.f of the MRP. Yearly minimum requirements were met for all monitoring parameters. WY 2018 POC monitoring data collected directly by the Countywide Program were evaluated, along with appropriate data collected by third parties such as the RMP's STLS. Highlights from WY 2018 included the following:

- The Countywide Program's PCBs and mercury monitoring continued to focus on San Mateo County WMAs containing high interest parcels with land uses potentially associated with PCBs, such as old industrial, electrical and recycling. During WY 2018, the Countywide Program collected 13 composite samples of stormwater runoff from the bottom of WMAs to help better characterize these catchments and 50 grab samples of sediment within priority WMAs to help identify source properties.
- The individual and composite grab sediment samples were collected in the public right-of-way (ROW), including locations adjacent to high interest parcels with land uses associated with PCBs and/or other characteristics potentially associated with pollutant discharge (e.g., poor housekeeping, unpaved areas). The samples were collected from a variety of types of locations, including manholes, storm drain inlets, driveways, streets, and sidewalks.
- Using similar methods, the RMP's STLS collected two additional stormwater runoff composite samples for PCBs and mercury analysis from the bottom of WMAs in South San Francisco. The Countywide Program assisted the STLS with selecting these monitoring stations.
- The two WY 2018 RMP STLS stormwater runoff sample stations located in South San Francisco and had both previously been sampled in WY 2016 using similar methods. PCBs concentrations in the WY 2016 samples were relatively low. However, in the WY 2018 resamples, PCBs concentrations (total PCBs and particle ratio) were elevated (particle ratios greater than 0.5 mg/kg) and roughly an order of magnitude higher than in WY 2016 (except that the PCBs particle ratio for one of the samples was at a similar elevated level for both events).
- Low PCBs concentrations in a composite stormwater runoff sample from the bottom of a WMA catchment suggest that either PCBs sources are not prevalent in the catchment or the sample is a "false negative." False negatives could be the result of low rainfall/runoff rates failing to mobilize sediments from source areas, or many other factors. The RMP is currently conducting an "Advanced Data Analysis" that will include attempting to develop a method to normalize results from this type of stormwater runoff monitoring based upon storm intensity.
- The Countywide Program evaluated the WY 2018 stormwater runoff and sediment monitoring data along with data from previous years collected in San Mateo County by the Countywide Program and other parties (e.g., the RMP's STLS). The evaluation results were used to update the existing provisional designation of WMAs as high, medium, or low priority. This provisional prioritization informs selecting WMAs for additional future investigation and identifying WMAs that provide opportunities for implementing cost-effective PCBs controls. Figure 4 is a map illustrating the current status of WMAs in San Mateo County, based upon the provisional prioritization.

- It is important to emphasize the provisional nature of these prioritizations, and especially the uncertainty surrounding designating a WMA as low priority due to a single bottom-of-catchment composite stormwater runoff sample having a low PCBs particle ratio. As noted above, low PCBs concentrations in any single stormwater runoff sample could be a false negative if the storm was too small to mobilize sediments with associated PCBs, or other factors. For example, based upon the WY 2018 resampling results, the above two WY 2016 RMP STLS stormwater runoff samples located in South San Francisco may have been false negatives.
- The PCBs monitoring data collected to-date has informed identification of several potential source properties located in the City of San Carlos. The Countywide Program is working with the City regarding next steps at these sites. This included recently developing and submitting to the Regional Water Board referrals of two areas for potential further PCBs investigation and abatement:
    - 270 Industrial Road (Delta Star) / 495 Bragato Road (Tiegel), which are adjacent properties in San Carlos.
    - 977 and 1007/1011 Bransten Road, another set of adjacent properties in San Carlos.
- The mean and median PCBs concentrations in WY 2018 sediment samples (n = 50) were somewhat lower than in previous years. In addition, in WY 2018 only 1 of the 50 sediment samples collected had a PCBs concentration that exceeded 1.0 mg/kg. One other sample had a PCBs concentration between 0.5 and 1.0 mg/kg. All of the remaining samples had a PCBs concentration below 0.5 mg/kg. In general, the WY 2018 POC monitoring data suggest that the PCBs monitoring program in the public ROW in San Mateo County may be approaching diminishing returns in terms of identifying new source properties.
- However, the stormwater runoff resamples in South San Francisco suggest the possibility of false negatives for PCBs in some WMAs provisionally designated low priority based on stormwater runoff data from previous years. The RMP's ongoing "Advanced Data Analysis" is evaluating normalizing results based upon storm intensity and the results may help inform planning any future stormwater runoff monitoring of this type.
- Samples for copper analysis were collected from two bottom-of-the-watershed locations during two monitoring events: a January storm event and during spring baseflow. Copper concentrations were higher in the storm samples compared to the baseflow samples, suggesting an influence by stormwater runoff. Similar concentrations at both sites was consistent with a lack of local sources.
- Samples for nutrient analysis were collected from two bottom-of-the-watershed locations during two monitoring events: a January storm event and during spring baseflow. Nutrient concentrations (nitrogen and phosphorus) were higher in the storm samples compared to the baseflow samples, suggesting an influence by stormwater runoff.
- None of the WY 2018 SMCWPPP or third-party water samples collected in San Mateo County exceeded applicable water quality objectives (WQOs).
- SMCWPPP participated in a BASMAA monitoring study that satisfied the provision C.12.e requirement to collect 20 composite caulk/sealant samples throughout the MRP permit area. The final project report was included with the Countywide Program's FY 2017/18 Annual Report, submitted to the Regional Water Board on September 30, 2018 (BASMAA 2018).

- SMCWPPP participated in a the BASMAA Regional Best Management Practices (BMP) Effectiveness Study which was developed to satisfy provision C.8.f requirements to collect at least eight PCBs and mercury samples that address Management Question No. 3 (Management Action Effectiveness). The study investigated the effectiveness of hydrodynamic separator (HDS) units and various types of biochar-amended bioretention soil media (BSM) at removing PCBs and mercury from stormwater. Results of the study are summarized by BASMAA (2019a and b), reports that are appended to SMCWPPP's WY 2018 UCMR.

5.0 NEXT STEPS

The Countywide Program will continue its POC monitoring program in compliance with Provision C.8.f of the MRP. As in previous years, yearly minimum requirements will be met for all monitoring parameters. In WY 2019, the Countywide Program will continue to:

- Conduct PCBs and mercury monitoring that focuses on San Mateo County WMAs containing high interest parcels with land uses potentially associated with PCBs such as old industrial, electrical and recycling. This monitoring will continue to be coordinated with stormwater runoff monitoring in San Mateo County catchments by the RMP's STLS.
- Assist the RMP's STLS to select its PCBs and mercury monitoring stations that are located in in San Mateo County catchments. The Countywide Program recently worked with the STLS to select its WY 2019 PCBs and mercury monitoring stations.
- Collect grab sediment samples for PCBs and mercury analysis within San Mateo County WMAs, targeting selected catchments and parcels of interest. During WY 2019, SMCWPPP will collect approximately 25 sediment samples (this fieldwork is scheduled for April 2019). Objectives will include attempting to identify source properties within WMAs, identifying which WMAs provide the greatest opportunities for implementing cost-effective PCBs controls, and prioritizing WMAs for potential future investigations.
- Evaluate the WY 2019 POC monitoring data collected in San Mateo County by SMCWPPP and other parties (e.g., the RMP's STLS), along with data from previous years. This will include tracking the results of the RMP's ongoing "Advanced Data Analysis," which includes an evaluation of normalizing stormwater runoff PCBs monitoring results based upon storm intensity. The results may help inform planning future stormwater runoff monitoring of this type (if any) in San Mateo County.
- Evaluate the cost-effectiveness of conducting additional POC monitoring (e.g., sediment and stormwater runoff sampling for PCBs and mercury, including the use of remote sediment samplers during storms) in future Water Years that would further inform implementation of controls in priority WMAs.
- Coordinate the POC monitoring program with planning scenarios for control measure implementation in priority WMAs in San Mateo County. High priority will continue to be given to the Pulgas Creek pump station north and south drainages (WMA 31 and WMA 210), which are the two WMAs in San Mateo County with the greatest number of samples with elevated concentrations of PCBs in sediment and stormwater runoff samples to-date.
- Attempt to identify new source properties for referral to the Regional Water Board, based on the evaluation of the results to-date from the POC monitoring program and other appropriate data, as they become available.
- Participate in the RMP, including the RMP's STLS, STLS Trends Strategy, and CEC Strategy.
- Work with the State's SPoT monitoring program to help address Management Question No. 5 (Trends). This will include tracking the results from the SPoT station near the mouth of San Mateo Creek in the City of San Mateo. SPoT collected sediment samples from this station in June 2018 and analyzed for a number of pollutants, including mercury, copper, and organic pollutants (but not PCBs), but the results are not yet available.

- Collect samples for copper analysis, primarily to address Management Question No. 4 (Loads and Status) and/or No. 5 (Trends). Details of the WY 2019 copper monitoring approach are currently under development.
- Collect samples for nutrient analysis. These samples will be collected from mixed land use watersheds during baseflow to address Management Question No. 4 (Loads and Status). Details of the WY 2019 nutrient monitoring approach are currently under development.

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Attachment 1

Quality Assurance / Quality Control Report

Pollutants of Concern Monitoring - Quality Assurance/Quality Control Report, WY 2018

1.0 INTRODUCTION

The San Mateo Countywide Pollution Prevention Program (SMCWPPP) conducted Pollutants of Concern (POC) Monitoring in Water Year (WY) 2018 to comply with Provision C.8.f (Pollutants of Concern Monitoring) of the National Pollutant Discharge Elimination Program (NPDES) Municipal Regional Permit for the San Francisco Bay Area (i.e., MRP). Monitoring included analysis for polychlorinated biphenyls (PCBs), total mercury, total and dissolved copper, suspended sediment concentration (SSC), and nutrients (i.e., ammonia, nitrate, nitrite, total Kjeldahl nitrogen, orthophosphate, and total phosphorus).

This project utilized the Clean Watersheds for Clean Bay Project (CW4CB) Quality Assurance Project Plan (QAPP; BASMAA 2013) as a basis for Quality Assurance and Quality Control (QA/QC) procedures. Missing components were supplemented by the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) QAPP (BASMAA 2016) and the QAPP for the California Surface Water Ambient Monitoring Program (SWAMP), specifically for nutrient and copper samples, respectively. Data were assessed for seven data quality attributes, which include (1) Representativeness, (2) Comparability, (3) Completeness, (4) Sensitivity, (5) Contamination, (6) Accuracy, and (7) Precision. These seven attributes were compared to Data Quality Objectives (DQOs), which were established to ensure that data collected are of adequate quality and sufficient for the intended uses. DQOs address both quantitative and qualitative assessment of the acceptability of data – representativeness and comparability are qualitative while completeness, sensitivity, precision, accuracy, and contamination are quantitative assessments. Specific DQOs are based on Measurement Quality Objectives (MQOs) for each analyte.

The MQOs for each of the POC analytes are summarized in Table 1 for water and Table 2 for sediment. As there was no reporting limit listed in the QAPP for copper, results were compared to the SWAMP recommended reporting limits for inorganic analytes in freshwater. Overall, the results of the QA/QC review suggest that the data generated during this study were of sufficient quality for the purposes of the project. While some data were flagged based on the MQOs and DQOs identified in the QAPPs, none of the data was rejected. Further details regarding the QA/QC review are provided in the sections below.

Table 1. Measurement quality objectives for analytes in water from the Clean Watersheds for a Clean Bay (CW4CB) Quality Assurance Project Plan (BASMAA 2013) and BASMAA RMC Quality Assurance Project Plan (BASMAA 2016)

Sample	Nutrients[1]	Hardness[1]	SSC[2]	Copper[2]	Mercury[2]	PCBs[2]
Laboratory Blank	< RL	<RL	< RL	< RL	< RL	< RL
Reference Material (Laboratory Control Sample) Recovery	90-110%	80-120%	NA	75-125%	75-125%	50-150%
Matrix Spike Recovery	80-120%	80-120%	NA	75-125%	75-125%	50-150%
Duplicates (Matrix Spike, Field, and Laboratory)[3]	RPD < 25%	RPD < 25%	RPD < 25%	RPD < 25%	RPD < 25%	RPD < 25%
Reporting Limit	0.01mg/L for all except: Ammonia (0.02mg/L) TKN[4] (0.5mg/L)	1 mg/L[5]	0.5 mg/L	0.10 µg/L[6]	0.0002 µg/L (0.2 ng/L)	0.002 µg/L (2000 pg/L)

RL = Reporting Limit; RPD = Relative Percent Difference

[1] From the BASMAA QAPP

[2] From the CW4CB QAPP

[3] NA if native concentration for either sample is less than the reporting limit

[4] TKN = Total Kjeldahl Nitrogen

[5] No hardness RL listed in either QAPP. Value is from SWAMP-recommended reporting limits for conventional analytes in freshwater. (https://www.waterboards.ca.gov/water_issues/programs/swamp/docs/tools/19_tables_fr_water/1_conv_fr_water.pdf)

[6] No copper RL listed in either QAPP. Value is from SWAMP-recommended reporting limits for inorganic analytes in freshwater. (http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/tools/19_tables_fr_water/4_inorg_fr_water.pdf)

Table 2. Measurement quality objectives for analytes in sediment from the Clean Watersheds for a Clean Bay (CW4CB) Quality Assurance Project Plan (BASMAA 2013).

Sample	Total Solids	Mercury	PCBs
Laboratory Blank	< RL	< RL	< RL
Reference Material (Laboratory Control Sample) Recovery	N/A	75-125%	50-150%
Matrix Spike Recovery	N/A	75-125%	50-150%
Duplicates [1] (Matrix Spike, Field, and Laboratory)	RPD < 25%	RPD < 25%	RPD < 25%[2]
Reporting Limit	0.1%[3]	30 µg/kg 0.03 mg/kg 30,000 ng/kg	0.2 µg/kg 0.0002 mg/kg 200 ng/kg

RL = Reporting Limit; RPD = Relative Percent Difference

[1] NA if native concentration for either sample is less than the reporting limit

[2] Only applicable for matrix spike duplicates. Method specific for field and laboratory duplicates

[3] RL for total solids in water

2.0 REPRESENTATIVENESS

Data representativeness assesses whether the data were collected so as to represent actual conditions at each monitoring location. For this project, all samples were assumed to be representative if they were collected and analyzed according to protocols specified in the CW4CB QAPP and RMC QAPP. All field and laboratory personnel received and reviewed the QAPPs, and followed prescribed protocols including laboratory methods.

3.0 COMPARABILITY

The QA/QC officer ensures that the data may be reasonably compared to data from other programs producing similar types of data. For POC monitoring, individual stormwater programs try to maintain comparability within the RMC. The key measure of comparability for all RMC data is the California Surface Water Ambient Monitoring Program.

Electronic data deliverables (EDDs) were submitted to the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) in Microsoft Excel templates developed by SWAMP, to ensure data comparability with SWAMP. In addition, data entry followed SWAMP documentation specific to each data type, including the exclusion of qualitative values that do not appear on SWAMP's look up lists[1]. Completed templates were reviewed using SWAMP's online data checker[2], further ensuring SWAMP-comparability.

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[1] Look up lists available online at http://swamp.waterboards.ca.gov/swamp_checker/LookUpLists.php.

[2] Checker available online at http://swamp.waterboards.ca.gov/swamp_checker/SWAMPUpload.php

4.0 COMPLETENESS

Completeness is the degree to which all data were produced as planned; this covers both sample collection and analysis. For chemical data and field measurements an overall completeness of greater than 90% is considered acceptable for RMC chemical data and field measurements.

During WY 2018, SMCWPPP collected 100% of planned samples. Four aqueous samples were collected and analyzed for nutrients (ammonia, nitrate, nitrite, total Kjeldahl nitrogen, phosphorus, and orthophosphate), copper, and hardness. A total of 13 aqueous samples were collected in WY 2018 and analyzed for PCBs, mercury, and SSC. Fifty (50) sediment samples were also collected in WY 2018 and analyzed for PCBs, mercury, and total solids.

5.0 SENSITIVITY

5.1. Water

Sensitivity analysis determines whether the methods can identify and/or quantify results at low enough levels. For the aqueous chemical analyses in this project, sensitivity is considered to be adequate if the reporting limits (RLs) comply with the specifications in RMC QAPP Appendix E (RMC Target Method Reporting Limits) and the CW4CB QAPP Appendix B (CW4CB Target Method Reporting Limits).

A summary of the target and actual reporting limits for each analyte is shown in Table 3. The reporting limits for all nitrate, suspended sediment concentration (SSC), copper, and hardness samples, plus the ammonia samples collected in January and mercury samples collected in March exceeded their respective target reporting limits.

Table 3. Target and actual reporting limits for SMCWPPP pollutants of concern monitoring in water in WY 2018

Analyte	Unit	Target	Actual	Exceeds Target RL?
Ammonia	mg/L	0.02	0.02-0.1	Yes
Nitrate	mg/L	0.01	0.1-0.2	Yes
Nitrite	mg/L	0.01	0.005	No
Total Kjeldahl Nitrogen	mg/L	0.5	0.1	No
Phosphorus	mg/L	0.01	0.01	No
Orthophosphate	mg/L	0.01	0.01	No
Suspended Sediment Concentration	mg/L	0.5	0.95-1.6	Yes
Copper	µg/L	0.1	0.1-0.5	Yes
Hardness	mg/L	1	5-10	Yes
Mercury	ng/L	0.2	0.5-2.5	Yes
PCBs	pg/L	2000	19.3-210	No

5.2. Sediment Analysis

Approximately 4% of sediment PCB samples (364 of 9460) did not meet the CW4CB reporting limit requirement of 200 ng/kg. However, all exceedances were due to elevated concentrations, which required dilutions to conduct the analysis.

The target reporting limit for mercury (0.03 mg/kg) was met for all samples. No analytical reporting limit was listed by the laboratory for total solids results in WY 2018. However, all total solids results were several orders of magnitude above the target reporting limit of 0.1%. The laboratory was instructed to use the target reporting limit of 0.1% for future analyses of total solids samples.

6.0 CONTAMINATION

For chemical data, contamination is assessed as the presence of analytical constituents in blank samples.

6.1. Water Analysis

Several laboratory and equipment (filter) blanks were run during the nutrient, copper, and hardness analyses. All associated blanks were non-detect. Analytes were detected in two laboratory blanks for mercury, but no analytes were detected in any PCB laboratory blanks.

6.2. Sediment Analysis

Several laboratory blanks were analyzed during sediment analysis. Mercury was detected in several blanks above the method detection limit, but below the reporting limit. Similarly, several PCBs were detected in a laboratory blank at concentrations below the reporting limit. The PCBs that were detected in laboratory blanks include the following:

- PCB 008
- PCB 011
- PCB 018/30
- PCB 020/28
- PCB 031
- PCB 052
- PCB 083/99
- PCB 090/101/113
- PCB 093/95/100
- PCB 110/115
- PCB 129/138/163
- PCB 132
- PCB 147/149
- PCB 153/168
- PCB 180/193
- PCB 187
- PCB 194
- PCB 198/199
- PCB 206
- PCB 209
- Total Di-PCB
- Total Tri-PCB
- Total Tetra-PCB
- Total Penta-PCB
- Total Hexa-PCB
- Total Hepta-PCB
- Total Octa-PCB
- Total Nona-PCB
- Total PCBs

Since concentrations were detected below the reporting limit, all laboratory blanks met the MQOs.

7.0 ACCURACY

Accuracy is assessed as the percent recovery of samples spiked with a known amount of a specific chemical constituent. The analytical laboratory evaluated and reported the Percent Recovery (PR) of Laboratory Control Samples (LCS; in lieu of reference materials) and Matrix Spikes (MS)/Matrix Spike Duplicates (MSD), which were recalculated and compared to the target ranges in the RMC and CW4CB QAPPs. If a QA sample did not meet MQOs, all samples in that batch for that analyte were flagged.

7.1. Water Analysis

All laboratory LCS and MS/MSD samples for nutrients, hardness, copper, mercury, and SSC were within their respective MQOs except for one SSC LCS in April, one total Kjeldahl nitrogen and two nitrite matrix spikes in January, and two phosphorous matrix spike samples in June. The associated samples were consequently flagged. Twenty-four (24) laboratory control samples exceeded the MQOs for PCBs, and all associated samples were flagged. No MS/MSD samples were analyzed for PCB congeners in water. However, the analytical laboratory affirmed that laboratory control and duplicate laboratory control samples were analyzed in lieu of matrix spike and duplicate matrix spike samples for the PCBs. In this case, it is acceptable to compare the percent recoveries calculated from the laboratory control samples to the MQOs for matrix spike percent recoveries. Given that the MQOs are the same in both cases, no other exceedances were found.

7.2. Sediment Analysis

All mercury laboratory control samples met their corresponding MQOs, but 81 LCS for PCB did not meet their MQOs. No MS/MSD samples were taken for PCB analytes in sediment. Laboratory control spike and duplicate laboratory control spike samples were again analyzed in lieu of matrix spike and duplicate matrix spikes for the PCB analytes with no exceedances observed.

8.0 PRECISION

Precision is the repeatability of a measurement and is quantified by the Relative Percent Difference (RPD) of two duplicate samples. Three measures of precision were used for this project – matrix spikes duplicates, laboratory duplicates, and field duplicates. The MQO for RPD specified by both the CW4CB QAPP and the BASMAA QAPP is <25%.

8.1. Water Analysis

8.1.1. Laboratory Duplicates

Matrix spike duplicates and laboratory control sample duplicates for nutrients, copper, hardness, and mercury were well below the targeted range of < 25%. As previously stated, duplicate laboratory control samples were analyzed in place of duplicate matrix spike samples to assess precision in the measurement of PCB concentrations. Given that the RPD MQOs are the same in both cases, no other exceedances were found.

No laboratory duplicates were analyzed for any analytes besides suspended sediment concentration, and suspended sediment concentration does not have an RPD MQO against which to compare.

8.1.2. Field Duplicates

One nutrient field duplicate was collected during WY 2018 creek status monitoring and is considered representative of nutrient sampling for POC monitoring. The field duplicate sample met the MQO for RPD for all analytes except for total Kjeldahl nitrogen and ammonia. Refer to the SMCWPPP Creek Status Monitoring QA/QC Report for more information.

Field duplicates were collected for copper, nutrients, and hardness during the January event in San Mateo County and the May event in Santa Clara County on behalf of SMCWPPP. The duplicate samples collected in January met the RPD MQO for all analytes except ammonia. Similarly, the duplicate samples collected in May met the RPD MQO for all analytes except ammonia and phosphorus. Additionally, a field duplicate was collected in San Mateo County for aqeuous mercury, PCBs, and SSC. The RPDs for all analytes except mercury and several PCB congeners met the MQO. The PCB congeners whose RPDs that exceeded the MQO include the following:

- PCB 061/70/74/76
- PCB 090/101/113
- PCB 093/95/100
- PCB 105
- PCB 110/115
- PCB 118
- PCB 194
- PCB 203
- Total Octa-PCB
- Total Penta-PCB
- Total Tetra-PCB

8.2. Sediment Analysis

8.2.1. Laboratory Duplicates

Two mercury matrix spike duplicates exceeded the corresponding MQO. Six laboratory duplicates were run for total solids and were well below the MQO (<25%). No mercury or PCB laboratory duplicates were run during the sediment analysis.

8.2.2. Field Duplicates

Five sediment field blind duplicates were collected in WY 2018. The field duplicates exceeded the RPD MQO for mercury and 102 PCBs. The sample taken at SM-SSF-01-J had the lowest amount of analytes exceeding the MQO with 16 total exceedances. The sample taken at SM-BUR-03-E had the highest amount of analytes exceeding the MQO with 40 total exceedances. The analytes that exceeded the MQO include the following (the number of samples that exceeded the MQO for that analyte are included in parentheses):

- Mercury (1)
- PCB 006 (1)
- PCB 007 (1)
- PCB 009 (1)
- PCB 011 (3)
- PCB 012/13 (1)
- PCB 016 (1)
- PCB 017 (2)
- PCB 018/30 (2)
- PCB 019 (1)
- PCB 021/33 (1)
- PCB 025 (1)
- PCB 026/29 (2)
- PCB 032 (3)
- PCB 035 (2)
- PCB 036 (1)
- PCB 040/41/71 (1)
- PCB 045/51 (2)
- PCB 046 (1)
- PCB 050/53 (2)
- PCB 052 (1)
- PCB 058 (1)
- PCB 059/62/75 (2)
- PCB 063 (1)
- PCB 079 (1)
- PCB 084 (1)
- PCB 086/87/97/109/119/125 (1)
- PCB 088/91 (1)
- PCB 089 (2)
- PCB 090/101/113 (1)
- PCB 093/95/100 (2)
- PCB 094 (1)
- PCB 096 (1)
- PCB 098/102 (2)
- PCB 103 (2)
- PCB 107 (1)
- PCB 108/124 (1)
- PCB 110/115 (1)
- PCB 114 (2)
- PCB 118 (1)
- PCB 122 (2)
- PCB 126 (1)
- PCB 128/166 (1)
- PCB 129/138/163 (2)
- PCB 131 (1)
- PCB 132 (1)
- PCB 133 (1)
- PCB 134 (1)
- PCB 135/151/154 (1)
- PCB 136 (1)
- PCB 137 (1)
- PCB 139/140 (2)
- PCB 141 (2)
- PCB 144 (1)
- PCB 145 (1)
- PCB 146 (1)
- PCB 147/149 (2)
- PCB 148 (1)
- PCB 150 (1)
- PCB 152 (1)
- PCB 153/168 (2)
- PCB 156/157 (1)
- PCB 158 (1)
- PCB 159 (1)
- PCB 162 (1)
- PCB 169 (1)
- PCB 170 (2)
- PCB 171/173 (1)
- PCB 172 (1)
- PCB 174 (3)
- PCB 177 (1)
- PCB 179 (2)
- PCB 180/193 (2)
- PCB 183/185 (2)
- PCB 184 (1)
- PCB 187 (2)
- PCB 188 (1)
- PCB 190 (2)
- PCB 191 (1)
- PCB 194 (1)
- PCB 195 (1)
- PCB 196 (1)
- PCB 197 (3)
- PCB 198/199 (2)
- PCB 200 (1)
- PCB 201 (1)
- PCB 203 (2)
- PCB 206 (1)
- PCB 207 (1)
- PCB 208 (1)
- PCB 209 (2)
- Total Di-PCB (3)

- Total Hepta-PCB (2)
- Total Hexa-PCB (1)
- Total Octa-PCB (2)
- Total PCBs (1)
- Total Penta-PCB (1)
- Total Tetra-PCB (1)
- Total Tri-PCB (1)

9.0 REFERENCES

Bay Area Stormwater Management Agency Association (BASMAA). 2013. Quality Assurance Project Plan. Clean Watersheds for a Clean Bay – Implementing the San Francisco Bay's PCB and Mercury TMDL with a Focus on Urban Runoff. Revision Number 1. EPA San Francisco Bay Water Quality Improvement Fund Grant # CFDA 66.202. Prepared for Bay Area Stormwater Management Agencies Association (BASMAA) by Applied Marine Sciences (AMS). August 2013.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition. 2016. Creek Status Monitoring Program Quality Assurance Project Plan, Final Draft Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program and the Contra Costa Clean Water Program. 128 pp.

Surface Water Ambient Monitoring Program (SWAMP). 2018. Quality Assurance Program Plan. May 2018. 140 pp.

Attachment 2

WY 2018 Embedded Sediment Monitoring Locations and Analytical Results

Permittee	WMA	WY 2017 Sample ID	Date Collected	Latitude	Longitude	Total PCBs (mg/kg)	Mercury (mg/kg)
Belmont	60	SM-BEL-60-A	5/22/2018	37.52699	-122.27609	0.002	0.214
		SM-BEL-60-B	5/22/2018	37.52667	-122.27568	0.003	0.019
		SM-BEL-60-C	5/22/2018	37.52297	-122.27790	0.010	0.170
		SM-BEL-60-I (Dup)				0.000	0.21
		SM-BEL-60-D	5/22/2018	37.52281	-122.27776	0.020	0.226
		SM-BEL-60-E	5/22/2018	37.52200	-122.27684	0.018	0.090
		SM-BEL-60-F	5/22/2018	37.52295	-122.27849	0.023	0.119
		SM-BEL-60-G	5/22/2018	37.52701	-122.27293	0.007	0.077
Brisbane	17	SM-BRI-02-B	5/29/2018	37.68798	-122.40584	1.020	0.120
		SM-BRI-02-C	5/29/2018	37.68796	-122.40441	0.044	0.070
		SM-BRI-02-D	5/29/2018	37.68975	-122.41143	0.007	0.040
		SM-BRI-02-G	5/29/2018	37.68781	-122.40592	0.011	0.060
		SM-BRI-02-H	5/29/2018	37.68933	-122.40681	0.014	0.050
		SM-BRI-02-I	5/29/2018	37.68743	-122.40316	0.043	0.230
		SM-BRI-02-E (Dup)				0.035	0.21
Burlingame	142	SM-BUR-03-C	5/23/2018	37.59087	-122.36455	0.014	0.071
		SM-BUR-03-D	5/23/2018	37.59043	-122.36304	0.032	0.120
		SM-BUR-03-E	5/23/2018	37.59030	-122.36303	0.030	0.146
		SM-BUR-03-J (Dup)				0.031	0.14
		SM-BUR-03-F	5/23/2018	37.59119	-122.36517	0.023	0.053
		SM-BUR-03-G	5/23/2018	37.59098	-122.36502	0.029	0.060
		SM-BUR-03-H	5/23/2018	37.59134	-122.36547	0.015	0.060
		SM-BUR-03-I	5/23/2018	37.59049	-122.36408	0.033	0.075
Daly City	350	SM-DCY-01-A	5/29/2018	37.70427	-122.41417	0.009	0.060
Redwood City	379	SM-RCY-07-E	5/29/2018	37.48604	-122.21158	0.036	0.066
		SM-RCY-07-F	5/29/2018	37.48554	-122.21191	0.044	0.060
		SM-RCY-12-G	5/22/2018	37.48419	-122.21715	0.006	0.095
San Carlos	59	SM-SCS-01-O	5/22/2018	37.51538	-122.26179	0.306	0.157
	75	SM-SCS-01-P	5/22/2018	37.51643	-122.26308	0.763	0.060
	210	SM-SCS-06-M	5/22/2018	37.49772	-122.24688	0.248	0.100
		SM-SCS-06-N	5/22/2018	37.49731	-122.24662	0.060	0.050
San Mateo	89	SM-SMO-09-A	5/23/2018	37.54157	-122.30636	0.035	0.070
	408	SM-SMO-07-D	5/23/2018	37.55756	-122.30338	0.014	0.110
		SM-SMO-07-E	5/23/2018	37.55402	-122.30207	0.004	0.039
		SM-SMO-07-F	5/23/2018	37.55515	-122.30259	0.003	0.060
		SM-SMO-07-G	5/23/2018	37.55513	-122.30234	0.002	0.040
		SM-SMO-07-H	5/23/2018	37.55674	-122.30272	0.017	0.100

Permittee	WMA	WY 2017 Sample ID	Date Collected	Latitude	Longitude	Total PCBs (mg/kg)	Mercury (mg/kg)
		SM-SMO-07-I	5/23/2018	37.55757	-122.30439	0.008	0.130
		SM-SMO-07-J	5/23/2018	37.55840	-122.30395	0.009	0.130
South San Francisco	291	SM-SSF-07-B	5/24/2018	37.64722	-122.41981	0.022	0.831
		SM-SSF-07-C	5/24/2018	37.64534	-122.42094	0.209	0.064
	295	SM-SSF-04-G	5/29/2018	37.64229	-122.40323	0.010	0.105
	316	SM-SSF-01-J	5/24/2018	37.65270	-122.39367	0.031	0.050
		SM-SSF-01-K (Dup)				0.032	0.07
	359	SM-SSF-03-F	5/24/2018	37.64449	-122.39690	0.055	0.073
		SM-SSF-03-G	5/24/2018	37.64458	-122.39694	0.007	0.076
		SM-SSF-03-H	5/24/2018	37.64463	-122.39747	0.017	0.090
	362	SM-SSF-05-H	5/24/2018	37.63642	-122.40572	0.008	0.080
	1001	SM-SSF-03-E	5/24/2018	37.64792	-122.40022	0.085	0.070
		SM-SSF-05-C	5/24/2018	37.64013	-122.40653	0.060	0.057
		SM-SSF-05-D	5/24/2018	37.63774	-122.40618	0.012	0.070
		SM-SSF-05-E	5/24/2018	37.64090	-122.40648	0.015	0.102
		SM-SSF-05-F	5/24/2018	37.64025	-122.40633	0.351	0.060
		SM-SSF-05-G	5/24/2018	37.64072	-122.40652	0.014	0.176
		SM-SSF-05-I (Dup)				0.013	0.183

Attachment 3

Summary of PCBs and Mercury Monitoring Results To-date for San Mateo County WMAs

WMA ID	Permittee	Area (acres)	Area High Interest Parcels (acres)	Percent High Interest Parcels	Sediment Samples			Water Samples		
					n	[PCBs] Median (ppm)	[PCBs] Range (ppm)	n	[PCBs] Particle Ratio Median (ppm)	[PCBs] Particle Ratio Range (ppm)
210	San Carlos	141	33	23.2%	47	0.11	0 - 192.91	33	1.78	0.20 - 373.36
17	Brisbane	1,639	55	3.4%	7	0.04	0.01 - 1.22	1	--	0.11
142	Burlingame	20	9	44.3%	9	0.03	0.01 - 0.15	1	--	0.67
359	South San Francisco	23	12	51.2%	3	0.02	0.01 - 0.06	1	--	0.79
408	San Mateo	43	7	16.3%	7	0.01	0 - 0.02	1	--	1.90
60	Belmont	298	6	1.9%	7	0.01	0 - 0.02	2	0.60	0.18 - 1.02
379	Redwood City	802	110	13.7%	44	0.06	0 - 6.93	2	0.14	0.11 - 0.18
291	South San Francisco	194	64	33.1%	19	0.05	0 - 2.72	1	--	0.74
1000	Redwood City	148	108	73.0%	3	0.57	0.02 - 0.75	0	--	--
75	San Carlos	66	38	58.3%	12	0.09	0.02 - 49.4	1	--	6.14
31	San Carlos	99	27	27.2%	26	0.19	0 - 1.61	4	1.12	0.41 - 2.15
1016	San Carlos	142	27	19.0%	8	0.54	0 - 6.19	0	--	--
239	Menlo Park / EPA	36	11	29.1%	5	0.04	0.01 - 0.57	0	--	--
358	South San Francisco	32	7	21.8%	4	0.07	0.01 - 1.46	0	--	--
70	East Palo Alto	490	16	3.3%	4	0.04	0.01 - 0.34	1	--	0.11
314	South San Francisco	66	4	5.4%	2	0.10	0.05 - 0.15	2	0.91	0.86 - 0.95
294	South San Francisco	67	21	31.2%	3	0.19	0.07 - 0.28	1	--	0.37
1001	South San Francisco	413	107	26.0%	17	0.04	0.01 - 0.43	2	1.03	0.35 - 1.71
407	Redwood City	18	10	52.9%	1	0.01	0.01 - 0.01	0	--	--
85	Burlingame	121	13	10.4%	2	0.03	0.03 - 0.03	1	--	0.24
164	Burlingame	241	79	32.6%	4	0.07	0.04 - 0.09	1	--	0.45
336	Redwood City	66	4	6.6%	0	--	--	0	--	--
1011	Redwood City	507	63	12.3%	25	0.03	0 - 0.72	4	0.19	0.17 - 0.23
25	San Mateo	219	6	2.9%	1	--	0.03	1	--	0.15
149	Burlingame	480	5	1.1%	2	0.13	0.07 - 0.19	1	--	0.11

WMA ID	Permittee	Area (acres)	Area High Interest Parcels (acres)	Percent High Interest Parcels	Sediment Samples			Water Samples		
					n	[PCBs] Median (ppm)	[PCBs] Range (ppm)	n	[PCBs] Particle Ratio Median (ppm)	[PCBs] Particle Ratio Range (ppm)
266	Redwood City	91	4	4.1%	0	--	--	1	--	0.00
77	Belmont	86	4	4.7%	0	--	--	0	--	--
59	San Carlos	28	9	32.1%	3	0.18	0.04 - 0.31	0	--	--
356	South San Francisco	10	2	18.0%	2	0.02	0 - 0.03	1	--	0.09
333	Redwood City	15	4	29.4%	1	--	0.02	1	--	0.02
111	San Mateo	95	5	4.8%	2	0.06	0.05 - 0.06	0	--	--
1008	San Mateo	111	1	0.5%	0	--	--	0	--	--
139	Burlingame	63	2	3.0%	0	--	--	0	--	--
181	Daly City	75	12	15.6%	0	--	--	0	--	--
298	South San Francisco	122	3	2.7%	0	--	--	0	--	--
307	Daly City	1,277	5	0.4%	0	--	--	0	--	--
401	Millbrae	52	7	12.6%	0	--	--	0	--	--
238	Menlo Park	345	84	24.2%	4	0.14	0.01 - 0.29	2	0.08	0.04 - 0.12
67	East Palo Alto	95	11	12.0%	2	0.12	0.02 - 0.21	0	--	--
114	San Mateo	85	8	9.3%	1	--	0.23	0	--	--
295	South San Francisco	25	3	11.7%	4	0.155	0 - 0.33	0	--	--
362	South San Francisco	18	9	51.6%	2	0.234	0.01 - 0.46	0	--	--
350	Daly City	317	15	4.8%	1	0.009	0.01	0	--	--
32	Belmont	67	2	3.3%	0	--	--	1	--	0.17
317	South San Francisco	32	9	27.1%	0	--	--	1	--	0.45
66	Menlo Park	64	19	29.8%	1	0.06	0.06	1	--	0.39
1006	Burlingame	306	49	15.9%	5	0.10	0.01 - 0.14	1	--	0.36
319	South San Francisco	99	31	31.2%	1	--	0.06	1	--	0.08
318	South San Francisco	70	32	45.4%	1	--	0.01	1	--	0.27
1004	Brisbane	804	507	63.0%	4	0.02	0.01 - 0.04	1	--	0.11

WMA ID	Permittee	Area (acres)	Area High Interest Parcels (acres)	Percent High Interest Parcels	Sediment Samples			Water Samples		
					n	[PCBs] Median (ppm)	[PCBs] Range (ppm)	n	[PCBs] Particle Ratio Median (ppm)	[PCBs] Particle Ratio Range (ppm)
156	San Mateo	40	7	17.0%	1	--	0.01	1	--	0.20
323	Redwood City	185	2	0.9%	0	--	--	1	--	0.19
306	South San Francisco	37	7	18.4%	0	--	--	2	0.18	0.17 - 0.18
315	South San Francisco	108	34	31.8%	1	--	0.12	2	0.60	0.17 - 1.02
324	Redwood City	44	1	2.0%	0	--	--	1	--	0.17
141	Burlingame	62	4	6.9%	0	--	--	1	--	0.17
89	San Mateo	98	10	10.3%	2	0.02	0.01 - 0.04	1	--	0.14
327	Redwood City	126	7	5.1%	3	0.05	0 - 0.08	1	--	0.13
337	Redwood City	138	16	11.5%	4	0.04	0.02 - 0.08	1	--	0.12
293	South San Francisco	654	58	8.9%	2	0.04	0.01 - 0.07	1	--	0.12
254	Redwood City	39	4	9.9%	1	--	0.09	1	--	0.11
316	South San Francisco	117	26	21.9%	3	0.02	0 - 0.03	1	--	0.10
72	East Palo Alto	26	12	44.4%	2	0.02	0.02 - 0.02	1	--	0.08
267	Redwood City	75	16	20.9%	1	--	0.01	1	--	0.06
388	Redwood City	42	1	1.4%	0	--	--	1	--	0.05
71	Menlo Park	1,394	22	1.6%	1	--	0.01	1	--	0.04
296	South San Francisco	1,272	7	0.6%	0	--	--	1	--	0.03
292	San Bruno	220	37	16.9%	19	0.12	0 - 0.18	1	--	0.01
313	South San Francisco	77	11	14.3%	1	--	0.01	0	--	--
1005	Millbrae	791	59	7.4%	1	--	0.01	0	--	--
1007	San Mateo	87	7	8.4%	1	--	0.01	0	--	--
1014	Menlo Park	176	18	10.3%	3	0.02	0.01 - 0.03	0	--	--
354	South San Francisco	10	4	44.7%	1	--	0.02	0	--	--
403	San Mateo	48	1	1.4%	1	--	0.02	0	--	--
332	Menlo Park	17	1	5.1%	1	--	0.03	0	--	--

WMA ID	Permittee	Area (acres)	Area High Interest Parcels (acres)	Percent High Interest Parcels	Sediment Samples			Water Samples		
					n	[PCBs] Median (ppm)	[PCBs] Range (ppm)	n	[PCBs] Particle Ratio Median (ppm)	[PCBs] Particle Ratio Range (ppm)
1009	San Mateo	175	43	24.3%	2	0.03	0.03 - 0.04	0	--	--
1015	East Palo Alto	52	48	92.7%	2	0.04	0.02 - 0.06	0	--	--
253	Redwood City	280	16	5.8%	1	--	0.05	0	--	--
16	Burlingame	24	8	31.4%	1	--	0.05	0	--	--
1012	Menlo Park	54	42	79.4%	1	--	0.06	0	--	--
101	San Mateo	221	10	4.3%	1	--	0.08	0	--	--
1002	South San Francisco	316	66	20.9%	3	0.08	0.02 - 0.12	0	--	--
357	South San Francisco	17	3	18.5%	1	--	0.09	0	--	--
1010	Foster City	273	8	3.1%	0	--	--	0	--	--
1013	Redwood City	40	4	8.9%	0	--	--	0	--	--
1017	San Mateo	19	4	21.1%	0	--	--	0	--	--
120	San Mateo	10	1	4.9%	0	--	--	0	--	--
138	Burlingame	15	5	29.9%	0	--	--	0	--	--
207	San Carlos	82	7	8.2%	0	--	--	0	--	--
247	Menlo Park	239	20	8.5%	0	--	--	0	--	--
252	Menlo Park	108	5	4.9%	0	--	--	0	--	--
261	Atherton	1,679	3	0.2%	0	--	--	0	--	--
269	Redwood City	45	4	9.2%	0	--	--	0	--	--
290	San Bruno	2,017	9	0.4%	0	--	--	0	--	--
297	South San Francisco	30	2	6.7%	0	--	--	0	--	--
311	South San Francisco	111	3	2.8%	0	--	--	0	--	--
325	Redwood City	21	1	4.8%	0	--	--	0	--	--
329	Colma	806	4	0.5%	0	--	--	0	--	--
334	Redwood City	19	4	18.3%	0	--	--	0	--	--
335	Redwood City	24	0	0.0%	0	--	--	0	--	--

WMA ID	Permittee	Area (acres)	Area High Interest Parcels (acres)	Percent High Interest Parcels	Sediment Samples			Water Samples		
					n	[PCBs] Median (ppm)	[PCBs] Range (ppm)	n	[PCBs] Particle Ratio Median (ppm)	[PCBs] Particle Ratio Range (ppm)
352	South San Francisco	40	7	16.7%	0	--	--	0	--	--
378	Menlo Park	138	4	2.9%	0	--	--	0	--	--
395	Millbrae	480	8	1.6%	0	--	--	0	--	--
399	San Mateo	32	1	4.6%	0	--	--	0	--	--
405	Redwood City	22	22	100.0%	0	--	--	0	--	--
57	San Carlos	63	4	5.6%	0	--	--	0	--	--
68	East Palo Alto	317	0.5	0.2%	0	--	--	0	--	--
80	San Carlos	21	1	4.7%	0	--	--	0	--	--
90	San Mateo	21	0.3	1.4%	0	--	--	0	--	--
92	San Mateo	136	4	2.7%	0	--	--	0	--	--
Other -	Unincorporated	10,917	343	3.1%	3	0.00	0 - 0.04	0	--	--
Other -	Woodside	7,286	5	0.1%	1	--	0	0	--	--
Other -	Menlo Park	2,487	25	1.0%	1	--	0.02	0	--	--
Other -	Colma	1,139	5	0.4%	4	0.03	0 - 16.81	0	--	--
Other -	San Carlos	2,517	2	0.1%	1	--	0.06	0	--	--
Other -	East Palo Alto	274	4	1.4%	1	--	0.07	0	--	--
Other -	Redwood City	6,030	6	0.1%	6	0.07	0.01 - 0.34	0	--	--
Other -	San Mateo	5,800	55	0.9%	1	--	0.09	0	--	--
Other -	South San Francisco	1,554	3	0.2%	1	--	0.19	0	--	--
Other -	Atherton	2,315	1	0.0%	0	--	--	0	--	--
Other -	Belmont	2,511	5	0.2%	0	--	--	0	--	--
Other -	Brisbane	245	0.4	0.2%	0	--	--	0	--	--
Other -	Burlingame	1,827	9	0.5%	0	--	--	0	--	--
Other -	Daly City	1,131	11	1.0%	0	--	--	0	--	--
Other -	Foster City	2,065	0	0.0%	0	--	--	0	--	--

WMA ID	Permittee	Area (acres)	Area High Interest Parcels (acres)	Percent High Interest Parcels	Sediment Samples			Water Samples		
					n	[PCBs] Median (ppm)	[PCBs] Range (ppm)	n	[PCBs] Particle Ratio Median (ppm)	[PCBs] Particle Ratio Range (ppm)
Other -	Hillsborough	3,974	3	0.1%	0	--	--	0	--	--
Other -	Millbrae	1,309	3	0.2%	0	--	--	0	--	--
Other -	Portola Valley	5,790	0	0.0%	0	--	--	0	--	--
Other -	San Bruno	542	0	0.0%	0	--	--	0	--	--

Appendix D

BASMAA Pollutant Removal from Stormwater with Biochar Amended BSM

Pollutant Removal from Stormwater with Biochar Amended Bioretention Soil Media (BSM)

Project Report

Prepared for:

Bay Area
Stormwater Management
Agencies Association

Prepared by:

OWP
AT SACRAMENTO STATE

EOA inc.

SFEI

KINNETIC
LABORATORIES
INCORPORATED

Final

February 8, 2019

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BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practices
BSM	Bioretention Soil Media
CW4CB	Clean Watersheds for a Clean Bay
DQO	Data Quality Objective
EPA	Environmental Protection Agency
In/hr	Inches per hour
KLI	Kinnetic Laboratories, Inc.
K_{sat}	Saturated Hydraulic Conductivity
LCS	Laboratory Control Sample
MDD	Maximum Dry Density
MDL	Method Detection Limit
MQO	Measurement Quality Objectives
MRP	Municipal Regional Permit
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MS4	Municipal Separate Storm Sewer System
ND	Non-detect
NPDES	National Pollutant Discharge Elimination System
OWP	Office of Water Programs
PCBs	Polychlorinated Biphenyls
PG&E	Pacific Gas and Electric Company
PMT	Project Management Team
POC	Pollutants of Concern
ppb	parts per billion
ppm	parts per million
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RL	Reporting Limit
RMP	Regional Monitoring Program
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SFEI	San Francisco Estuary Institute
SSC	Suspended Sediment Concentration

TMDL	Total Maximum Daily Loads
TOC	Total Organic Carbon

EXECUTIVE SUMMARY

The Bay Area Stormwater Management Agencies Association (BASMAA) implemented this regional study to evaluate the effectiveness of biochar-amended bioretention soil media (BSM) to remove polychlorinated biphenyls (PCBs) and mercury from stormwater collected from storm drains within the area covered by the Municipal Regional Permit (MRP; Order R2-2015-0049)[1] that are known to be impacted by diffuse PCB sources. The MRP requires that permittees[2] provide information to support the implementation of the wasteload allocations for mercury and PCB total maximum daily loads (TMDLs) as described in MRP Provisions C.11 and C.12. This study also contributes to implementation of MRP Provision C.8.f (Pollutant of Concern (POC) Monitoring) Priority #3, “Management Action Effectiveness,” which focuses on monitoring the effectiveness of specific management actions in reducing or avoiding loads of mercury and PCBs in municipal separate storm sewer system (MS4) discharges.

A prior BASMAA study, the Clean Watershed for a Clean Bay (CW4CB) project, found that BSM amended with biochar substantially improved PCBs removal compared to the standard BSM specified in MRP Provision C.3 at the same location (BASMAA 2017). The BSM contained 60 percent sand and 40 percent compost. The amended BSM contained 75 percent BSM and 25 percent biochar, which equates to 45 percent sand, 30 percent compost, and 25 percent biochar. Only one biochar source was tested, so it was unknown whether there would be substantial performance differences among differing biochar sources.

The goal of this study was to identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs. The primary management question supporting that goal was: “Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?” And the particular purpose of the laboratory testing in this study was: “screen alternative biochar-amended BSM and identify the most promising for further field testing.” (Monitoring Study Design, Appendix A)

The study was carried out by a project team comprised of the Office of Water Programs at Sacramento State (OWP), EOA Inc., Kinnetic Laboratories, Inc. (KLI), the San Francisco Estuary Institute (SFEI), and ALS Environmental (ALS). A BASMAA project management team (PMT) consisting of representatives from BASMAA stormwater programs and municipalities provided oversight and guidance to the project team throughout the monitoring study. Stormwater was collected in March and April of 2018, and the BSM testing was conducted in April and May of 2018.

METHODS

This study compared the removal of PCBs and mercury from stormwater in laboratory column tests of five locally-available biochars produced from a variety of feedstock and methods admixed at a 1-to-3 ratio by volume with BSM. The biochars used in this study were compared against each other and against a standard BSM. Due to availability, the BSM contained 65 percent sand and 35 percent

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[1] http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/Municipal/R2-2015-0049.pdf

[2] A total of 76 cities, towns, unincorporated counties, and flood control and water conservation districts covered by the MRP.

compost, which is still within the acceptable range specific in the MRP Provision C.3 and the BASMAA specification (BASMAA 2016). The BSM-biochar blend ratio matched the CW4CB study (75% BSM and 25%). The resulting amended BSM contained 49 percent sand, 26 percent compost, and 25 percent biochar. Each of the test biochars was mixed with the standard BSM and placed in 7.5-inch-diameter glass columns to a depth of 18 inches, typical of standard field installations. One additional column was prepared as a control and filled with 18 inches of standard BSM. The stormwater used for all tests was collected during two storms from two sites that were located in the portion of the San Francisco Bay Area subject to the MRP and that had previously observed elevated levels of PCBs. Four sampling runs were performed on the columns, three runs using undiluted stormwater on all columns and the fourth run using stormwater diluted at a one-to-nine ratio to test removal effectiveness at lower influent concentrations on two[3] columns. Column influent and effluent samples were collected during each test run and analyzed for PCBs, total mercury, total organic carbon (TOC), suspended solids concentration (SSC), and turbidity.

RESULTS

Influent concentrations of PCBs (9,860 to 19,600 picograms/liter or pg/L) were consistent with samples previously taken at the sampling sites during the CW4CB study (BASMAA 2017). The standard BSM control column had effluent concentrations of PCBs similar to the standard BSM tested alongside biochar in the CW4CB study. Two of the five biochar-amended BSM columns, Phoenix and Agrosorb, exhibited lower effluent concentrations of PCBs than the standard BSM column for all test runs. A third column, BioChar Solutions, produced three effluents with lower concentrations and a single effluent sample at a slightly higher concentration than that produced by the standard BSM. The remaining two biochar-amended BSM columns had one or two effluent samples that were much higher than those from the standard BSM, and one sample showed a substantial export of PCBs. However, these high PCB concentrations corresponded to unusually high infiltration rates compared to the testing conditions for all other data, suggesting channelizing or otherwise insufficient compaction of media within the column and so these data are not used in analysis and graphs. The remaining results collected for those two biochars under typical infiltration conditions exhibited PCB removal, and at least half of those results were superior to BSM.

Mercury influent concentrations (9.9-10.2 ng/L) were very similar across all samples. Mercury removal across all test runs occurred in two biochar-amended BSM columns, Phoenix and Agrosorb. The other columns showed variable treatment, including some export of mercury (the worst of which corresponds to a sample removed from the dataset due to abnormally high infiltration rates). The standard BSM column was the only column to export mercury for all test runs.

CONCLUSIONS

All five biochar-BSM blends showed evidence of overall improved PCB and mercury performance compared to the standard BSM. The results support these additional observations:

- Phoenix, Sunriver, BioChar Solutions, and Agrosorb appear to offer improved PCB removal compared to standard BSM and the other biochar-amended BSM.

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[3] The effluent of one column (CO6) in the dilution run could not be analyzed by the lab at the time of this study report so it is presumed lost.

- Phoenix and Agrosorb appear to offer improved mercury removal compared to standard BSM and the other biochar-amended BSM.
- Biochar may decrease performance variability from variable influent concentrations compared to standard BSM.
- Based on a single run on one column to explore removal at lower influent concentrations, biochar-amended BSM provided removal of PCBs at an influent concentration of 2,100 pg/L. BSM performance at this lower influent concentration could not be reported due to the sample being lost. Neither BSM nor biochar-amended BSM provided removal of mercury at an influent concentration of 3.00 ng/L.
- High initial infiltration rates correlated to poor performance (higher rates are associated with short-circuiting and higher pore velocities).
- Saturated hydraulic conductivity was poorly correlated to the falling head infiltration rates estimated during the water quality sampling runs, so biochars that were eliminated from column testing based on saturated hydraulic conductivity tests may be candidates for future testing.

RECOMMENDATIONS

Based on this study, biochar shows promise in marginally increasing performance; however, increased benefit relative to increased cost was not analyzed. With such limited data, benefit/cost analysis may be more appropriate after collection of substantial field data. Because of the marginal increase in performance, standard BSM should be a component of future side-by-side testing of biochar-amended BSM. If further biochar testing is pursued, the following recommendations should be considered.

If selecting biochar for PCB removal, the best-performing biochars were Phoenix, Sunriver, BioChar Solutions, and Agrosorb. If mercury removal is a design consideration, Phoenix and Agrosorb should be further studied. Because there was no correlation between performance and cost, less costly biochars that were not tested here (including those that were eliminated from this study based on possible inappropriate use of saturated hydraulic conductivity test procedures) might be considered for further field testing alongside one or more biochars from this study.

Site selection should consider the collective experience in this and other studies on irreducible minimum concentrations. This study suggests that value may be around 1,000 pg/L for PCBs. It is unclear for total mercury. Watersheds likely to have concentrations near or below irreducible concentrations should be avoided.

The most substantial enhancement to performance may be the use of outlet controls to increase contact time with biochar-amended BSM. Outlet controls should be considered for further study of both biochar-amended and standard BSM.

And finally, further development of procedures for laboratory tests of hydraulic conductivity or infiltration rate is recommended. Improving correlation between field-measured infiltration rates and laboratory test procedures for hydraulic conductivity may avoid screening out BSM blends and amendments based on tests that do not relate to field conditions.

1 INTRODUCTION

1.1 BACKGROUND

PCBs and mercury are pollutants of concern in the San Francisco Bay Area and removal of both from stormwater runoff using BSM amended with biochar has shown some promise in a previous investigation (BASMAA 2017).

Biochar is a highly porous, granular charcoal produced from a variety of organic materials and primarily marketed as a soil amendment. The majority of biochar research conducted to date has focused on agricultural applications, where biochar has been shown to improve plant growth, soil fertility, and soil water holding, especially in sandier soils. But investigation of stormwater treatment benefit is limited, especially for removal of mercury or PCBs.

A recent laboratory study on the effect of biochar addition to contaminated sediments showed that biochar is one to two orders of magnitude more effective at removing PCBs from soil pore water than natural organic matter, and may be effective at removing methylmercury but not total mercury (Gomez-Eyles et al. 2013). A laboratory column test study to determine treatment effectiveness of 10 media mixtures showed that a mixture of 70% sand/20% coconut coir/10% biochar was one of the top performers and less expensive than similarly effective mixtures using activated carbon (Kitsap County 2015). Liu et al. (2016) tested 36 different biochars for their potential to remove mercury from aqueous solution and found that concentrations of total mercury decreased by >90% for biochars produced at >600°C and by 40–90% for biochars produced at 300°C.

A prior BASMAA study, the CW4CB project (BASMAA 2017), examined whether BSM amended with biochar would substantially improve PCBs removal compared to the standard BSM specified in MRP Provision C.3. In the CW4CB study, the effect of adding a biochar to BSM was evaluated using data collected from two bioretention cells (LAU 3 and LAU 4) that treat roadway runoff just outside the Richmond Pacific Gas and Electric (PG&E) Substation at 1st Street and Cutting Boulevard. At this site, a standard bioretention cell (LAU 3) contains standard BSM (60 percent sand and 40 percent compost) while an enhanced bioretention cell (LAU 4) contains a mix of 75 percent standard BSM and 25 percent pine wood-based biochar (by volume), which equates to 45 percent sand, 30 percent compost, and 25 percent biochar. The results suggest that the addition of biochar to BSM is likely to increase removal of PCBs in bioretention best management practices (BMPs; BASMAA 2017).

Figure 1 shows a cumulative frequency plot of influent and effluent concentrations of PCBs for the two CW4CB bioretention cells. Although influent concentrations at the two cells were generally similar, effluent concentrations were much lower for the biochar enhanced bioretention cell (LAU 4) compared to those for the standard bioretention cell (LAU 3). The results for total mercury were different from those for PCBs, with both cells demonstrating little difference between influent and effluent concentrations. These CW4CB monitoring results suggest that the addition of biochar to BSM may increase removal of PCBs from stormwater. There was little effect on total mercury.

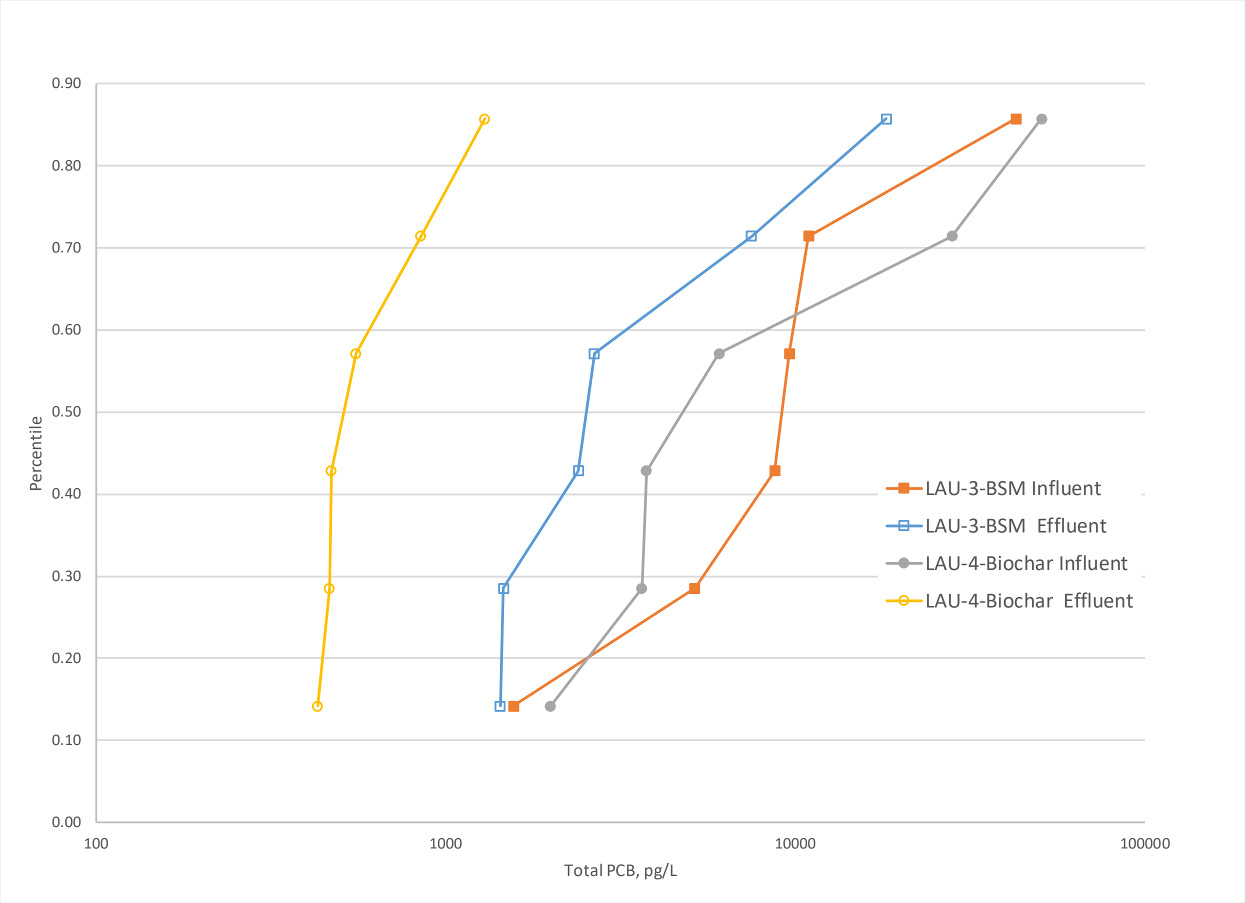

Figure 1. Cumulative Frequency Distribution of Total PCB Influent Concentrations for Bioretention Media with and without Biochar from CW4CB (BASMAA, 2017a)

Monitoring of the two bioretention cells at the CW4CB pilot site showed greater PCBs removal for a biochar-amended BSM than for standard BSM. However, to date, sampling has been limited to one test site and one biochar amendment. Besides the CW4CB study, there are no published literature studies on field PCBs and mercury removal from stormwater using biochars. Additional field testing can confirm the effectiveness of biochar in bioretention, but very little data is available on the selection of biochar for further field study. Laboratory testing of different biochars using actual stormwater from the Bay Area is a cost-effective tool to screen biochar media to identify good candidates for PCBs removal in future field testing.

1.2 STUDY GOALS

The goal of this study, as identified in the Monitoring Study Design (Appendix A), was to identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs. The primary management question supporting that goal was: “Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?” And the particular purpose of the laboratory testing in this study was: “screen alternative biochar-amended BSM and identify the most promising for further field testing.”

The MRP requires that permittees provide information to support the implementation of the wasteload allocations for mercury and PCB total maximum daily loads (TMDLs) as described in MRP Provisions C.11 and C.12. This study also contributes to implementation of MRP Provision C.8.f (POC Monitoring) Priority #3, “Management Action Effectiveness,” which focuses on monitoring the effectiveness of specific management actions in reducing or avoiding loads of mercury and PCBs in MS4 discharges.

The MRP infiltration rate requirements are described in Provision C.3.c of the MRP. This provision states: “Biotreatment (or bioretention) systems shall be designed to have a surface area no smaller than what is required to accommodate a 5 inches/hour stormwater runoff surface loading rate, infiltrate runoff through biotreatment soil media at a minimum of 5 inches per hour, and maximize infiltration to the native soil during the life of the Regulated Project.” In addition to the 5 inches per hour MRP requirement, for any application that uses a non-standard BSM, the recently updated BASMAA specification requires “certification from an accredited geotechnical testing laboratory that the bioretention soil has an infiltration rate between 5 and 12 inches per hour” (BASMAA 2016).

To accomplish the purpose of this study, the following tasks were identified:

1. Collect all readily available west coast biochar;
2. Test each biochar-amended BSM and select those for water quality testing that meet infiltration requirements using saturated hydraulic conductivity tests;
2. Compare performance among select media mixes with biochar using influent-effluent column tests with Bay Area stormwater for PCBs and mercury removal;
3. Estimate whether PCBs and mercury reduction can occur at lower concentrations by using influent-effluent column tests for the best mix with diluted Bay Area stormwater

Because the purpose of the study design is to screen biochars for further field testing, the number of samples was spread out over as many biochars as possible while still producing enough data points for each biochar to distinguish large performance differences between biochars and BSM similar to what was observed in the CW4CB study.

This report presents the results of the BSM testing study conducted from March through May, 2018. The study was implemented by a project team comprised of the Office of Water Programs (OWP), EOA Inc., Kinnetic Laboratories, Inc. (KLI), the San Francisco Estuary Institute (SFEI), and ALS Environmental (ALS). A BASMAA project management team (PMT) consisting of representatives from BASMAA stormwater programs and municipalities provided oversight and guidance to the project team throughout the study.

The Methods section explains the study approach and methods used to complete this study. This is followed by the Results section that includes PCBs and mercury removal data. The Conclusions and Recommendations section summarizes the findings of this study and gives brief recommendations for media selection for future field sites. Appendices include the Monitoring Study Plan, Sampling and Analysis Plan and Quality Assurance Project Plan, Proposed Biochar Selection Factors, Hydraulic Test Results, Biochar Particle Size Distribution, and Water Quality Laboratory Reports.

2 METHODS

2.1 STUDY APPROACH

The study approach called for: 1. Gathering biochar products that are readily available locally (west coast) at the time of the study; 2. Collecting product information, including feedstock, pyrolysis temperature; 3. Testing saturated hydraulic conductivity of each biochar blended into standard BSM at a 1-to-3 ratio; 4. Selecting five biochars; and 5. Performing three runs through side-by-side column tests alongside a standard BSM serving as a control using Bay Area stormwater; and 5. Performing a single run on two columns[4] using diluted Bay Area stormwater. Details and adjustments to this approach are described below.

2.2 INITIAL MEDIA SELECTION AND BLENDS

A total of nine samples from all identified locally available biochar producers were gathered. The samples were mixed at a ratio of one-to-three by volume with standard BSM to match the CW4CB biochar-amended pilot project amendment ratio. All biochars used in this study were unmodified (i.e., the biochars were not sieved, rinsed, or chemically treated in any way; all were used as received from their manufacturers). When blending the biochar-amended BSM, care was taken to use a representative subsample of the biochar. The BSM vendor was L.H.Voss Materials, and the BSM consisted of 65% sand and 35% compost by volume. These percentages are slightly different from the CW4CB study (60% sand and 40% compost), but still within the requirements of the MRP Provision C.3 and BASMAA standard. A precise match could not be accommodated due to the project schedule and approaching stormwater sampling opportunities.

2.3 BIOCHAR SELECTION

Primary biochar selection factors included availability in the Western United States, to ensure any biochar tested would likely be available for use in the San Francisco Bay Area, and acceptable hydraulic conductivity. Initially, the goal of hydraulic testing was to identify biochar-BSM blends that had a hydraulic conductivity in an acceptable range of 5 to 12 in/hr (Appendix C). However, destruction of biochar during the Modified Proctor compaction procedure required adjustments in procedures that made the 5 to 12 in/hr an inappropriate comparison. Instead, biochar-BSM blends that provided the most consistent hydraulic conductivity relative to the standard BSM were selected for testing. Secondary biochar selection factors included a range of pyrolysis temperatures and costs. Up to five biochars could be tested under limitations of timing, resources, and desired minimum samples per column (Appendix A).

2.4 HYDRAULIC TESTING

The BASMAA specification for alternatives to BSM requires testing of saturated hydraulic conductivity (k_{sat}) at a compaction of 85% maximum dry density (MDD) using the Modified Proctor method (BASMAA 2016). Because of the observation that the standard level of compaction was crushing the biochar particles, and thus changing their characteristics, it was decided to compact to 85% MDD using the Standard Proctor method, which uses reduced energy. Before hydraulic testing, a compaction curve was developed by the Standard Proctor method to determine MDD for each biochar-amended BSM.

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[4] One column was not analyzed due to a sample that is presumed lost after being shipped to the water chemistry laboratory.

Hydraulic testing was used as a screening tool to select the five media for the columns from the nine media tested. This testing, using deionized water that was de-gassed under vacuum and agitation overnight, was performed according to ASTM D2434 Standard Test Method for Permeability of Granular Soils (Constant Head) using a six-inch-diameter permeameter. All test equipment was purchased from the Humboldt Manufacturing Company.

2.5 COLUMN SETUP AND SEASONING RUNS

Six columns were constructed for this study, each column consisting of a 36-inch-long glass pipe with an internal diameter of 7.5 inches (Figure 2). Each column was capped with a Teflon plate that was milled to create a circular channel to nest the pipe in and make a water tight seal. Seven drainage holes were milled through each plate. To create flow paths for draining water to each of the seven drainage holes, each plate had additional drainage veins milled in the top side of each plate. To match each biochar-amended BSM column flow rate to the control BSM flow rate (i.e., outlet control), stainless steel screws were used to block the drainage holes (Figure 3). To create a water tight seal between Teflon cap and glass pipe without an adhesive or caulking (which could adsorb PCBs), ratcheting straps were used to apply force to the top of the glass columns to keep them firmly seated in their Teflon caps. Plugging the drainage holes and filling the empty column with water proved the seal was sufficient. Stainless steel mesh screen (number 40, opening size nominally 0.42 mm) was cut to shape and placed on top of the Teflon cap to keep media from filling the drainage channels and exiting the column. A two-inch layer of sand was placed on top of the stainless steel screen, followed by 18 inches of either the standard BSM control media or one of the five biochar-amended BSM.

Figure 2. Column test setup at Sacramento State showing five of six columns

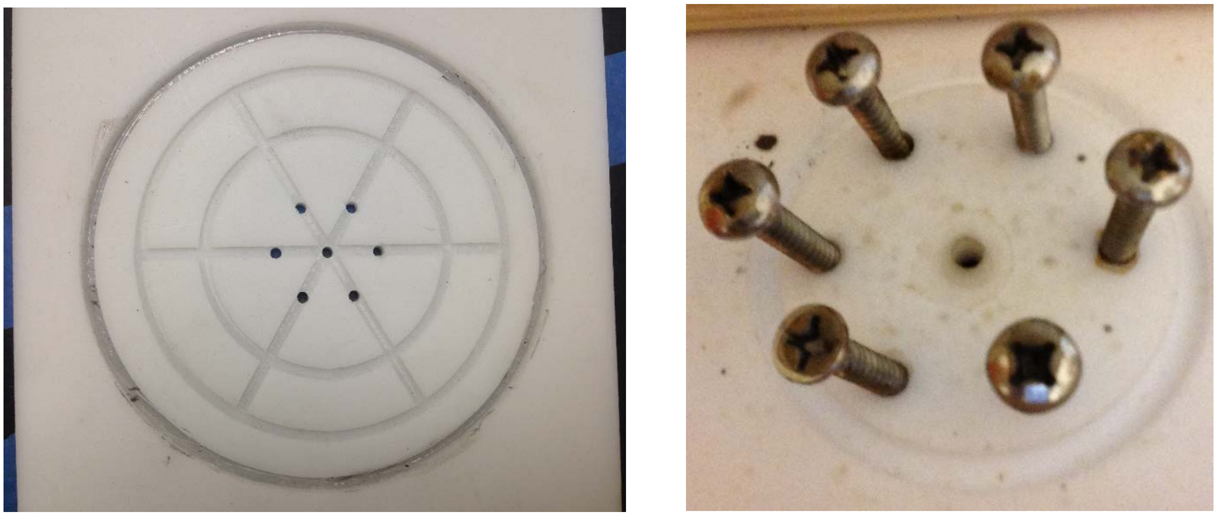

Figure 3. Teflon Column Cap with Drainage Veins and Holes (left) and Stainless Steel Throttling Screws (right)

Initial attempts at media placement and top-down hydro-compaction failed to achieve adequate infiltration rates so a wet placement technique was used to introduce water from the bottom of the column via a water supply cap fitted to the invert column cap. While placing the media in 1- to 2-inch lifts, water was slowly introduced and allowed to flow up through the media. As the previous lift was saturated and water reached the surface, an additional lift of media was placed. This technique allowed the air in the pore space of the media to be pushed out of a relatively thin overlying layer of media. Once all 18 inches of media were placed, the water was allowed to continue rising above the surface of the media until six inches of ponded water was achieved. Once this occurred, the water supply cap at the bottom of the column was removed and the water was allowed to drain. This draining of the six inches of ponded water served to hydraulically compact the media. An additional volume of water—equivalent to a depth of 18 inches of water—was added slowly to the top of the column to maintain the six inches of ponded water until the column was fully drained.

After the columns were filled with media and hydraulically compacted, the media was tested again to verify that infiltration rates were similar to field conditions. Columns were saturated and a falling head test was performed. The standard BSM had the slowest drain time and many of the biochar-amended columns had much faster drain times. Once the drain times had stabilized, a minimum level of outlet control was used on five columns so that the drain time in each column was more consistent with the slowest draining column.

During the first sampling run it was observed that all column effluents had high turbidity. To further stabilize the columns, two “seasoning” runs were performed. Turbidity was the only water quality measurement taken during these seasoning runs. Each run applied 18 inches of stormwater to the column. These seasoning runs were successful in decreasing turbidity in the effluent. Because stormwater was used, additional pollutant loading to the columns occurred during these two runs.

2.6 STORMWATER COLLECTION

Stormwater used during the seasoning and sampling runs was collected during storm events at two sites within the area covered by the MRP that were identified in previous studies as having consistently elevated concentrations of PCBs in the runoff (BASMAA 2017). Both sites were tree well locations that were installed in Oakland, CA, and tested during the CW4CB project. In addition to being previously monitored, tree well 2 (Ettie St and 28th NW) and tree well 6 (Poplar and 26th SW) were considered safe locations to conduct stormwater monitoring. To collect the necessary volume of stormwater for the study, OWP staff accompanied KLI staff to each site during two storm events and pumped stormwater directly from the street gutter into clean five-gallon glass carboys. These were then transported back to OWP in Sacramento, CA, by OWP staff and stored at room temperature until use. Stormwater had to be collected before the columns were ready for experimental runs. Complications in acquiring suitable BSM, hydraulic testing, and preparing columns delayed the experiment for three months, far enough into the wet season that the likelihood of ample rain events was quickly diminishing. To hedge against a lack of late-season rain events, sufficient stormwater was collected from two storm events to perform all sampling runs and seasoning runs. The weather was tracked in hopes of sampling a third storm event, but additional storm events failed to materialize. Nine carboys were filled from each sampling location during each monitored storm event. The preference was to use the stormwater within 72 hours of collection, but additional time was needed to finish the construction and initial seasoning of the columns. The stormwater was stored for four days before the first run. The stormwater for the dilution run was used two weeks after collection. The stormwater for a replacement run (required as a result of bottle breakage during shipping) was used four weeks after collection. This was not a concern for PCB analysis because of the stability of PCBs, though particle agglomeration likely occurred causing associated pollutants to be more easily removed. This was counteracted by using high-sheer mixing as described below.

2.7 SAMPLING RUNS

Following the purpose to screen as many biochars as possible for further study (see Appendix A), only three sampling runs were performed for all six columns using undiluted stormwater. A fourth run was conducted on one biochar-amended BSM column (CO4; BioChar Solutions) and the standard BSM control column[5] (CO6; Control) using stormwater diluted at a one-to-nine ratio. A single replacement run was performed for the first undiluted run for one column (CO1; Sunriver) due to loss of a sample bottle that was damaged in transit between laboratories. A unique influent had to be generated for this replacement run. Each run applied 18 inches of water to each column to simulate the hydraulic loading from storm events near typical water quality design storms. For example, if bioretention is sized to 4 percent of a drainage area that has a volumetric runoff coefficient of 0.8, a 0.9-inch storm size would generate 18 inches of hydraulic loading to the bioretention surface.

A variety of influent concentrations was desired, however, all runs were performed within a period of 30 days so water quality analysis from the first run was not known when performing later runs. Consequently, the selection of which stormwater source (sampling location) and which storm event to use for each run was based on past data from the sampling locations (Table 3). Additionally, each run was sequentially dosed directly from a subset of carboys from each storm. Because all carboys were not used in a run, the visual quality of the stormwater in each carboy was used to select carboys with the most sediment for each run. The dosing sequence is described below.

At the start of each sample run, six cleaned and empty carboys were labeled for effluent collection for all columns and one clean and empty carboy was labeled for influent doses. All sample bottles were labeled to associate them with the collection carboys. Stormwater in the five-gallon storage carboys

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[5] As previously explained, this sample was not analyzed.

were vigorously agitated before each dose with a stainless steel paddle mixer until all sediment was suspended. A glass beaker marked for the level of a single dose was filled from the carboy and used to dose each column in turn. The dose was sized to be equivalent to one inch of water depth inside the 7.5-inch-diameter column. Each column and the carboy collecting influent received 18 total doses. If the stormwater storage carboy did not have sufficient volume for a complete round of dosing (six column doses and one influent dose), additional water was added to the carboy from the next carboy selected for dosing. This assured that the same batch of stormwater was used for a single dose to each column and influent carboy. Dosing the influent carboy for each round of column dosing allowed a single influent sample from the influent carboy at the end of all 18 doses to represent the composite influent of all columns for that run. If at any time during dosing a column had more than six inches of ponded water the dosing would stop until the water drained to a height of three inches. Figure 4 presents the column test setup.

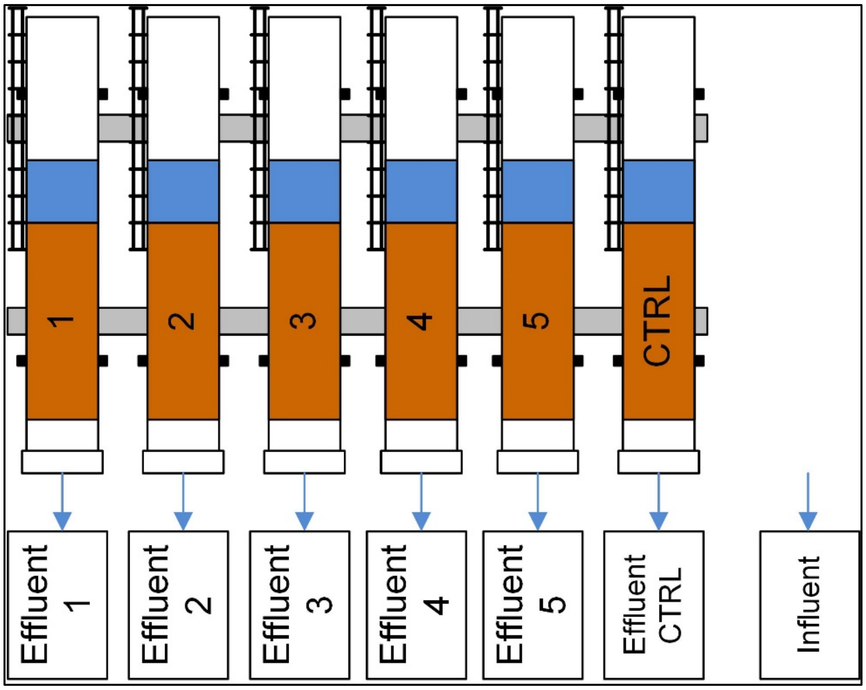

Figure 4. Column Test Setup

Column test observation forms were kept for each column and the time at which each dose was applied and the height of ponded water in the column was recorded. By recording the height of the water in the column at regular time intervals, it was possible to calculate an infiltration rate at each time step over the course of the sampling run. Three times during the dosing of the columns a grab sample was taken from the effluent of each column and tested using on-site meters to measure pH, temperature, and turbidity. At the midpoint of each sampling run, as specified in the sampling protocol to achieve ultra-low detection limits, mercury samples were collected directly from the effluent stream of the column into a preserved sample bottle. Direct collection eliminated losses that would occur if collecting from the effluent carboy. One person was able to handle bottle filling without the aid of a second pair of hands because the sampling person did not have to touch anything while handling the bottle because flow was collected at the air gap as water fell between the column and the effluent carboy.

After all influent water was applied, the columns were allowed to drain until no water was visible in the pore spaces of the soil and the effluent discharge had slowed to a drip. Once the columns drained, the carboy that received influent doses and the effluent carboys of each column were agitated with their own stainless steel paddle mixer before filling all required sample bottles. Sample bottles were refrigerated for up to two days then packed in blue ice and shipped overnight via FedEx to ALS for analysis.

Additional details are presented in Appendix B.

2.8 CONSTITUENTS AND LABORATORY METHODS

As specified in the study design (Appendix A) and Sampling and Analysis Plan (Appendix B), total PCBs[6] and total mercury were analyzed for all samples. Constituents for analysis of water samples must be consistent with Table 8.3 of the MRP. Table 1 lists the constituents and test methods for this study.

In addition to PCBs and total mercury, the other constituents selected for influent and effluent analysis were suspended solids concentration (SSC), turbidity, and total organic carbon (TOC). Suspended solids concentration was selected for measurement rather than total suspended solids (TSS) because the method more accurately characterizes larger-sized fractions within the sample by avoiding subsampling, while turbidity was selected because it is an inexpensive and quick test to describe treatment efficiency where a strong correlation to other pollutants has been established. As with the SSC analysis, TOC was included because it is a MRP Provision C.8.f POC monitoring parameter and is useful in cases where methylation is a concern.

Table 1. Selected Aqueous Constituents for Media Testing in Laboratory Columns

Constituent	Test Method	Reporting Limit
SSC	ASTM D3977-97	1 mg/L
Turbidity	Field meter	1 NTU
TOC	EPA 9060	2 mg/L
Total Mercury	EPA 1631E	0.5 ng/L
Total PCBs (Sum of RMP 40 congeners) in Water	EPA 1668C	190-220 pg/L

2.9 ANALYSIS AND STATISTICAL TESTING

Effluent and influent concentrations are presented independently and in chronological order to observe potential trends with loading. Additional analysis was performed for PCBs. Effluent concentration is also presented normalized by influent concentration for comparison to CW4CB study results. Normalization allows caparisons where influent concentrations vary between studies and where effluent concentration is dependent on influent concentration. In addition to traditional graphical or tabular comparisons, statistical testing was performed for PCBs using the Mann-Whitney U test (a rank sum test) on columns showing the greatest differentiation of performance. Correlations between PCB and SSC, and total mercury and TOC were also examined. Comparing total PCBs to suspended solids indicates whether suspended solids have a consistent quantity of associated PCBs.

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[6] The 40 individual congeners routinely quantified by the Regional Monitoring Program (RMP) for Water Quality in San Francisco Bay include: PCBs 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, 105, 110, 118, 128, 132, 138, 141, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203. The sum of these congeners are referred to as the PCBs or RMP 40 throughout this report.

3 RESULTS

3.1 BIOCHAR CHARACTERISTICS, HYDRAULIC CONDUCTIVITY, AND SELECTION

The study design called for water quality column testing of five biochars. Nine biochars produced in the Western United States were identified as potential candidates (Table 2). Hydraulic tests of the nine biochar-BSM blends produced a wide range of results. More details of the hydraulic conductivity calculations and particle size distributions are presented in Appendices D and E, respectively. Pulverization[7] of biochar during the compaction process could be a contributing factor to the range of the observed results, even when using the lower-energy Standard Proctor method. The five biochar-BSM blends that provided the most consistent hydraulic conductivity compared to the standard BSM were selected for further testing. The selected biochar are highlighted in Table 2, and include Sunriver, Rogue, Phoenix, BioChar Solutions (also used in CW4CB), and Agrosorb. Their associated conductivity measurements were within 4 in/hr of the standard BSM, except for Agrosorb, which was 4.3 in/hr above the value for standard BSM. The selected biochar cover a range of pyrolysis temperatures and costs, but all were manufactured at 500 ˚C or above. Contrary to expectations, cost did not correlate with pyrolysis temperature.

Table 2. Characteristics for Biochar Considered for Water Quality Testing

Biochar[a]	**Ksat[b] (in/hr)**	**Texture[c]**	**Cost ($\$/yd^3$)**	**Pyrolysis Temp (˚C)**	**Supplier Location**
Blacksorb	2.56	Variable size, 3mm to fines	250	900	CA
Sonoma	5.11	Variable size, 1 cm chips to sand size particles, lots of fines	240	1315	CA
Pacific	5.41	Variable size, 1 cm chips to sand size particles, some fines	90	700	CA
Sunriver	7.67	Variable size, mostly pine needles with some small twigs and chips, 2 cm, little fines	500	500	OR
Rogue	7.85	Uniform size, 4mm, little to no fines	250	700	OR
Phoenix	10.4	chips, 1-.5 cm, little to no fines	254	700	CA
Control – Standard BSM from Voss	10.8	Organics and sand	40	N/A	CA
Biochar Solutions Large	11.0	Chips, 2.5 cm, lots of fines	225	700	CO
Agrosorb	15.1	Large chips, 2 cm, lots of fines	250	900	CA
Biochar Now Medium	17.2	Uniform size, 3mm to 26 mesh, little to no fines	350	600	CO

a. Biochars are sorted by Ksat and the five biochars closest to BSM were selected for column tests (shaded).
b. Ksat values are at 85% maximum dry density using standard Proctor. Computations are presented in Appendix D.
c. Particle Size Distribution of each biochar is presented in Appendix E.

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[7] Hydraulic compaction was used in the water quality testing columns to avoid pulverization.

3.2 QUALITY ASSURANCE AND QUALITY CONTROL

Data quality assurance (QA) and quality control (QC) was performed in accordance with the project's SAP/QAPP (Appendix B). The SAP/QAPP established data quality objectives (DQOs) to ensure that data collected are sufficient and of adequate quality for their intended use. These DQOs include both quantitative and qualitative assessments of the acceptability of data. The qualitative goals include representativeness and comparability, and the quantitative goals include completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination. Measurement quality objectives (MQOs) are the acceptance thresholds or goals for the data. The quality assurance summary is presented for PCBs followed by total mercury, TOC, and SSC.

3.2.1 PCBs

The column water dataset included 26 field samples (including 1 field replicate), with 3 blanks, 5 laboratory control samples (LCSs), and one matrix spike/matrix spike duplicate (MS/MSD) pair reported for the RMP 40 PCB analytes (with their coeluters, yielding 38 unique analytes). This met the minimum number of QC samples required. All samples were analyzed within 30 days, less than the recommended hold time of 1 year. Three of the analytes had poor recovery (>70% deviation from target values in MS samples) and were rejected as were 2 analytes that had individual field sample results <3x higher than blanks. Overall 91% of the field sample results were reportable. Two PCBs were non-detect (ND) in 100% of the samples, but all the rest had detects in more than half the samples. However, a large percentage of results were below the lab's reporting limit, and 17 analytes had relative percent differences (RPDs) in the field replicates below 100%, and thus 62% of all results were flagged as estimated. Additionally 25 of the 38 unique analytes had recoveries between 35–70% above target values, so they were flagged as qualified. Nearly half of the data is flagged as estimated (i.e., below the reporting limit (RL) but above the method detection limit (MDL)) or qualified (not compliant with project SAP/QAPP), and approximately 5% of the data were rejected for the reasons mentioned above. Thus individual results are not quantitative at the target levels of confidence (+/- 30%) and thus the data should not be used to draw conclusions regarding attainment of set performance or water quality thresholds. However, the primary management question in this study is answered using the relative comparison of results within this study. Consequently, the data quality is satisfactory for the purpose of this study and all data were used.

3.2.2 Total Mercury (Hg), TOC, and SSC

All field sample results in the Hg/TOC/SSC dataset for water were reportable. The column water dataset included 25 field samples for Hg and SSC, and 1 field replicate for SSC, with 23 samples reported for TOC. All TOC results were analyzed at least in duplicate (some 3 or 4 times). Blanks were reported for all analytes, MS/MSDs for Hg and TOC, and LCSs for SSC and TOC, meeting the minimum number of QC samples required (1 per 20 or per batch of blank, precision, and recovery sample types). Samples were all analyzed within their respective hold times (28 days for Hg and TOC, 7 days for SSC). No results were non-detect, although a few Hg and TOC were DNQ (detected not quantified). Mercury was detected in blanks averaging 2-3x MDL in the two batches, but field sample results were all over 3x higher than blanks, so all results were flagged for blank contamination, but no results were censored. Precision was acceptable, averaging <10% RPD for SSC, <5% for TOC, and <20% for Hg, so no precision qualifiers were added. Similarly, average recovery deviated <10% from target values for all analytes, so no recovery flags were added. Overall, data quality is satisfactory for the purpose of this study and all data were used.

3.3 COLUMN TEST RUNS

Five sampling runs were performed and influent concentrations and stormwater collection characteristics for each run are presented in Table 3. Not all stormwater collected at one location during one storm was used in a single run, so extra water was available for later runs as described in Table 3. In each run, the storage carboys with more sediment (visual judgement) were preferred in early runs. Consequently, water remaining for later runs had less sediment. Infiltration rates and influent and effluent concentrations grouped by column and run are presented in Table 4. Graphical comparisons and discussion is presented in the following sections.

Table 3. Influent Descriptions, PCB and Mercury Concentrations, and Columns Dosed for each Sampling Run

Influent ID	**Run Type**	**Storm ID: No. - Location[a] - Collection Date**	**Column Run Date**	**Influent Concentrations**				**Columns Loaded**
				PCB (pg/L)	Total Hg (ng/L)	TOC (mg/L)	SSC (mg/L)	
Influent 1	no dilution	Storm 2 - TW2 - 4/6/18	4/10/2018	19600	9.99	5.39	19.4	all
Influent 2	no dilution	Storm 1 - TW2 - 3/1/18	4/13/2018	18600	10.2	1.71	40.2	all
Influent 3	no dilution	Storm 2 - TW6 - 4/6/18	4/17/2018	9860	9.86	1.64	16.3	all
Influent 4	9X dilution	Storm 1 - TW2 - 3/1/18[b]	4/19/2018	2100	3	NA	1.9	CO4, CO6
Influent 5	no dilution	Mix of Storm 1 and 2 - TW2 - 3/1/18 and 4/6/18[c]	5/9/2018	8160	NA	NA	NA	CO1

a. Stormwater collection locations were at two sites in West Oakland: TW2 is the influent to the Tree Well Site 2 (TW2) on Poplar at 26th and TW6 is the influent to Tree Well Site 6 (TW6) on Ettie St. near 28th

b.TW2 selected because CW4CB indicated it had lower concentrations and was selected to avoid dilution of a high-concentration sample (in this study TW2 had higher concentrations but those results were not available at the time)

c. The dirtiest (visually) of the remaining storage carboys from storms 1 and 2 that were not used in previous runs were selected to get a concentration near what was dosed in Run 1 because this was a makeup for Run 1.

Table 4. Infiltration Rates and PCB, Mercury, TOC, and SSC Results for each Sampling Run

Column ID	Biochar	Test Runs	Inf. Rate (in/hr)	PCBs		Total Mercury		TOC		SSC	
				Influent (pg/L)	Effluent (pg/L)	Influent (ng/L)	Effluent (ng/L)	Influent (mg/L)	Effluent (mg/L)	Influent (mg/L)	Effluent (mg/L)
CO6	Control (BSM only)	Run 1	6.7	19600	2920	9.99	14	5.39	32.9	19.4	118
		Run 2	6.0	18600	4680	10.2	13.1	1.71	15.9	40.2	35
		Run 3	3.7	9860	960	9.86	11.3	1.64	17.2	16.3	26.7
		Run 4	N/A	2100	NA[a]	3	7.41	NA	10.9	1.9	11.1
CO1	Sunriver	Run 1	>20	19600	NA[a]	9.99	24.4[b]	5.39	26.7[b]	19.4	116[b]
		Run 2	>12	18600	32000[b]	10.2	9.68[b]	1.71	12.3[b]	40.2	21.9[b]
		Run 3	5.7	9860	383	9.86	9.74	1.64	12.1	16.3	12.5
		Run 5	N/A	8160	662	NA	NA[c]	NA	NA	NA	NA
CO2	Rogue	Run 1	>20	19600	19400[b]	9.99	16.3[b]	5.39	11[b]	19.4	104[b]
		Run 2	3.2	18600	926	10.2	8.58	1.71	5.72	40.2	13.3
		Run 3	5	9860	4510	9.86	2.17	1.64	5.12	16.3	8.4
CO3	Phoenix	Run 1	8	19600	2000	9.99	6.77	5.39	42	19.4	50.3
		Run 2	7.3	18600	2270	10.2	5.69	1.71	19.1	40.2	14.5
		Run 3	3.8	9860	411	9.86	6.02	1.64	21.6	16.3	19.3
CO4	BioChar Solutions	Run 1	8.5	19600	3270	9.99	15.2	5.39	28.9	19.4	89.1
		Run 2	>12	18600	2310	10.2	11.2	1.71	13.8	40.2	17
		Run 3	3.7	9860	839	9.86	7.58	1.64	14.4	16.3	16.5
		Run 4	5.5	2100	782	3	5.26	NA	NA	1.9	9.7
CO5	Agrosorb	Run 1	8.4	19600	2160	9.99	7.57	5.39	27.7	19.4	78
		Run 2	4.9	18600	2920	10.2	4.53	1.71	12.5	40.2	17.3
		Run 3	5.2	9860	586	9.86	7.36	1.64	12	16.3	11.7

a. Lost sample

b. Values are not used in further analysis due to unusually high initial infiltration rates

c. No Hg for Run 5 because three samples were successfully analyzed and only PCB required a replacement run.

3.3.1 PCBs

Both qualified and estimated influent and effluent PCBs concentrations are presented chronologically in Figure 5. The first two runs had similar influent concentrations and effluent quality was generally similar, despite sediment and turbidity increases in the first run. Effluent concentrations were generally lower for the third run, but influent concentration for the third run was nearly half that of the previous runs. The fourth run is the dilution run for only two columns. The fifth run is the replacement run for the first Sunriver run, which could not be analyzed for PCBs due to a broken sample bottle. All columns reduced concentrations of PCBs. This is expected because PCBs are largely bound to particles and media filters work well to remove these particles. Biochar-amended BSM seems to have improved treatment when compared to the control BSM (CO6), but a more explicit comparison is presented later in this report.

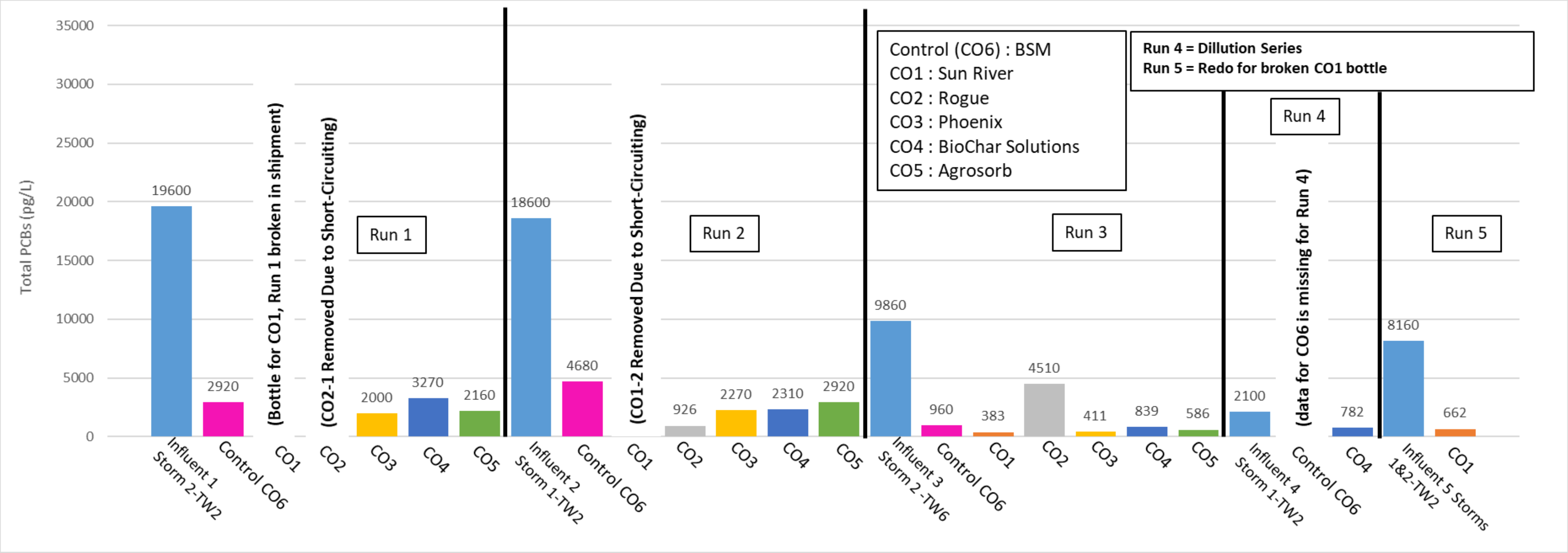

Figure 5. Total PCB Concentrations over Time

The data from Sunriver biochar-amended BSM (CO1) for test runs one and two, and the Rogue biochar-amended BSM (CO2) for test run one have been censored because both of these columns experienced unusually high initial infiltration rates that is indicative of short-circuiting of the media. The infiltration rates were so high that water did not remain in the column at the beginning of a subsequent dose when water level and time would be recorded. To drain this fast, the Sunriver column would have had an infiltration rate above 12 inches per hour and the Rogue column above 20 inches per hour. Because the occurrence of high infiltration rates are not successively repeated for later runs or in the initial runs of other columns, these two measurements have been deemed not representative of a properly compacted media and are not included in further analysis in this report. All other runs had had initial infiltration rates of 3 to 9 in/hr. Run 2 for BioChar Solutions (CO4) exceeded 12 in/hr, but that data was used because the first run was in an acceptable range, signifying that the variation in hydraulic performance could not be attributed to a lack of media seasoning or insufficient compaction. Consequently, later hydraulic variability could be an important longer-term characteristic of the media that would be important to consider in the study.

Despite initial seasoning that fully saturated the media, small air pockets were observed in some columns and it is probable that none of the columns were fully saturated during runs, so infiltration values are not representative of saturated hydraulic conductivity. Air pockets were not fully removed during the sampling runs because, unlike the initial seasoning and hydraulic compaction, water was introduced from the top of the columns.

Figure 6 displays the influent and effluent concentrations for PCBs grouped by column, along with means. There are four influent values because run 5 for Sunriver (CO1) required a unique influent (8,160 pg/L) which replaced the run 1 influent value (19,600 pg/L). Mean effluent concentrations for all biochar-amended BSM are lower than the mean effluent concentration of the control BSM (CO6), with the Rogue biochar-amended BSM (CO2) average just under the control BSM average.

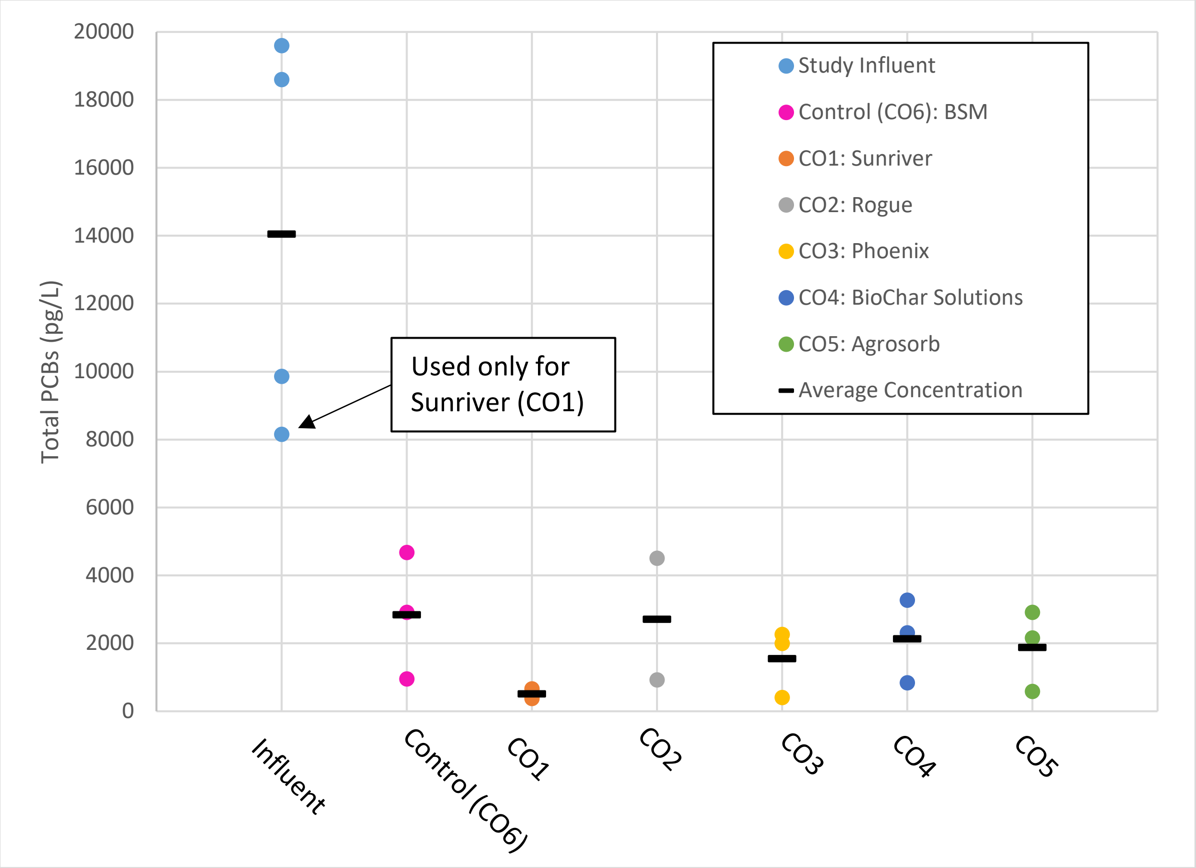

Figure 6. Observed Total PCB Concentrations for Undiluted Influent Runs and Column Test Media Effluent

Dividing each column effluent concentration by the paired influent concentration (Ce/Ci) normalizes the data to the influent and aids in comparison. In Figure 7, a red line has been placed at the mean value for the control BSM data. The noticeable difference between the Ce/Ci graph and the concentrations graph is that Rogue biochar-amended BSM (CO2) now has a higher mean than that of the control, while the average means for all other biochar-amended BSM are below the control. This is because each column had similar effluent values (4,680 and 4,510 pg/L, for the control and Rogue, respectively), but the influent concentration was substantially different (18,600 and 9,860 pg/L). This analysis indicates that all biochar may outperform the standard BSM mix with the possible exception of Rogue, but the data are limited. Further, the duplicate sample of run 3 for Rogue indicates it has better performance than the control but more data would be needed to show the primary sample was an outlier. The dilution run is not included in the analysis presented in Figure 6 because the lower influent concentration was not applied across all columns.

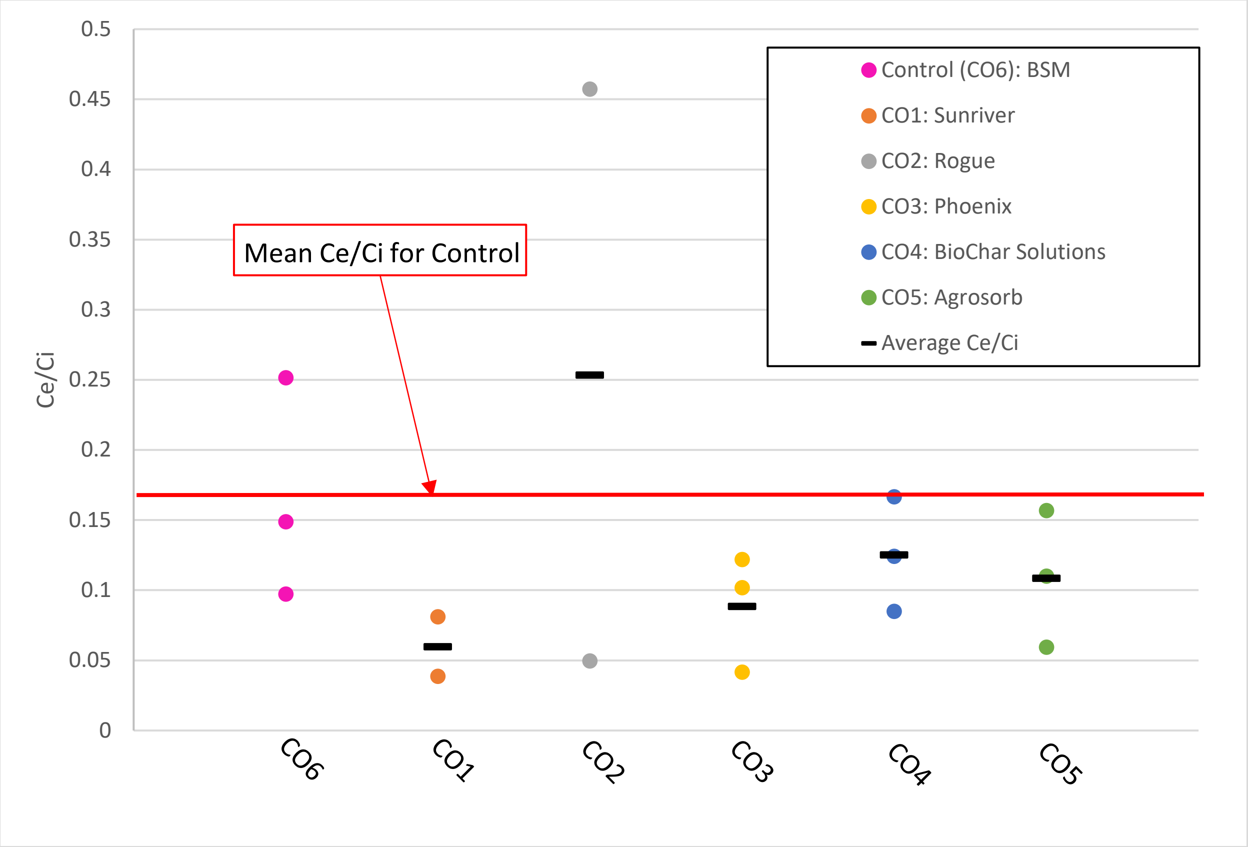

Figure 7. Ce/Ci Total PCB Concentrations for Column Test Media

Figure 8 compares the concentrations from this study to those from the CW4CB pilot site that tested BSM next to BSM with biochar. For ease of comparison, the influent concentrations from both field site influents are combined into one dataset under the label CW4CB Combined Influent. All five of the biochar-amended BSM columns are combined into one dataset under the label Study Biochar.

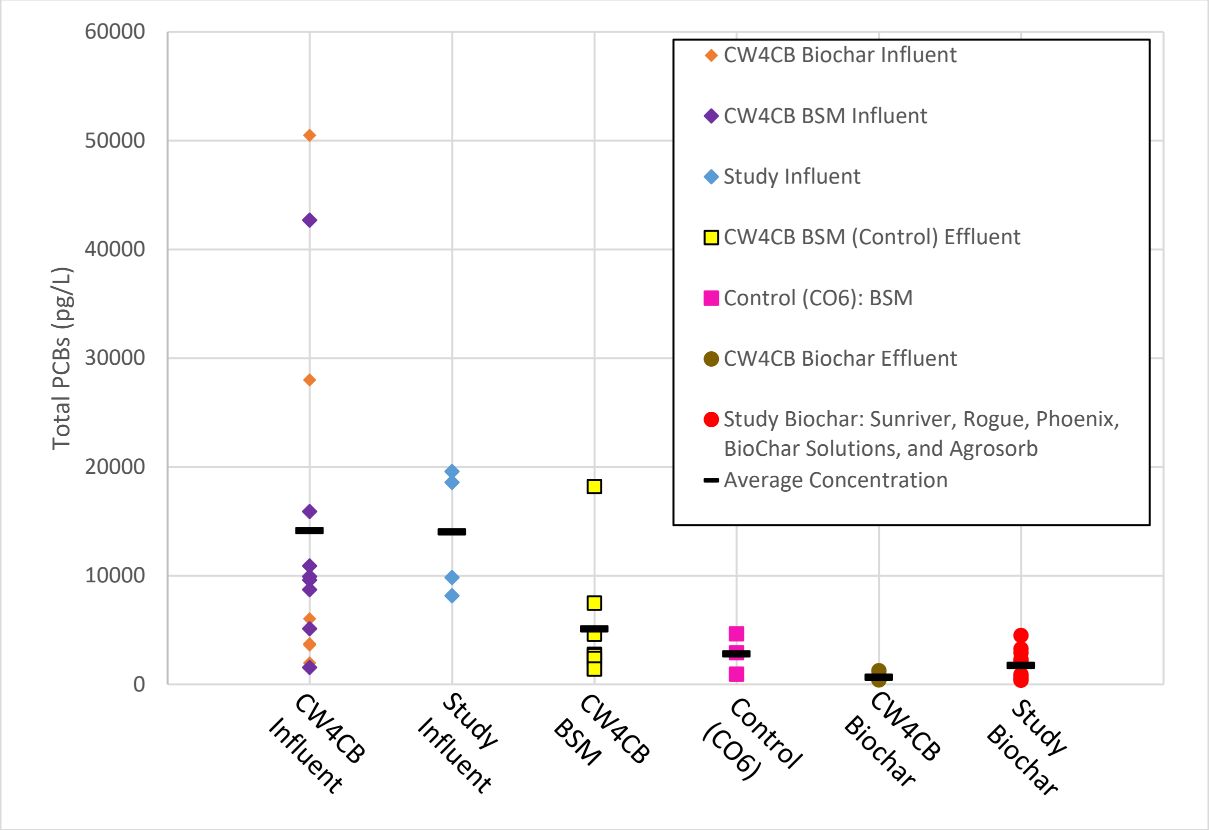

Figure 8. Total PCB Concentrations for CW4CB Pilot Sites Influent, Undiluted Influent Runs, CW4CB BSM Effluent, and Column Test BSM Effluent, CW4CB Biochar-amended Effluent, and Column Test Biochar-amended Effluent

The PCB concentrations in stormwater used in this study were within the range of PCB concentrations in influent at the CW4CB location that compared BSM and biochar-amended BSM. The range of influent concentrations for this study (9,860 pg/L to 19,600 pg/L) was narrower than the ranges of influent concentrations for both the CW4CB BSM site (1,560 pg/L to 42,700 pg/L) and the CW4CB biochar-amended site (1,990 pg/L to 50,500 pg/L). The range of influent concentrations from this study overlapped the middle range of the CW4CB grouped influent concentrations with the influent mean concentration from this study lower by 116 pg/L (less than 1% difference). The Control BSM effluent concentrations of this study were nearly half the concentrations of the CW4CB study BSM effluent concentrations. However, the biochar-amended BSM effluent concentrations from this study were higher than the biochar-amended CW4CB study. As before, normalized effluent is examined for the case that effluent has some dependence on influent.

Figure 9 compares effluent concentrations normalized by their paired influent concentrations for the CW4CB BSM, study BSM, the CW4CB biochar, and all study biochars combined.

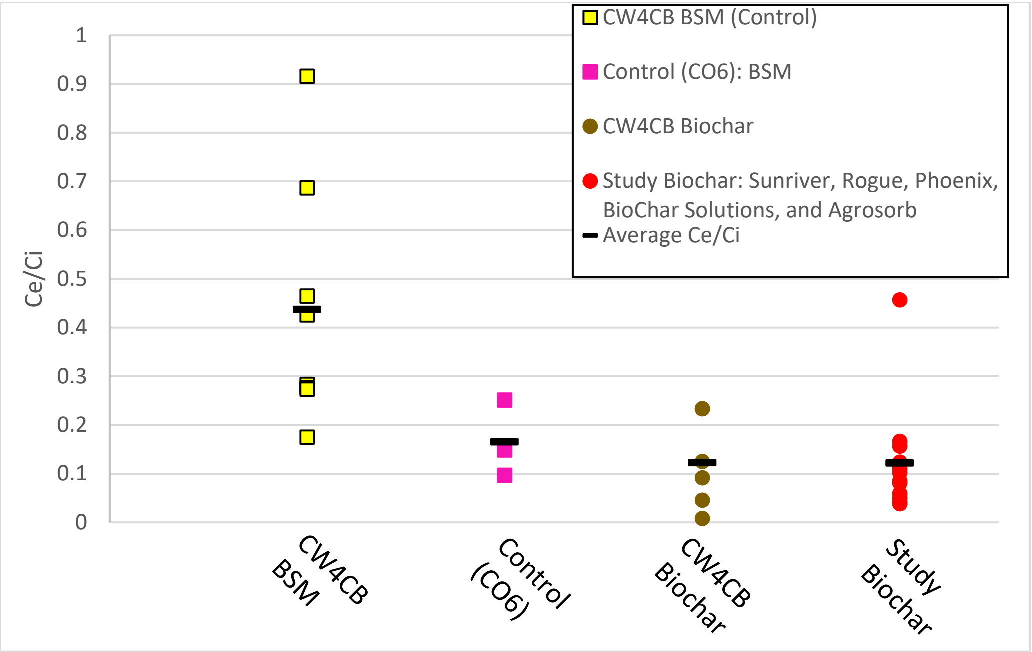

Figure 9. Ce/Ci Total PCB Concentrations for CW4CB Pilot Sites and All Biochar Test Media

Results from both CW4CB and this study indicate that PCB removal by biochar-amended BSM is less sensitive to influent concentrations than standard BSM. The influent-normalized performance (Ce/Ci) for the standard BSM (control) in this study appeared slightly improved compared to the CW4CB control BSM pilot site. In contrast, BioChar Solutions (CO4) influent-normalized performance (Ce/Ci) in this study was similar to the CW4CB biochar-amended pilot site (also using BioChar Solutions).

The improved performance suggests that conditions in the column tests were more ideal, or at least not worse, than field conditions. The normalized biochar data showed better agreement, but a secondary control to the field condition was planned to allow a more direct comparison between the same biochar. This was accomplished by using the same biochar (BioChar Solutions, CO4) as was used at the CW4CB site. The CW4CB biochar site and the column constructed with the same biochar (CO4) are compared in Figure 10, including the dilution run. Though data are limited, it appears that the CW4CB performance is slightly superior, which is in contrast to the comparison of standard BSM. This suggests that there are performance factors influencing the CW4CB site that were not replicated in this study, and there may be differences, besides biochar, contributing to the improvement of performance of the CW4CB biochar over the standard BSM. The CW4CB biochar site also tested a wider range of influent concentrations (Figure 8), which may be another cause for differing results.

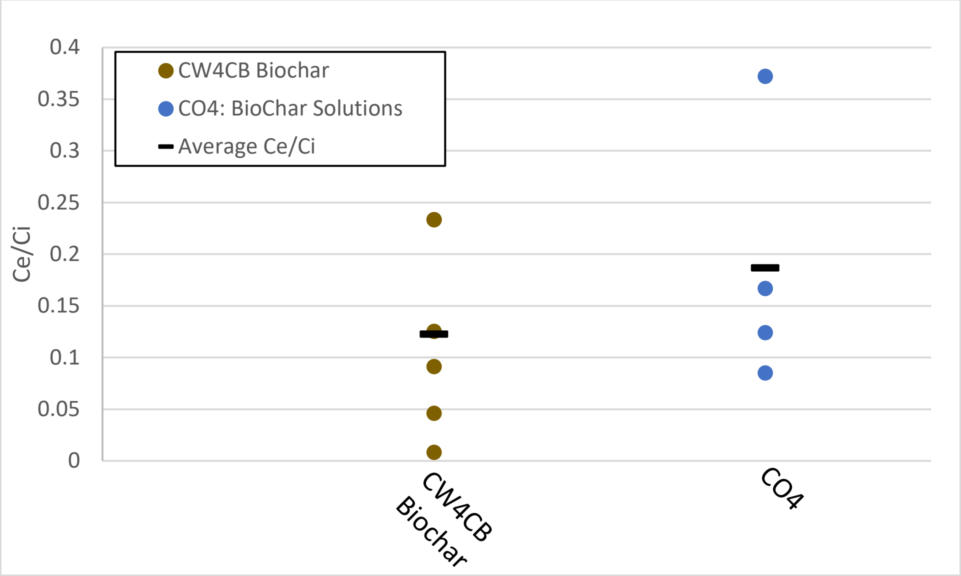

Figure 10. Ce/Ci Total PCB Concentrations for CW4CB Biochar Pilot Site and BioChar Solutions Test Media

All effluent concentrations are plotted against influent concentrations in Figure 11, and all media show removal of PCBs as evidenced by all points appearing under the 1:1 line representing no treatment. The effluent data appears stacked due to the common influent for three of the five runs. Overall, the data may be indicating an irreducible concentration somewhere around 300 pg/L (select Run 3 effluent concentrations) to 800 pg/L (Run 4 dilution effluent concentration), but only a single data point represents the lower end of the influent range.

The dilution run gives a rough estimation of whether biochar-amended BSM would be effective in treatment of concentrations that are lower than the sampled watershed. The single run was performed with stormwater diluted at a one-to-nine ratio to assess one biochar-amended BSM (BioChar Solutions) and the control BSM (The control BSM analysis is not available). The biochar-amended BSM continued to show reduction potential, but the removal relative to influent was not as great, indicating that the influent value may be approaching an irreducible concentration. Even though this analysis is on the most limited basis, the data indicate that biochar may also show benefits at lower concentrations. However, the variation in water column concentration is much larger than that tested in this study. The range of the total PCBs concentration of influent samples was compared to the range found in a summary of water column PCBs concentration data in the Bay Area (McKee et al. 2015). Of 31 locations sampled over several years, seven had concentrations lower than the range of the media study, 16 were within the range, and eight were above. Most of these monitoring locations were in-channel rather than higher upstream in the drainage system where BSM is more traditionally used. Consequently, actual concentrations at upstream BSM locations could vary even more since discrete PCB source areas should get diluted as other cleaner water and sediment combine downstream. Gilbreath et al. (2018) reported a maximum of 160,000 pg/L, a minimum of 533 pg/L, and a median stormwater concentration of 8,923 pg/L, but that is also based on many of the same in-channel monitoring locations. As a result, the biochars that show some promise for further field testing were exposed to a fairly small range of concentrations that would likely be found at random green infrastructure locations.

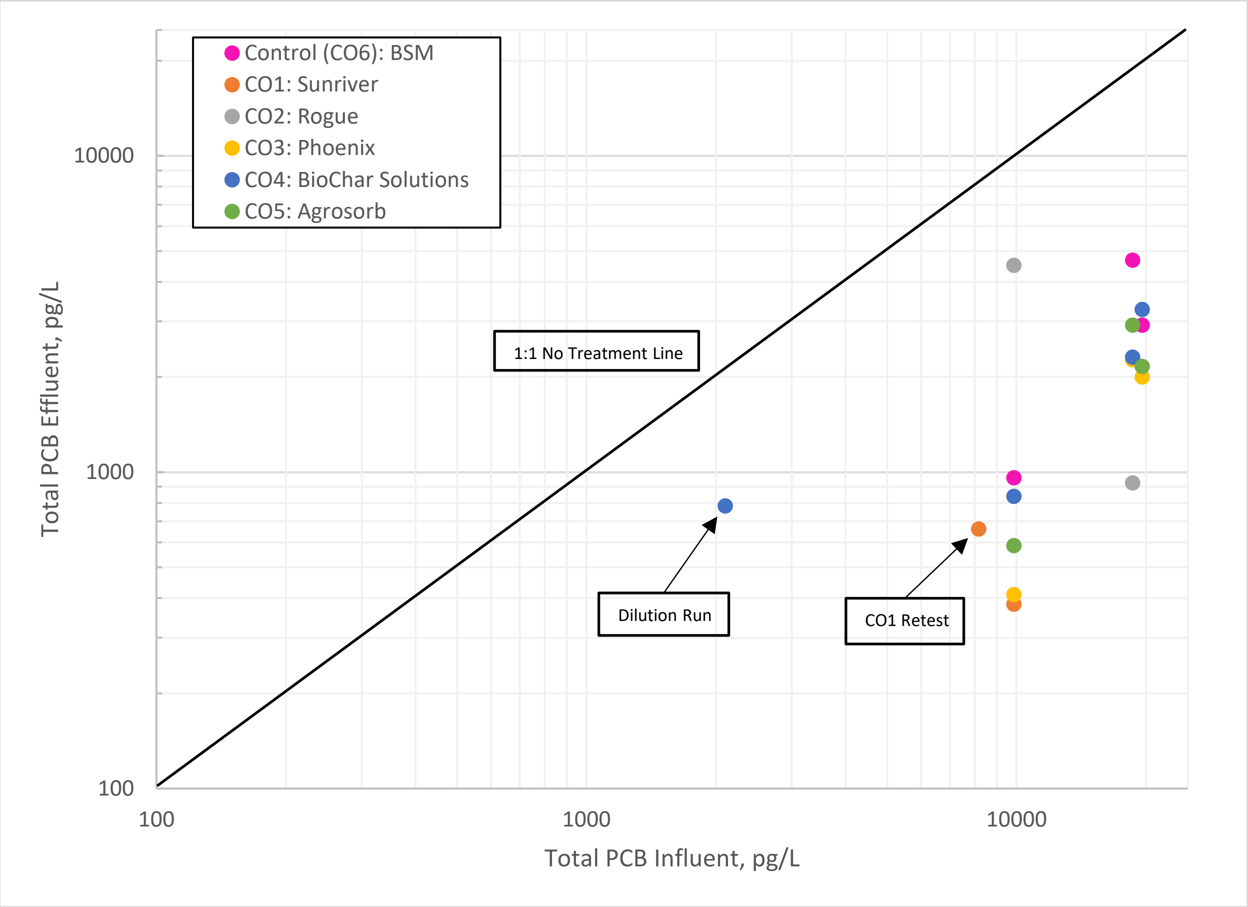

Figure 11. Total PCB Concentrations for all Study Effluent versus Influent

3.3.2 Mercury

Figure 12 shows mercury concentrations for all four test runs in chronological order. Phoenix (CO3) and Agrosorb (CO5) biochar-amended BSM show mercury removal across all three test runs. All biochar-amended BSM shows improved treatment over the standard BSM, except for BioChar Solutions (CO4) in the first and second run.

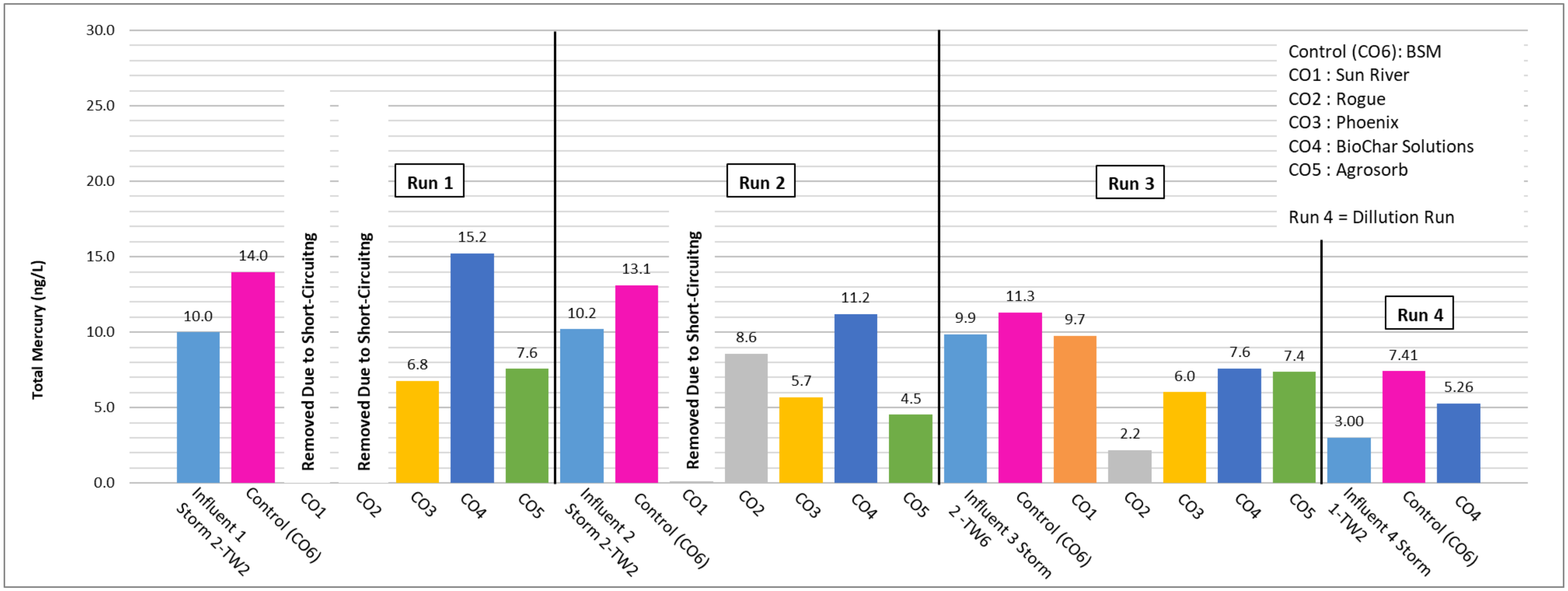

Figure 12. Mercury Concentrations over Time

As stated in the PCB results section, Sunriver biochar-amended BSM (CO1) had unusually high infiltration rates for the first and second test runs and Rogue biochar-amended BSM (CO2) had high rates for the first test run. These data points were removed from the total PCBs dataset for all analyses and were also removed from the mercury dataset.

The mercury export by the control BSM (CO6) for all test runs could indicate that the media itself is releasing mercury. Biochar-amended BSM contain less BSM by volume, which may partially explain the lower mercury concentrations for those columns. Mercury export will likely decrease at locations with higher influent concentrations, and mercury removal is possible if the influent concentration is substantially higher than the export concentration. Gilbreath et al. (2018) reported a median stormwater concentration of 29.2 ng/L, which is almost three times the influent concentration in the three primary test runs.

3.3.3 Other Constituents

Total PCB and mercury concentrations were compared to SSC and TOC respectively. Turbidity was collected during sampling and seasoning runs to provide immediate insight into the performance of the filters throughout the experiment.

Figure 13 shows the relationship between total PCBs and SSC divided into two groups, Influent and Effluent samples.

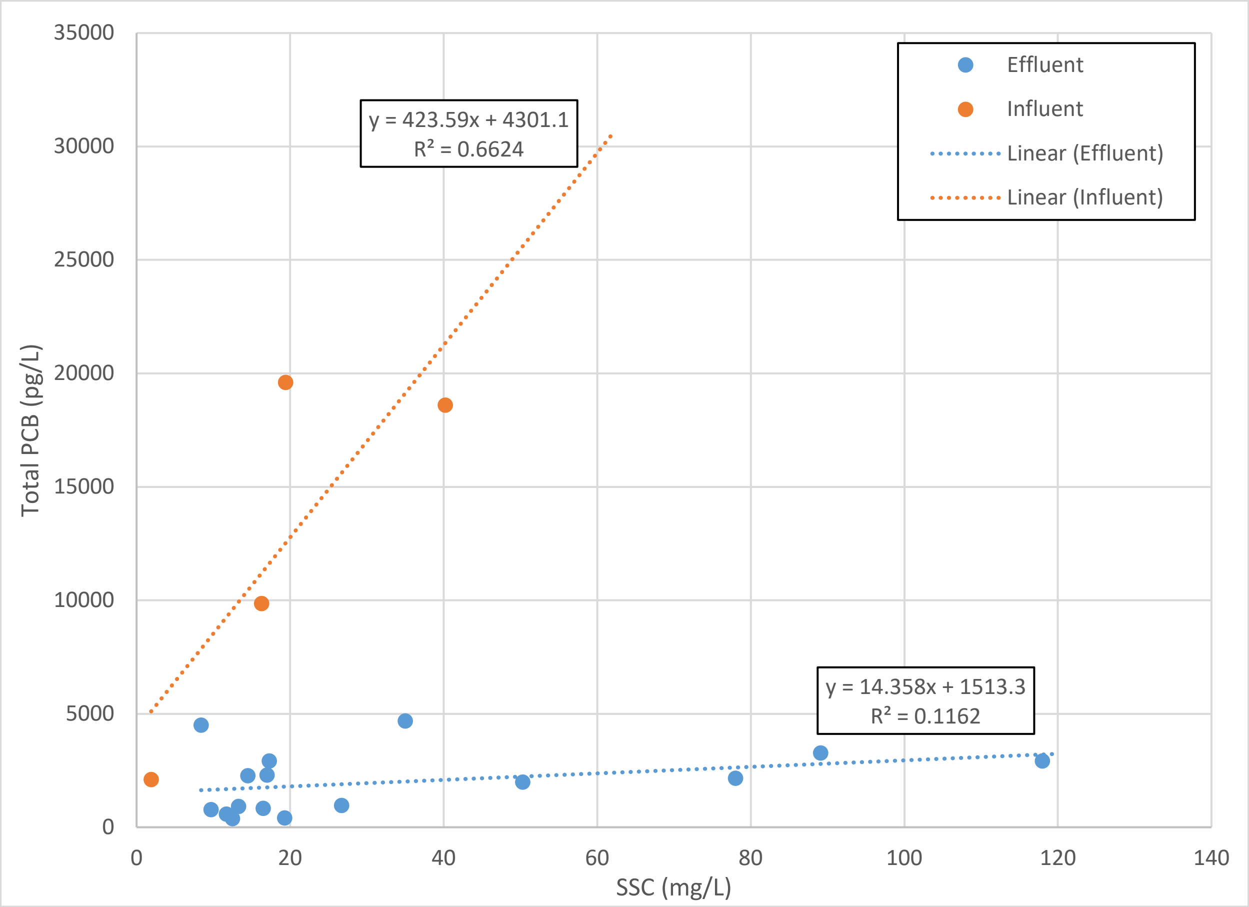

Figure 13. Comparison of Total PCB to SSC Concentrations

Figure 13 confirms the relationship between PCBs and SSC in influent samples (R^2 value of 0.66). The effluent samples have a much shallower regression line with a very low R^2 value of 0.116. This poor correlation is also evidence of contribution of solids from the media rather than the passing of influent solids through the media to the effluent sample, assuming low PCB concentration in the media.

There is no expected correlation between TOC and mercury. It is presented for consideration in cases where methylation is a concern. Figure 14 presents total mercury versus TOC. Normalizing the TOC effluent concentrations by dividing them by influent concentrations shows that TOC at least doubles from influent to effluent, with more typical increases around eight times (Figure 15). This increase is likely from both loss of BSM and leaching of dissolved organic content. Figure 16 shows normalized SSC effluent, which demonstrates substantial export of media, but not as much as TOC. The higher export of TOC is likely due to TOC analysis accounting for particulate and dissolved organic content, while SSC only measures particulates. SSC and TOC increases in these column tests should not be construed as representing field performance. To minimize the concentration reduction in the underdrain, a thin (2-inch) layer of washed coarse sand was used. This underlying coarse sand layer may have exacerbated loss of media solids and consequential increase in TOC and SSC compared to a traditional underdrain with more depth, more fines, and more restriction to infiltration rate.

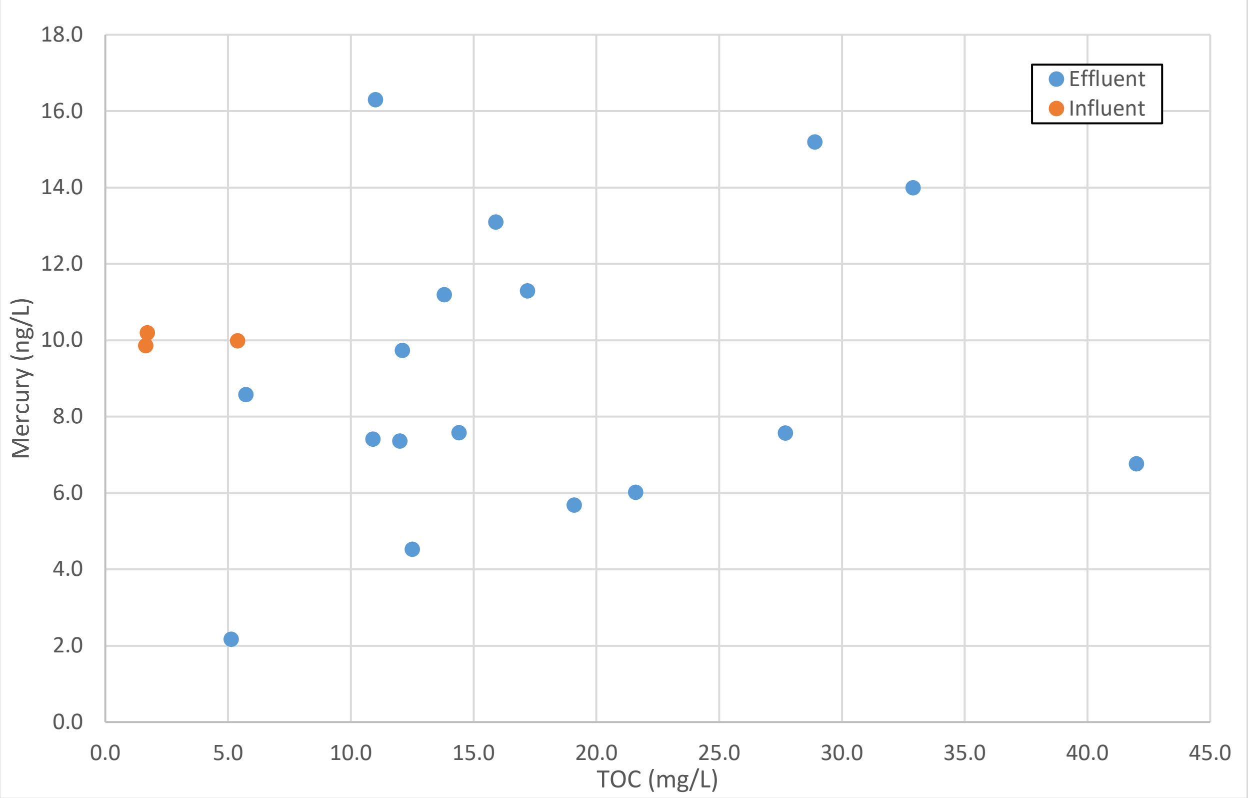

Figure 14. Comparison of Mercury to TOC Concentrations

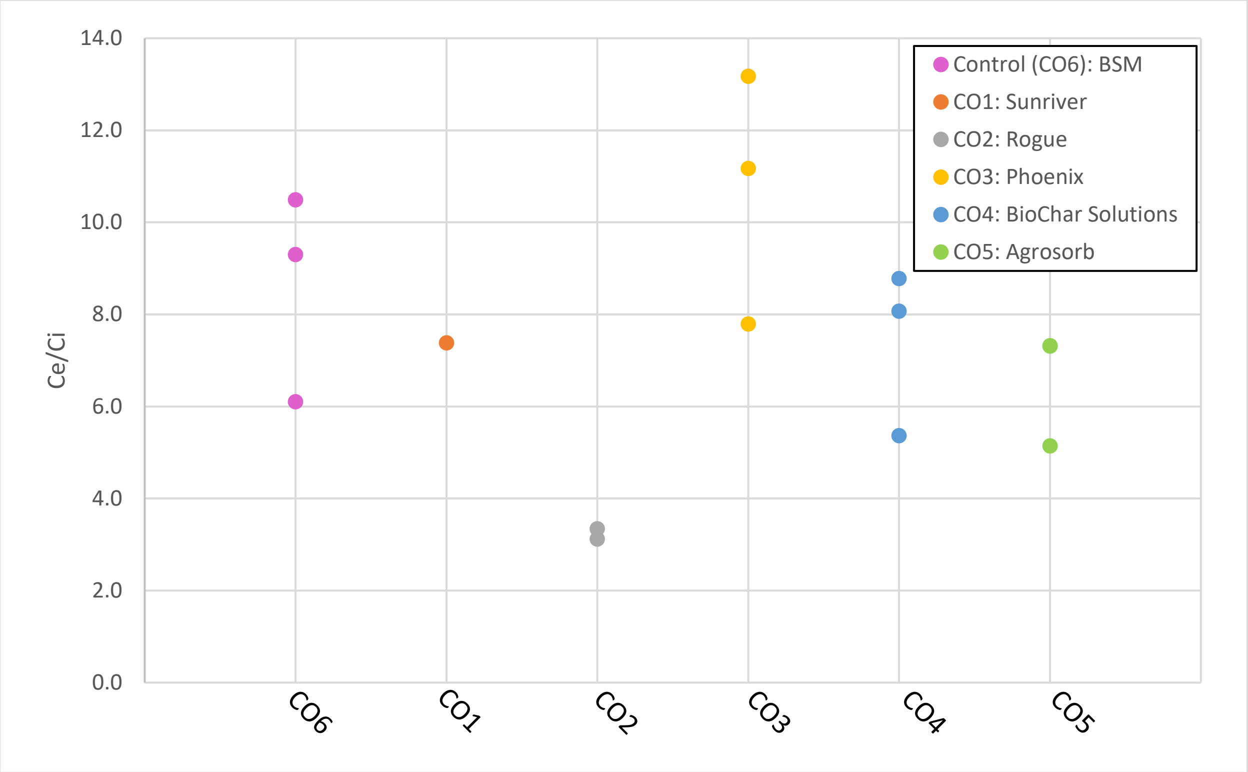

Figure 15. Ce/Ci TOC Concentrations for Column Test Media

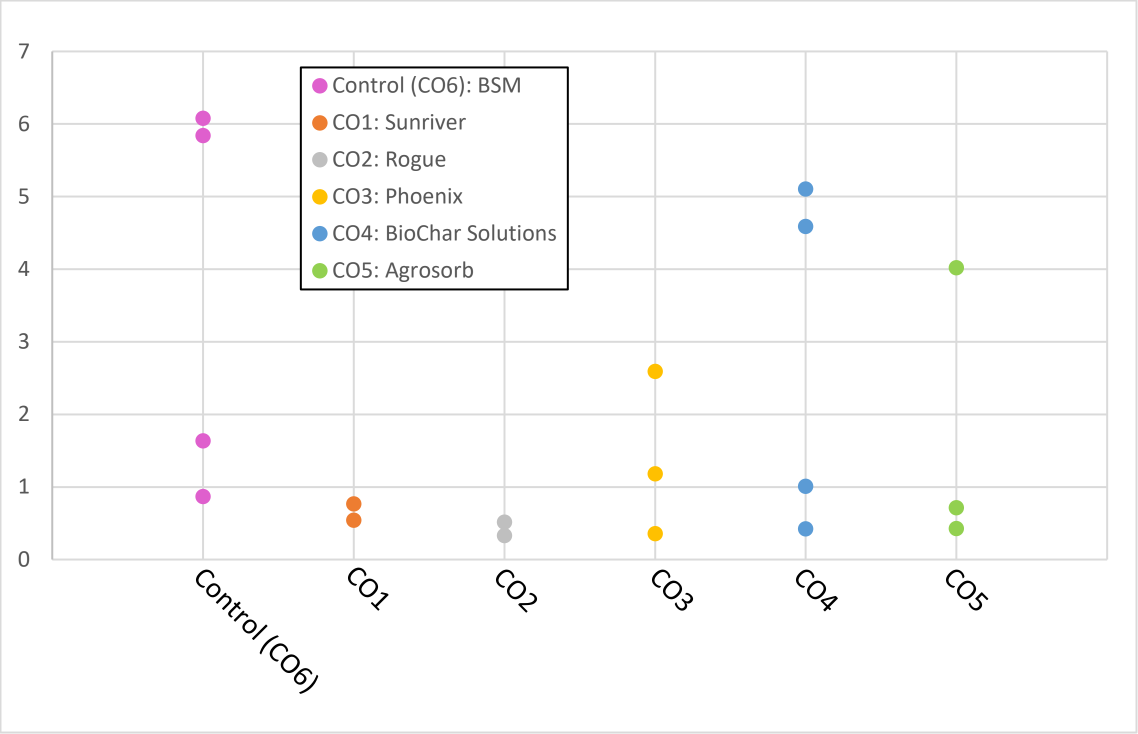

Figure 16. Ce/Ci SSC Concentrations for Column Test Media

Figure 17 shows turbidity measurements for all columns in chronological order over all runs (sampling and seasoning). During the first sampling test run, it was observed that the effluents of all columns had high turbidity and were not representative of a well-established media (see Table 4 for all concentrations). Two seasoning runs were performed next, and the effluent turbidity of all columns stabilized by the end of the second run. Turbidity data is in Appendix F.

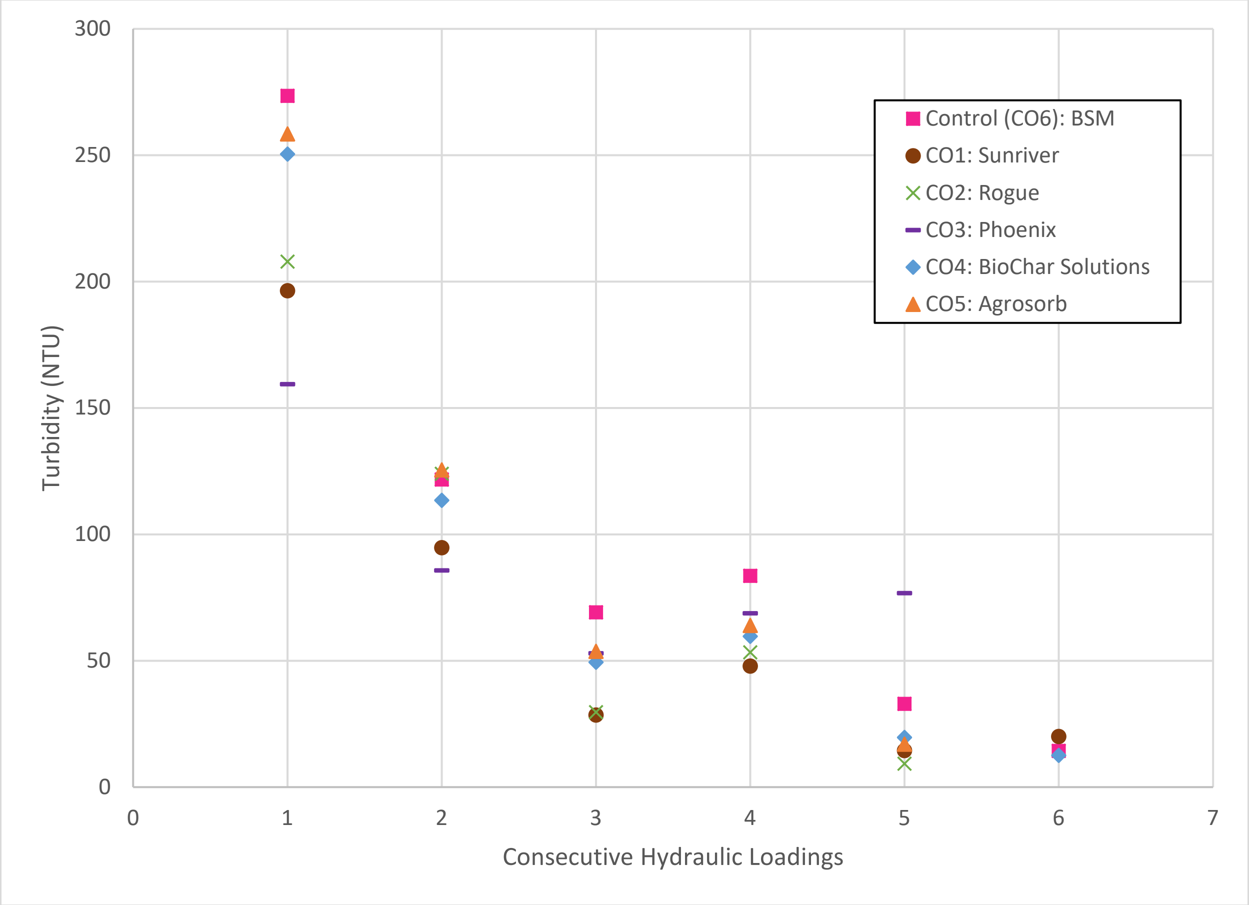

Figure 17. Average Turbidity versus Consecutive Hydraulic Loading (Sampling Runs are labeled 1, 3, 4, 5, and 6 and Seasoning Loading are labeled 2 and 3)

3.4 STATISTICAL TESTS

The statistical analysis (Mann-Whitney U test) on normalized effluent PCB concentrations was unable to establish statistical significance at 90% confidence among media type due to the small sample size, even when grouped by class (e.g., with biochar and without). This also held for mercury. Consequently, further statistical tests were not pursued.

4 CONCLUSIONS AND RECOMMENDATIONS

The goal of this study, as identified in the Monitoring Study Design (Appendix A), was to identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs. The primary management question supporting that goal was: “Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?” And the particular purpose of the laboratory testing in this study was: “screen alternative biochar-amended BSM and identify the most promising for further field testing.” This study’s use of bench scale column testing suggests that there may be some utility in pre-testing materials before use in field applications to ensure that they are likely to meet infiltration requirements at the project site, as well as provide some preliminary evidence of improved or at least equivalent pollutant removal as standard BSM.

4.1 CONCLUSIONS

Nine biochar were readily available from suppliers in the Western United States, and five were tested in this study to compare their impacts on PCBs and mercury concentrations in effluent. All five biochar-BSM blends showed evidence of overall improved PCB and mercury performance compared to the standard BSM for influent concentrations ranging from 9,860 pg/L to 19,600 pg/L[8]. Though performance varied, no biochars could be conclusively eliminated from consideration in future field study. The results support the following observations:

- Phoenix, Sunriver, BioChar Solutions, and Agrosorb appear to offer improved PCB removal compared to standard BSM and the other biochar-amended BSM.
- Phoenix and Agrosorb appear to offer improved mercury removal compared to standard BSM and the other biochar-amended BSM.
- Based on a single run on one column to explore removal at lower influent concentrations, biochar-amended BSM provided removal of PCBs at an influent concentration of 2,100 pg/L. BSM performance at this lower influent concentration could not be reported due to the sample being lost. Neither BSM nor biochar-amended BSM provided removal of mercury at an influent concentration of 3.00 ng/L.
- High initial infiltration rates (associated with short-circuiting and higher pore velocities) correlated to poor performance. Three of four runs with high infiltration rates correlated with poor reduction of PCBs and mercury. All three runs with poor performance (two of which were on one column) occurred prior to a run with a moderate infiltration rate (< 12 in/hr).
- Saturated hydraulic conductivity had poor correlation to the falling head infiltration rates estimated during the water quality sampling runs so biochar that were eliminated from column testing based on saturated hydraulic conductivity tests may be candidates for future testing.

Because the study was a screening level analysis of biochars for potential further study, the limited data for each biochar did not allow for exploration of several factors that are presented in the following section for consideration in development of future study designs.

4.2 RECOMMENDATIONS

Based on this study, biochar shows promise in marginally increasing performance for PCB and mercury removal, however, increased benefit relative to increased cost was not analyzed. With such limited data, meaningful benefit-cost analysis may require collection of substantial field data. Because of the marginal increase in performance, standard BSM should be a component of future side-by-side testing of biochar-amended BSM. Sample size should be selected to provide suitable statistical power to better understand and qualify the performance differences. Other study considerations include long-term performance, media life expectancy, performance for other pollutants, impacts to plant health and water use, and maintenance ramifications. The study team developed the following recommendations for potential biochar testing.

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[8] The lowest influent concentration for Sunriver (CO1) was 8,160 pg/L.

4.2.1 Biochar Selection

For enhanced PCB removal, biochar candidates for further field testing are Phoenix, Sunriver, BioChar Solutions, or Agrosorb. If mercury removal is a design consideration, Phoenix and Agrosorb should be selected over Sunriver and BioChar Solutions. All biochar-amended BSM have falling head drain times in the column tests that were faster than the control BSM, so hydraulic performance should not influence selection. Other factors, such as cost and local sourcing should be considered in final biochar selection. Due to a lack of differentiation of performance and a lack of correlation between performance and cost, less expensive biochar that were not tested here may offer higher benefit/cost. Column tests could provide data for an indication of benefit/cost prior to field testing, but more data is recommended to quantify performance than what was specified in this study for screening-level analysis.

4.2.2 Site Selection

The results of this study could also have implications on site selection for future study. As a general principal, study locations should represent concentrations typical of watersheds that will be receiving green infrastructure, unless those concentrations are below the irreducible concentration. The data indicate that irreducible PCBs concentrations may be occurring around 1,000 pg/L. It is unclear for total mercury. Data from other studies in the San Francisco Bay Area should be consulted to develop a better estimate of irreducible concentrations so future study can avoid areas that are too clean for the technology to be effective for these pollutants.

4.2.3 Outlet Control

Outlet control may be the most important factor in performance. Outlet controls minimize short-circuiting (preferential flow paths) and they increase contact time. Elevated outlets can also increase contact time in between storm events, but this may also affect mercury speciation by providing an anoxic environment where methylation may occur. Further study should control for both contact time and presence of biochar to determine which has the greatest effect in field conditions. Further investigation into contact time (i.e., infiltration rates) and underdrain behavior at the CW4CB biochar location may also be helpful in development of future study plans.

4.2.4 Saturated Hydraulic Conductivity Testing Requirements

The representativeness and utility of the saturated hydraulic conductivity test under typical compaction conditions for highly organic and friable material may be a matter worth discussion within the appropriate BASMAA bioretention working groups. Use of outlet control could obviate the verification of the upper-end conductivity. A lower-end conductivity may still be recommended to assure that the outlet control governs flow rather than the media.

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APPENDIX A: MONITORING STUDY DESIGN

POC Monitoring for Management Action Effectiveness

Monitoring Study Design

Final, September 2017

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1. Introduction

Discharges of PCBs and mercury in stormwater have caused impairment to the San Francisco Bay estuary. In response, the Regional Water Board adopted total maximum daily loads (TMDLs) to address these pollutants of concern (POC) (SFBRWQCB, 2012). Provisions C.11 and C.12 the Municipal Regional Stormwater NPDES Permit, MRP (SFBRWQCB, 2015) implement the Mercury and PCB Total Maximum Daily Loads (TMDLs) for the San Francisco Bay Area. These provisions require mercury and PCB load reductions and the development of a Reasonable Assurance Analysis (RAA) demonstrating that control measures will be sufficient to attain the TMDL waste load allocations within specified timeframes. Provision C.8.f of the MRP supports implementation of the mercury and PCB TMDLs provisions by requiring that Permittees conduct pollutants of concern (POC) monitoring to address the five priority information needs listed below.

1. *Source Identification* – identifying which sources or watershed source areas provide the greatest opportunities for reductions of POCs in urban stormwater runoff;
2. *Contributions to Bay Impairment* – identifying which watershed source areas contribute most to the impairment of San Francisco Bay beneficial uses (due to source intensity and sensitivity of discharge location);
3. *Management Action Effectiveness* – providing support for planning future management actions or evaluating the effectiveness or impacts of existing management actions;
4. *Loads and Status* – providing information on POC loads, concentrations, and presence in local tributaries or urban stormwater discharges; and
5. *Trends* – evaluating trends in POC loading to the Bay and POC concentrations in urban stormwater discharges or local tributaries over time.

Table 8.2 of Provision C.8.f identifies the minimum number of samples that each MRP Countywide Program (i.e., Santa Clara, San Mateo, Alameda, and Contra Costa) must collect and analyze to address each monitoring priority. Although individual Countywide monitoring programs can meet these monitoring requirements, some requirements can be conducted more efficiently and will likely yield more valuable information if coordinated and implemented on a regional basis. The minimum of eight (8) PCB and mercury samples required by each Program to address information priority #3 is one such example. Findings from a regionally-coordinated monitoring effort would better support development of the RAA.

This Study Design describes monitoring and sample collection activities designed to meet the requirements of information priority #3 of Provision C.8.f of the MRP. The activities planned include field sampling of hydrodynamic separators and laboratory experiments with amended bioretention soils. Study planning is important to ensure that the right type of data are collected and there is a sufficient sample size and power to help address the management questions within the available time and budget constraints. Essential components of the study plan include describing problems, defining study goals, identifying important study parameters, specifying methodologies, and validating and optimizing the study design.

2. Problem Definition

Studies conducted to date have identified PCB source areas in the Bay Area where pollutant management options may be feasible and beneficial. Enhanced municipal operational PCB management options (e.g., street sweeping, storm drain line cleanout) have the advantage of being familiar and well-practiced, address multiple benefits, and the cost-benefit may exceed that for stormwater treatment (BASMAA, 2017a). Site-specific stormwater treatment via bioretention, however, is now commonly implemented to meet new and redevelopment (MRP Provision C.3) requirements. An added benefit of redevelopment is that PCB-laden sediment sources can be immobilized. However, many areas where certain land uses or activities generate higher PCB concentrations in runoff are unlikely to undergo near-term redevelopment, and instead may only be subject to maintenance operations or stormwater BMP retrofit projects implemented by the municipality. Consequently it is valuable to maximize cost effective PCB removal benefit of both operations and maintenance, and stormwater treatment.

Two treatment options that have the potential to reduce PCB discharges include hydrodynamic separators (HDS units) and enhanced bioretention filters. These options were pilot-tested in the Clean Watersheds for a Clean Bay (CW4CB) Project (BASMAA, 2017a). HDS units are being implemented for trash control throughout the Bay Area and collect sediment to some extent along with trash and other debris. Quantifying PCB mass removed by these units will help MRP Permittees account for the associated load reductions. For these and other control measures, an Interim Accounting Methodology has been developed based on relative mercury and PCBs yields from different land use categories (BASMAA, 2017c). Bioretention is a common treatment practice for new development and redevelopment in the San Francisco Bay Area, so enhancing the performance of bioretention is also attractive.

At this time reducing mercury loads in stormwater runoff is a lower priority than PCBs load reduction. The assumption during the MRP 2.0 permit term is that actions taken to reduce PCBs loads in stormwater runoff are generally sufficient to address mercury. Therefore, optimizing stormwater controls for PCBs is the primary focus in this study.

2.1 HDS Units

Limited CW4CB monitoring conducted at two HDS sites was used to calculate the mass of PCBs in trapped sediment (BASMAA, 2017a). The two sites sampled were Leo Avenue in San Jose and City of Oakland Alameda and High Street. The Leo Avenue HDS unit treats runoff from approximately 178 acres of watershed with a long history of industrial land uses, including auto repair and salvage yards, metal recyclers, and historic rail lines. The City of Oakland Alameda and High Street HDS has a tributary drainage area of approximately 35 acres with a high concentration of old industrial and commercial land uses, including historic rail lines.

Sampling of the two CW4CB HDS units was opportunistic and associated with scheduled cleanouts. Two sump cleanout events took place in August 2013, one at the Leo Avenue HDS unit and one at the Alameda and High Street HDS unit. However, due to a lack of captured sediment the samples collected were aqueous phase samples instead of sediment samples. An additional cleanout took place at Leo Avenue in October 2014. A sump sediment sample collected and analyzed during this cleanout contained total PCB concentrations of 1.5 mg/kg and mercury concentrations of 0.33 mg/kg for sediment less than 2 mm in size, and estimated annual total PCB and mercury removals were 375 mg and 82.4 mg, respectively (Table 2.1). The HDS sediment concentrations are comparable to previous Leo Avenue watershed measurements in sediments from piping assessed via manholes, drop inlets/catch basins, streets/gutters, and private properties (ND to 27 mg/kg for PCBs and 0.089 to 6.2 mg/kg for mercury) (BASMAA, 2014). At the Alameda and High Street HDS unit, tidal influences of Bay water prevented additional monitoring.

Table 2.1 Summary of Data Collected from Leo Avenue HDS during October, 2014 Annual Cleanout Event

Parameter	Result	Units
Volume of Sediment Removed	4	Cubic yards
Total PCBs Concentration	1.5	mg/Kg
Mercury Concentration	0.33	mg/Kg
Bulk density	0.67	g/cm^3
Percent solids	39	%
Particle Size (< 2 mm)	31	%

There are no known published studies characterizing HDS sediment for PCBs or mercury, so the Leo Avenue results are compared to relevant drain inlet/catch basin sediment studies. In the Bay Area, different municipalities have collected and analyzed drain inlet cleaning sediment samples. The analytical results for these drain inlet sediment samples are summarized in Table 2.2 (BASMAA, 2014). As can be seen from Table 2.2, the Leo Avenue sediment PCB concentrations are higher than those measured in Bay Area drain inlet sediment by up to an order-of-magnitude, but mercury concentrations are comparable.

Table 2.2 Summary of Bay Area Drain Inlet Sediment Concentration Data

(Based on readily available data; see BASMAA (2016b) for additional summaries for street and storm drain sediment)

	PCBs			Mercury		
Municipality	**No. Drain Inlet Sediment Samples**	**Mean PCB DI Sediment Concentration (mg/Kg)**	**Median PCB DI Sediment Concentration (mg/Kg)**	**No. Drain Inlet Sediment Samples**	**Mean Mercury DI Sediment Concentration (mg/Kg)**	**Median Mercury DI Sediment Concentration (mg/Kg)**
Fairfield & Suisun	8	0.244	0.055	16	0.510	0.228
San Mateo County Municipalities	29	0.318	0.123	28	0.160	0.147
San Carlos	22	0.267	0.129	25	0.167	0.147
Alameda County Municipalities	47	0.294	0.122	75	0.384	0.204
Berkeley	8	0.147	0.122	11	0.343	0.241
Oakland	24	0.402	0.155	28	0.539	0.297
San Leandro	11	0.219	0.106	21	0.230	0.151
Contra Costa County Municipalities	46	0.515	0.168	48	0.413	0.308
Richmond	31	0.736	0.482	28	0.460	0.349

Notes:

Mean and median drain inlet sediment concentrations were calculated from the SFEI database (SFEI 2010, KLI and EOA 2002; City of San Jose and EOA 2003).

Monitoring by the City of Spokane, Washington, showed total PCBs in catch basin sediment ranged between 0.025 mg/kg and 1.7 mg/kg for an industrial area with known PCB contamination (City of Spokane, 2015). A City of San Diego study characterized sediments in eight catch basins in a 9.5 acre area of downtown San Diego classified as high density mixed use with roads, sidewalks, and parking lots (City of San Diego, 2012). Concentrations of common aroclors in the catch basin sediments varied from about 0.040 to over 0.9 mg/kg. Monitoring by the City of Tacoma showed PCB concentrations in stormwater sediment traps varied from nondetect to a maximum near 2 mg/kg (City of Tacoma, 2015). The highest PCB concentrations in catch basin sediments ranged from 16 mg/kg in downtown Tacoma to 18 mg/kg in East Tacoma. These published drain inlet/catch basin studies show that PCB and mercury concentrations can vary substantially in storm drain sediments depending on the characteristics of the watershed.

Sampling of captured sediment at the Leo Avenue HDS in San Jose highlighted the potential of HDS maintenance as a management practice for controlling PCB and mercury loads. The BASMAA Interim Accounting Methodology that is currently being used to calculate load reductions assumes a default 20% reduction of the area-weighted land-used based pollutant yields for a given catchment. This default value was based on average percent removal of TSS from HDS units based on analysis of paired influent/effluent data. However, significant data gaps remain in determining the effectiveness of this practice and expected load reductions. HDS sediment sampling has been limited to a few samples. PCB concentrations in the Leo Avenue HDS sample were much higher than average concentrations in Bay Area drain inlet sediment. Drain inlet/catch basin sediment sampling by others suggests that sediment PCB and mercury concentrations can vary substantially from watershed to watershed. **The monitoring performed to date is not sufficient to characterize pollutant concentrations of sediment captured in HDS units that drain catchments with different loading scenarios (e.g., land-uses, stormwater volumes, etc.), nor to estimate the percent removal based on the pollutant load captured by the HDS unit. Additional sampling is needed to better quantify the PCB and mercury loads capture by these devices, and calculate the percent removal achieved**. Consequently, quantification of PCBs removed at other HDS locations and evaluation of the percent load reduction achieved is needed to provide better estimates of PCB load reductions from existing HDS unit maintenance practices.

2.2 Bioretention

The results of monitoring the performance of bioretention soil media (BSM) amended with biochar at one CW4CB pilot site suggest that the addition of biochar to BSM is likely to increase removal of PCBs in bioretention BMPs. Biochar is a highly porous, granular material similar to charcoal. In the CW4CB study, the effect of adding biochar to BSM was evaluated using data collected from two bioretention cells (LAU 3 and LAU 4) at the Richmond PG&E Substation 1st and Cutting site. At this site, cell LAU 3 contains standard engineered soil mix (60% sand and 40% compost) while cell LAU 4 contains a mix of 75% standard engineered soil and 25% pine wood-based biochar (by volume).

Figure 2.1 shows a cumulative frequency plot of influent and effluent PCB concentrations for the two bioretention cells. Although influent PCB concentrations at the two cells were generally similar, effluent PCB concentrations were much lower for the enhanced bioretention cell (LAU 4) compared to those for the standard bioretention cell (LAU 3). The results for total mercury were different from those for PCBs, with both cells demonstrating little difference between influent and effluent concentrations. These CW4CB monitoring results suggest that the addition of biochar to BSM may increase removal of PCBs but not mercury from stormwater. However, analysis of methylmercury indicated that BSM may encourage methylation while biochar may mitigate the effect such that there is no substantial transformation of mercury to methylmercury. Tidal influences at 1st and Cutting also may be a contributing factor that should be controlled in future study.

The majority of biochar research conducted to date has focused on agricultural applications, where biochar has been shown to improve plant growth, soil fertility, and soil water holding, especially in sandier soils. Only a handful of field-scale projects have investigated the effects of biochar in stormwater treatment and no known field studies have investigated removal of mercury or PCBs from stormwater by biochar-amended media.

A recent laboratory study on the effect of biochar addition to contaminated sediments showed that biochar is one to two orders of magnitude more effective at removing PCBs from soil pore water than natural organic matter, and may be effective at removing methylmercury but not total mercury (Gomez-Eyles et al., 2013). A laboratory column testing study to determine treatment effectiveness of 10 media mixtures showed that a mixture of 70% sand/20% coconut coir/10% biochar was one of the top performers and cheaper than similarly effective mixtures using activated carbon (Kitsap County, 2015). Liu et al (2016) tested 36 different biochars for their potential to remove mercury from aqueous solution and found that concentrations of total mercury decreased by >90% for biochars produced at >600◦C but about 40–90% for biochars produced at 300◦C.

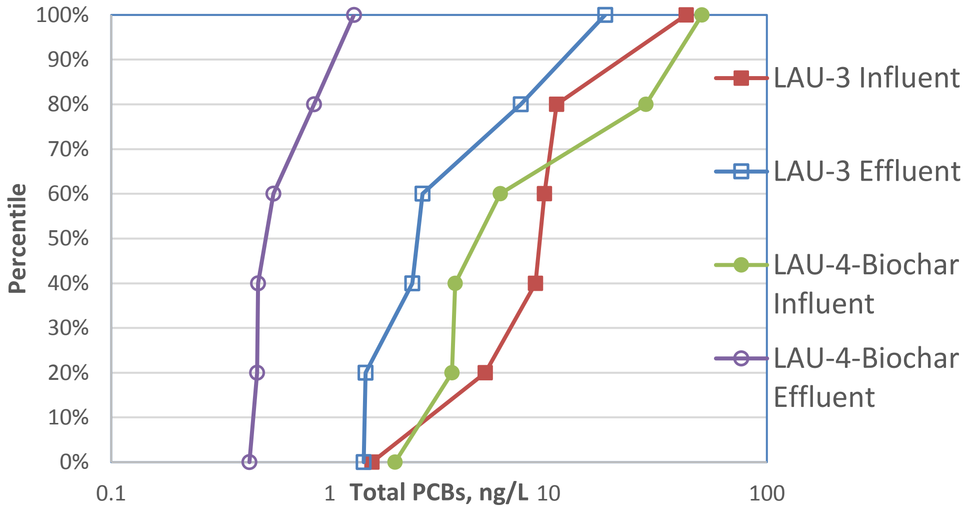


Figure 2.1 Cumulative Frequency Distribution of Total PBCs Influent Concentrations for Bioretention Media with and without Biochar

Monitoring of two bioretention cells at the Richmond PG&E Substation 1st and Cutting pilot site showed greater PCB removal for a biochar-amended BSM than that for standard BSM.

However, to date sampling has been limited to one test site and one biochar amendment, and the operational life of the amended media is unknown. **Besides the CW4CB study, there are no published literature studies on field PCB and mercury removal for biochars. Additional field testing can confirm the effectiveness of bioretention implementation in more typical conditions, and laboratory testing is recommended as an initial screening to help identify potential biochars for field testing**. Laboratory testing using actual stormwater from the Bay Area can be a cost-effective screening tool to identify biochar media that are effective for PCB removal, do not exacerbate mercury problems or even improve mercury removal, and meet operational requirements, including an initial maximum infiltration rate of 12 in/h and a minimum long-term infiltration capacity of 5 in/h.

3. Study Goals

The goals of this study identified from the problem statements are as follows:

1. Quantify annual PCB and mercury load removals during maintenance (cleanout) of HDS units
2. Identify biochar media amendments that improve PCB and mercury load removal by bioretention BMPs

To reach these goals, the following management questions are prioritized as primary or secondary management questions.

3.1 Primary Management Questions

A properly conceived study will address the study goals in a manner that supports planning for future management actions or evaluating the effectiveness or impacts of existing management actions. The resulting primary management questions focus on performance and are:

1. What are the average annual PCB and mercury loads captured by existing HDS units in Bay Area urban watersheds?
2. Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?

The MRP infiltration rate requirements are described in Provision C.3.c of the MRP (SFBRWQCB, 2015). This provision states the following: "Biotreatment (or bioretention) systems shall be designed to have a surface area no smaller than what is required to accommodate a 5 inches/hour stormwater runoff surface loading rate, infiltrate runoff through biotreatment soil media at a minimum of 5 inches per hour, and maximize infiltration to the native soil during the life of the Regulated Project. In addition to the 5 inches/hour MRP requirement, for non-standard BSM the recently updated BASMAA specification requires "certification from an accredited geotechnical testing laboratory that the bioretention soil has an infiltration rate between 5 and 12 inches per hour" (BASMAA, 2016a).

3.2 Secondary Management Questions

Secondary management questions are helpful, but they are not critical to the usefulness of the study. Study scope, budget, and schedule constraints limit the extent to which they can be addressed. Possible secondary management questions include the following:

HDS

1. How does sizing of HDS units affect annual PCB and mercury loads captured in HDS sediment?
2. Do design differences between HDS units (e.g., single vs multiple chambers) result in significant differences in pollutant capture?
3. How does the frequency of cleanout of HDS units affect load capture?

4. If present, does washout of HDS sediment depend on remaining sediment volume capacity?
5. Are there significant concentrations of PCBs in the pore (interstitial) water of HDS sediment?
6. Are PCBs and mercury removal correlated to removal of better-studied surrogate constituents, such as TSS?
7. Is there evidence of increased methylation within HDS sediment chambers?

Enhanced Bioretention

1. How does biochar performance vary with feedstock?
2. How does biochar performance vary with manufacturing method?
3. Should the biochar be mixed with the BSM or provided as a separate layer below the standard BSM?
4. Does biochar have leaching issues or require conditioning before use?
5. How long does the improved performance of biochar-amended BSM last?
6. Does the promising media increase methylation of mercury?
7. What is the expected increase in BSM costs due to inclusion of media amendment?
8. Does knowledge of the association of PCBs and mercury to specific particle sizes improve understanding of performance?
9. Is mass removal comparable to that expected from a conceptual understanding of removal mechanisms?

The above secondary management questions are provided as examples, and the questions answered will depend on budget, schedule, and actual data collected.

3.3 Level of Confidence

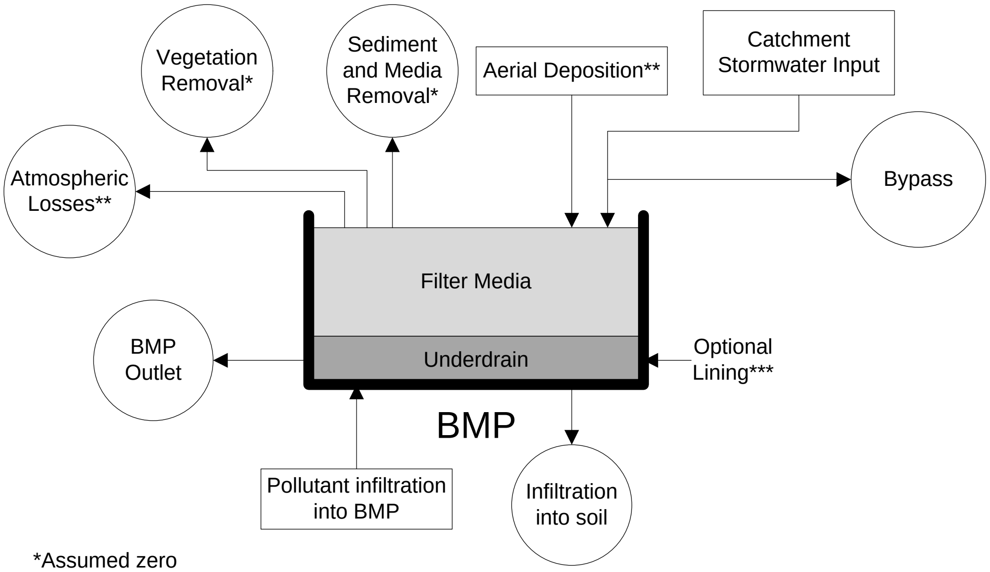
The level of confidence in the answers to the above management questions depends on sample representativeness and size. Samples are considered representative if they are derived from sites or test conditions that are representative of the watershed or treatment being considered. A power analysis can be used after monitoring commences or at the end of a study to determine if sample size is sufficient to draw statistically valid conclusions at a pre-selected level of confidence. Power analysis can also be used prior to study commencement, but its usefulness in estimating sample size requirements may be limited by lack of knowledge of variability in the biochar-amended BSM data to be collected.

Level of confidence can also be assessed in terms of consistency of treatment (e.g., a particular biochar consistently shows better removals than other biochars for a variety of stormwaters), which can be assessed with non-parametric approaches such as a sign-rank test.

Data analysis approaches are discussed in Section 8.5.

4. Study Design Options

An overview of the available study designs is presented here to understand the methods, value, and constraints of each design. This information is helpful in identifying which study designs are appropriate for the various management questions. To answer the primary management questions, the mass of pollutants captured must be quantified. This is accomplished by monitoring pollutant input and export for each HDS unit or media option, or directly quantifying captured pollutant. For example, the typical input and output pathways for a stormwater treatment measure (i.e., BMP) are illustrated in **Error! Reference source not found.**4.1. This overview describes how data are collected and how they are used to answer the primary study questions.



*Assumed zero
** Assumed minor (usually unmeasured)
*** Lining, when present, helps prevent losses and gains from interaction with surrounding soils and water.

Figure 4.1 Typical BMP system and pollutant pathways

The study designs discussed here address major inputs and losses, but not all. Selection of study design is based on the management questions, the type of BMP(s), the study constraints, and the current and historic conditions of the study area. Each type of study has associated strengths and weaknesses as described below:

- Influent-effluent monitoring
  Influent and effluent monitoring tests water going into and discharging from a selected BMP or treatment option for a particular storm event. This approach is typically used to assess BMP effectiveness. An advantage of this approach is its ability to discern differences in limited data sets. A weakness of this approach is that measured load reductions may not be representative of true load reductions if there is infiltration to the native soil, baseflow entering the BMP, or bypass flows that are not monitored

- Sediment sampling
  Sediment sampling occurs within the BMP or treatment option and is used to estimate cumulative load removed over several storms. Sediment sampling can occur in dry periods.
- Before-after monitoring
  Before-after monitoring occurs at the same location. In the before-after approach, data are collected at some location, a change is made (i.e., a BMP is implemented or modified), and additional data are then collected at the same location. This introduces variability because in field monitoring the storms monitored before BMP implementation may not have the same characteristics as those after implementation.
- Paired watershed monitoring
  Paired watershed attempts to characterize two watersheds that are as similar as possible, except one has BMP treatment (e.g., an HDS unit). The paired watershed approach is typically used when monitoring the influent of the BMP is infeasible. While the storms monitored are the same, inevitable differences in the watersheds often lead to unexplainable variability.

  Paired watershed monitoring is not discussed further because it is not applicable to this study. The scope of work does not require influent monitoring at field sites or monitoring of paired sites without BMPs.

Volume measurement is critical to estimating load removal efficiency for BMPs that have volume losses. Volumes can be measured at influent, effluent, and bypass locations and within the BMP for individual storms or over a longer period.

The following subsections provide more detail on each monitoring approach.

4.1 Influent-Effluent Monitoring

Comparison of influent and effluent water quality and load is the method most often used in studies of treatment BMPs. This method is used to estimate the pollutant removal capability of field devices such as individual BMPs or a series of in-line BMPs (i.e., a treatment train) or laboratory treatment systems such as filter media columns. This type of study results in paired samples. Paired samples are beneficial because fewer samples are needed to show statistically significant levels of pollutant reduction compared to unpaired samples. This can result in substantial cost savings for sample collection and sample analysis.

Comparison of performance among BMPs may not be possible if there are only a limited number of locations because of different influent qualities. This is illustrated in **Error! Reference source not found.** for two non-overlapping BMP data sets, which show confidence intervals for effluent estimates (vertical dashed and dotted lines with arrows) expand as the distance between the hypothetical influent *x*-value and the mean *x*-value of the data increases. Although the effluent estimates at a common influent concentration (solid black square and diamond) may reflect true effluent qualities, confidence in these predictions is low because of this extrapolation and the performance of the two BMPs may not be statistically distinguishable. A better study design is one that selects sites with similar influent characteristics or ensures collection of a sufficient number of samples at or close to the common influent level.

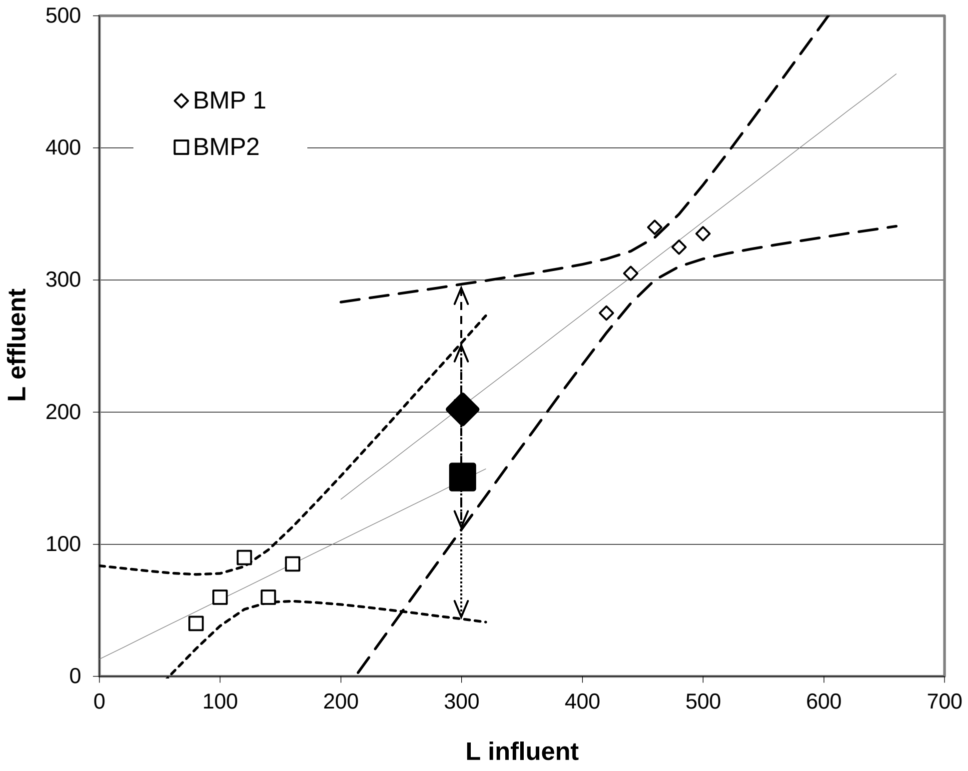


Figure 4.2 Comparison of two hypothetical non-overlapping BMP regressions

4.2 Sediment Sampling

Sediment sampling involves taking samples of actual sediment captured in a BMP in lieu of influent and effluent monitoring. Analysis of the accumulated sediment can provide estimates of the total mass of conservative pollutants removed[1]. An advantage of sediment sampling is reduced cost because expensive storm event sampling is not required. Another advantage is that the measure of pollutants is direct and it is not possible to obtain negative results as in the case of sampling highly variable influent/effluent.

There are a number of limitations to sediment sampling. Annual sediment sampling during a maintenance interval generates fewer data points than influent-effluent sampling throughout a storm season, so comparisons among BMP factors (design, loading, etc.) may require a greater number of monitoring sites. Another limitation is that influent monitoring data are not available to describe how the mass removal estimates may be sensitive to influent loading, and influent monitoring may be required in addition to sediment sampling to

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[1] In the context of sediment sampling, "conservative pollutants" are those that are not substantially lost to volatilization or plant uptake in between periods of sediment analysis. Sediment analysis underestimates performance where volatilization or plant uptake is substantial.

characterize pollutant loading. This limitation is addressed in this study during the data analysis by using model estimates of stormwater flows and pollutant loads from each HDS unit catchment to provide estimates of the influent and associated percent removals achieved.

Another limitation of sediment sampling is the potential error resulting in non-homogeneous pollutant distribution within the sediment. Compositing multiple samples will better characterize the sediment, much as the collection of several aliquots throughout a stormwater runoff event can better represent the total volume of water. Mixing the removed sediment before compositing can provide samples that are more homogeneous.

Consequently, the effectiveness of sediment sampling depends on the type of BMP. HDS are the best candidates for sediment sampling. The sumps are cleaned and empty at the start of the study, and the entire mass of retained sediment is removed at each maintenance event (sump cleanout). Conversely, bioretention has background sediment (planting media) that obscure pollutant accumulation. Since pollutants tend to accumulate on the surface of media (typically within the first few inches), surface sediments should be targeted when sampling these systems. Coring these systems and compositing the core sediments will most likely result in further dilution of the PCBs retained in the media, making quantification more difficult. For all systems, larger pieces of litter and vegetation may be difficult to include in the analysis. A conservative approach is to exclude larger material and assume these have little association with PCBs.

4.3 Before-After Monitoring

Pollutant removal can also be estimated by monitoring discharge quality for treatment devices before and after installation. This may be attractive for green street projects that have multiple BMPs with multiple influent and effluent locations. Monitoring all of these individual systems is almost impossible because of space constraints. Note that since the data from before/after implementation are unpaired, variability is expected to be larger and the number of samples required to show significant removal much higher than for paired samples.

Before-after monitoring is also applicable to laboratory test systems in which water quality is measured before and after a change is made. For example, the rate of adsorption or the adsorptive capacity of media can be determined by measuring the water quality before and after addition of a known quantity of media.

5. Primary Data Objectives

The study design options discussed previously are matched to the primary management questions. The primary management questions require two data objectives: determine annual mass captured by HDS units and load removal by biochar-amended BSM. The primary management questions are:

1. What are the **annual PCB and mercury loads captured** by existing HDS units in Bay Area urban watersheds?
2. Are there readily available biochar-amended BSM that provide significantly better **PCB and mercury load reductions** than standard BSM and meet MRP infiltration rate requirements?

Monitoring to address the first management question should at minimum provide the average annual PCB and mercury loads captured by HDS units.

5.1 Data Objective 1: Annual Loads Captured by HDS Units

Determined by influent-effluent monitoring for individual storm events over one or more seasons or filter media/sediment sampling at end of each season.

Options:

- ❖ Influent-effluent monitoring. Requires monitoring of as many storms as possible over a season and flow measurement in addition to water quality sampling. Flow measurement is a critical component for estimating stormwater volumes treated, retained, and bypassed, and is often associated with additional measurements such as water depth within a BMP to estimate bypass and retention.
- ❖ Filter media/sediment sampling. Requires sampling at end of season but does not require influent/effluent water quality or flow measurement. Sediment sampling has a high value for estimating annual mass removal because a single composite sample of retained sediment over a season can yield an estimate of load removal for the constituents analyzed. However, influent characterization would also help explain mass removal performance. This method is most appropriate when applied to HDS systems because they can isolate retained sediment.

5.2 Data Objective 2: Loads Reduced by Biochar-Amended BSM

Determined by influent-effluent monitoring or filter media/sediment sampling for individual events until sufficient data are available for statistical analysis.

Options:

- ❖ Influent-effluent monitoring. Requires monitoring of multiple individual events and flow measurement in addition to water quality sampling. Accurate flow measurement in BMPs is difficult because flows can vary an order of magnitude during individual events and measurements may be required at multiple locations within a device because of bypass, infiltration etc. (see Figure 4.2). This complexity introduces a great degree of variability in the monitored data that can substantially increase the number of data points required to show statistically significant load removals, particularly for BMPs such as HDS units that show relatively small differences between influent and effluent load reductions. This option is most appropriate for testing filter media, for example in laboratory experiments, in which accurate flow measurements are possible and sampling of accumulated sediment is infeasible.

- Filter media/sediment sampling. Requires sampling after individual events but does not require influent/effluent water quality or flow measurement. This method is not feasible for filter media because the retained sediment cannot be isolated from the filter media.

6. BMP Processes and Key Study Variables

The treatment mechanisms that occur in a BMP help inform selection and control of the study variables. These treatment mechanisms, also called *unit processes*, may include physical, chemical, or biological processes. The primary physical, chemical, and biological processes that are responsible for removing contaminants include the following:

- Sedimentation – The physical process by which suspended solids and other particulate matter are removed by gravity settling. Sedimentation is highly sensitive to many factors, including size of BMP, flow rate/regime, particle size, and particle concentration, and it does not remove dissolved contaminants. Treated water quality is less consistent compared to other mechanisms due to high dependence on flow regime, particle characteristics, and scour potential.
- Flocculation – Flocculation is a process by which colloidal size particles come out of suspension in the form of larger flocs either spontaneously or due to the addition of a flocculating agent. The process of sedimentation can physically remove flocculated particles.
- Filtration – The physical process by which suspended solids and other particulate matter are removed from water by passage through layers of porous media. Filtration provides physical screening of particles and trapping of particles within the porous media. Filtration depends on a number of factors, including hydraulic loading and head, media type and physical properties (composition, media depth, grain size, permeability), and water quality (proportion of dissolved contaminants, particle size, particle size distribution). Compared to sedimentation, filtration provides a more consistent treated quality over a wider range of contaminant concentrations.
- Infiltration – The physical process by which water percolates into underlying soils. Infiltration is similar to filtration except it results in overall volume reduction.
- Screening – The physical process by which suspended solids and other particulate matter are removed by means of a screen. Unlike filtration, screening is used to occlude and remove relatively larger particles and provide little or no removal for particles smaller than the screen opening size and for dissolved contaminants.
- Sorption – The processes of absorption and adsorption occur when water enters a permeable material and contaminants are brought into contact with the surfaces of substrate media, plant roots, and sediments, resulting in short-term retention or long-term immobilization of contaminants. The effectiveness of sorptive processes depends on many factors, including the properties of the water (contaminant concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, pH, particle size and charge), media type (surface charge, absorptive capacity), and contact time.

- Chemical Precipitation – The conversion of contaminants in the influent stream, through contact with the substrate or root zone, to an insoluble solid form that settles out. Consistent performance often depends on controlling other parameters such as pH.
- Aerobic/Anaerobic Biodegradation – The metabolic processes of microorganisms, which play a significant role in removing organic compounds and nitrogen in filters.
- Phytoremediation – The uptake, accumulation, and transpiration of organic and inorganic contaminants, especially nutrients, by plants.

The relative importance of individual treatment mechanisms depend to a large extent on the chemical and physical properties of the contaminant(s) to be removed i.e. the influent quality. The two contaminants of interest in this study are PCBs and mercury. PCBs are relatively inert hydrophobic compounds that have very limited solubility and a strong affinity for organic matter. They are often associated with fine and medium-grained particles in stormwater runoff, making them subject to removal through gravitational settling or filtering through sand, soils, media or vegetation. Most of the mercury in water, soil, and sediments is in the form of inorganic mercury salts and organic forms of mercury such as methylmercury that are strongly adsorbed to organic matter (e.g., humic materials). In general, mercury is most strongly associated with fine particles while PCBs are generally associated with relatively larger and/or heavier particles. It is therefore expected that sedimentation, flocculation, and related processes will be less effective for mercury removal than for removal of PCBs (Yee and McKee, 2010).

The following subsections provide a brief description of the BMP types being evaluated in this study, the unit processes involved in each, and key variables that indicate possible data collection approaches. The final selection of the quantity and type of data to collect is presented in the “Optimized Study Design” section.

6.1 HDS Units

Hydrodynamic separators rely on sedimentation and screening as the primary removal mechanism for sediment and particulate pollutants. Treatment performance is highly dependent on the following:

- Influent quality (contaminant concentration, proportion of dissolved contaminants, particle size, particle size distribution, and particle density)
- BMP design and hydraulic loading/flow regime (size of unit versus catchment area)
- Operational factors (remaining sediment capacity)

HDS effluent quality is highly variable, particularly for contaminants such as mercury that are associated with fine particles that are not as effectively removed in HDS. These devices are expected to require a relatively large number of influent-effluent samples to demonstrate statistically significant reductions in pollutant concentrations. Therefore, analysis of retained sediment is an appropriate alternative to influent-effluent sampling for determining pollutant mass captured. Sediment can be analyzed when the device is cleaned.

6.2 Bioretention

Bioretention is a slow-rate filter bed system. It is planted with macrophytes (typically shrubs and smaller non-woody vegetation). The major sediment removal mechanism is physical filtration through the planting media. When retention time is sufficient, dissolved constituents can be removed by sorption to plant roots in the planting media, which typically contains clays and organics to enhance sorption. Treatment performance is highly dependent on the following variables:

- Influent quality (contaminant concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, particle size distribution)
- BMP design and hydraulic loading rate/head (size of the unit in relation to catchment area and storm character)
- Media type and properties (composition, grain size, grain size distribution, adsorptive properties, and hydraulic conductivity)
- Volume reduction by infiltration
- Operational factors (surface clogging, short-circuiting)

The effluent quality from bioretention and enhanced bioretention is expected to be consistently higher than for sedimentation-type BMPs. These devices are expected to require a relatively fewer number of samples than HDS units to demonstrate statistically significant reduction because of better treatment of fine particles and dissolved contaminants.

It is important to note that laboratory and not field bioretention systems are of interest in this study. These laboratory systems, essentially cylindrical columns filled with the media being tested, attempt to simulate most, but not all, of the chemical, biological, and physical processes that occur in field devices. For example, volume reductions due to infiltration are not simulated in laboratory column experiments. The advantages of using media columns as proxies for field devices include improved control over operation, monitoring, and sample collection in ways that would be impractical in the field. This improved control makes it possible to test a large number of potential media and identify the most promising for future field testing.

7. Monitoring and Sampling Options

Key variables that affect water quality and sediment quality data are identified from knowledge of treatment processes. The following lists the process variables identified through knowledge of the treatment processes:

- Influent quality (contaminant concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, particle size distribution, particle density)
- BMP design and hydraulic loading (flow rate, hydraulic head, flow regime)
- Media type and properties (composition, grain size, grain size distribution, adsorptive properties, and hydraulic conductivity)
- Operational factors (surface clogging, short-circuiting, remaining sediment capacity)

Some of the above variables can be controlled and others are measured to determine their effect on water quality and sediment quality. Inevitably, some variables will be beyond the control of the study but their expected impact should be considered based on theory, past experience, models, or observations from other studies.

7.1 HDS Units

7.1.1 Influent Quality

The location of the BMP can greatly affect influent water quality such as pollutant concentrations and particle characteristics because land use and land cover affect sediment mobilization and pollutant concentrations within the sediments. Land use is often used as an indicator of pollutant loading. The land uses of the areas of interest include industrial, commercial/mixed use, roads/rail, institutional, and residential. Because of past use of PCB and past PCB and mercury handling practices, age of the land use is also important, with generally higher concentrations from older industrial, commercial, and transportation areas, and lower concentrations from newer residential areas. However, PCB analysis by the San Francisco Estuary Institute (SFEI) showed that PCB concentration patterns were patchy within larger urban watersheds with higher concentrations. This finding indicates that mass reductions of PCBs may require site-specific sampling of influent loads or site-specific quantification of mass removed. Mercury data suggest areas with higher mercury concentrations are not as pronounced although generally where there is PCB contamination there is also high to moderate Hg contamination (Yee and McKee, 2010).

Since HDSs are primarily installed for trash capture, their distribution within the study area is assumed to be random. However, the primary interest is in watersheds with relatively high pollutant loads that are most likely to result in significant removal in HDSs (e.g., the Leo Avenue watershed). Land use or land use based pollutant yields can be used to represent average influent water quality when influent monitoring is not conducted.

Figure 7.1 shows the land use based PCB and mercury loadings for key designated land use types. It can be seen that unit PCB loading from watersheds with higher PCB concentrations and mercury loading from old industrial watersheds are substantially higher than the other land uses. Assuming particle size, particle size distribution, and other stormwater characteristics are similar for the different land uses, HDSs in higher concentration watersheds or old industrial watersheds are expected to capture much higher pollutant loads than those in other watersheds.

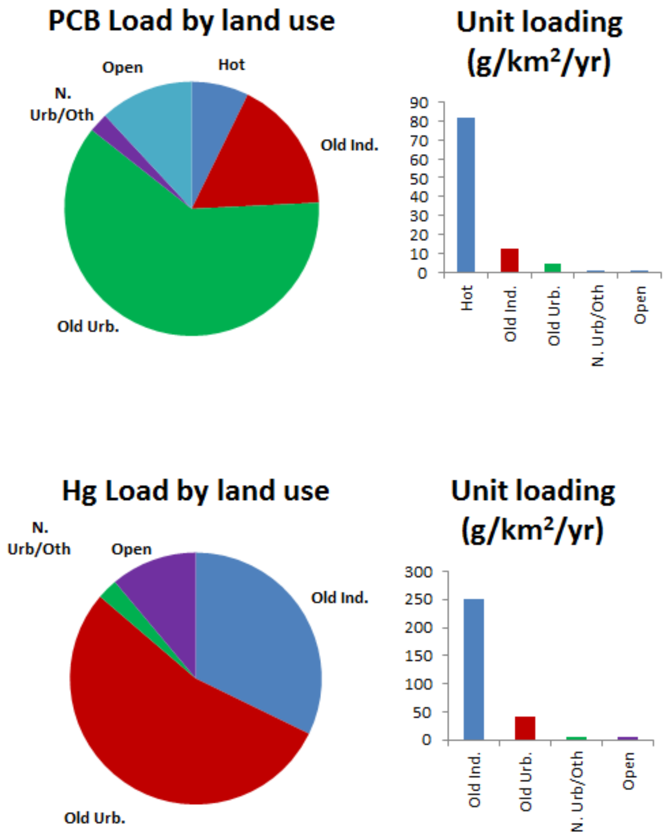

Figure 7.1 Land Use based PCB and Mercury Loading based on BASMAA Integrated Monitoring Reports (SFEI, 2015)

A preliminary land use based study design could categorize HDS sites as show in Table 7.1.

Table 7.1 HDS Sampling Design based on Watershed Land Use

Land Use	HDS Samples
Higher Concentration	X, X, X[1]
Old Industrial	X, X, X[1]
Old Urban	X, X, X[1]

1 – "X" represents a sample from a selected HDS unit in the specified land use category.

The above design is appropriate if HDS units can be categorized easily into one of the three land use categories. A review of the land uses within HDS watersheds indicates that most HDS units are in predominantly old urban watersheds, and it is unclear how many HDSs are within areas with higher PCB concentrations (Table 7.2).

Table 7.2 Percent of Land Use in HDS Watershed Areas

(Based on FY 2015-16 Co-permittee Annual Reports, Section 10 - Trash Load Reduction. Source: Chris Sommers Personal Communication)

HDS Catchment ID	New Urban	Old Industrial	Old Urban	Open Space	Other
287; Sonora Ave		16	84	1	
27A	15	50	34	2	
996; Parkmoor Ave		1	98	1	
1084; Oswego		0	89	0	10
600; Edwards Ave		33	39	28	
611; Balfour		14	55	30	
1082; Melody/33rd		0	97	3	
612; Lewis			93	7	
604; Sunset			96		4
1012; Blossom Hill/Shadowcrest			100	0	
1083; Lucretia		0	98	1	1
1002; Selma Olinder		10	86	5	
995; Dupont St.		9	91	0	
9-A; 73rd Ave and International Blvd		0	94	6	
475; 7th		68	29	3	
509; Coyote	22		77	1	
47			99	1	
8-A; Alameda Ave near Fruitvale		40	57	4	
575; Bulldog		6	93	1	
601; W. Virginia		7	90	3	
1504; Phelps			100	0	
390; Remillard		4	87	10	
Tennyson at Ward Creek		1	97	2	
W Meadow Dr		2	97	1	
Leland and Fair Oaks		1	99		
Ward and Edith			100	0	
5-D; 22nd and Valley		1	99	0	
8-C; High St @ Alameda Bridge		67	32	0	
5-G; Perkins & Bellvue (Nature Center)			100		
999; William		0	95	5	
Main St and Hwy 1			85	15	
Central Expy at Fair Oaks		11	89	0	
393; Wool Creek		18	78	4	
5-C; 27 St & Valdez Ave		2	98		
998; Pierce		1	96	3	
Maple and Ebensburg			98	2	
Ventura Ave			99	1	
Golden Gate and St Patrick			100	0	
5-A; Euclid Ave @ Grand Ave			100		
5-H; Lake Merritt (SD Outfall 11)			100		
5-B; Staten Ave & Bellvue			100		
Central Expy at De la Cruz		33	67		
5-I; Lake Merritt (SD Outfall 26)			100		
Mathilda overpass project CDS2		0	100		
Mathilda overpass project CDS1		10	84	7	

Given the few sites in categories other than old urban, an alternative study design based on mixed land uses may be more appropriate (Table 7.3).

Table 7.3 HDS Sampling Design based on Predominant Land Use

Predominant Land Use	HDS Samples
Higher Concentration/Old Industrial	X, X, X[1]
Old Urban/Old Industrial	X, X, X[1]
New Urban/Old Urban	X, X, X[1]

1 – "X" represents a sample from a selected HDS unit in the specified land use category.

The sampling design in Table 7.3 assumes that at least three HDS units are available for sampling in each PCB land use category. The sampling design may need to be modified further if there are an insufficient number of units available for sampling. For example, any site with more than 30% old industrial may be considered especially if it is a mixed zoned watershed (with industrial, commercial, residential and transportation land uses). The range of values in each land use category can be determined upon review of the most recent information. The design in Table 7.3 assumes that the characteristics of the runoff (e.g., particle sizes) are similar for the different land uses and only the yield is different.

Only sediment sampling is proposed for HDS. Since HDS influent-effluent monitoring is not required, variables such as proportion of dissolved contaminants, particle size, particle size distribution, and particle density are not measured or controlled, but their effect on influent quality and treatment is accounted for by randomly selecting HDSs within each land use category.

7.1.2 BMP Design and Hydraulic Loading

BMP design and hydraulic loading, which depends on the size of the BMP, can have a substantial impact on effluent water quality and the quantity of sediment retained in a BMP. Consequently, a full range of BMP designs and sizes are of interest. Properly sized, BMPs infrequently exceed their design capacity. However, BMPs are not always sized to standard specification, especially in retrofit environments in which typical hydraulic loading is much higher due to space constraints.

HDS units are typically proprietary and designs and sizing vary widely. Sediment capture may vary because of design differences such as number of chambers and design of overflow weirs and baffles, as well as different sizing criteria that can greatly affect both hydraulic loading and flow regime. The purpose of the study is to characterize sediment in HDS units in the study area. Since BMP design and sizing are important factors affecting HDS performance, it is necessary to include a range of HDS units in the study design and not just randomly select HDS units. A randomized blocked study design is therefore considered more appropriate than a completely random one that may result in an insufficient number of HDS units of a certain size.

In a randomized design, one factor or variable is of primary interest (e.g., land use), but there are one or more other confounding variables that may affect the measured result but are not of primary interest (e.g., HDS design, HDS size). Blocking is used to remove the effects of one or more of the most important confounding variables and randomization within blocks is then used to reduce the effects of the remaining confounding variables. An appropriate sampling design could therefore be land use as the primary factor and HDS size as the blocking factor. Since the population of HDS units in the land use categories of interest is limited, only two size blocks are used (≤ 50^{th} percentile, > 50^{th} percentile), and other variables such as design differences are accounted for by random selection within each block (Table 7.4).

Table 7.4 HDS Sampling Design based on Predominant Land Use and HDS Size

Predominant Land Use	HDS Size	
	≤50th percentile	>50th percentile
Higher Concentration/Old Industrial	X, X, X[1]	X, X, X[1]
Old Urban/Old Industrial	X, X, X[1]	X, X, X[1]
New Urban/Old Urban	X, X, X[1]	X, X, X[1]

1 – "X" represents a sample from a selected HDS unit in the specified land use category.

For the sampling design in Table 7.4, an HDS size factor is required to differentiate the two types of sizes that are of interest. In controlled field study of 4 different proprietary HDS units and laboratory testing of 2 other units, Wilson et al. (2009) developed a *performance function* (treatment factor) that reasonably predicted the removal efficiency of a given hydrodynamic separator. The performance function explained particle removal efficiency in terms of a Péclet number, P_e, which accounts for particle settling and turbulent diffusion. In the following equation, V_s is the particle settling velocity, h is the settling depth in the device, d is the device diameter, and Q is the flow through the device:

$$P_e = \frac{V_s h d}{Q}$$

The above Péclet number (Wilson et al's performance function) can be used in the sampling design as the HDS size factor. For grouping the available HDS units into the two blocks, information is required on the particle diameter and design parameters for each device (settling depth, diameter, and design flow). Particle diameter can be assumed to be 75 µm, which is the critical size used for partitioning PCB fractions in Yee and McKee (2010), and is also approximately the size separating silt and fine sand size particles. The design flow can be calculated from knowledge of the drainage area to the device and a standard design storm. Note that the design flow should not be based on manufacturer guidance because different manufacturers use different sizing criteria and device sizing may not always follow manufacturer guidance.

The final sampling design may need revision depending on the monitoring approach, availability of HDSs, information on watershed land use and sizing, and the level of participation from municipalities.

7.1.3 Operation and Maintenance

Maintenance frequency can greatly impact BMP performance. For sedimentation BMPs such as HDS, sediment levels may exceed the sediment capacity of the BMP, decreasing the volume for sedimentation and increasing scour.

Operation and maintenance (e.g., cleanout frequency) are not of direct interest in this study and their effect on treatment is not being tested. However, these are confounding variables that need to be excluded. In the HDS sediment sampling design, HDS units that are considered at capacity or will reach capacity during the study should be excluded from the population of interest. Field observations are required to make this determination (e.g., whether the screen is blocked). These units can be cleaned out and sampled in a subsequent year. For each selected HDS unit, maintenance schedules (past and current) will need to be reviewed to determine the time period over which sediment accumulated.

7.2 Enhanced Bioretention

7.2.1 Influent Quality

The purpose of the laboratory testing is to screen alternative biochar-amended BSM and identify the most promising for further field testing. The laboratory testing requires influent-effluent monitoring. Influent water characteristics can vary depending on the source of the test water. PCB and mercury loading is largely a result of historic activities that result in accumulation in sediments of pervious areas. Mobilization of these sediments may require exceeding site-specific intensity and volume thresholds. Storm intensity is critical to detach and mobilize particles and storm volume must exceed any depression storage within the pervious areas. However, the precise effect of storm intensity and volume on the mobilization of PCB-contaminated and mercury-contaminated sediments has not been established. Influent water characteristics also depend greatly on drainage area characteristics including traffic and industrial and commercial activity.

Since the purpose of the laboratory study is to screen alternative biochar-amended BSM that can be used throughout the Bay Area, collection and use of stormwater from one or more representative watersheds is preferred. A preliminary review of available Bay Area stormwater runoff monitoring data from 27 sites (Table 7 of SFEI 2015) suggests median PCB concentration is about 9 ng/L. Therefore, one or more previously monitored watersheds with mean PCB concentrations well above 10 ng/L may be appropriate for collection of stormwater for the laboratory testing. Since the relative treatment performance of the various media at even lower concentrations may be different, additional tests with diluted stormwater may be required to confirm study results.

Storms from the representative watershed should be targeted randomly without bias, thereby accounting for the effects of storm intensity and ensuring variability in contaminant concentration, proportion of dissolved contaminants, particle size, particle size distribution, and particle density. To achieve this, minimal mobilization criteria should be used to ensure predicted storm intensity and runoff volume are likely to yield the desired volume.

7.2.2 BMP Design and Hydraulic Loading

The design variables in the enhanced bioretention testing laboratory study include media type, media depth, and media configuration. Media type is a key variable that is discussed further below. Testing the effect of different media depths or media configurations is not a research objective of the laboratory study, so these can be fixed for all experiments. Typical bioretention media depth in the Bay Area is 18 inches, so all column experiments should use 18 inches of BSM. In the Richmond PG&E Substation 1st and Cutting enhanced BSM testing, the biochar was not installed as a separate layer but was instead mixed with the standard BSM. It is unclear how treatment is affected by these two media configurations, but for consistency with previous field work the biochar and standard BSM should be mixed.

Hydraulic loading is a controlled variable that can be kept constant for all columns. Since the laboratory study is attempting to replicate field bioretention, the hydraulic loading can be the design loading for bioretention. Bioretention designs in the Bay Area typically have a maximum ponding depth of 6 inches, so a loading of 6 inches could be used for the column tests. There are two options for loading the columns: pump and manual. Peristaltic pumps are ideal for controlled loading, but in this study manual loading (batch loading) is more appropriate because of the potential for PCBs and mercury to stick to tubing, pump parts, etc. For manual loading, up to 10 inches of stormwater may be needed each time to ensure sufficient sample volume.

7.2.3 Media Type and Properties

Media type and properties have a substantial effect on the treatment performance of filtration devices. This group of variables include composition, grain size, grain size distribution, adsorptive properties such as surface area, and hydraulic conductivity. Media composition is a primary variable that accounts for differences in the biochars used and the proportion of each biochar in the amended BSM mix. The other variables (grain size, grain size distribution, adsorptive properties, and hydraulic conductivity) are not of direct interest in this study and are assumed to vary randomly or are controlled through screening experiments that limit their variability.

Biochar is produced from nearly any biomass feedstock, such as crop residues (both field residues and processing residues such as nut shells, fruit pits, and bagasse); yard, food, and forestry wastes; animal manures, and solid waste. Biochar feedstock and production conditions can vary widely and significantly affect biochar properties and performance in different applications, making it difficult to compare performance results from one study to another (BASMAA, 2017a). A laboratory study that characterized the physical properties of six different waste wood derived biochars found particle sizes ranging from over 20mm to fine powder and surface areas ranging from 0.095 to 155.1 m^2/g (Yargicoglu et al., 2015). The variability in biochar types and properties is expected to result in large variation in treatment efficiency and infiltration rates. Given the large number of potential biochars that could be tested and the need to meet an initial maximum 12 in/h infiltration rate and a minimum long-term infiltration rate of 5 in/h, a phased study design is appropriate. In such a phased study, promising readily available biochars are first identified through a review of the literature, and hydraulic screening experiments are performed on biochar-BSM media mixes to ensure infiltration rates are met prior to performance testing. This approach is expected to be the most cost-effective because it reduces analytical costs.

There is little information on hydraulic properties of bioretention media amended with biochar, and it is not clear what percentage of the amended BSM should be biochar to maximize treatment benefit. Given the variable physical size of the biochar media, relatively fine biochars could result in a mix that does not meet the initial 12 in/h maximum infiltration rate or minimum 5 in/h long-term infiltration rate. Kitsap County (2015) tested a BSM mix containing 60% sand, 15% Compost, 15% Biochar, and 10% shredded bark, and found that the biochar mix had an infiltration rate of only 6.0 in/h. One conclusion of the study was that the reduction in infiltration rate with the biochar additive was most likely because of fines in the biochar. To overcome this, hydraulic screening experiments are required in which the infiltration rate for each media mix is measured prior to water quality testing to ensure that both the maximum and minimum rates are met. Initially, each biochar can be mixed with standard BSM at a rate of 25% biochar by volume (the same as that at the CW4CB Richmond PG&E Substation 1st and Cutting site). Hydraulic conductivity can be determined using the method stated in the BASMAA soil specification, method ASTM D2434, which requires measurement of water levels and drain times. If a mix does not meet the infiltration requirements, the percentage of biochar is adjusted and the new mix tested. Amended mixes that do not meet the infiltration rate requirements are removed from further consideration (i.e. the effect of hydraulic conductivity is controlled by screening).

The final phase of the laboratory study can be column testing to identify the most effective amended BSM mixes for field testing. An influent-effluent monitoring design is typically used in column testing and media effectiveness is assessed on a storm-to-storm basis with real stormwater collected in the Bay Area. Only media mixes that have passed the hydraulic screening should be tested. All media columns should be sufficiently large or replicated to account for or minimize the impact of variability in media installation and experimental technique. Standard BSM should be used as a control since the primary interest is to identify media mixes that perform significantly better than standard BSM. An example of the column sampling design for 5 new media mixes and one standard BSM control is shown in Table 7.5. The key variable of interest in the sampling design in Table 7.5 is the media mix (composition).

Table 7.5 Example Sampling Design for Laboratory Column Experiments

Biochar/BSM Mix	Column Samples
A Mix	X, X, X[1]
B Mix	X, X, X[1]
C Mix	X, X, X[1]
D Mix	X, X, X[1]
E Mix	X, X, X[1]
Control Mix	X, X, X[1]

1 – "X" represents an influent or effluent sample.

7.2.4 Operation and Maintenance Parameters

Operational life depends on the capacity to pass the minimum required stormwater flows. Like media life, operational life is important because it determines the frequency and cost of maintenance requirements. Maintenance frequency can greatly impact BMP performance, and lack of maintenance can lead to surface clogging and sediment clogging in the inlets which reduces treatment capacity and increases bypass and overflow. Operation and maintenance are not of direct interest in this study and their effect on treatment is not being tested. However, these are confounding variables that need to be excluded.

Media mixes that do not meet the maximum 12 in/h and minimum 5 in/h infiltration rates can be excluded by hydraulic screening experiments (discussed above). As well as meeting the maximum 12 in/h initial infiltration rate requirement, these screening experiments help ensure that the BSM mixes do not fail during the laboratory testing. However, operational performance in laboratory experiments is not expected to be representative of that in the field because of differences in influent quality, variability in loading, effects of vegetation, etc. Therefore, laboratory estimates of long term infiltration rate are of little use and field testing is required to confirm that selected media mixes meet the long-term minimum infiltration rate of 5 in/h. The laboratory testing, however, can provide relative comparisons of hydraulic performance that can be used to decide and screen out media mixes that are likely to hydraulically fail in the field.

7.3 Uncontrolled Variables and Study Assumptions

The following assumptions were adapted from the Caltrans PSGM (Caltrans, 2009):

- Site Assumptions
  - HDS sediment concentrations are representative of the land use within the watershed, i.e. there are no sources of sediment from adjoining watersheds, from illicit discharges, or from construction activities
  - HDS sediment or influent is not affected by base flow, groundwater, or saltwater intrusion
  - Differences in storm patterns throughout the Bay Area are not sufficient to change the HDS performance measurements
  - Water quality of stormwater collected for laboratory testing is representative of that observed in Bay Area urban watersheds

- BMP Operation Assumptions
  - Sampled HDS units operated as designed (e.g., no significant scouring)
  - Volatilization of pollutants is negligible
  - There is no short-circuiting of flows in laboratory column studies

- Media Selection Assumptions
  - The readily available biochars selected are representative of all biochars
  - Selected media do not leach contaminates and media conditioning (e.g., washing) is not required

- Monitoring Assumptions

- Data collected from a few sites over a relatively short time span will accurately represent sediment at all HDS sites over longer time frames
- There are minimal contaminant losses in collecting and transporting water for laboratory experiments
- Water quality of stormwater for laboratory tests does not change significantly during each test
- Stormwater loading of laboratory columns is representative of loading in the field
- Long-term infiltration performance of biochar mixes is to be tested in the field

8. Final Study Design

The study design is optimized to answer the primary management questions within the available budget. The design used prioritizes sampling of HDS units, but allocates sufficient funding for minimum sampling requirements for the laboratory media testing study. Monitoring that does not relate directly to the primary management questions is considered lower priority.

8.1 Statistical Testing & Sample Size

In a traditional test of a treatment, the null hypothesis is that there is no difference between the influent and effluent of a treatment (i.e., the treatment does not work). In the case of HDS sampling, influent-effluent sampling is not required, and interest is only in determining if HDS units remove PCBs and mercury and how the sediment concentrations and load removals vary for different land uses, and for different rainfall and stormwater flow characteristics. Statistical testing in the HDS study is therefore limited to testing if there is a difference in the concentrations and loads captured by HDS units in different watersheds. This testing will require sampling of a sufficient number of HDS units in each land use category associated with differing pollutant load yields.

In the laboratory study, influent-effluent sampling is required and traditional statistical tests can be used depending on sample size.

As well as traditional statistical testing, confidence in the conclusions can be established by comparing total PCB and mercury performance to that for other constituents that directly affect it (e.g., suspended solids, total organic carbon) or have similar chemistry (e.g., other organics). As stated previously, total PCB and mercury concentrations are expected to correlate to some extent with particulates and organics. Comparisons to other constituents are particularly useful for studies in which treatment is expected to be low and the corresponding sample size requirements very high.

Sample size requirements are smaller for paired sampling designs (i.e., influent and effluent sampling for the same storm event) than for independent sampling designs. Paired sampling is not possible for the HDS sampling study that has no influent-effluent monitoring, but is possible in the laboratory media testing study. Additionally, the number of samples required to show significant treatment are generally fewer for filtration-type BMPs than sedimentation-type BMPs because of their better and more consistent treatment.

8.2 Constituents for Sediment Analysis

Constituents selected for HDS sediment analysis must meet the data objectives discussed previously in “Primary Data Objectives”, and be consistent with Table 8.3 of the MRP (SFRWQCB, 2015). Sediment samples will be screened using a 2 mm screen prior to analysis. Table 8.1 lists the constituents for sediment quality analysis. Total organic carbon (TOC) is included because it is a MRP requirement and can be useful for normalizing PCBs data collected for the sediment.

The primary objective of sediment analysis is quantification of the mass of PCBs and mercury accumulating within HDS units. Consequently, PCBs and total mercury are analyzed for all screened sediment samples. The secondary objective is to establish a relationship between total PCBs, mercury, and particle size. Correlating total PCBs and mercury to particle sizes will complement past studies and provide insight into the type of BMPs that are appropriate to achieve the most cost-effective mass removal.

Analysis of PCBs at the CW4CB Leo Avenue HDS showed that PCBs in the water above the sediment may be minor when compared to sediment-associated PCBs (BASMAA, 2017b). PCB concentrations in overlying water are expected to be low and sampling of this water is not included in this study design.

Table 8.1 Selected Constituents for HDS Sediment Monitoring

Constituent
TOC
Total Mercury[1]
PCBs (40 congeners) in Sediment
Particle Size Distribution
Bulk Density

1 – Only total mercury analyzed. Methyl mercury is not relevant for SF Bay TMDL.

8.3 Constituents for Water Quality Analysis

Constituents for analysis of water samples must meet the data objectives discussed previously in “Primary Data Objectives”, and be consistent with Table 8.3 of the MRP (SFRWQCB, 2015). Table 8.2 lists the constituents for the laboratory media testing studies. The list of water quality constituents must provide data to address the primary management question to quantify total PCB and mercury reduction, so PCBs and total mercury are analyzed for all samples. Secondary management questions relate to understanding removal performance for total PCB and mercury.

In addition to PCBs and total mercury, the other constituents selected for influent and effluent analysis are SSC, turbidity, and TOC. SSC was selected because it more accurately characterizes larger size fractions within the water column, while turbidity was selected because it is an inexpensive and quick test to describe treatment efficiency where strong correlation to other pollutants has been established. As with the sediment analysis, TOC is included because it is a MRP requirement and can be useful for normalizing PCBs data collected for water samples.

Table 8.2 Selected Aqueous Constituents for Media Testing in Laboratory Columns

Constituent
SSC
Turbidity
TOC
Total Mercury[1]
PCBs (40 congeners) in Water

[1] – Only total mercury analyzed. Methyl mercury is not relevant for SF Bay TMDL.

8.4 Budget and Schedule

The monitoring budget for the study is approximately $200,000. A contingency of 10 percent of the water quality monitoring budget is recommended to account for unforeseen costs such as equipment failure. Another constraint is that all sampling will occur in one wet season.

8.5 Optimized Study Design

The optimized study designs are presented in Tables 8.3 and 8.4 for the HDS Monitoring and Enhanced Bioretention studies, respectively. Several iterations were analyzed and the study designs shown are based on best professional judgment to allocate the budget to the various data collection options.

The final design for the HDS monitoring study is based on selection and sampling of 9 HDS units in key land use areas. The number of units that can be sampled is limited because sampling is expected to be opportunistic as part of regular maintenance programs. Therefore, a simple design with 9 units is appropriate. The data analysis will evaluate the percent removal achieved for each HDS unit during the time period of interest (i.e., the time period between the date of the previous cleanout, and the current cleanout date for each HDS unit sampled) by incorporating modeled estimates of stormwater volumes and associated pollutant loads for each HDS unit catchment. Because HDS units are sized to treat stormwater runoff from storms of a given size and intensity, excess flows for storms exceeding the design capacity will bypass the unit and are not treated. Storm by storm analysis of rainfall data during the time period of interest will allow estimation of the total stormwater volume and pollutant load to the catchment during each storm, as well as the volume and pollutant load that bypassed the HDS unit and was not treated. This information will then be combined with the measured pollutant mass captured by each HDS unit to quantify the percent removal of PCBs and mercury from the total catchment flow, and the percent removal of PCBs and mercury from the treated flow. For each HDS unit sampled in the study, the total and treated pollutant mass removed will be calculated using the following equations.

(1) Total Pollutant Mass Removed (%) = $[M_{HDS\text{-}i}/M_{Catchment\text{-}i}] \times 100\%$

(2) Treated Pollutant Mass Removed (%) = $[M_{HDS\text{-}i}/(M_{Catchment\text{-}i} - M_B)] \times 100\%$

Where:

$M_{HDS\text{-}i}$	the total POC mass captured in the sump of HDS Unit i over the time period of interest
$M_{Catchment\text{-}i}$	the total POC mass discharged from Catchment-A (the catchment draining to HDS unit A) over the time period of interest
M_B	the total POC mass that bypassed HDS unit A over the time period of interest

The following inputs will be measured or modeled for the time period of interest for use in the equations above:

- Total PCBs and mercury mass captured by a given HDS unit. This is the mass measured in each HDS unit during this project.
- The total stormwater volume and associated PCBs and mercury load from the HDS unit catchment. This will be modeled on a storm by storm basis using available rainfall data, catchment runoff coefficients, and assumed pollutant stormwater concentrations.
- The stormwater volume and associated PCBs and mercury load that bypassed the HDS unit. The bypass volume (and associated pollutant load) during each storm (if any) will be calculated based on the design criteria for a given HDS unit.
- The total PCBs and mercury load treated by a given HDS unit. This will be determined by subtracting the bypass load (if any) from the total pollutant load for the catchment.

The corresponding design for the enhanced BSM study is based on testing of readily available biochars in hydraulic screening experiments followed by column testing of up to five promising BSM mixes as well as a standard BSM control mix. The final number of BSM mixes will depend on availability and media properties (e.g., expected hydraulic conductivity). The optimized designs will yield 33 data points for the key data objectives, 9 from the HDS monitoring study and 24 from the enhanced BSM media testing column study.

Table 8.3 HDS Monitoring Study Design

<table>
<tr><td>Primary Management Question(s)</td><td>What are the annual PCB and mercury loads captured by existing HDS units in Bay Area urban watersheds and the associated percent removal?</td></tr>
<tr><td>Type of Study</td><td>Sediment monitoring; modeling stormwater volume and pollutant load</td></tr>
<tr><td>Data Objective(s)</td><td>Annual PCB and mercury mass captured in HDS units and percent removal</td></tr>
<tr><td>Description of Key Treatment Processes</td><td>Sedimentation, Flocculation & Screening
• Removal by gravity settling and physical screening of particulates
• Effectiveness depends on water quality, BMP design and hydraulic loading/flow regime, and operational factors</td></tr>
<tr><td>Key Variables</td><td>• Sediment quality and quantity
• Influent quantity and quality (contaminant concentration,)
• BMP design and hydraulic loading/flow regime
• BMP maintenance (remaining sediment capacity)</td></tr>
<tr><td>Monitoring Needs</td><td>Monitored variables: sediment quality, sediment mass
Controlled variables: influent quality, BMP maintenance (remaining sediment capacity)
Uncontrolled variables: HDS design, hydraulic loading, flow regime</td></tr>
<tr><td>Monitoring Approach</td><td>Influent quantity and quality: based on rainfall/runoff characteristics and on land use pollutant yield (old urban, new urban, etc.)
Hydraulic loading: base on HDS size (diameter and settling depth) and flow (design flow for known watershed size)
BMP maintenance: base on remaining sump capacity</td></tr>
<tr><td>Sampling Design</td><td>Sampling expected to be opportunistic as part of regular maintenance programs.
Targeted predominant land uses for HDS selection and corresponding data generation:
<table>
<tr><th>Predominant Land Use</th><th>HDS Samples</th><th>No. Samples (Total 9)</th></tr>
<tr><td>Higher Concentration/Old Industrial</td><td>X, X, X[1]</td><td>3</td></tr>
<tr><td>Old Urban/Old Industrial</td><td>X, X, X[1]</td><td>3</td></tr>
<tr><td>New Urban/Old Urban</td><td>X, X, X[1]</td><td>3</td></tr>
</table>
1 – “X” represents a sample from a selected HDS unit. Yield categories will be determined during site selection.
• Exclude units at full sump capacity (cleanout and monitor subsequent year if possible)</td></tr>
<tr><td>Constituent List</td><td>TOC, total mercury, PCBs (40 congeners) in sediment, particle size distribution, and bulk density</td></tr>
<tr><td>Data Analysis</td><td>Independent (unpaired) samples. Present range of total PCB and mercury concentrations measured and mass removed/area treated. Analyze using ANOVA. Model estimates of catchment stormwater volumes and PCB and mercury stormwater loads combined with the measured mass captured in the unit to calculate the percent removal.</td></tr>
</table>

Table 8.4 Enhanced BSM Testing Study Design

<table>
<tr><td>Primary Management Question(s)</td><td>Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?</td></tr>
<tr><td>Type of Study</td><td>Influent-effluent monitoring</td></tr>
<tr><td>Data Objective(s)</td><td>PCB and mercury load removal</td></tr>
<tr><td>Description of Key Treatment Processes</td><td>Filtration and Adsorption
• Removal by physical screening, trapping in media, and retention on media surface
• Effectiveness depends on influent water quality, BMP design and hydraulic loading/flow regime, media type and properties, and operational factors</td></tr>
<tr><td>Key Variables</td><td>• Influent and effluent quality (PCB concentration, particle concentration, organic matter, proportion of dissolved contaminants, particle size, particle size distribution)
• BMP design (media depth) and hydraulic loading/head
• Media type and properties (composition, grain size/size distribution, adsorptive properties, hydraulic conductivity)
• BMP maintenance (surface clogging, short-circuiting)</td></tr>
<tr><td>Monitoring Needs</td><td>Monitored variables: Influent and effluent quality contaminant concentration, particle concentration, organic matter, surface clogging
Controlled variables: media depth, hydraulic loading/head, media composition and adsorptive properties, hydraulic conductivity
Uncontrolled variables: Influent and effluent proportion of dissolved contaminants, particle size, particle size distribution, short-circuiting</td></tr>
<tr><td>Monitoring Approach</td><td>Phased approach because of number of media/need to ensure MRP infiltration rates
1. Hydraulic tests to ensure amended media meet infiltration requirements
2. Influent-effluent column tests for select mixes with Bay Area stormwater
3. Influent-effluent column tests for best mix with Bay Area stormwater at lower concentrations</td></tr>
<tr><td>Sampling Design</td><td>Phase I Hydraulic Tests:
- Determine infiltration rates for media mixes with 25% biochar by volume
- If MRP infiltration rates not met, adjust biochar proportion and retest
- Target infiltration rate of 5 - 12 in/h for all mixes, attempt to control rate to +/- 1 in/hr.

Phase II Influent-Effluent Column Tests with Bay Area Stormwater (up to 5 mixes)
<table>
<tr><th>Biochar/BSM Mix</th><th>Column Samples</th><th>No. Samples (Total 21)</th></tr>
<tr><td>A Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>B Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>C Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>D Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>E Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>Control Mix</td><td>X, X, X</td><td>3</td></tr>
<tr><td>Influent</td><td>X, X, X</td><td>3</td></tr>
</table>
Phase III Influent-Effluent Column Tests for Select Mix with Diluted Bay Area Stormwater
- Perform tests with diluted stormwater, if necessary, to confirm effectiveness at concentrations representative of New Urban and New Industrial land
- Test at one dilution (1 influent and 1 mix and 1 control effluent) (3 samples)</td></tr>
<tr><td>Constituent List</td><td>SSC, turbidity, TOC, total mercury, PCBs (40 congeners) in water</td></tr>
<tr><td>Data Analysis</td><td>Dependent (paired) samples. Present range of total PCB and mercury concentrations measured and mass removal efficiencies. Analyze using ANOVA and regressions of influent/effluent quality. Perform sign-rank test to compare consistency in relative performance among the columns.</td></tr>
</table>

8.6 Adequacy of Study Design

The primary management questions are reviewed in this section in light of the budgeted data collection efforts. The primary management questions are restated and followed by an analysis of the adequacy of the data collection effort.

1. *What are the annual PCB and mercury loads captured by existing HDS units in Bay Area urban watersheds?*

Table 8.3 lists the number of data points that are anticipated for the HDS monitoring study.

This selected design will provide 9 data points for each of the following: PCB sediment concentration, mercury sediment concentration, and sediment mass. This design will not be able to assess the effect of HDS size and hydraulic loading on pollutant removal, and may not be able to statistically differentiate load capture between different land uses because of the small sample count for each land use (3). However, this design is selected because of the lack of information available on HDS sizing and the opportunistic nature of the sampling which limits the number of HDS units that can be sampled. The effect of maintenance is eliminated by ensuring that samples are not collected from units that have no remaining sump capacity.

The HDS study design collects independent (unpaired) samples since each HDS unit is sampled independently and there is no relationship between the various HDS units. This limits ability to discern differences due to land use or HDS size, especially when sample size is relatively low and there is considerable variability in the data collected. Although the study design yields 9 data points for each data objective, it may not be sufficient to draw statistically-based conclusions. However, the study will provide point estimates of loads removed during cleanouts and how they vary for different land uses (e.g., X g of PCBs are removed per unit area of Y land use). This is the metric used for effectiveness of HDS cleanouts, so the study will provide a practical improvement in knowledge that can be applied to future HDS effectiveness estimates.

In addition, modeled stormwater flows and associated POC loads to each HDS unit catchment during the time period between cleanouts will be developed. These modeled estimates will be used along with the measured mass captured in the HDS unit between cleanouts to quantify the percent removal for each unit during the study.

2. *Are there readily available biochar-amended BSM that provide significantly better PCB and mercury load reductions than standard BSM and meet MRP infiltration rate requirements?*

Table 8.4 lists the number of data points that are anticipated for the enhanced BSM testing study. The sampling design will yield 19 data points for each of the following: effluent PCB concentration, effluent mercury concentration. Including influent analysis, a total of 24 samples will be analyzed. The purpose of this study is to identify the best biochar amended BSM mixes for field testing and not test the effect of confounding variables such as influent quality and hydraulic loading on load removals. The study design accounts for these confounding variables by either ensuring their effect is randomized (e.g., influent water quality) or keeps them fixed (e.g., hydraulic loading). To ensure influent stormwater concentrations are representative of typical Bay Area concentrations, an additional column test with diluted stormwater is performed on an effective media mix. Standard BSM controls are used for each column run so that removal by biochar amended mixes can be compared directly to removal by standard BSM. Infiltration experiments are performed prior to the column testing to ensure media selected for final column testing will meet the MRP infiltration rate requirements.

The enhanced BSM column study design collects dependent (paired) samples since each effluent sample is related to a corresponding influent sample. Additionally, standard BSM controls are used for each run which makes it possible to directly compare effluent quality for each amended BSM to standard BSM. The paired sampling design, use of standard BSM controls, and ability to control or fix many of the variables that effect load removal increase the ability to discern differences in treatment. Therefore, only 3 column runs are proposed, and available budget is instead used in initial hydraulic screening experiments to ensure selected media mixes meet MRP infiltration rate requirements. The study design may not be sufficient to draw statistically-based conclusions because it yields only 3 data points for each biochar mix tested. However, the study will enable direct comparisons of effluent quality and treatment between mixes for individual events and consistency of treatment between events. The information provided by the study is expected to be sufficient to identify the most promising biochar mixes for field testing.

The study designs for the HDS monitoring and enhanced bioretention studies meet MRP sample collection requirements. The sampling design for the HDS monitoring study will yield a minimum of 9 PCB and mercury data points, while the sampling design for the enhanced bioretention laboratory study will yield 24 PCB and mercury data points (including influent analysis). The minimum number of PCB samples for this study plan is 33 (9+24). Because 3 of the 32 BMP effectiveness samples required by the current MRP have already been collected, the minimum number required for this project is 29. This study must yield 29 of the 32 permit-required samples, per Provision C.8.f of the MRP. To ensure that at least 29 samples are collected to meet the MRP requirement, additional samples will be collected during the laboratory media testing runs if fewer than 5 HDS units are available for sampling.

9. Recommendations for Sampling and Analysis Plans

This section presents specific recommendations for the development of SAPs. More detailed information is available in Section 6 of the Caltrans Monitoring Guidance Manual (Caltrans, 2015) and in the Urban Stormwater BMP Performance Monitoring (WERF 2009). Analysis of constituents should follow the CW4CB Quality Assurance Project Plan (BASMAA 2013).

9.1 HDS Monitoring

The following SAP recommendations are based on the lessons learned from sampling the Leo Avenue HDS site (BASMAA, 2017b):

- Include equipment to determine sump capacity before sampling. The study design does not require sampling of units that are full (i.e., have no remaining sump capacity). The depth of the unit can make it difficult to inspect for sump basin contents, and use of a “sludge judge” or other similar equipment may not be possible because of difficulty penetrating through compacted organic materials.
- The sampling is expected to be opportunistic sampling during regular cleanouts. Since it coincides with regular maintenance patterns, the occurrence of a clean and empty vactor truck from which samples of the sediment can be taken is unlikely. To obtain representative samples, multiple grab samples that extend from the top of the sediment layer to the bottom of the sump will need to be collected and composited prior to analyses.
- Sediment samples will require screening to remove coarse particles, trash, etc. In the CW4CB study (BASMAA, 2007b), only sediment less than 2 mm in size was analyzed.

It is unclear how samples of the HDS sediment were taken in the Leo Avenue HDS sampling. Appropriate sampling methods should be developed to ensure the samples collected are representative of the sediment in the HDS units.

HDS sediment sampling is not expected to require additional handling/safety precautions beyond normal drain cleaning safety procedures. Human health criteria for PCBs are for exposure via ingestion or vapor intake and not for contact. OSHA directive STD 01-04-002 state that “repeated skin contact hazards with all PCB's could be addressed by the standards 1910.132 and 1910.133”. Both 1910.132 and 1910.133 OSHA standards require use of personal protective equipment, including eye and face protection.

9.2 Enhanced Bioretention Media Testing

The following SAP recommendations are based on past experience and specific guidance provided in DEMEAU (2014):

- The enhanced BSM testing will use real stormwater for the column experiments to account for the effect of influent water quality on load removal. A stormwater collection site will need to be identified in a watershed with typical PCB concentrations to ensure PCB concentrations are representative of those expected in Bay Area urban watersheds. Also, guidance will need to be developed on mobilization to ensure storms are targeted randomly.

- Stormwater properties are known to change significantly with time due to natural flocculation and settling of particles. Appropriate procedures should be developed to ensure collected stormwater is well mixed at all times, and experiments are performed in a timely manner to insure the stormwater used is representative.
- PCBs can readily attach to test equipment, including the inside of tubing that may be used for pumps and the inside of PVC columns. Alternatives should be considered that eliminate the need for pumping equipment and reduce attachment within columns (e.g., by use of glass columns).
- The results of column experiments can be affected by channeling and wall effects. Use a column diameter to particle diameter ratio greater than about 40 to minimize these.
- How media is packed in columns will affect infiltration rates and treatment performance. Therefore, detailed procedures should be developed for the packing of media in columns to ensure consistency between columns and between experiments.

9.3 Data Quality Objectives

Data quality objectives (DQOs) should follow standard stormwater monitoring protocols and be described in detail in individual SAPs. Both sampling and laboratory data quality objectives should be included. For sampling, the SAP should specify sediment and water collection procedures and equipment as well as sample volume and handling requirements. For laboratories, numeric DQOs are appropriate for sample blanks, duplicates (or field splits), and matrix spike recovery.

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APPENDIX B: SAMPLING AND ANALYSIS PLAN AND QUALITY ASSURANCE PROJECT PLAN

BASMAA
Regional Monitoring Coalition

Pollutants of Concern Monitoring for Source Identification and Management Action Effectiveness, 2017-2018

Sampling and Analysis Plan and Quality Assurance Project Plan

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Prepared for:

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Version 2
September 29, 2017

Title and Approval Sheet

Program Title	Pollutants of Concern (POC) Monitoring for Source Identification and Management Action Effectiveness
Lead Organization	Bay Area Stormwater Management Agencies Association (BASMAA) P.O. Box 2385, Menlo Park, CA 94026, 510-622-2326 info@basmaa.org
Primary Contact	Geoff Brosseau
Effective Date	September 29, 2017
Revision Number	Version 2

Approval Signatures:

A signature from the BASMAA Executive Director approving the BASMAA POC Monitoring for Source Identification and Management Action Effectiveness is considered approval on behalf of all Program Managers.

Geoff Brosseau

Date

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List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
ALS	ALS Environmental Laboratory
BASMAA	Bay Area Stormwater Management Agencies Association
BSM	Bioretention Soil Media
CCCWP	Contra Costa Clean Water Program
CCV	continuing calibration verification
CEDEN	California Environmental Data Exchange Network
CEH	Center for Environmental Health
COC	Chain of Custody
Consultant-PM	Consultant Team Project Manager
CRM	Certified Reference Material
CSE	Confined Space Entry
ECD	Electron capture detection
EDD	Electronic Data Deliverable
EOA	Eisenberg, Olivieri & Associates, Inc.
EPA	Environmental Protection Agency (U.S.)
FD	Field duplicate
Field PM	Field Contractor Project Manager
FSURMP	Fairfield-Suisun Urban Runoff Management Program
GC-MS	Gas Chromatography-Mass Spectroscopy
IDL	Instrument Detection Limits
ICV	initial calibration verification
KLI	Kinnetic Laboratories Inc.
LCS	Laboratory Control Samples
Lab-PM	Laboratory Project Manager
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MDL	Method Detection Limit
MQO	Measurement Quality Objective
MRL	Method Reporting Limit
MRP	Municipal Regional Permit
NPDES	National Pollutant Discharge Elimination System
OWP-CSUS	Office of Water Programs at California State University Sacramento
PCB	Polychlorinated Biphenyl
PM	Project Manager
PMT	Project Management Team
POC	Pollutants of Concern
QA	Quality Assurance
QA Officer	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	Quality Control
ROW	Right-of-way
RPD	Relative Percent Difference
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program for Water Quality in the San Francisco Estuary
SFRWQCB	San Francisco Regional Water Quality Control Board (Regional Water Board)
SAP	Sampling and Analysis Plan
SCCVURPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SCVWD	Santa Clara Valley Water Department
SFEI	San Francisco Estuary Institute

SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Procedure
SWAMP	California Surface Water Ambient Monitoring Program
TOC	Total Organic Carbon
TMDL	Total Maximum Daily Load
VSFCD	Vallejo Sanitation and Flood Control District

1. Problem Definition/Background

The Bay Area Stormwater Management Agencies Association (BASMAA) member agencies will implement a regional monitoring program for Pollutants of Concern (POC) Monitoring for Source Identification and Management Action Effectiveness (Monitoring Program). The Monitoring Program is intended to fulfill components of the Municipal Regional Stormwater NPDES Permit (MRP; Order No. R2-2015-0049), which implements the polychlorinated biphenyls (PCBs) and Mercury Total Maximum Daily Loads (TMDLs) for the San Francisco Bay Area. Monitoring for Source Identification and Management Action Effectiveness are two of five monitoring priorities for POCs identified in the MRP. Source identification monitoring is conducted to identify the sources or watershed source areas that provide the greatest opportunities for reductions of POCs in urban stormwater runoff. Management action effectiveness monitoring is conducted to provide support for planning future management actions or to evaluate the effectiveness or impacts of existing management actions.

BASMAA developed two study designs to implement each component of the Monitoring Program. The ***Evaluation of PCBs Presence in Public Roadway and Storm Drain Infrastructure Caulk and Sealants Study Design*** (BASMAA 2017a) addresses the source identification monitoring requirements of Provision C.8.f, as well as requirements of Provision C.12.e to investigate PCBs in infrastructure caulk and sealants. The ***POC Monitoring for Management Action Effectiveness Study Design*** (BASMAA 2017b) addresses the management action effectiveness monitoring requirements of Provision C.8.f. The results of the Monitoring Program will contribute to ongoing efforts by MRP Permittees to identify PCB sources and improve the PCBs and mercury treatment effectiveness of stormwater control measures in the Phase I permittee area of the Bay Area. This Sampling and Analysis Plan and Quality Assurance Project Plan (SAP/QAPP) was developed to guide implementation of both components of the Monitoring Program.

1.1. Problem Statement

Fish tissue monitoring in San Francisco Bay (Bay) has revealed bioaccumulation of PCBs and mercury. The measured fish tissue concentrations are thought to pose a health risk to people consuming fish caught in the Bay. As a result of these findings, California has issued an interim advisory on the consumption of fish from the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act "Section 303(d) list" due to PCBs and mercury. In response, the California Regional Water Quality Control Board, San Francisco Bay Region (Regional Water Board) has developed TMDL water quality restoration programs targeting PCBs and mercury in the Bay. The general goals of the TMDLs are to identify sources of PCBs and mercury to the Bay and implement actions to control the sources and restore water quality.

Since the TMDLs were adopted, Permittees have conducted a number of projects to provide information that supports implementation of management actions designed to achieve the wasteload allocations described in the Mercury and PCBs TMDL, as required by Provisions of the MRP. The Clean Watersheds for a Clean Bay project (CW4CB) was a collaboration among BASMAA member agencies that pilot tested various stormwater control measures and provided estimates of the PCBs and mercury load reduction effectiveness of these controls (BASMAA, 2017c). However, the results of the CW4CB project identified a number of remaining data gaps on the load reduction effectiveness of the control measures that were tested. In addition, MRP Provisions C.8.f. and C.12.e require Permittees to conduct further source identification and management action effectiveness monitoring during the current permit term.

1.2. Outcomes

The Monitoring Program will allow Permittees to satisfy MRP monitoring requirements for source identification and management action effectiveness, while also addressing some of the data gaps identified by the CW4CB project (BASMAA, 2017c). Specifically, the Monitoring Program is intended to provide the following outcomes:

1. Satisfy MRP Provision C.8.f. requirements for POC monitoring for source identification; and Satisfy MRP Provision C.12.e.ii requirements to evaluate PCBs presence in caulks/sealants used in storm drain or roadway infrastructure in public ROWs;
    a. Report the range of PCB concentrations observed in 20 composite samples of caulk/sealant collected from structures installed or rehabilitated during the 1970's;
2. Satisfy MRP Provision C.8.f. requirements for POC monitoring for management action effectiveness;
    a. Quantify the annual mass of mercury and PCBs captured in HDS Unit sumps during maintenance; and
    b. Identify bioretention soil media (BSM) mixtures for future field testing that provide the most effective mercury and PCBs treatment in laboratory column tests.

The information generated from the Monitoring Program will be used by MRP Permittees and the Regional Water Board to better understand potential PCB sources and better estimate the load reduction effectiveness of current and future stormwater control measures.

2. Distribution List and Contact Information

The distribution list for this BASMAA SAP/QAPP is provided in Table 2-1.

Table 2-1. BASMAA SAP/QAPP Distribution List.

Project Group	Title	Name and Affiliation	Telephone No.
BASMAA Project Management Team	BASMAA Project Manager, Stormwater Program Specialist	Reid Bogert, SMCWPPP	650-599-1433
	Program Manager	Jim Scanlin, ACCWP	510-670-6548
	Watershed Management Planning Specialist	Lucile Paquette, CCCWP	925-313-2373
	Program Manager	Rachel Kraai, CCCWP	925-313-2042
	Technical Consultant to ACCWP and CCCWP	Lisa Austin, Geosyntec Inc. CCCWP	510-285-2757
	Supervising Environmental Services Specialist	James Downing, City of San Jose	408-535-3500
	Senior Environmental Engineer	Kevin Cullen, FSURMP	707-428-9129
	Pollution Control Supervisor	Doug Scott, VSFCD	707-644-8949 x269
Consultant Team	Project Manager	Bonnie de Berry, EOA Inc.	510-832-2852 x123
	Assistant Project Manager SAP/QAPP Author and Report Preparer	Lisa Sabin, EOA Inc.	510-832-2852 x108
	Technical Advisor	Chris Sommers, EOA Inc.	510-832-2852 x109
	Study Design Lead and Report Preparer	Brian Currier, OWP-CSUS	916-278-8109
	Study Design Lead and Report Preparer	Dipen Patel, OWP-CSUS	
	Technical Advisor	Lester McKee, SFEI	415-847-5095
	Quality Assurance Officer	Don Yee, SFEI	510-746-7369
	Data Manager	Amy Franz, SFEI	510-746-7394
	Field Contractor Project Manager	Jonathan Toal, KLI	831-457-3950
Project Laboratories	Laboratory Project Manager	Howard Borse, ALS	360-430-7733
	XRF Laboratory Project Manager	Matt Nevins, CEH	510-655-3900 x318

3. Program Organization

3.1. Involved Parties and Roles

BASMAA is a 501(c)(3) non-profit organization that coordinates and facilitates regional activities of municipal stormwater programs in the San Francisco Bay Area. BASMAA programs support implementation of the MRP (Order No. R2-2015-0049), which implements the PCBs and Mercury TMDLs for the San Francisco Bay Area. BASMAA is comprised of all 76 identified MRP municipalities and special districts, the Alameda Countywide Clean Water Program (ACCWP), Contra Costa Clean

Water Program (CCCWP), the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), the Fairfield-Suisun Urban Runoff Management Program (FSURMP), the City of Vallejo and the Vallejo Sanitation and Flood Control District (VSFCD) (Table 3-1).

MRP Permittees have agreed to collectively implement this Monitoring Program via BASMAA. The Program will be facilitated through the BASMAA Monitoring and Pollutants of Concern Committee (MPC). BASMAA selected a consultant team to develop and implement the Monitoring Program with oversight and guidance from a BASMAA Project Management Team (PMT), consisting of representatives from BASMAA stormwater programs and municipalities (Table 3-1).

Table 3-1. San Francisco Bay Area Stormwater Programs and Associated MRP Permittees Participating in the BASMAA Monitoring Program.

Stormwater Programs	MRP Permittees
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 District
Contra Costa Clean Water Program (CCCWP)	Cities of, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, , 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 County Wide Water Pollution Prevention Program (SMCWPPP)	Cities of Belmont, Brisbane, Burlingame, Daly City, East Palo Alto, Foster City, Half Moon Bay, Menlo Park, Millbrae, Pacifica, Redwood City, San Bruno, San Carlos, San Mateo, South San Francisco, Atherton, Colma, Hillsborough, Portola Valley, and Woodside; San Mateo County Flood Control District; and, San Mateo County
Fairfield-Suisun Urban Runoff Management Program (FSURMP)	Cities of Fairfield and Suisun City
Vallejo Permittees (VSFCD)	City of Vallejo and Vallejo Sanitation and Flood Control District

3.2. BASMAA Project Manager (BASMAA-PM)

The BASMAA Project Manager (BASMAA-PM) will be responsible for directing the activities of the below-described PMT, and will provide oversight and managerial level activities, including reporting status updates to the PMT and BASMAA, and acting as the liaison between the PMT and the Consultant Team. The BASMAA PM will oversee preparation, review, and approval of project deliverables, including the required reports to the Regional Water Board.

3.3. BASMAA Project Management Team (PMT)

The BASMAA PMT will assist the BASMAA-PM and the below described Consultant Team with the design and implementation of all project activities. PMT members will assist the BASMAA-PM and Consultant Team to complete project activities within scope, on-time, and within budget by having specific responsibility for planning and oversight of project activities within the jurisdiction of the BASMAA agency that they represent. In addition, the PMT will coordinate with the municipal project partners and key regional agencies, including the Regional Water Board. The PMT is also responsible for reviewing and approving project deliverables (e.g., draft and final project reports).

3.4. Consultant Team Project Manager (Consultant-PM)

The Consultant Team Project Manager (Consultant-PM) will be responsible for ensuring all work performed during the Monitoring Program is consistent with project goals, and provide oversight of all day-to-day operations associated with implementing all components of the Monitoring Program, including scheduling, budgeting, reporting, and oversight of subcontractors. The Consultant-PM will ensure that data generated and reported through implementation of the Monitoring Program meet measurement quality objectives (MQOs) described in this SAP/QAPP. The Consultant -PM will work with the Quality Assurance Officer as required to resolve any uncertainties or discrepancies. The Consultant -PM will also be responsible for overseeing development of draft and final reports for the Monitoring Program, as described in this SAP/QAPP.

3.5. Quality Assurance Officer (QA Officer)

The role of the Quality Assurance Officer (QA Officer) is to provide independent oversight and review of the quality of the data being generated. In this role, the QA Officer has the responsibility to require data that is of insufficient quality to be flagged, or not used, or for work to be redone as necessary so that the data meets specified quality measurements. The QA Officer will oversee the technical conduct of the field related components of the Monitoring Program, including ensuring field program compliance with the SAP/QAPP for tasks overseen at the programmatic level.

3.6. Data Manager (DM)

The Data Manager will be responsible for receipt and review of all project related documentation and reporting associated with both field efforts and laboratory analysis. The Data Manager will also be responsible for storage and safekeeping of these records for the duration of the project.

3.7. Field Contractor Project Manager (Field-PM)

The Field Contractor Project Manager (Field-PM) will be responsible for conduct and oversight of all field monitoring- and reporting-related activities, including completion of field datasheets, chain of custodies, and collection of field measurements and field samples, consistent with the monitoring methods and procedures in the SAP/QAPP. The Field-PM will also be responsible for ensuring that personnel conducting monitoring are qualified to perform their responsibilities and have received appropriate training. The Field-PM will be responsible for initial receipt and review of all project related documentation and reporting associated with both field efforts and laboratory analysis.

The Field-PM will also be responsible for receiving all samples collected opportunistically by participating municipalities, including all caulk/sealant samples, initial review of sample IDs to ensure there are no duplicate sample IDs, and shipping the samples under COC to the appropriate laboratory (CEH for the caulk/sealant samples; ALS for all other samples). Participating municipalities should ship all samples they collect to the Field PM at the following address:

Jon Toal
Kinnetic Laboratories, Inc.
307 Washington Street
Santa Cruz, CA 95060
Reference: BASMAA POC Monitoring Project
(831)457-3950

3.8. Laboratory Project Manager (Lab-PM)

The Laboratory Project Manager (Lab-PM) and chemists at each analytical laboratory will be responsible for ensuring that the laboratory's quality assurance program and standard operating procedures (SOPs) are consistent with this SAP/QAPP, and that laboratory analyses meet all applicable requirements or explain any deviations. Each Lab-PM will also be responsible for coordinating with the Field-PM and other staff (e.g., Consultant -PM, Data Manager, QA Officer) and facilitating communication between the Field-PM, the Consultant -PM, and analytical laboratory personnel, as required for the project.

The Center for Environmental Health (CEH) will provide chlorine content screening of all caulk/sealant samples collected using X-Ray Fluorescence (XRF) technology to assist in selection of samples for further laboratory analysis of PCBs. This XRF-screening will also provide additional information on the utility of XRF in prioritizing samples for chemical PCBs analyses.

All other laboratory analyses will be provided by ALS Environmental.

3.1. Report Preparer

The Report Preparer (RP) will be responsible for developing draft and final reports for each of the following components of the Monitoring Program: (1) Source identification; and (2) Management action effectiveness. All draft reports will be submitted to the PMT for review and input prior to submission for approval by the BASMAA Board of Directors (BOD).

4. Monitoring Program Description

4.1. Work Statement and Program Overview

The Monitoring Program consists of the following three major tasks, each of which has a field sampling component:

- **Task 1. Evaluate presence and possible concentrations of PCBs in roadway and storm drain infrastructure caulk and sealants**. This task involves analysis of 20 composite samples of caulk/sealant collected from public roadway and storm drain infrastructure throughout the permit area to investigate PCB concentrations. The goal of this task is to evaluate, at a limited screening level, whether and in what concentrations PCBs are present in public roadway and storm drain infrastructure caulk and sealants in the portions of the Bay Area under the jurisdiction of the Phase I Permittees identified in Table 3-1 (Bay Area).

- **Task 2. Evaluate Annual mass of PCBs and mercury captured in Hydrodynamic Separator (HDS) Unit sumps during maintenance.** This task involves collecting sediment samples from the sumps of public HDS unit during maintenance cleanouts to evaluate the mass of PCBs and mercury captured by these devices. The goal of this task is to provide data to better characterize the concentrations of POCs in HDS Unit sump sediment and improve estimates of the mass captured and removed from these units during current maintenance practices for appropriate TMDL load reduction crediting purposes.

- **Task 3. Bench-scale testing of the mercury and PCBs removal effectiveness of selected BSM mixtures enhanced with biochar.** This task involves collecting stormwater from the Bay Area that will then be used to conduct laboratory column tests designed to evaluate the mercury and PCBs treatment effectiveness of various biochar-amended BSM mixtures. Real stormwater will be used for the column tests to account for the effect of influent water quality on load removal. The goal of this task is to identify BSM mixtures amended with biochar that meet operational infiltration requirements and are effective for PCBs and mercury removal for future field testing.

All monitoring results and interpretations will be documented in BASMAA reports for submission to the Regional Water Board according to the schedule in the MRP.

4.2. Sampling Detail

The Monitoring Program includes three separate sampling tasks that involve collection and analysis of the following types of samples: caulk/sealants (Task 1); sediment from HDS units (Task 2); and stormwater collected and used for column tests in the lab (Task 3). Additional details specific to the sampling design for each task are provided below.

4.2.1. Task 1 - Caulk/Sealant samples

The PMT will recruit municipal partners from within each stormwater program to participate in this task. All caulk/sealant samples will be collected from locations within public roadway or storm drain infrastructure in the participating municipalities. Exact sample sites will be identified based on available information for each municipal partner, including: age of public infrastructure; records of infrastructure repair or rehabilitation (aiming for the late 1960s through the 1970s); and current municipal staff knowledge about locations that meet the site selection criteria identified in the study design (BASMAA, 2017a). Field crews led by the Field-PM and/or municipal staff will conduct field reconnaissance to further identify specific sampling locations and if feasible, will collect caulk/sealant samples during these initial field visits. Follow-up sampling events will be conducted for any sites that require additional planning or equipment for sample collection (e.g., confined space entry, parking controls, etc.). Sample locations will include any of the following public infrastructure where caulk/sealant are present: roadway or sidewalk surfaces, between expansion joints for roadways, parking garages, bridges, dams, or storm drain pipes, and/or in pavement joints (e.g., curb and gutter). Sampling will only occur during periods of dry weather when urban runoff flows through any structures that will be sampled are minimal, and do not present any safety hazards or other logistical issues during sample collection. Sample collection methods are described further in Section 9.

As opportunities arise, municipal staff will also collect samples following the methods and procedures described in this SAP/QAPP during ongoing capital projects that provide access to public infrastructure locations with caulk/sealant that meet the sample site criteria. All samples collected by participating municipal staff will be delivered to the Field PM under COC. The Field-PM will be responsible for storing all caulk/sealant samples and shipping the samples under COC to CEH for XRF screening analysis.

All caulk/sealant samples collected will be screened for chlorine content using XRF technology described in Section 9. Samples will be grouped for compositing purposes as described in the study design (BASMAA, 2017a). Up to three samples will be included per composite and a total of 20 composite caulk/sealant samples will be analyzed for the RMP 40 PCB congeners[1]. All compositing and PCBs analysis will be conducted blind to the location where each sample was collected. Laboratory analysis methods must be able to detect a minimum PCBs concentration of 200 parts per billion (ppb, or µg/Kg). Laboratory analytical methods are described further in Section 12. The range of PCB concentrations found in caulk based on this documented sampling design will be reported to the Regional Water Board within the Permittees’ 2018 Annual Reports.

4.2.2. Task 2 - Sediment samples from HDS Units

The PMT will recruit municipal partners that maintain public HDS units to participate in this task. All sediment samples will be collected from the sump of selected HDS units during scheduled cleaning and maintenance. Selection of the HDS units for sampling will be opportunistic, based on the units that are scheduled for maintenance by participating municipalities during the project period. Field crews led by the Field-PM and municipal maintenance staff will coordinate sampling with scheduled maintenance events. As needed, municipal staff will dewater the HDS unit sumps prior to sample collection, and provide assistance to field crews with access to the sump sediment as needed (e.g., confined space entry, parking controls, etc.). All sump sediment samples will be collected following the methods and procedures described in this SAP/QAPP. Sampling will only occur during periods of dry weather when urban runoff flows into the HDS unit sumps are minimal, and do not present any safety hazards or other logistical issues during sample collection. Sample collection methods are described further in Section 9.

All sediment samples collected will be analyzed for the RMP 40 PCB congeners, total mercury, total organic carbon (TOC), particle size distribution (PSD), and bulk density. Laboratory analytical methods are described further in Section 12. The range of PCB and mercury concentrations observed in HDS Unit sump sediments and the annual pollutant masses removed during cleanouts will be reported to the Regional Water Board in March 2019.

4.2.3. Task 3 - Storm Water and Column Test Samples

This task will collect stormwater from Bay Area locations that will then be used as the influent for column tests of biochar-amended BSM. Bay Area stormwater samples will be collected from locations

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[1] The 40 individual congeners routinely quantified by the Regional Monitoring Program (RMP) for Water Quality in the San Francisco Estuary include: PCBs 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, l05, 110, 118, 128, 132, 138, 141, 149, l51, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203

within public roadway or storm drain infrastructure in participating municipalities. Field personnel lead by the Field PM will collect stormwater samples during three qualifying storm events and ensure all samples are delivered to the lab of OWP at CSUS within 24-hours of collection. Stormwater will be collected from one watershed that has a range of PCB concentrations and is considered representative of Bay Area watersheds (e.g. the West Oakland Ettie Street Pump Station watershed). Storms from the representative watershed should be targeted randomly without bias, thereby accounting for the effects of storm intensity and ensuring variability in contaminant concentration, proportion of dissolved contaminants, particle size, particle size distribution, and particle density. To achieve this, minimal mobilization criteria should be used to ensure predicted storm intensity and runoff volume are likely to yield the desired volume. Sample collection methods are described further in Section 9.

The stormwater collected will be used as the influent for column tests of various BSM mixtures amended with biochar. These tests will be implemented in three phases. First, hydraulic screening tests will be performed to ensure all amended BSM mixtures meet the MRP infiltration rate requirements of 12 in/h initial maximum infiltration or minimum 5 in/h long-term infiltration rate. Second, column tests will be performed using Bay Area stormwater to evaluate pollutant removal. Third, additional column tests will be performed using lower concentration (e.g., diluted) Bay Area stormwater to evaluate relative pollutant removal performance at lower concentrations. Further details about the column testing are provided in Section 9.3.

All influent and effluent water samples collected will be analyzed for the RMP 40 PCB congeners, total mercury, suspended sediment concentrations (SSC), TOC, and turbidity. Laboratory analytical methods are described further in Section 12. The range of PCB and mercury concentrations observed in influent and effluent water samples and the associated pollutant mass removal efficiencies for each BSM mixture tested will be reported to the Regional Water Board in March 2019.

4.3. Schedule

Caulk/sealant sampling (Task 1) will be conducted between July 2017 and December 2017. HDS Unit sampling (Task 2) will be conducted between July 2017 and May 2018. Stormwater sample collection and BSM column tests (Task 3) will occur between October 2017 – April 2018.

4.4. Geographical Setting

Field operations will be conducted across multiple Phase I cities in the San Francisco Bay region within the counties of San Mateo, Santa Clara, Alameda, and Contra Costa, and the City of Vallejo.

4.5. Constraints

Caulk/sealant sampling and HDS unit sampling will only be conducted during dry weather, when urban runoff flows through the sampled structures are minimal and do not present safety hazards or other logistical concerns. Caulk/sealant sampling will be limited to the caulk/sealant available and accessible at sites that meet the project site criteria (described in the Study Design, BASMAA 2017a). HDS unit sampling will be limited by the number of public HDS units that are available for maintenance during the project period. Extreme wet weather may pose a safety hazard to sampling personnel and may therefore impact wet season sampling.

5. Measurement Quality Objectives (MQO)

The quantitative measurements that estimate the true value or concentration of a physical or chemical property always involve some level of uncertainty. The uncertainty associated with a measurement generally results from one or more of several areas: (1) natural variability of a sample; (2) sample handling conditions and operations; (3) spatial and temporal variation; and (4) variations in collection or analytical procedures. Stringent Quality Assurance (QA) and Quality Control (QC) procedures are essential for obtaining unbiased, precise, and representative measurements and for maintaining the integrity of the sample during collection, handling, and analysis, as well and for measuring elements of variability that cannot be controlled. Stringent procedures also must be applied to data management to assure that accuracy of the data is maintained.

MQOs are established to ensure that data collected are sufficient and of adequate quality for the intended use. MQOs include both quantitative and qualitative assessment of the acceptability of data. The qualitative goals include representativeness and comparability, and the quantitative goals include completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination.

MQOs associated with representativeness, comparability, completeness, sensitivity, precision, accuracy, and contamination are presented below in narrative form.

5.1. Representativeness and Comparability

The representativeness of data is the ability of the sampling locations and the sampling procedures to adequately represent the true condition of the sample sites. The comparability of data is the degree to which the data can be compared directly between all samples collected under this SAP/QAPP. Field personnel, including municipal personnel that collect samples, will strictly adhere to the field sampling protocols identified in this SAP/QAPP to ensure the collection of representative, uncontaminated, comparable samples. The most important aspects of quality control associated with chemistry sample collection are as follows:

- Field personnel will be thoroughly trained in the proper use of sample collection equipment and will be able to distinguish acceptable versus unacceptable samples in accordance with pre-established criteria.
- Field personnel are trained to recognize and avoid potential sources of sample contamination (e.g., dirty hands, insufficient field cleaning).
- Samplers and utensils that come in direct contact with the sample will be made of non-contaminating materials, and will be thoroughly cleaned between sampling stations.
- Sample containers will be pre-cleaned and of the recommended type.
- All sampling sites will be selected according to the criteria identified in the project study design (BASMAA, 2017a)

Further, the methods for collecting and analyzing PCBs in infrastructure caulk and sealants will be comparable to other studies of PCBs in building material and infrastructure caulk (e.g., Klosterhaus et al., 2014). This SAP/QAPP was also developed to be comparable with the California Surface Water Ambient Monitoring Program (SWAMP) Quality Assurance Program Plan (QAPrP, SWAMP 2013). All sediment and water quality data collected during the Monitoring Program will be performed in a manner so that data are SWAMP comparable [2].

5.2. Completeness

Completeness is defined as the percentage of valid data collected and analyzed compared to the total expected to being obtained under normal operating conditions. Overall completeness accounts for both sampling (in the field) and analysis (in the laboratory). Valid samples include those for analytes in which the concentration is determined to be below detection limits.

Under ideal circumstances, the objective is to collect 100 percent of all field samples desired, with successful laboratory analyses on 100% of measurements (including QC samples). However, circumstances surrounding sample collections and subsequent laboratory analysis are influenced by numerous factors, including availability of infrastructure meeting the required sampling criteria (applies to both infrastructure caulk sampling and HDS Unit sampling), flow conditions, weather, shipping damage or delays, sampling crew or lab analyst error, and QC samples failing MQOs. An overall completeness of greater than 90% is considered acceptable for the Monitoring Program.

5.3. Sensitivity

Different indicators of the sensitivity of an analytical method to measure a target parameter are often used including instrument detection limits (IDLs), method detection limits (MDLs), and method reporting limits (MRLs). For the Monitoring Program, MRL is the measurement of primary interest, consistent with SWAMP Quality Assurance Project Plan (SWAMP 2013). Target MRLs for all analytes by analytical method provided in Section 13.

5.4. Precision

Precision is used to measure the degree of mutual agreement among individual measurements of the same property under prescribed similar conditions. Overall precision usually refers to the degree of agreement for the entire sampling, operational, and analysis system. It is derived from reanalysis of individual samples (laboratory replicates) or multiple collocated samples (field replicates) analyzed on equivalent instruments and expressed as the relative percent difference (RPD) or relative standard deviation (RSD). Analytical precision can be determined from duplicate analyses of field samples, laboratory matrix spikes/matrix spike duplicates (MS/MSD), laboratory control samples (LCS) and/or reference material samples. Analytical precision is expressed as the RPD for duplicate measurements:

$$\text{RPD} = \text{ABS}\,([X1 - X2] / [(X1 + X2) / 2])$$

Where: X1 = the first sample result
X2 = the duplicate sample result.

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[2] SWAMP data templates and documentation are available online at http://waterboards.ca.gov/water_issues/programs/swamp/data_management_resources/templates_docs.shtml

Precision will be assessed during the Monitoring Program by calculating the RPD of laboratory replicate samples and/or MS/MSD samples, which will be run at a frequency of 1 per analytical batch for each analyte. Target RPDs for the Monitoring Program are identified in Section 13.

5.5. Accuracy

Accuracy describes the degree of agreement between a measurement (or the average of measurements of the same quantity) and its true environmental value, or an acceptable reference value. The “true” values of the POCs in the Monitoring Program are unknown and therefore “absolute” accuracy (and representativeness) cannot be assessed. However, the analytical accuracy can be assessed through the use of laboratory MS samples, and/or LCS. For MS samples, recovery is calculated from the original sample result, the expected value (EV = native + spike concentration), and the measured value with the spike (MV):

$$\% \text{ Recovery} = (MV-N) \times 100\% / (EV-N)$$

Where: MV = the measured value
EV = the true expected (reference) value
N = the native, unspiked result

For LCS, recovery is calculated from the concentration of the analyte recovered and the true value of the amount spiked:

$$\% \text{ Recovery} = (X/TV) \times 100\%$$

Where: X = concentration of the analyte recovered
TV = concentration of the true value of the amount spiked

Surrogate standards are also spiked into samples for some analytical methods (i.e., PCBs) and used to evaluate method and instrument performance. Although recoveries on surrogates are to be reported, control limits for surrogates are method and laboratory specific, and no project specific recovery targets for surrogates are specified, so long as overall recovery targets for accuracy (with matrix spikes) are achieved. Where surrogate recoveries are applicable, data will not be reported as surrogate-corrected values.

Analytical accuracy will be assessed during the Monitoring Program based on recovery of the compound of interest in matrix spike and matrix spike duplicates compared with the laboratory’s expected value, at a frequency of 1 per analytical batch for each analyte. Recovery targets for the Monitoring Program are identified in Section 13.

5.6. Contamination

Collected samples may inadvertently be contaminated with target analytes at many points in the sampling and analytical process, from the materials shipped for field sampling, to the air supply in the analytical laboratory. When appropriate, blank samples evaluated at multiple points in the process chain help assure that compound of interest measured in samples actually originated from the target matrix in the sampled environment and are not artifacts of the collection or analytical process.

Method blanks (also called laboratory reagent blanks, extraction blanks, procedural blanks, or preparation blanks) are used by laboratory personnel to assess laboratory contamination during all stages of sample preparation and analysis. The method blank is processed through the entire analytical procedure in a manner identical to the samples. A method blank concentration should be less than the RL or should not exceed a concentration of 10% of the lowest reported sample concentration. A method blank concentration greater than 10% of the lowest reported sample concentration will require corrective action to identify and eliminate the source(s) of contamination before proceeding with sample analysis. If eliminating the blank contamination is not possible, all impacted analytes in the analytical batch shall be flagged. In addition, a detailed description of the likely contamination source(s) and the steps taken to eliminate/minimize the contaminants shall be included in narrative of the data report. If supporting data is presented demonstrating sufficient precision in blank measurement that the 99% confidence interval around the average blank value is less than the MDL or 10% of the lowest measured sample concentration, then the average blank value may be subtracted.

A field blank is collected to assess potential sample contamination levels that occur during field sampling activities. Field blanks are taken to the field, transferred to the appropriate container, preserved (if required by the method), and treated the same as the corresponding sample type during the course of a sampling event. The inclusion of field blanks is dependent on the requirements specified in the relevant MQO tables or in the sampling method.

6. Special Training Needs / Certification

All fieldwork will be performed by contractor staff that has appropriate levels of experience and expertise to conduct the work, and/or by municipal staff that have received the appropriate instruction on sample collection, as determined by the Field PM and/or the PMT. The Field-PM will ensure that all members of the field crew (including participating municipal staff) have received appropriate instructions based on methods described in this document (Section 9) for collecting and transporting samples. As appropriate, sampling personnel may be required to undergo or have undergone OSHA training / certification for confined space entry in order to undertake particular aspects of sampling within areas deemed as such.

Analytical laboratories are to be certified for the analyses conducted at each laboratory by ELAP, NELAP, or an equivalent accreditation program as approved by the PMT. All laboratory personal will follow methods described in Section 13 for analyzing samples.

7. Program Documentation and Reporting

The Consultant Team in consultation with the PMT will prepare draft and final reports of all monitoring data, including statistical analysis and interpretation of the data, as appropriate, which will be submitted to the BASMAA BOD for approval. Following approval by the BASMAA BOD, Final project reports will be available for submission with each stormwater program's Annual Report in 2018 (Task 1) or in the March 31, 2019 report to the Regional Water Board (Tasks 2 and 3). Procedures for overall management of project documents and records and report preparation are summarized below.

7.1. Field Documentation

All field data gathered for the project are to be recorded in field datasheets, and scanned or transcribed to electronic documents as needed to permit easy access by the PMT, the consultant team, and other appropriate parties.

7.1.1. Sampling Plans, COCs, and Sampling Reports

The Field-PM will be responsible for development and submission of field sampling reports to the Data Manager and Consultant-PM. Field crews will collect records for sample collection, and will be responsible for maintaining these records in an accessible manner. Samples sent to analytical laboratories will include standard Chain of Custody (COC) procedures and forms; field crews will maintain a copy of originating COCs at their individual headquarters. Analytical laboratories will collect records for sample receipt and storage, analyses, and reporting. All records, except lab records, generated by the Monitoring Program will be stored at the office of the Data Manager for the duration of the project, and provided to BASMAA at the end of the project.

7.1.2. Data Sheets

All field data gathered by the Monitoring Program will be recorded on standardized field data entry forms. The field data sheets that will be used for each sampling task are provided in Appendix A.

7.1.3. Photographic Documentation

Photographic documentation is an important part of sampling procedures. An associated photo log will be maintained documenting sites and subjects associated with photos. If an option, the date function on the camera shall be turned on. Field Personnel will be instructed to take care to avoid any land marks when taking photographs, such as street signs, names of buildings, road mile markers, etc. that could be used later to identify a specific location. A copy of all photographs should be provided at the conclusion of sampling efforts and maintained for project duration.

7.2. Laboratory Documentation

The Monitoring Program requires specific actions to be taken by contract laboratories, including requirements for data deliverables, quality control, and on-site archival of project-specific information. Each of these aspects is described below.

7.2.1. Data Reporting Format

Each laboratory will deliver data in electronic formats to the Field-PM, who will transfer the records to the Data Manager, who is responsible for storage and safekeeping of these records for the duration of the project. In addition, each laboratory will deliver narrative information to the QA Officer for use in data QA and for long-term storage.

The analytical laboratory will report the analytical data to the Field-PM via an analytical report consisting of, at a minimum:

1. Letter of transmittal
2. Chain of custody information
3. Analytical results for field and quality control samples (Electronic Data Deliverable, EDD)
4. Case narrative

5. Copies of all raw data.

The Field-PM will review the data deliverables provided by the laboratory for completeness and errors. The QA Officer will review the data deliverables provided by the laboratory for review of QA/QC. In addition to the laboratory's standard reporting format, all results meeting MQOs and results having satisfactory explanations for deviations from objectives shall be reported in tabular format on electronic media. SWAMP-formatted electronic data deliverable (EDD) templates are to be agreed upon by the Data Manager, QA Officer, and the Lab-PM prior to onset of any sampling activities related to that laboratory.

Documentation for analytical data is kept on file at the laboratories, or may be submitted with analytical results. These may be reviewed during external audits of the Monitoring Program, as needed. These records include the analyst's comments on the condition of the sample and progress of the analysis, raw data, and QC checks. Paper or electronic copies of all analytical data, field data forms and field notebooks, raw and condensed data for analysis performed on-site, and field instrument calibration notebooks are kept as part of the Monitoring Program archives for a minimum period of eight years.

7.2.2. Other Laboratory QA/QC Documentation

All laboratories will have the latest version of this Monitoring Program SAP/QAPP in electronic format. In addition, the following documents and information from the laboratories will be current, and they will be available to all laboratory personnel participating in the processing of samples:

1. Laboratory QA plan: Clearly defines policies and protocols specific to a particular laboratory, including personnel responsibilities, laboratory acceptance criteria, and corrective actions to be applied to the affected analytical batches, qualification of data, and procedures for determining the acceptability of results.

2. Laboratory Standard Operation Procedures (SOPs): Contain instructions for performing routine laboratory procedures, describing exactly how a method is implemented in the laboratory for a particular analytical procedure. Where published standard methods allow alternatives at various steps in the process, those approaches chosen by the laboratory in their implementation (either in general or in specific analytical batches) are to be noted in the data report, and any deviations from the standard method are to be noted and described.

3. Instrument performance information: Contains information on instrument baseline noise, calibration standard response, analytical precision and bias data, detection limits, scheduled maintenance, etc.

4. Control charts: Control charts are developed and maintained throughout the Program for all appropriate analyses and measurements for purposes of determining sources of an analytical problem or in monitoring an unstable process subject to drift. Control charts serve as internal evaluations of laboratory procedures and methodology and are helpful in identifying and correcting systematic error sources. Control limits for the laboratory quality control samples are ±3 standard deviations from the certified or theoretical concentration for any given analyte.

Records of all quality control data, maintained in a bound notebook at each workstation, are signed and dated by the analyst. Quality control data include documentation of standard calibrations, instrument maintenance and tests. Control charts of the data are generated by the analysts monthly or for analyses done infrequently, with each analysis batch. The laboratory quality assurance specialist will review all QA/QC records with each data submission, and will provide QA/QC reports to the Field-PM with each batch of submitted field sample data.

7.3. Program Management Documentation

The BASMAA-PM and Consultant-PM are responsible for managing key parts of the Monitoring Program's information management systems. These efforts are described below.

7.3.1. SAP/QAPP

All original SAP/QAPPs will be held by the Consultant-PM. This SAP/QAPP and its revisions will be distributed to all parties involved with the Monitoring Program. Copies will also be sent to the each participating analytical laboratory's contact for internal distribution, preferably via electronic distribution from a secure location.

Associated with each update to the SAP/QAPP, the Consultant-PM will notify the BASMAA-PM and the PMT of the updated SAP/QAPP, with a cover memo compiling changes made. After appropriate distributions are made to affected parties, these approved updates will be filed and maintained by the SAP/QAPP Preparers for the Monitoring Program. Upon revision, the replaced SAP/QAPPs will be discarded/deleted.

7.3.2. Program Information Archival

The Data Manager and Consultant-PM will oversee the actions of all personnel with records retention responsibilities, and will arbitrate any issues relative to records retention and any decisions to discard records. Each analytical laboratory will archive all analytical records generated for this Program. The Consultant-PM will be responsible for archiving all management-level records.

Persons responsible for maintaining records for this Program are shown in Table 7-1.

Table 7-1. Document and Record Retention, Archival, and Disposition

Type	Retention (years)	Archival	Disposition
Field Datasheets	8	Data Manager	Maintain indefinitely
Chain of Custody Forms	8	Data Manager	Maintain indefinitely
Raw Analytical Data	8	Laboratory	Recycling
Lab QC Records	8	Laboratory	Recycling
Electronic data deliverables	8	Data Manager	Maintain indefinitely
Reports	8	Consultant-PM	Maintain indefinitely

As discussed previously, the analytical laboratory will archive all analytical records generated for this Program. The Consultant-PM will be responsible for archiving all other records associated with implementation of the Monitoring Program.

All field operation records will be entered into electronic formats and maintained in a dedicated directory managed by the BASMAA-PM.

7.4. Reporting

The Consultant team will prepare draft and final reports for each component of the Monitoring Program. The PMT will provide review and input on draft reports and submit to the BASMAA BOD for approval. Once approved by the BASMAA BOD, the Monitoring Program reports will be available to each individual stormwater program for submission to the Regional Water Board according to the schedule outlined in the MRP and summarized in Table 7.2.

Table 7-2. Monitoring Program Final Reporting Due Dates.

Monitoring Program Component	Task	MRP Reporting Due Date
Source Identification	Task 1 - Evaluation of PCB concentrations in roadway and storm drain infrastructure caulk and sealants	September 30, 2018
Management Action Effectiveness	Task 2 - Evaluation of the annual mass of PCBs and mercury captured in HDS Unit sump sediment	March 31, 2019
	Task 3 - Bench-scale testing of the mercury and PCBs removal effectiveness of selected BSM mixtures.	

8. Sampling Process Design

All information generated through conduct of the Monitoring Program will be used to inform TMDL implementation efforts for mercury and PCBs in the San Francisco Bay region. The Monitoring Program will implement the following tasks: (1) evaluate the presence and concentrations of PCB in caulk and sealants from public roadway and stormdrain infrastructure; (2) evaluate mass of PCBs and mercury removed during HDS Unit maintenance; and (3) evaluate the mercury and PCBs treatment effectiveness of various BSM mixtures in laboratory column tests using stormwater collected from Bay Area locations. Sample locations and the timing of sample collection will be selected using the directed sampling design principle. This is a deterministic approach in which points are selected deliberately based on knowledge of their attributes of interest as related to the environmental site being monitored. This principle is also known as "judgmental," "authoritative," "targeted," or "knowledge-based." Individual monitoring aspects are summarized further under Field Methods (Section 9) and in the task-specific study designs (BASMAA 2017a,b).

8.1. Caulk/Sealant Sampling

Caulk/sealant sampling will support the Monitoring Program's Task 1 to evaluate PCBs in roadway and stormdrain infrastructure caulk/sealant, as described previously (see Section 4). Further detail on caulk/sealant sampling methods and procedures are provided under Field Methods (Section 9).

8.2. Sediment Quality Sampling

Sediment sampling will support the Monitoring Program's Task 2 to evaluate the mass of mercury and PCBs removed during HDS unit maintenance, as described previously (see Section 4). Further detail on sediment sampling methods and procedures are provided under Field Methods (Section 9).

8.3. Water Quality Sampling

Water sampling will support the Monitoring Program's Task 3 to evaluate the mercury and PCBs treatment effectiveness of various BSM mixtures, as described previously (see Section 4). Further detail on water sampling methods and procedures are provided under Field Methods (Section 9).

8.4. Sampling Uncertainty

There are multiple sources of potential sampling uncertainty associated with the Monitoring Program, including: (1) measurement error; (2) natural (inherent) variability; (3) undersampling (or poor representativeness); and (4) sampling bias (statistical meaning). Measures incorporated to address these areas of uncertainty are discussed below:

(1) Measurement error combines all sources of error related to the entire sampling and analysis process (i.e., to the measurement system). All aspects of dealing with uncertainty due to measurement error have been described elsewhere within this document.

(2) Natural (inherent) variability occurs in any environment monitored, and is often much wider than the measurement error. Prior work conducted by others in the field of stormwater management have demonstrated the high degree of variability in environmental media, which will be taken into consideration when interpreting results of the various lines of inquiry.

(3) Under- or unrepresentative sampling happens at the level of an individual sample or field measurement where an individual sample collected is a poor representative for overall conditions encountered given typical sources of variation. To address this situation, the Monitoring Program will be implementing a number of QA-related measures described elsewhere within this document, including methods refined through implementation of prior, related investigations.

(4) Sampling bias relates to the sampling design employed and whether the appropriate statistical design is employed to allow for appropriate understanding of environmental conditions. To a large degree, the sampling design required by the Monitoring Program is judgmental, which will therefore incorporate an unknown degree of sampling bias into the Project. There are small measures that have been built into the sampling design to combat this effect (e.g., homogenization of sediments for chemistry analyses), but overall this bias is a desired outcome designed to meet the goals of this Monitoring Program, and will be taken into consideration when interpreting results of the various investigations.

Further detail on measures implemented to reduce uncertainty through mobilization, sampling, sample handling, analysis, and reporting phases are provided throughout this document.

9. Sampling Methods

The Monitoring Program involves the collection of three types of samples: Caulk/sealants; sediment from HDS unit sumps; and water quality samples. Field collection will be conducted by field contractors or municipal staff using a variety of sampling protocols, depending on the media and parameter monitored. These methods are presented below. In addition, the Monitoring Program will utilize several field sampling SOPs previously developed by the BASMAA Regional Monitoring Coalition identified in Table 9-3 (RMC, BASMAA, 2016).

9.1. Caulk/Sealant Sampling (Task 1)

Procedures for collecting caulk and sealant samples are not well established. Minimal details on caulk or sealant sample collection methodologies are available in peer-reviewed publications. The caulk/sealant sampling procedures described here were adapted from a previous study examining PCBs in building materials conducted in the Bay Area (Klosterhaus et al., 2014). The methods described by Klosterhaus et al. (2014) were developed through consultation with many of the previous authors of caulk literature references therein, in addition to field experience gained during the Bay Area study. It is anticipated that lessons will also be learned during the current study.

9.1.1. Sample Site Selection

Once a structure has been identified as meeting the selection criteria and permission is granted to perform the testing or collection of sealant samples, an on-site survey of the structure will be used to identify sealant types and locations on the structure to be sampled. It is expected that sealants from a number of different locations on each structure may sampled; however, inconspicuous locations on the structure will be targeted.

9.1.2. Initial Equipment Cleaning

The sampling equipment that is pre-cleaned includes:

- Glass sample jars
- Utility knife, extra blades
- Stainless-steel forceps

Prior to sampling, all equipment will be thoroughly cleaned. Glass sample containers will be factory pre-cleaned (Quality Certified™, ESS Vial, Oakland, CA) and delivered to field team at least one week prior to the start of sample collection. Sample containers will be pre-labeled and kept in their original boxes, which will be transported in coolers. Utility knife blades, forceps, stainless steel spoons, and chisels will be pre-cleaned with Alconox, Liquinox, or similar detergent, and then rinsed with deionized water and methanol. The cleaned equipment will then be wrapped in methanol-rinsed aluminum foil and stored in clean Ziploc bags until used in the field.

9.1.3. Field Cleaning Protocol

Between each use the tool used (utility knife blade, spoon or chisel) and forceps will be rinsed with methanol and then deionized water, and inspected to ensure all visible sign of the previous sample have been removed. The clean tools, extra blades, and forceps will be kept in methanol-rinsed aluminum foil and stored in clean Ziploc bags when not in use.

9.1.4. Blind Sampling Procedures

The intention of this sampling is to better determine whether sealants in road and storm drain infrastructure contain PCBs at concentrations of concern, and to understand the relative importance of PCBs in this infrastructure among the other known sources of PCBs that can affect San Francisco Bay. At this phase of the project, we are not seeking to identify specific facilities requiring mitigation (if PCBs are identified, this could be a future phase). Therefore, in this initial round of sampling, we are not identifying sample locations, but instead implementing a blind sampling protocol, as follows:

- All samples will be collected without retaining any information that would identify structure locations. The information provided to the contractor on sampling locations will not be retained. Structure location information will not be recorded on any data sheets or in any data spreadsheets or other electronic computer files created for the Project. Physical sealant samples collected will be identified only by a sample identification (ID) designation (Section 4). Physical sealant sample labels will contain only the sample ID (see Section 4 and example label in Appendix A). Samples will be identified only by their sample ID on the COC forms.
- As an added precaution and if resources allow, oversampling will occur such that more samples will be collected than will be sent to the laboratory for compositing and analysis. In this case, the Project team would select a subset of samples for PCB analysis based on factors such as application type and/or chlorine content, but blind to the specific location where each sample was collected.
- Up to three individual sealant samples will be composited by the laboratory prior to analysis for PCBs, following instructions from the Consultant PM. This further ensures a blind sampling approach because samples collected at different locations will be analyzed together.

9.1.5.Caulk/Sealant Collection Procedures

At each sample location, the Field-PM, and/or municipal staff, will make a final selection of the most accessible sampling points at the time of sampling. From each point sampled, a one inch strip (aiming for about 10 g of material) of caulk or sealant will be removed from the structure using one of the following solvent-rinsed tools: a utility knife with a stainless-steel blade, stainless steel spoon to scrape off the material, or a stainless steel chisel. The Field-PM or municipal staff at the site will select the appropriate tool based on the conditions of the caulk/sealant at each sample point. Field personnel will wear nitrile gloves during sample collection to reduce potential sample contamination. The sample will then be placed in a labeled, factory-cleaned glass jar. For each caulk sample collected, field personnel will fill out a field data sheet at the time of sample collection, which includes the following information:

- Date and time of sample collection,
- sample identification designation,
- qualitative descriptions of relevant structure or caulk/sealant features, including use profile, color and consistency of material collected, surface coating (paint, oily film, masonry residues etc.)
- crack dimensions, the length and/or width of the caulk bead sampled, spacing of expansion joints in a particular type of application, and
- a description of any unusual occurrences associated with the sampling event (especially those that could affect sample or data quality).

Appendix A contains an example field data sheet. All samples will be kept in a chilled cooler in the field (i.e., at 4 ºC ± 2 ºC), and kept refrigerated pending delivery under COC to the Field PM at KLI. Further, the field data sheets will remain with the samples when they are shipped to KLI, and will then be maintained by the Field PM at KLI.

As needed, the procedure for replacement of the caulk/sealant will be coordinated with the appropriate municipal staff to help ensure that the sampling does not result in damage to the structure.

9.1.6. Sample ID Designation

Every sample must have a unique sample ID to ensure analytical results from each sample can be differentiated from every other sample. This information should follow the sample through the COC, analytical, and interpretation and reporting processes. For the infrastructure caulk/sealant samples, the sample ID must not contain information that can be used to identify where the sample was collected. The following 2-step process will be followed to assign sample IDs to the caulk/sealant samples.

1. Upon collection, the sample will be labeled according to the following naming convention:

   MMDDYYYY-TTTT-##

   Where:

MM	2 digit month of collection
DD	2 digit date of collection
YYYY	4 digit year of collection
TTTT	4 digit time of collection (military time)
##	Sequential 2-digit sample number (i.e., 01, 02, 03…etc.)

   For example, a sample collected on September 20, 2017 at 9 AM could be assigned the following sample ID: 09202017-0900-01.

2. This second step was added to avoid issues that could arise due to duplicate sample IDs, while maintaining the blind sampling approach. While the sample naming system identified above is unlikely to produce duplicate sample IDs, there is a chance that different groups may collect samples simultaneously. This second step will be implemented by the Field PM at KLI upon receipt of caulk/sealant samples from participating municipalities. The Field PM at KLI will review the sample IDs on the COC forms for all samples and compare the sample IDs to all caulk samples for this project already in storage at KLI. If any two samples have the same sample IDs, the Field PM will add a one-digit number to the end of one of the sample IDs, selected at random. This extra number will be added to the sample container label, the field data sheet, and the COC form for that sample.

9.2. HDS Unit Sampling Procedures (Task 2)

9.2.1. Sample Site Selection

Sample site selection will be opportunistic, based on the public HDS units that participating municipalities schedule for cleaning during the project. The project team will coordinate with participating municipalities to schedule sampling during HDS unit cleanouts.

9.2.2. Field Equipment and Cleaning

A list of potential sampling equipment for soil/sediment is presented in Table 5. The equipment list should be reviewed and tailored by field contractors to meet the needs of each individual sampling site. Appropriate sampling equipment is prepared in the laboratory a minimum of four days prior to sampling. Prior to sampling, all equipment will be thoroughly cleaned. Equipment is soaked (fully immersed) for three days in a solution of Alconox, Liquinox, or similar phosphate-free detergent and deionized water. Equipment is then rinsed three times with deionized water. Equipment is next rinsed with a dilute solution

(1-2%) of hydrochloric acid, followed by a rinse with reagent grade methanol, followed by another set of three rinses with deionized water. All equipment is then allowed to dry in a clean place. The cleaned equipment is then wrapped in aluminum foil or stored in clean Ziploc bags until used in the field.

Table 9-1 Field Equipment for HDS Unit Sampling.

Description of Equipment	Material (if applicable)
Sample scoops	Stainless steel or Kynar coated
Sample trowels	Stainless steel or Kynar coated
Compositing bucket	Stainless steel or Kynar coated
Ekman Dredge (as needed)	Stainless steel
Sample containers (with labels)	As coordinated with lab(s)
Methanol, Reagent grade (Teflon squeeze bottle with refill)	
Hydrochloric acid, 1-2%, Reagent grade (Teflon squeeze bottle)	
Liquinox detergent (diluted in DI within Teflon squeeze bottle)	
Deionized / reverse osmosis water	
Plastic scrub brushes	
Container for storage of sampling derived waste, dry	
Container for storage of sampling derived waste, wet	
Wet ice	
Coolers, as required	
Aluminum foil (heavy duty recommended)	
Protective packaging materials	Bubble / foam bags
Splash proof eye protection	
PPE for sampling personnel, including traffic mgmt as required	
Gloves for dry ice handling	Cotton, leather, etc.
Gloves for sample collection, reagent handling	Nitrile
Field datasheets	
COC forms	
Custody tape (as required)	
Shipping materials (as required)	
GPS	

9.2.3.Soil / Sediment Sample Collection

Field sampling personnel will collect sediment samples from HDS unit sumps using methods that minimize contamination, losses, and changes to the chemical form of the analytes of interest. The samples will be collected in the field into pre-cleaned sample containers of a material appropriate to the analysis to be conducted. Pre-cleaned sampling equipment is used for each site, whenever possible and/or when necessary. Appropriate sampling technique and measuring equipment may vary depending on the location, sample type, sampling objective, and weather. Additional safety measures may be necessary in some cases; for example, if traffic control or confined space entry is required to conduct the sampling.

Ideally and where a sufficient volume of soil/sediment allows, samples are collected into a composite container, where they are thoroughly homogenized, and then aliquoted into separate jars for chemical analysis. Sediment samples for metals and organics are submitted to the analytical laboratories in separate jars, which have been pre-cleaned according to laboratory protocol. It is anticipated that soil / solid media will be collected for laboratory analysis using one of two techniques: (1) Remote grab of submerged sediments within HDS unit sumps using Ekman dredge or similar; or (2) direct grab sampling of sediments after dewatering HDS unit sumps using individual scoops, push core sampling, or similar. Each of these techniques is described briefly below.

- Soil and Sediment Samples, Submerged. Wet soil and sediment samples may be collected from within HDS unit sumps. Sample crews must exercise judgment on whether submerged samples can be collected in a manner that does not substantially change the character of the soil/sediment collected for analysis (e.g., loss of fine materials). It is anticipated that presence of trash within the sumps may interfere with sample collection by preventing complete grab closure and loss of significant portion of the sample. Field crews will have the responsibility to determine the best method for collection of samples within each HDS Unit sump. If sampling personnel determine that sample integrity cannot be maintained throughout collection process, it is preferable to cancel sampling operations rather than collect samples with questionable integrity. This decision making process is more fully described in Section 11, Field Variances.

- Soil and Sediment Samples, Dry. Soils / sediments may be collected from within the HDS unit sump after dewatering. Field crews will have the responsibility to identify areas of sediment accumulation within areas targeted for sampling and analysis, and determine the best method for collection of samples with minimal disturbance to the sampling media.

After collection, all soil/sediment samples for PCBs and mercury analyses will be homogenized and transferred from the sample-dedicated homogenization pail into factory-supplied wide-mouth glass jars using a clean trowel or scoop. The samples will be transferred to coolers containing double-bagged wet ice and chilled to 6°C immediately upon collection.

For each sample collected, field personnel will fill out a field data sheet at the time of sample collection. Appendix A contains an example field data sheet. All samples will be kept in a chilled cooler in the field, and kept refrigerated pending delivery under COC to the field-PM. The Field PM will be responsible for sending the samples in a single batch to CEH for XRF analysis under COC. Following XRF analysis, CEH will deliver the samples under COC to the Consultant-PM. The Consultant-PM will be responsible for working with the project team to group samples for compositing, and sending those samples to the analytical laboratory under COC.

9.2.4.Sample ID Designation

Every sample must have a unique sample ID so that the analytical results from each sample can be differentiated from every other sample. This information should follow the sample through the COC, analytical, and interpretation and reporting processes. Each sediment/soil sample collected from HDS units will be labeled according to the following naming convention:

MMM-UUU-##

where:

MMM	Municipal Abbreviation (i.e., SJC=San Jose; OAK=Oakland; SUN=Sunnyvale).
UUU	HDS Unit Catchment ID; this is the number provided by the municipality for a specific HDS unit.
##	Sequential Sample Number (i.e., 01, 02, 03…etc.)

9.3. Water Quality Sampling and Column Testing Procedures (Task 3)

For this task, monitoring will be conducted during three storm events. The stormwater collected during these events will then be used as the influent for the laboratory column tests of amended BSM mixtures. Four influent samples (i.e., one sample of Bay Area stormwater from each of the three monitored storm events plus one diluted stormwater sample) and 20 effluent samples from the column tests that includes 3 tests for each of the six columns, plus one test with the diluted stormwater in two columns (one test column and one control column) will be collected and analyzed for pollutant concentrations.

9.3.1. Sample Site Selection

Two stormwater collection sites have been selected based on influent PCB concentrations measured during CW4CB (BASMAA, 2017c). Both sites are near tree wells located on Ettie Street in West Oakland. The first site is the influent to tree well #6 (station code = TW6). During CW4CB, influent stormwater concentrations at this location were average to high, ranging from 30 ng/L to 286 ng/L. Stormwater collected from this site will be used as the influent for one of the main column tests and some water will be reserved for the dilution series column tests. The amount of dilution will be determined after results are received from the lab from the first run. The second site is the influent to tree well #2 (station code=TW2). During CW4CB, influent stormwater concentrations at this location were low to average, ranging from 6 ng/L to 39 ng/L. Stormwater collected from this site will be used for the remaining two main column tests..

9.3.2. Field Equipment and Cleaning

Field sampling equipment includes:

1. Borosilicate glass carboys
2. Glass sample jars
3. Peristaltic pump tubing

Prior to sampling, all equipment will be thoroughly cleaned. Glass sample containers and peristaltic pump tubing will be factory pre-cleaned. Prior to first use and after each use, glass carboys (field carboys and effluent collection carboys) will be washed using phosphate-free laboratory detergent and scrubbed with a plastic brush. After washing the carboy will be rinsed with methylene chloride, then de-ionized water, then 2N nitric acid, then again with de-ionized water. Glass carboys will be cleaned after each sample run before they are returned to the Field PM for reuse in the field.

9.3.3. Water Sampling Procedures

During each storm event, stormwater will be collected in six, five-gallon glass carboys. To fill the carboys, the Field PM will create a backwater condition in the gutter before the drain inlet at each site and use a peristaltic pump to pump the water into glass carboys. Field personnel will wear nitrile gloves during sample collection to prevent contamination. Carboys will be stored and transported in coolers with either wet ice or blue ice, and will be delivered to OWP within 24 hours of collection.

9.3.4. Hydraulic Testing

Based on the literature review and availability, the best five biochars will be mixed with the standard BSM to create biochar amended BSMs. Initially, each biochar will be mixed with standard BSM at a rate of 25% biochar by volume (the same as that at the CW4CB Richmond PG&E Substation 1st and Cutting site). Hydraulic conductivity can be determined using the method stated in the BASMAA soil specification, method ASTM D2434.

1. Follow the directions for permeability testing in ASTM D2434 for the BSM.
2. Sieve enough of the sample biochar to collect at least 15 in^3 on a no. 200 sieve.
3. Mix the sieved biochar with standard BSM at a 1 to 4 ratio.
4. Thoroughly mix the soil.
5. Follow the directions for permeability testing in ASTM D2434.
6. If the soil mix is more than 1 in/hr different from the BSM, repeat steps 1-4 but on step 3, adjust the ratio as estimated to achieve the same permeability as the BSM.
7. Repeat steps 2-6 for each biochar.

9.3.5.Column Testing Procedures

Column Setup: Up to five biochar amended BSMs and one standard BSM will be tested (based on performance and availability of biochars). Six glass columns with a diameter of eight inches and a height of three feet will be mounted to the wall with sufficient height between the bottom of the columns and the floor to allow for effluent sample collection. Each column will be capped at the bottom and fitted with a spigot to facilitate sampling. Soil depth for all columns will be 18" after compaction, which is a standard depth used in bay area bioretention installations (see Figure 9-1 below). To retain soil the bottom of the soil layer will be contained by a layer of filter fabric on top of structural backing. Behind each column, a yardstick will be mounted to the wall so that the depth of water in the column can be monitored.

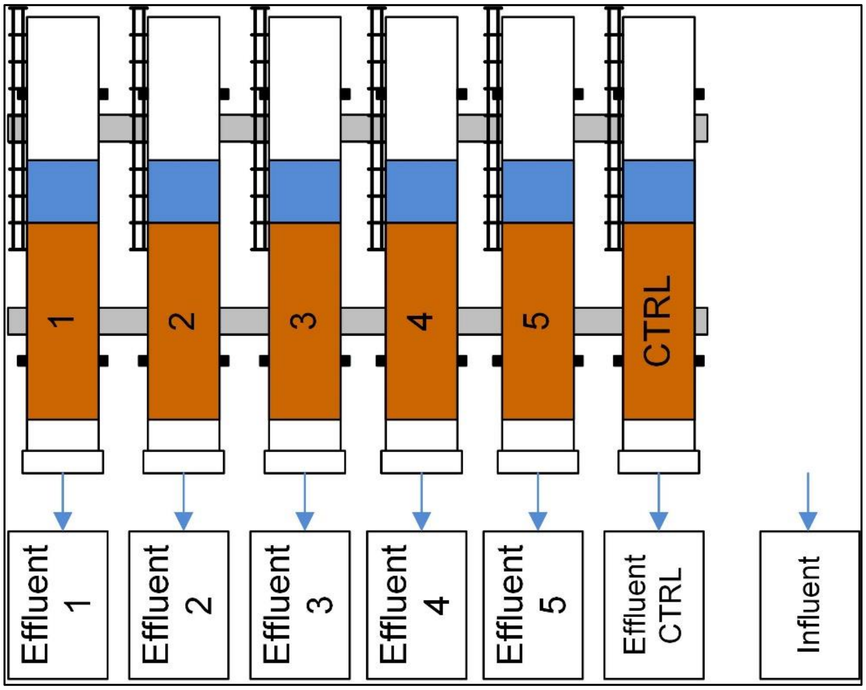

Figure 9-1. Column Test Setup

Dilution Run Column Setup: One of the existing biochar-amended BSM column and the standard BSM will be tested using diluted stormwater.

Testing procedure pre run setup: Before a sampling run begins a clean glass carboy will be placed under each soil column and labeled to match, this carboy will be sized to collect the full effluent volume of the sample run. A glass beaker will also be assigned and labeled for each column of sufficient volume to accurately measure a single influent dose equivalent to 1 inch of depth in the column. An additional beaker will be prepared and labeled influent.

Media conditioning: Within 24 to 72 hours prior to the first column test run, pre-wet each column with a stormwater matrix collected from the CSUS campus by filling each column from the invert until water ponds above the media. Drain the water after 3 hours.

Sampling run: When the six glass carboys are delivered:

1. Inspect each carboy and fill out the Sample Receiving worksheet.
2. The runs will begin within 72 hours of delivery.
3. Select one carboy at random and fully mix it using a portable lab mixer for five minutes.
4. Turn off and remove the mixer, allow the sample to rest for one minute to allow the largest particles to settle to the bottom.
5. Fill each of the six dosing beakers and the one influent sample jar.
6. Pour each aliquot beaker into its respective column; record the time and height of water in each column.
7. Repeat steps 3-6 for each of the remaining carboys until a total of 18 inches of water is applied to each column. Before pouring an aliquot record the height of water in each column and the time. Pour each successive aliquot from the carboy when all columns have less than three inches of water above the soil surface. The water level should never be above 6 inches in any column at any time (6 inches is a standard ponding depth used in the bay area). Pour all aliquots from a single carboy into the columns at the same time.
8. Collect turbidity samples from the effluent of each column at the beginning, middle, and end of the sampling run. Fill the cuvettes for turbidity measurement directly from the effluent stream of each column and dispose of them after testing.
9. Collect mercury samples from the effluent of each column at the middle of the sample run using pre-labeled sample containers provided by the lab for that purpose.
10. Fill a pre-labeled sample jar from each columns effluent. The jar will be obtained from the laboratory performing the PCB analysis.
11. Pack each jar in ice and complete the lab COCs.
12. Ship the samples to the lab for analysis.

9.3.6.Sample ID Designations

Every sample must have a unique sample identification to ensure analytical results from each sample can be differentiated from every other sample. This information should follow the sample through the COC, analytical, and interpretation and reporting processes. Each influent and effluent water quality sample will be labeled according to the following naming convention:

SSS-TT-MMDDYYYY-##

Where:

SSS	Station code (see Table 9-2 for station codes)
TT	Sample Type (IN=influent; EF=Effluent)
MM	2 digit month of collection
DD	2 digit date of collection
YYYY	4 digit year of collection
##	Sequential 2-digit sample number (i.e., 01, 02, 03…etc.)

For example, a sample collected at the West Oakland Tree Well #2 site on October 20, 2017 and used for the influent sample for run #3 could be assigned the following sample ID: TW2-IN-09202017-03.

Table 9-2 Station Codes for Stormwater Influent Samples and Column Tests.

Station Code	Station Description
TW2	Stormwater sample collected from the West Oakland Tree Well #2
TW6	Stormwater sample collected from the West Oakland Tree Well #6
CO1	Effluent sample collected from column number 1
CO2	Effluent sample collected from column number 2
CO3	Effluent sample collected from column number 3
CO4	Effluent sample collected from column number 4
CO5	Effluent sample collected from column number 5
CO6	Effluent sample collected from column number 6

9.4. Collection of Samples for Archiving

Archive samples will not be collected for this Monitoring Program. The sample size collected will be enough to support additional analyses if QA/QC issues arise. Once quality assurance is certified by the QA Officer, the laboratory will be instructed to dispose of any leftover sample materials.

9.5. Waste Disposal

Proper disposal of all waste is an important component of field activities. At no time will any waste be disposed of improperly. The proper methods of waste disposal are outlined below:

9.5.1. Routine Garbage

Regular garbage (paper towels, paper cups, etc.) is collected by sampling personnel in garbage bags or similar. It can then be disposed of properly at appropriate intervals.

9.5.2. Detergent Washes

Any detergents used or detergent wash water should be collected in the field in a water-tight container and disposed of appropriately.

9.5.3. Chemicals

Methanol, if used, should be disposed of by following all appropriate regulations. It should always be collected when sampling and never be disposed in the field.

9.1. Responsibility and Corrective Actions

If monitoring equipment fails, sampling personnel will report the problem in the comments section of their field notes and will not record data values for the variables in question. Actions will be taken to replace or repair broken equipment prior to the next field use.

9.2. Standard Operating Procedures

SOPs associated with sampling and sample handling expected to be used as part of implementation of The Monitoring Program are identified in Table 9-3. Additional details on sample container information, required preservation, holding times, and sample volumes for all Monitoring Program analytes are listed in Table 10-1 of Section 10.

Table 9-3. List of BASMAA RMC SOPs Utilized by the Monitoring Program.

RMC SOP #	RMC SOP	Source
FS-2	Water Quality Sampling for Chemical Analysis, Pathogen Indicators, and Toxicity	BASMAA 2016
FS-3	Field Measurements, Manual	BASMAA 2016
FS-4	Field Measurements, Continuous General Water Quality	BASMAA 2016
FS-5	Temperature, Automated, Digital Logger	BASMAA 2016
FS-6	Collection of Bedded Sediment Samples for Chemical Analysis and Toxicity	BASMAA 2016
FS-7	Field Equipment Cleaning Procedures	BASMAA 2016
FS-8	Field Equipment Decontamination Procedures	BASMAA 2016
FS-9	Sample Container, Handling, and Chain of Custody Procedures	BASMAA 2016
FS-10	Completion and Processing of Field Datasheets	BASMAA 2016
FS-11	Site and Sample Naming Convention	BASMAA 2016

In addition, contractor-specific plans and procedures may be required for specific aspects of the Monitoring Program implementation (e.g., health and safety plans, dry ice shipping procedures).

10. Sample Handling and Custody

Sample handling and chain of custody procedures are described in detail in RMC SOP FS-9 (Table 9-3) (BASMAA 2016). The Field-PM or designated municipal staff on site during sample collection will be responsible for overall collection and custody of samples during field sampling. Field crews will keep a field log, which will consist of sampling forms for each sampling event. Sample collection methods described in this document and the study designs (BASMAA 2017a, b) will be followed for each sampling task. Field data sheets will be filled out for each sample collected during the project. Example field data sheets are provided in Appendix A, and described further in Section 9.

The field crews will have custody of samples during field sampling, and COC forms will accompany all samples from field collection until delivery to the analyzing laboratory. COC procedures require that possession of samples be traceable from the time the samples are collected until completion and submittal of analytical results. Each laboratory will follow sample custody procedures as outlined in its QA plans.

Information on sampling containers, preservation techniques, packaging and shipping, and hold times is described below and summarized in Table 10.1.

10.1. Sampling Containers

Collection of all sample types require the use of clean containers. Factory pre-cleaned sample containers of the appropriate type will be provided by the contracted laboratory and delivered to field team at least one week prior to the start of sample collection. Individual laboratories will be responsible for the integrity of containers provided. The number and type of sample containers required for all analytes by media type for each sampling task are provided in Table 10.1.

10.2. Sample Preservation

Field Crews will collect samples in the field in a way that neither contaminates, loses, or changes the chemical form of the analytes of interest. The samples will be collected in the field into pre-cleaned sample containers of a material appropriate to the analysis to be conducted. Pre-cleaned sampling equipment is used for each site, whenever possible and/or when necessary. Appropriate sampling technique and measurement equipment may vary depending on the location, sample type, sampling objective, and weather.

In general, all samples will be packed in sufficient wet ice or frozen ice packs during shipment, so that they will be kept between 2 and 4º C (Table 10.1). When used, wet ice will be double bagged in Zip-top bags to prevent contamination via melt water. Where appropriate, samples may be frozen to prevent degradation. If samples are to be shipped frozen on dry ice, then appropriate handling procedures will be followed, including ensuring use of appropriate packaging materials and appropriate training for shipping personnel.

10.3. Packaging and Shipping

All samples will be handled, prepared, transported, and stored in a manner so as to minimize bulk loss, analyte loss, contamination, or biological degradation. Sample containers will be clearly labeled with an indelible marker. All caps and lids will be checked for tightness prior to shipping. Ice chests will be sealed with packing tape before shipping. Samples will be placed in the ice chest with enough ice or frozen ice packs to maintain between 2 and 4º C. Additional packing material will be added as needed. COC forms will be placed in a zip-top bag and placed inside of the ice chest.

10.4. Commercial Vehicle Transport

If transport of samples to the contracted laboratories is to be by commercial carriers, pickup will be pre-arranged with the carrier and all required shipping forms will be completed prior to sample pickup by the commercial carrier.

10.5. Sample Hold Times

Sample hold times for each analyte by media type are presented in Table 10-1.

Table 10-1 Sample Handling for the Monitoring Program Analytes by media type.

Analyte	Sample Media	Sample Container	Minimum Sample / Container Size^a	Preservative	Hold Time (at 6º C)
PCBs (40-RMP Congeners)	Caulk or sealant	Pre-cleaned 250-mL glass sample container (e.g., Quality Certified™, ESS Vial, Oakland, CA)	10 g	Cool to 6° C within 24 hours, then freeze to ≤-20° C	1 year at -20º C; Samples must be analyzed within 14 days of collection or thawing.
	Sediment	Pre-cleaned 250-mL I-Chem 200 Series amber glass jar with Teflon lid liner	500 mL (two jars)	Cool to 6° C within 24 hours, then freeze to ≤-20° C	1 year at -20º C; Samples must be analyzed within 14 days of collection or thawing.
	Water	1000-mL I-Chem 200-Series amber glass bottle, with Teflon lid-liner	1000 mL/per individual analyses	Cool to 6º C in the dark.	1 year until extraction, 1 year after extraction
Total Mercury	Sediment	Pre-cleaned 250-mL I-Chem 200 Series amber glass jar with Teflon lid liner	100 g	Cool to 6º C and in the dark	1 year at -20º C; Samples must be analyzed within 14 days of collection or thawing.
	Water	250-mL glass or acid-cleaned Teflon bottle	250 mL	Cool to 6º C in the dark and acidify to 0.5% with pre-tested HCl within 48 hours	6 months at room temperature following acidification
Bulk Density	Sediment	250-mL clear glass jar; pre-cleaned	250 mL	Cool to 6º C	7 days
Grain Size and TOC	Sediment	250-mL clear glass jar; pre-cleaned	250 mL	Cool to 6º C, in the dark up to 28 days^2	28 days at ≤6 ◦C; 1 year at ≤-20 ◦C
SSC	Water	125-mL amber glass jar or Polyethylene Bottles	125 mL	Cool to 6º C and store in the dark	7 days
Turbidity	Water				
Total Solids	Water	1 L HDPE	1 L	Cool to ≤6 ◦C	7 days
TOC	Water	40-mL glass vial	40 mL	Cool to 6º C and store in the dark. If analysis is to occur more than two hours after sampling, acidify (pH < 2) with HCl or H_2SO_4.	28 days
Particle Size Distribution	Water	1 L HDPE	2 L	Cool to 6º C and store in the dark	7 days

^{a}QC samples or other analytes require additional sample bottles.

11. Field Health and Safety Procedures

All field crews will be expected to abide by their employer's (i.e., the field contractor's) health and safety programs. Additionally, prior to the fieldwork, field contractors are required to develop site-specific Health and Safety plans that include the locations of the nearest emergency medical services.

Implementation of the Monitoring Program activities may require confined space entry (CSE) to accomplish sampling goals. Sampling personnel conducting any confined space entry activities will be expected to be certified for CSE and to abide by relevant regulations.

12. Laboratory Analytical Methods

12.1. Caulk/Sealant Samples (Task 1)

12.1.1. XRF Chlorine analysis

XRF technology will be used in a laboratory setting to rank samples for chlorine content before sending the samples to the project laboratory for chemical analysis. Procedures for testing caulk or sealants using X-Ray fluorescence (XRF) and collecting caulk and sealant samples are not well described, and minimal detail on caulk or sealant sample collection is available in peer-reviewed publications. Sealant sampling procedures were adapted from the previous study examining PCBs in building materials (Klosterhaus et al., 2014).

An XRF analyzer will be used at the Center for Environmental Health (CEH) as a screening tool to estimate the concentration of chlorine (Cl) in collected caulk and sealant samples from various structures. Settings for the analyzer will be 'standardized' using procedures developed/ recommended by CEH each time the instrument is turned on and prior to any measurement. European plastic pellet reference materials (EC680 and EC681) will be used as 'check' standards upon first use to verify analyzer performance. A 30 second measurement in 'soil' mode will be used. CEH personnel will inspect the caulk/sealant surfaces and use a stainless steel blade to scrape off any paint, concrete chips, or other visible surface residue. The caulk/sealant surface to be sampled will then be wiped with a laboratory tissue to remove any remaining debris that may potentially interfere with the XRF analysis. At least two XRF readings will be collected from each sample switching the orientation or position of the sample between readings. If Cl is detected, a minimum of four additional readings will be collected on the same material to determine analytical variability. Each individual Cl reading and its detection limit will be recorded on the data sheet. After XRF analysis, all samples will be returned to their original sample container. Results of the XRF analysis will be provided to the project team as a table of ranked Cl screening results for possible selection for chemical (PCBs) analysis.

12.1.2. Selection of Samples for PCB analysis and Compositing

Once samples have been ranked for their chlorine content, primarily samples with the highest Cl will preferentially be selected for chemical analysis. About 75% of samples to be analyzed should be selected from samples with the top quartile Cl content. The remaining 25% should be selected from samples with medium (25 to 75th percentile) Cl, as the previous study using XRF screening showed inconsistent correlation between total Cl and PCB. Although samples with very low Cl seldom had much PCBs, samples with medium Cl on occasion had higher PCBs than samples with high Cl, and within the high Cl group, Cl content was not a good predictor of their ranks of PCB concentration.

In addition to Cl content, other factors about each sample that were recorded on the field data sheets at the time of sample collection, including the color or consistency of the sample, the type and/or age of the structure that was sampled, or the type of caulk or sealant application will be considered in selecting the samples that will be sent to the laboratory for PCBs analysis, as well as how the samples will be grouped for compositing purposes. Those factors are described in more detail in the study design (BASMAA, 2017a).

The Consultant PM will work with the project team to identify up to three samples for inclusion in each composite. A common composite ID will then be assigned to each sample that will be composited together (i.e., all samples the lab should composite together will be identified by the common composite ID). The composite ID will consist of a single letter designation and will be identical for all samples (up to 3 total) that will be composited together. The Consultant PM will add the composite ID to each sample container label, to each sample ID on all COC forms, and to each field data sheet for all samples prior to sending the samples to the laboratory for PCBs analysis.

12.1.3. Sample Preparation

The project laboratory will composite the samples prior to extraction and PCBs analysis according to the groupings identified by the common composite ID. Sample preparation will include removal of any paint, concrete chips, or other surface debris, followed by homogenization of the caulk/sealant material and compositing up to three samples per composite. Each sample will have a composite ID that will be used to identify which samples should be composited together. Samples with the same composite ID will be combined into a single composite sample. For example, all samples with composite ID = “A” will be composited together; all samples with composite ID = “B” will be composited together, etc. Sample preparation and compositing will follow the procedures outlined in the laboratory SOPs (Appendix B). After compositing, each composite sample will be assigned a new sample ID using the following naming convention:

X-MMDDYYYY

Where:

X	the single letter Composite ID that is common to all samples included in a given composite.
MM	2 digit month of composite preparation
DD	2 digit date of composite preparation
YYYY	4 digit year of composite preparation

For example, if three samples with the composite ID= “A” are combined into a single composite sample on December 12, 2017, the new (composite) sample ID would be the following: A-12122017.

12.1.4. PCBs Analysis

All composite caulk/sealant samples will be extracted by Method 3540C, and analyzed for the RMP-40 PCB congeners[3] using a modified EPA Method 8270C (GC/MS-SIM), in order to obtain positive

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[3] The 40 individual congeners routinely quantified by the Regional Monitoring Program (RMP) for Water Quality in the San Francisco Estuary include: PCBs 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, l05, 110, 118, 128, 132, 138, 141, 149, l51, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, and 203

identification and quantitation of PCBs. PCB content of these material covers an extremely wide range, so the subsampling of material should include sufficient material for quantification assuming that the concentration is likely to be around the median of previous results. There may be samples with much higher concentrations, which can be reanalyzed on dilution as needed. Method Reporting Limits (MRLs) for each of the RMP-40 PCB Congeners are 0.5 µg/Kg.

12.2. Sediment Samples Collected from HDS Units (Task 2)

All sediment samples collected from HDS units under Task 2 will be analyzed for TOC, grain size, bulk density, total mercury, and PCBs (RMP 40 Congeners1) by the methods identified in Table 12-1. All sediment samples (with the exception of grain size) will be sieved by the laboratory at 2 mm prior to analysis.

Table 12-1. Laboratory Analytical Methods for Analytes in Sediment

Analyte	Sampling Method	Recommended Analytical Method	Reporting Units
Total Organic Carbon (TOC)	Grab	EPA 415.1, 440.0, 9060, or ASTM D4129M	%
Grain Size	Grab	ASTM D422M/PSEP	%
Bulk Density	Grab	ASTM E1109-86	g/cm3
Mercury	Grab	EPA 7471A, 7473, or 1631	µg/kg
PCBs (RMP 40 Congeners)	Grab	EPA 1668	µg/kg

12.3. Water Samples – Stormwater and Column Tests (Task 3)

All water samples submitted to the laboratory will be analyzed for SSC, TOC, total mercury and PCBs (RMP-40 congeners) according to the methods identified in Table 12-2.

Table 12-2. Laboratory Analytical Methods for Analytes in Water

Analyte	Sampling Method	Recommended Analytical Method	Reporting Units
Suspended Sediment Concentration (SSC)	Grab	ASTM D3977-97 (Method C)	mg/L
Total Organic Carbon (TOC)	Grab	EPA 415.1 or SM 5310B	%
Mercury (Total)	Grab	EPA 1631	µg/L
PCBs (RMP 40 Congeners)	Grab	EPA 1668	ng/L

12.4. Method Failures

The QA Officer will be responsible for overseeing the laboratory implementing any corrective actions that may be needed in the event that methods fail to produce acceptable data. If a method fails to provide acceptable data for any reason, including analyte or matrix interferences, instrument failures, etc., then the involved samples will be analyzed again if possible. The laboratory in question's SOP for handling these types of problems will be followed. When a method fails to provide acceptable data, then the laboratory's

SOP for documenting method failures will be used to document the problem and what was done to rectify it.

Corrective actions for chemical data are taken when an analysis is deemed suspect for some reason. These reasons include exceeding accuracy or precision ranges and/or problems with sorting and identification. The corrective action will vary on a case-by-case basis, but at a minimum involves the following:

- A check of procedures.
- A review of documents and calculations to identify possible errors.
- Correction of errors based on discussions among analysts.
- A complete re-identification of the sample.

The field and laboratory coordinators shall have systems in place to document problems and make corrective actions. All corrective actions will be documented to the FTL and the QA Officer.

12.5. Sample Disposal

After analysis of the Monitoring Program samples has been completed by the laboratory and results have been accepted by QA Officer and the Field-PM, they will be disposed by laboratory staff in compliance with all federal, state, and local regulations. The laboratory has standard procedures for disposing of its waste, including left over sample materials

12.6. Laboratory Sample Processing

Field samples sent to the laboratories will be processed within their recommended hold time using methods agreed upon method between the Lab-PM and Field-PM. Each sample may be assigned unique laboratory sample ID numbers for tracking processing and analyses of samples within the laboratory. This laboratory sample ID (if differing from the field team sample ID) must be included in the data submission, within a lookup table linking the field sample ID to that assigned by the lab.

Samples arriving at the laboratory are to be stored under conditions appropriate for the planned analytical procedure(s), unless they are processed for analysis immediately upon receipt. Samples to be analyzed should only be removed from storage when laboratory staff are ready to proceed.

13. Quality Control

Each step in the field collection and analytical process is a potential source of contamination and must be consistently monitored to ensure that the final measurement is not adversely affected by any processing steps. Various aspects of the quality control procedures required by the Monitoring Program are summarized below.

13.1. Field Quality Control

Field QC results must meet the MQOs and frequency requirements specified in Tables 13-1 – 13-4 below.

13.1.1. Field Blanks

A field blank is collected to assess potential sample contamination levels that occur during field sampling activities. Field blanks are taken to the field, transferred to the appropriate container, preserved (if required by the method), and treated the same as the corresponding sample type during the course of a sampling event. The inclusion of field blanks is dependent on the requirements specified in the relevant MQO tables or in the sampling method or SOP.

Collection of caulk or sealant field blank samples has been deemed unnecessary due to the difficulty in collection and interpretation of representative blank samples and the use of precautions that minimize contamination of the samples. Additionally, PCBs have been reported to be present in percent concentrations when used in sealants; therefore any low level contamination (at ppb or even ppm level) due to sampling equipment and procedures is not expected to affect data quality because it would be many orders of magnitude lower than the concentrations deemed to be a positive PCB signal.

For stormwater samples, field blanks will be generated using lab supplied containers and clean matrices. Sampling containers will be opened as though actual samples were to be collected, and clean lab-supplied matrix (if any) will be transferred to sample containers for analysis.

13.1.2. Field Duplicates

Field samples collected in duplicate provide precision information as it pertains to the sampling process. The duplicate sample must be collected in the same manner and as close in time as possible to the original sample. This effort is to attempt to examine field homogeneity as well as sample handling, within the limits and constraints of the situation. These data are evaluated in the data analysis/assessment process for small-scale spatial variability.

Field duplicates will not be collected for caulk/sealant samples (Task 1), as assessment of within-structure variability of PCB concentrations in sealants is not a primary objective of the Project. Due to budget limitations, PCBs analysis of only one caulk/sealant sample per application will be targeted to maximize the number of Bay Area structures and structure types that may be analyzed in the Project. The selected laboratory will conduct a number of quality assurance analyses (see Section 13), including a limited number of sample duplicates, to evaluate laboratory and method performance as well as variability of PCB content within a sample.

For all sediment and water samples, 5% of field duplicates and/or column influent/effluent duplicates will be collected along with primary samples in order to evaluate small scale spatial or temporal variability in sample collection without specifically targeting any apparent or likely bias (e.g. different sides of a seemingly symmetrical unit, or offset locations in making a composite, or immediately following collection of a primary water sample would be acceptable, whereas collecting one composite near an inlet and another near the outlet, or intentionally collecting times with vastly different flow rates, would not be desirable).

13.1.3. Field Corrective Action

The Field PM is responsible for responding to failures in their sampling and field measurement systems. If monitoring equipment fails, personnel are to record the problem according to their documentation protocols. Failing equipment must be replaced or repaired prior to subsequent sampling events. It is the combined responsibility of all members of the field organization to determine if the performance requirements of the specific sampling method have been met, and to collect additional samples if necessary. Associated data is to be flagged accordingly. Specific field corrective actions are detailed in Table 13-8.

13.2. Laboratory Quality Control

Laboratories providing analytical support to the Monitoring Program will have the appropriate facilities to store, prepare, and process samples in an ultra-clean environment, and will have appropriate instrumentation and staff to perform analyses and provide data of the required quality within the time period dictated by the Monitoring Program. The laboratories are expected to satisfy the following:

1. Demonstrate capability through pertinent certification and satisfactory performance in inter-laboratory comparison exercises.
2. Provide qualification statements regarding their facility and personnel.
3. Maintain a program of scheduled maintenance of analytical balances, laboratory equipment and instrumentation.
4. Conduct routine checking of analytical balances using a set of standard reference weights (American Society of Testing and Materials Class 3, NIST Class S-1, or equivalents). Analytical balances are serviced at six-month intervals or when test weight values are not within the manufacturer’s instrument specifications, whichever occurs first.
5. Conduct routine checking and recording the composition of fresh calibration standards against the previous lot. Acceptable comparisons are within 2% of the precious value.
6. Record all analytical data in bound (where possible) logbooks, with all entries in ink, or electronically.
7. Monitor and document the temperatures of cold storage areas and freezer units on a continuous basis.
8. Verify the efficiency of fume/exhaust hoods.
9. Have a source of reagent water meeting specifications described in Section 8.0 available in sufficient quantity to support analytical operations.
10. Label all containers used in the laboratory with date prepared, contents, initials of the individual who prepared the contents, and other information as appropriate.
11. Date and safely store all chemicals upon receipt. Proper disposal of chemicals when the expiration date has passed.
12. Have QAPP, SOPs, analytical methods manuals, and safety plans readily available to staff.
13. Have raw analytical data readily accessible so that they are available upon request.

In addition, laboratories involved in the Monitoring Program are required to demonstrate capability continuously through the following protocols:

1. Strict adherence to routine QA/QC procedures.
2. Regular participation in annual certification programs.
3. Satisfactory performance at least annually in the analysis of blind Performance Evaluation Samples and/or participation in inter-laboratory comparison exercises.

Laboratory QC samples must satisfy MQOs and frequency requirements. MQOs and frequency requirements are listed in Tables 13-1 – 13-3. Frequency requirements are provided on an analytical batch level. The Monitoring Program defines an analytical batch as 20 or fewer samples and associated quality control that are processed by the same instrument within a 24-hour period (unless otherwise specified by method). Target Method Reporting Limits are provided in Tables 13.4 – 13.8. Details regarding sample preparation are method- or laboratory SOP-specific, and may consist of extraction, digestion, or other techniques.

13.2.1. Calibration and Working Standards

All calibration standards must be traceable to a certified standard obtained from a recognized organization. If traceable standards are not available, procedures must be implemented to standardize the utilized calibration solutions (*e.g.*, comparison to a CRM – see below). Standardization of calibration solutions must be thoroughly documented, and is only acceptable when pre-certified standard solutions are not available. Working standards are dilutions of stock standards prepared for daily use in the laboratory. Working standards are used to calibrate instruments or prepare matrix spikes, and may be prepared at several different dilutions from a common stock standard. Working standards are diluted with solutions that ensure the stability of the target analyte. Preparation of the working standard must be thoroughly documented such that each working standard is traceable back to its original stock standard. Finally, the concentration of all working standards must be verified by analysis prior to use in the laboratory.

13.2.2. Instrument Calibration

Prior to sample analysis, utilized instruments must be calibrated following the procedures outlined in the relevant analytical method or laboratory SOP. Each method or SOP must specify acceptance criteria that demonstrate instrument stability and an acceptable calibration. If instrument calibration does not meet the specified acceptance criteria, the analytical process is not in control and must be halted. The instrument must be successfully recalibrated before samples may be analyzed.

Calibration curves will be established for each analyte covering the range of expected sample concentrations. Only data that result from quantification within the demonstrated working calibration range may be reported unflagged by the laboratory. Quantification based upon extrapolation is not acceptable; sample extracts above the calibration range should be diluted and rerun if possible. Data reported below the calibration range must be flagged as estimated values that are Detected not Quantified.

13.2.3. Initial Calibration Verification

The initial calibration verification (ICV) is a mid-level standard analyzed immediately following the calibration curve. The source of the standards used to calibrate the instrument and the source of the standard used to perform the ICV must be independent of one another. This is usually achieved by the purchase of standards from separate vendors. Since the standards are obtained from independent sources and both are traceable, analyses of the ICV functions as a check on the accuracy of the standards used to calibrate the instrument. The ICV is not a requirement of all SOPs or methods, particularly if other checks on analytical accuracy are present in the sample batch.

13.2.4. Continuing Calibration Verification

Continuing calibration verification (CCV) standards are mid-level standards analyzed at specified intervals during the course of the analytical run. CCVs are used to monitor sensitivity changes in the instrument during analysis. In order to properly assess these sensitivity changes, the standards used to perform CCVs must be from the same set of working standards used to calibrate the instrument. Use of a second source standard is not necessary for CCV standards, since other QC samples are designed to assess the accuracy of the calibration standards. Analysis of CCVs using the calibration standards limits this QC sample to assessing only instrument sensitivity changes. The acceptance criteria and required frequency for CCVs are detailed in Tables 13-1 through 13-3. If a CCV falls outside the acceptance limits, the analytical system is not in control, and immediate corrective action must be taken.

Data obtained while the instrument is out of control is not reportable, and all samples analyzed during this period must be reanalyzed. If reanalysis is not an option, the original data must be flagged with the appropriate qualifier and reported. A narrative must be submitted listing the results that were generated while the instrument was out of control, in addition to corrective actions that were applied.

13.2.5. Laboratory Blanks

Laboratory blanks (also called extraction blanks, procedural blanks, or method blanks) are used to assess the background level of a target analyte resulting from sample preparation and analysis. Laboratory blanks are carried through precisely the same procedures as the field samples. For both organic and inorganic analyses, a minimum of at least one laboratory blank must be prepared and analyzed in every analytical batch or per 20 samples, whichever is more frequent. Some methods may require more than one laboratory blank with each analytical run. Acceptance criteria for laboratory blanks are detailed in Tables 13-1 through 13-3. Blanks that are too high require corrective action to bring the concentrations down to acceptable levels. This may involve changing reagents, cleaning equipment, or even modifying the utilized methods or SOPs. Although acceptable laboratory blanks are important for obtaining results for low-level samples, improvements in analytical sensitivity have pushed detection limits down to the point where some amount of analyte will be detected in even the cleanest laboratory blanks. The magnitude of the blanks must be evaluated against the concentrations of the samples being analyzed and against project objectives.

13.2.6. Reference Materials and Demonstration of Laboratory Accuracy

Evaluation of the accuracy of laboratory procedures is achieved through the preparation and analysis of reference materials with each analytical batch. Ideally, the reference materials selected are similar in matrix and concentration range to the samples being prepared and analyzed. The acceptance criteria for reference materials are listed in Tables 13-1 – 13-3. The accuracy of an analytical method can be assessed using CRMs only when certified values are provided for the target analytes. When possible, reference materials that have certified values for the target analytes should be used. This is not always possible, and often times certified reference values are not available for all target analytes. Many reference materials have both certified and non-certified (or reference) values listed on the certificate of analysis. Certified reference values are clearly distinguished from the non-certified reference values on the certificate of analysis.

13.2.7. Reference Materials vs. Certified Reference Materials

The distinction between a reference material and a certified reference material does not involve how the two are prepared, rather with the way that the reference values were established. Certified values are determined through replicate analyses using two independent measurement techniques for verification. The certifying agency may also provide "non-certified or "reference" values for other target analytes. Such values are determined using a single measurement technique that may introduce bias. When available, it is preferable to use reference materials that have certified values for all target analytes. This is not always an option, and therefore it is acceptable to use materials that have reference values for these analytes. Note: Standard Reference Materials (SRMs) are essentially the same as CRMs. The term "Standard Reference Material" has been trademarked by the National Institute of Standards and Technology (NIST), and is therefore used only for reference materials distributed by NIST.

13.2.8. Laboratory Control Samples

While reference materials are not available for all analytes, a way of assessing the accuracy of an analytical method is still required. LCSs provide an alternate method of assessing accuracy. An LCS is a specimen of known composition prepared using contaminant-free reagent water or an inert solid spiked with the target analyte at the midpoint of the calibration curve or at the level of concern. The LCS must be analyzed using the same preparation, reagents, and analytical methods employed for regular samples. If an LCS needs to be substituted for a reference material, the acceptance criteria are the same as those for the analysis of reference materials..

13.2.9. Prioritizing Certified Reference Materials, Reference Materials, and Laboratory Control Samples

Certified reference materials, reference materials, and laboratory control samples all provide a method to assess the accuracy at the mid-range of the analytical process. However, this does not mean that they can be used interchangeably in all situations. When available, analysis of one certified reference material per analytical batch should be conducted. Certified values are not always available for all target analytes. If no certified reference material exists, reference values may be used. If no reference material exists for the target analyte, an LCS must be prepared and analyzed with the sample batch as a means of assessing accuracy. The hierarchy is as follows: analysis of a CRM is favored over the analysis of a reference material, and analysis of a reference material is preferable to the analysis of an LCS. Substitution of an LCS is not acceptable if a certified reference material or reference material is available, contact the Project Manager and QAO for approval before relying exclusively on an LCS as a measure of accuracy.

13.2.10.Matrix Spikes

A MS is prepared by adding a known concentration of the target analyte to a field sample, which is then subjected to the entire analytical procedure. The MS is analyzed in order to assess the magnitude of matrix interference and bias present. Because these spikes are often analyzed in pairs, the second spike is called the MSD. The MSD provides information regarding the precision of measurement and consistency of the matrix effects. Both the MS and MSD are split from the same original field sample. In order to properly assess the degree of matrix interference and potential bias, the spiking level should be approximately 2-5x the ambient concentration of the spiked sample. To establish spiking levels prior to sample analysis, if possible, laboratories should review any relevant historical data. In many instances, the laboratory will be spiking samples blind and will not meet a spiking level of 2-5x the ambient concentration. In addition to the recoveries, the relative percent difference (RPD) between the MS and MSD is calculated to evaluate how matrix affects precision. The MQO for the RPD between the MS and MSD is the same regardless of the method of calculation. These are detailed in Tables 13-1 – 13-3. Recovery data for matrix spikes provides a basis for determining the prevalence of matrix effects in the samples collected and analyzed. If the percent recovery for any analyte in the MS or MSD is outside of the limits specified in Tables 13-1 – 13-3, the chromatograms (in the case of trace organic analyses) and raw data quantitation reports should be reviewed. Data should be scrutinized for evidence of sensitivity shifts (indicated by the results of the CCVs) or other potential problems with the analytical process. If associated QC samples (reference materials or LCSs) are in control, matrix effects may be the source of the problem. If the standard used to spike the samples is different from the standard used to calibrate the instrument, it must be checked for accuracy prior to attributing poor recoveries to matrix effects.

13.2.11.Laboratory Duplicates

In order to evaluate the precision of an analytical process, a field sample is selected and prepared in duplicate. Specific requirements pertaining to the analysis of laboratory duplicates vary depending on the type of analysis. The acceptance criteria for laboratory duplicates are specified in Tables 13-1 – 13-3.

13.2.12.Laboratory Duplicates vs. Matrix Spike Duplicates

Although the laboratory duplicate and matrix spike duplicate both provide information regarding precision, they are unique measurements. Laboratory duplicates provide information regarding the precision of laboratory procedures at actual ambient concentrations. The matrix spike duplicate provides information regarding how the matrix of the sample affects both the precision and bias associated with the results. It also determines whether or not the matrix affects the results in a reproducible manner. MS/MSDs are often spiked at levels well above ambient concentrations, so thus are not representative of typical sample precision. Because the two concepts cannot be used interchangeably, it is unacceptable to analyze only an MS/MSD when a laboratory duplicate is required.

13.2.13.Replicate Analyses

The Monitoring Program will adopt the same terminology as SWAMP in defining replicate samples, wherein replicate analyses are distinguished from duplicate analyses based simply on the number of involved analyses. Duplicate analyses refer to two sample preparations, while replicate analyses refer to three or more. Analysis of replicate samples is not explicitly required.

13.2.14.Surrogates

Surrogate compounds accompany organic measurements in order to estimate target analyte losses or matrix effects during sample extraction and analysis. The selected surrogate compounds behave similarly to the target analytes, and therefore any loss of the surrogate compound during preparation and analysis is presumed to coincide with a similar loss of the target analyte. Surrogate compounds must be added to field and QC samples prior to extraction, or according to the utilized method or SOP. Surrogate recovery data are to be carefully monitored. If possible, isotopically labeled analogs of the analytes are to be used as surrogates.

13.2.15.Internal Standards

To optimize gas chromatography mass spectrometry (GC-MS) analysis, internal standards (also referred to as “injection internal standards”) may be added to field and QC sample extracts prior to injection. Use of internal standards is particularly important for analysis of complex extracts subject to retention time shifts relative to the analysis of standards. The internal standards can also be used to detect and correct for problems in the GC injection port or other parts of the instrument. The analyst must monitor internal standard retention times and recoveries to determine if instrument maintenance or repair or changes in analytical procedures are indicated. Corrective action is initiated based on the judgment of the analyst. Instrument problems that affect the data or result in reanalysis must be documented properly in logbooks and internal data reports, and used by the laboratory personnel to take appropriate corrective action. Performance criteria for internal standards are established by the method or laboratory SOP.

13.2.16.Dual-Column Confirmation

Due to the high probability of false positives from single-column analyses, dual column confirmation should be applied to all gas chromatography and liquid chromatography methods that do not provide definitive identifications. It should not be restricted to instruments with electron capture detection (ECD).

13.2.17.Dilution of Samples

Final reported results must be corrected for dilution carried out during the process of analysis. In order to evaluate the QC analyses associated with an analytical batch, corresponding batch QC samples must be analyzed at the same dilution factor. For example, the results used to calculate the results of matrix spikes must be derived from results for the native sample, matrix spike, and matrix spike duplicate analyzed at the same dilution. Results derived from samples analyzed at different dilution factors must not be used to calculate QC results.

13.2.18.Laboratory Corrective Action

Failures in laboratory measurement systems include, but are not limited to: instrument malfunction, calibration failure, sample container breakage, contamination, and QC sample failure. If the failure can be corrected, the analyst must document it and its associated corrective actions in the laboratory record and complete the analysis. If the failure is not resolved, it is conveyed to the respective supervisor who should determine if the analytical failure compromised associated results. The nature and disposition of the problem must be documented in the data report that is sent to the Consultant-PM. Suggested ccorrective actions are detailed in Table 13-9.

Table 13-1. Measurement Quality Objectives - PCBs.

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Tuning[2]	Per analytical method	Per analytical method
Calibration	Initial method setup or when the calibration verification fails	• Correlation coefficient (r^2 >0.990) for linear and non-linear curves • If RSD<15%, average RF may be used to quantitate; otherwise use equation of the curve • First- or second-order curves only (not forced through the origin) • Refer to SW-846 methods for SPCC and CCC criteria[2] • Minimum of 5 points per curve (one of them at or below the RL)
Calibration Verification	Per 12 hours	• Expected response or expected concentration ±20% • RF for SPCCs=initial calibration[4]
Laboratory Blank	Per 20 samples or per analytical batch, whichever is more frequent	<RL for target analytes
Reference Material	Per 20 samples or per analytical batch	70-130% recovery if certified; otherwise, 50-150% recovery
Matrix Spike	Per 20 samples or per analytical batch, whichever is more frequent	50-150% or based on historical laboratory control limits (average±3SD)
Matrix Spike Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	50-150% or based on historical laboratory control limits (average±3SD); RPD<25%
Surrogate	Included in all samples and all QC samples	Based on historical laboratory control limits (50-150% or better)
Internal Standard	Included in all samples and all QC samples (as available)	Per laboratory procedure
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	5% of total Project sample count (sediment and water samples only)	RPD<25% (n/a if concentration of either sample<RL)
Field Blank	Not required for the Monitoring Program	<RL for target analytes

Table 13-2. Measurement Quality Objectives – Inorganic Analytes.

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Calibration Standard	Per analytical method or manufacturer's specifications	Per analytical method or manufacturer's specifications
Continuing Calibration Verification	Per 10 analytical runs	80-120% recovery
Laboratory Blank	Per 20 samples or per analytical batch, whichever is more frequent	<RL for target analyte
Reference Material	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery
Matrix Spike Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	75-125% recovery ; RPD<25%
Laboratory Duplicate	Per 20 samples or per analytical batch, whichever is more frequent	RPD<25% (n/a if concentration of either sample<RL)
Internal Standard	Accompanying every analytical run when method appropriate	60-125% recovery
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	5% of total Project sample count	RPD<25% (n/a if concentration of either sample<RL), unless otherwise specified by method
Field Blank, Equipment Field, Eqpt Blanks	Not required for the Monitoring Program	Blanks<RL for target analyte

Table 13-3. Measurement Quality Objectives – Conventional Analytes.

Laboratory Quality Control	Frequency of Analysis	Measurement Quality Objective
Calibration Standard	Per analytical method or manufacturer's specifications	Per analytical method or manufacturer's specifications
Laboratory Blank	Total organic carbon only: one per 20 samples or per analytical batch, whichever is more frequent (n/a for other parameters)	80-120% recovery
Reference Material	One per analytical batch	RPD<25% (n/a if native concentration of either sample<RL)
Laboratory Duplicate	(TOC only) one per 20 samples or per analytical batch, whichever is more frequent (n/a for other parameters)	80-120% recovery
Field Quality Control	**Frequency of Analysis**	**Measurement Quality Objective**
Field Duplicate	5% of total Project sample count	RPD<25% (n/a if concentration of either sample<RL)
Field Blank, Travel Blank, Field Blanks	Not required for the Monitoring Program analytes	NA

Consistent with SWAMP QAPP and as applicable, percent moisture should be reported with each batch of sediment samples. Sediment data must be reported on a dry weight basis.

Table 13-4. Target MRLs for Sediment Quality Parameters.

Analyte	MRL
Sediment Total Organic Carbon	0.01% OC
Bulk Density	n/a
%Moisture	n/a
%Lipids	n/a
Mercury	30 µg/kg

Table 13-5. Target MRLs for PCBs in Water, Sediment and Caulk

Congener	Water MRL (µg/L)	Sediment MRL (µg/kg)	Caulk/Sealant MRL (µg/kg)
PCB 8	0.002	0.2	0.5
PCB 18	0.002	0.2	0.5
PCB 28	0.002	0.2	0.5
PCB 31	0.002	0.2	0.5
PCB 33	0.002	0.2	0.5
PCB 44	0.002	0.2	0.5
PCB 49	0.002	0.2	0.5
PCB 52	0.002	0.2	0.5
PCB 56	0.002	0.2	0.5
PCB 60	0.002	0.2	0.5
PCB 66	0.002	0.2	0.5
PCB 70	0.002	0.2	0.5
PCB 74	0.002	0.2	0.5
PCB 87	0.002	0.2	0.5
PCB 95	0.002	0.2	0.5
PCB 97	0.002	0.2	0.5
PCB 99	0.002	0.2	0.5
PCB 101	0.002	0.2	0.5
PCB 105	0.002	0.2	0.5
PCB 110	0.002	0.2	0.5
PCB 118	0.002	0.2	0.5
PCB 128	0.002	0.2	0.5
PCB 132	0.002	0.2	0.5
PCB 138	0.002	0.2	0.5
PCB 141	0.002	0.2	0.5
PCB 149	0.002	0.2	0.5
PCB 151	0.002	0.2	0.5
PCB 153	0.002	0.2	0.5
PCB 156	0.002	0.2	0.5
PCB 158	0.002	0.2	0.5
PCB 170	0.002	0.2	0.5
PCB 174	0.002	0.2	0.5
PCB 177	0.002	0.2	0.5
PCB 180	0.002	0.2	0.5
PCB 183	0.002	0.2	0.5
PCB 187	0.002	0.2	0.5
PCB 194	0.002	0.2	0.5
PCB 195	0.002	0.2	0.5
PCB 201	0.002	0.2	0.5
PCB 203	0.002	0.2	0.5

Table 13-6. Size Distribution Categories for Grain Size in Sediment

Wentworth Size Category	Size	MRL
Clay	<0.0039 mm	1%
Silt	0.0039 mm to <0.0625 mm	1%
Sand, very fine	0.0625 mm to <0.125 mm	1%
Sand, fine	0.125 mm to <0.250 mm	1%
Sand, medium	0.250 mm to <0.5 mm	1%
Sand, coarse	0.5 mm to < 1.0 mm	1%
Sand, very coarse	1.0 mm to < 2 mm	1%
Gravel	2 mm and larger	1%

Table 13-7. Target MRLs for TOC, SSC, and Mercury in Water

Analyte	MRL
Total Organic Carbon	0.6 mg/L
Suspended Sediment Concentration	0.5 mg/L
Mercury	0.0002 µg/L

Table 13-8. Corrective Action – Laboratory and Field Quality Control

Laboratory Quality Control	Recommended Corrective Action
Calibration	Recalibrate the instrument. Affected samples and associated quality control must be reanalyzed following successful instrument recalibration.
Calibration Verification	Reanalyze the calibration verification to confirm the result. If the problem continues, halt analysis and investigate the source of the instrument drift. The analyst should determine if the instrument must be recalibrated before the analysis can continue. All of the samples not bracketed by acceptable calibration verification must be reanalyzed.
Laboratory Blank	Reanalyze the blank to confirm the result. Investigate the source of contamination. If the source of the contamination is isolated to the sample preparation, the entire batch of samples, along with the new laboratory blanks and associated QC samples, should be prepared and/or re-extracted and analyzed. If the source of contamination is isolated to the analysis procedures, reanalyze the entire batch of samples. If reanalysis is not possible, the associated sample results must be flagged to indicate the potential presence of the contamination.
Reference Material	Reanalyze the reference material to confirm the result. Compare this to the matrix spike/matrix spike duplicate recovery data. If adverse trends are noted, reprocess all of the samples associated with the batch.
Matrix Spike	The spiking level should be near the midrange of the calibration curve or at a level that does not require sample dilution. Reanalyze the matrix spike to confirm the result. Review the recovery obtained for the matrix spike duplicate. Review the results of the other QC samples (such as reference materials) to determine if other analytical problems are a potential source of the poor spike recovery.
Matrix Spike Duplicate	The spiking level should be near the midrange of the calibration curve or at a level that does not require sample dilution. Reanalyze the matrix spike duplicate to confirm the result. Review the recovery obtained for the matrix spike. Review the results of the other QC samples (such as reference materials) to determine if other analytical problems are a potential source of the poor spike recovery.
Internal Standard	Check the response of the internal standards. If the instrument continues to generate poor results, terminate the analytical run and investigate the cause of the instrument drift.
Surrogate	Analyze as appropriate for the utilized method. Troubleshoot as needed. If no instrument problem is found, samples should be re-extracted and reanalyzed if possible.
Field Quality Control	**Recommended Corrective Action**
Field Duplicate	Visually inspect the samples to determine if a high RPD between results could be attributed to sample heterogeneity. For duplicate results due to matrix heterogeneity, or where ambient concentrations are below the reporting limit, qualify the results and document the heterogeneity. All failures should be communicated to the project coordinator, who in turn will follow the process detailed in the method.
Field Blank	Investigate the source of contamination. Potential sources of contamination include sampling equipment, protocols, and handling. The laboratory should report evidence of field contamination as soon as possible so corrective actions can be implemented. Samples collected in the presence of field contamination should be flagged.

14. Inspection/Acceptance for Supplies and Consumables

Each sampling event conducted for the Monitoring Program will require use of appropriate consumables to reduce likelihood of sample contamination. The Field-PM will be responsible for ensuring that all supplies are appropriate prior to their use. Inspection requirements for sampling consumables and supplies are summarized in Table 14-1.

Table 14-1. Inspection / Acceptance Testing Requirements for Consumables and Supplies

Project-related Supplies	Inspection / Testing Specifications	Acceptance Criteria	Frequency	Responsible Person Sampling Containers
Sampling supplies	Visual	Appropriateness; no evident contamination or damage; within expiration date	Each purchase	Field Crew Leader

15. Non Direct Measurements, Existing Data

No data from external sources are planned to be used with this project.

16. Data Management

As previously discussed, the Monitoring Program data management will conform to protocols dictated by the study designs (BASMAA 2017a, b). A summary of specific data management aspects is provided below.

16.1. Field Data Management

All field data will be reviewed for legibility and errors as soon as possible after the conclusion of sampling. All field data that is entered electronically will be hand-checked at a rate of 10% of entries as a check on data entry. Any corrective actions required will be documented in correspondence to the QA Officer.

16.2. Laboratory Data Management

Record keeping of laboratory analytical data for the proposed project will employ standard record-keeping and tracking practices. All laboratory analytical data will be entered into electronic files by the instrumentation being used or, if data is manually recorded, then it will be entered by the analyst in charge of the analyses, per laboratory standard procedures.

Following the completion of internal laboratory quality control checks, analytical results will be forwarded electronically to the Field-PM. The analytical laboratories will provide data in electronic format, encompassing both a narrative and electronic data deliverable (EDD).

17. Assessments and Response Actions

17.1. Readiness Reviews

The Field-PM will review all field equipment, instruments, containers, and paperwork to ensure that everything is ready prior to each sampling event. All sampling personnel will be given a brief review of the goals and objectives of the sampling event and the sampling procedures and equipment that will be used to achieve them. It is important that all field equipment be clean and ready to use when it is needed. Therefore, prior to using all sampling and/or field measurement equipment, each piece of equipment will be checked to make sure that it is in proper working order. Equipment maintenance records will be checked to ensure that all field instruments have been properly maintained and that they are ready for use. Adequate supplies of all preservatives, bottles, labels, waterproof pens, etc. will be checked before each field event to make sure that there are sufficient supplies to successfully support each sampling event, and, as applicable, are within their expiration dates. It is important to make sure that all field activities and measurements are properly recorded in the field. Therefore, prior to starting each field event, necessary paperwork such as logbooks, chain of custody record forms, etc. will be checked to ensure that sufficient amounts are available during the field event. In the event that a problem is discovered during a readiness review it will be noted in the field log book and corrected before the field crew is deployed. The actions taken to correct the problem will also be documented with the problem in the field log book. This information will be communicated by the Field-PM prior to conducting relevant sampling. The Field-PM will track corrective actions taken.

17.2. Post Sampling Event Reviews

The Field-PM will be responsible for post sampling event reviews. Any problems that are noted will be documented along with recommendations for correcting the problem. Post sampling event reviews will be conducted following each sampling event in order to ensure that all information is complete and any deviations from planned methodologies are documented. Post sampling event reviews will include field sampling activities and field measurement documentation in order to help ensure that all information is complete. The reports for each post sampling event will be used to identify areas that may be improved prior to the next sampling event.

17.3. Laboratory Data Reviews

The Field-PM will be responsible for reviewing the laboratory's data for completeness and accuracy. The data will also be checked to make sure that the appropriate methods were used and that all required QC data was provided with the sample analytical results. Any laboratory data that is discovered to be incorrect or missing will immediately be reported to the both the laboratory and Consultant-PM. The laboratory's QA manual details the procedures that will be followed by laboratory personnel to correct any invalid or missing data. The Consultant-PM has the authority to request re-testing if a review of any of the laboratory data is found to be invalid or if it would compromise the quality of the data and resulting conclusions from the proposed project.

18. Instrument/Equipment Testing, Inspection and Maintenance

18.1. Field Equipment

Field measurement equipment will be checked for operation in accordance with manufacturer's specifications. All equipment will be inspected for damage when first employed and again when returned from use. Maintenance logs will be kept and each applicable piece of equipment will have its own log that documents the dates and description of any problems, the action(s) taken to correct problem(s), maintenance procedures, system checks, follow-up maintenance dates, and the person responsible for maintaining the equipment.

18.2. Laboratory Equipment

All laboratories providing analytical support for chemical or biological analyses will have the appropriate facilities to store, prepare, and process samples. Moreover, appropriate instrumentation and staff to provide data of the required quality within the schedule required by the program are also required. Laboratory operations must include the following procedures:

- A program of scheduled maintenance of analytical balances, microscopes, laboratory equipment, and instrumentation.
- Routine checking of analytical balances using a set of standard reference weights (American Society of Testing and Materials (ASTM) Class 3, NIST Class S-1, or equivalents).
- Checking and recording the composition of fresh calibration standards against the previous lot, wherever possible. Acceptable comparisons are < 2% of the previous value.
- Recording all analytical data in bound (where possible) logbooks, with all entries in ink, or electronic format.
- Monitoring and documenting the temperatures of cold storage areas and freezer units once per week.
- Verifying the efficiency of fume hoods.
- Having a source of reagent water meeting ASTM Type I specifications (ASTM, 1984) available in sufficient quantity to support analytical operations. The conductivity of the reagent water will not exceed 18 megaohms at 25°C. Alternately, the resistivity of the reagent water will exceed 10 mmhos/cm.
- Labeling all containers used in the laboratory with date prepared, contents, initials of the individual who prepared the contents, and other information, as appropriate.
- Dating and safely storing all chemicals upon receipt. Proper disposal of chemicals when the expiration date has passed.
- Having QAPP, SOPs, analytical methods manuals, and safety plans readily available to staff.
- Having raw analytical data, such as chromatograms, accessible so that they are available upon request.

Laboratories will maintain appropriate equipment per the requirements of individual laboratory SOPs and will be able to provide information documenting their ability to conduct the analyses with the required level of data quality. Such information might include results from interlaboratory comparison studies, control charts and summary data of internal QA/QC checks, and results from certified reference material analyses.

19. Instrument/Equipment Calibration and Frequency

19.1. Field Measurements

Any equipment used should be visually inspected during mobilization to identify problems that would result in loss of data. As appropriate, equipment-specific SOPs should be consulted for equipment calibration.

19.2. Laboratory Analyses

19.2.1. In-house Analysis – XRF Screening

A portable XRF analyzer will be used as a screening tool to estimate the chlorine concentration in each caulk sample. Since caulk often contains in excess of 1% PCBs and detection limits of portable XRF may be in the ppm range, the portable XRF may be able to detect chlorine within caulk containing PCBs down to about 0.1%. The analysis will be performed on the field samples using a test stand. The analyzer will be calibrated for chlorine using plastic pellet European reference materials (EC680 and EC681) upon first use, and standardized each time the instrument is turned on and prior to any caulk Cl analysis. The standardization procedure will entail a calibration analysis of the materials provided/recommended with the XRF analyzer. Analyses will be conducted in duplicate on each sample and notes kept. The mean will be used for comparison to GC–MS results.

19.2.2. Contract Laboratory Analyses

The procedures for and frequency of calibration will vary depending on the chemical parameters being determined. Equipment is maintained and checked according to the standard procedures specified in each laboratory's instrument operation instruction manual.

Upon initiation of an analytical run, after each major equipment disruption, and whenever on-going calibration checks do not meet recommended DQOs (see Section 13), analytical systems will be calibrated with a full range of analytical standards. Immediately after this procedure, the initial calibration must be verified through the analysis of a standard obtained from a different source than the standards used to calibrate the instrumentation and prepared in an independent manner and ideally having certified concentrations of target analytes of a CRM or certified solution. Frequently, calibration standards are included as part of an analytical run, interspersed with actual samples.

Calibration curves will be established for each analyte and batch analysis from a calibration blank and a minimum of three analytical standards of increasing concentration, covering the range of expected sample concentrations. Only those data resulting from quantification within the demonstrated working calibration range may be reported by the laboratory.

The calibration standards will be prepared from reference materials available from the EPA repository, or from available commercial sources. The source, lot number, identification, and purity of each reference material will be recorded. Neat compounds will be prepared weight/volume using a calibrated analytical balance and Class A volumetric flasks. Reference solutions will be diluted using Class A volumetric glassware. Individual stock standards for each analyte will be prepared. Combination working standards will be prepared by volumetric dilution of the stock standards. The calibration standards will be stored at -20º C. Newly prepared standards will be compared with existing standards prior to their use. All solvents used will be commercially available, distilled in glass, and judged suitable for analysis of selected chemicals. Stock standards and intermediate standards are prepared on an annual basis and working standards are prepared every three months.

Sampling and analytical logbooks will be kept to record inspections, calibrations, standard identification numbers, the results of calibrations, and corrective action taken. Equipment logs will document instrument usage, maintenance, repair and performance checks. Daily calibration data will be stored with the raw sample data

20. Data Review, Verification, and Validation

Defining data review, verification, and validation procedures helps to ensure that Monitoring Plan data will be reviewed in an objective and consistent manner. Data review is the in-house examination to ensure that the data have been recorded, transmitted, and processed correctly. The Field-PM will be responsible for initial data review for field forms and field measurements; QA Officer will be responsible for doing so for data reported by analytical laboratories. This includes checking that all technical criteria have been met, documenting any problems that are observed and, if possible, ensuring that deficiencies noted in the data are corrected.

In-house examination of the data produced from the proposed Monitoring Program will be conducted to check for typical types of errors. This includes checking to make sure that the data have been recorded, transmitted, and processed correctly. The kinds of checks that will be made will include checking for data entry errors, transcription errors, transformation errors, calculation errors, and errors of data omission.

Data generated by Program activities will be reviewed against MQOs that were developed and documented in Section 13. This will ensure that the data will be of acceptable quality and that it will be SWAMP-comparable with respect to minimum expected MQOs.

QA/QC requirements were developed and documented in Sections 13.1 and 13.2, and the data will be checked against this information. Checks will include evaluation of field and laboratory duplicate results, field and laboratory blank data, matrix spike recovery data, and laboratory control sample data pertinent to each method and analytical data set. This will ensure that the data will be SWAMP-comparable with respect to quality assurance and quality control procedures.

Field data consists of all information obtained during sample collection and field measurements, including that documented in field log books and/or recording equipment, photographs, and chain of custody forms. Checks of field data will be made to ensure that it is complete, consistent, and meets the data management requirements that were developed and documented in Section 13.1.

Lab data consists of all information obtained during sample analysis. Initial review of laboratory data will be performed by the laboratory QA/QC Officer in accordance with the lab's internal data review procedures. However, upon receipt of laboratory data, the Lab-PM will perform independent checks to ensure that it is complete, consistent, and meets the data management requirements that were developed and documented in Section 13.2. This review will include evaluation of field and laboratory QC data and also making sure that the data are reported in compliance with procedures developed and documented in Section 7.

Data verification is the process of evaluating the completeness, correctness, and conformance / compliance of a specific data set against the method, procedural, or contractual specifications. The Lab-PM and Data Manager will conduct data verification, as described in Section 13 on Quality Control, in order to ensure that it is SWAMP-comparable with respect to completeness, correctness, and conformance with minimum requirements.

Data will be separated into three categories for use with making decisions based upon it. These categories are: (1) data that meets all acceptance requirements, (2) data that has been determined to be unacceptable for use, and (3) data that may be conditionally used and that is flagged as per US EPA specifications.

21. Verification and Validation Methods

Defining the methods for data verification and validation helps to ensure that Program data are evaluated objectively and consistently. For the proposed Program many of these methods have been described in Section 20. Additional information is provided below.

All data records for the Monitoring Program will be checked visually and will be recorded as checked by the checker's initials as well as with the dates on which the records were checked. Consultant Team staff will perform an independent re-check of at least 10% of these records as the validation methodology.

All of the laboratory's data will be checked as part of the verification methodology process. Each contract laboratory's Project Analyst will conduct reviews of all laboratory data for verification of their accuracy.

Any data that is discovered to be incorrect or missing during the verification or validation process will immediately be reported to the Consultant-PM. If errors involve laboratory data then this information will also be reported to the laboratory's QA Officer. Each laboratory's QA manual details the procedures that will be followed by laboratory personnel to correct any invalid or missing data. The laboratory’s QA Officer will be responsible for reporting and correcting any errors that are found in the data during the verification and validation process.

If there are any data quality problems identified, the QA Officer will try to identify whether the problem is a result of project design issues, sampling issues, analytical methodology issues, or QA/QC issues (from laboratory or non-laboratory sources). If the source of the problems can be traced to one or more of these basic activities then the person or people in charge of the areas where the issues lie will be contacted and efforts will be made to immediately resolve the problem. If the issues are too broad or severe to be easily corrected then the appropriate people involved will be assembled to discuss and try to resolve the issue(s) as a group. The QA Officer has the final authority to resolve any issues that may be identified during the verification and validation process.

22. Reconciliation with User Requirements

The purpose of the Monitoring Program is to comply with Provisions of the MRP and provide data that can be used to identify sources of PCBs to urban runoff, and to evaluate management action effectiveness in removing POCs from urban runoff in the Bay Area. The objectives of the Monitoring Program are to provide the following outcomes:

1. Satisfy MRP Provision C.8.f. requirements for POC monitoring for source identification;

2. Satisfy MRP Provision C.12.e.ii requirements to evaluate PCBs presence in caulks/sealants used in storm drain or roadway infrastructure in public ROWs;
3. Report the range of PCB concentrations observed in 20 composite samples of caulk/sealant collected from structures installed or rehabilitated during the 1970's;
4. Satisfy MRP Provision C.8.f. requirements for POC monitoring for management action effectiveness;
5. Quantify the annual mass of mercury and PCBs captured in HDS Unit sumps during maintenance; and
6. Identify BSM mixtures for future field testing that provide the most effective mercury and PCBs treatment in laboratory column tests.

Information from field data reports (including field activities, post sampling events, and corrective actions), laboratory data reviews (including errors involving data entry, transcriptions, omissions, and calculations and laboratory audit reports), reviews of data versus MQOs, reviews against QA/QC requirements, data verification reports, data validation reports, independent data checking reports, and error handling reports will be used to determine whether or not the Monitoring Program's objectives have been met. Descriptions of the data will be made with no extrapolation to more general cases.

Data from all monitoring measurements will be summarized in tables. Additional data may also be represented graphically when it is deemed helpful for interpretation purposes.

The above evaluations will provide a comprehensive assessment of how well the Program meets its objectives. The final project reports will reconcile results with project MQOs.

23. References

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24. Appendix A: Field Documentation

Caulk/Sealant Sampling Field Data Sheet	**Composite ID:**		Contractor:	Pg of Pgs
Sample ID:	Date (mm/dd/yyyy):		Personnel:	Failure Reason
Photos (Y / N)	ArrivalTime:	DepartureTime:		
Photo Log Identifier	**Land-Use at the Sample Location:**		Commercial (pre-1980; post 1980)	Open Space
	Industrial (pre-1980; post-1980)		Residential (pre 1980; post 1980)	Other:

Description of Structure: (Do not include any information on the location of the structure)						**Diagram of Structure (if needed) to identify where caulk/sealants were located in/on structure**
Structure Type:	Storm Drain Catch Basin	Roadway Surface	Sidewalk	Curb/Gutter	Bridge	
	Other:					
Structure Material:	Concrete	Asphalt	Other:			
Condition of Structure:	Good	Fair	Poor	Other:		
Year of Strucutre Construction						
Year of Repair						
Description of Caulk or Sealant Sample Collected:						

Application or Usage	Caulk	caulk between adjoining surfaces of same material (e.g., concrete-concrete); Describe:					
		caulk between adjoining surfaces of different types of material (e.g., concrete-asphalt); Describe:					
		Other:					
	Sealant	Crack Repair (describe):					
		Other:					
Color							
Texture	Hard/brittle	Soft/pliable	Other:				
Condition	Good (intact/whole)	Poor (crumbling/disintegrating)	Other:				
Location	Surface	Between Joints	Submerged	Exposed	At street level	Below street level	Other:
Amount of Caulk/Sealant observed on structure	Crack dimensions:		Spacing of expansion joints				
	Length&width of caulk bead sampled:				Other:		

Samples Taken	
COLLECTION DEVICE:	Equiptment type used:
SITE/SAMPLING DESCRIPTION AND COMMENTS:	

HDS Unit Sampling Field Data Sheet (Sediment Chemistry)

Contractor:
Pg of Pgs

City:
Date (mm/dd/yyyy): / /
*Contractor:
HDS Catchment ID:
ArrivalTime:
DepartureTime:
*SampleTime (1st sample):
Failure Reason
Personnel:

Photos (Y / N)
Photo Log Identifier

*GPS/DGPS	Lat (dd.ddddd)	Long (ddd.ddddd)
Target (if known):		
***Actual:**		

GPS Device:

Address, Location, and Sketches (if needed)

Estimate of Volume of Sediment in the HDS unit sump prior to cleanout:	
Estimate of Volume of Sediment REMOVED from the HDS unit sump during the cleanout:	

Env. Conditions

WIND DIRECTION (from): N W E S

SITE ODOR:	None,Sulfides,Sewage,Petroleum,Smoke,Other_______
SKY CODE:	Clear, Partly Cloudy, Overcast, Fog, Smoky, Hazy
PRECIP:	None, Fog, Drizzle, Rain
PRECIP (last 24 hrs):	Unknown, <1", >1", None
SOILODOR:	None, Sulfides, Sewage, Petroleum, Mixed, Other_______________
SOILCOLOR:	Colorless, Green, Yellow, Brown
SOILCOMPOSITION:	Silt/Clay, Sand, Gravel, Cobble, Mixed, Debris
SOILPOSITION	Submerged, Exposed

Samples Taken (3 digit ID nos. of containers filled)

Field Dup at Site? YES / NO: (create separate datasheet for FDs, with unique IDs (i.e., blind samples)

COLLECTION DEVICE: Equiptment type used: Scoop (SS / PC / PE), Core (SS / PC / PE), Grab (Van Veen / Eckman / Petite Ponar), Broom (nylon, natural fiber)

Sample ID (City-Catchment ID-Sample	DepthCollec (cm)	Composite / Grab (C / G)	Grain Size	PCBs	Hg	Bulk Density	TOC	OTHER		

SITE/SAMPLING DESCRIPTION AND COMMENTS:

Stormwater Field Data Sheet (Water Chemistry)			Entered in d-base (initial/date)			Pg of Pgs
***Station Code:**	*Date (mm/dd/yyyy):	/ /			*PurposeFailure:	*Agency:
Personnel:	ArrivalTime:	DepartureTime:				*Protocol:

		*GPS/DGPS	**Lat (dd.ddddd)**	**Long (ddd.ddddd)**	OCCUPATION METHOD: Walk-in Bridge R/V __________ Other
GPS Device:		**Target:**		-	
Datum: NAD83	Accuracy (ft / m):	***Actual:**		-	Sampling Location (e.g., gutter at SW corner of 10th Street)

Habitat Observations (CollectionMethod = Habitat_generic)		WADEABILITY: Y / N / Unk	BEAUFORT SCALE (see attachment)		
SITE ODOR:	None,Sulfides,Sewage,Petroleum,Smoke,Other____				
SKY CODE:	Clear, Partly Cloudy, Overcast, Fog, Smoky, Hazy	WIND DIRECTION (from):	N W E S	**PHOTOS** (RB & LB assigned when facing downstream; RENAME to StationCode_yyyy_mm_dd_uniquecode):	
OTHER PRESENCE:	Vascular,Nonvascular,OilySheen,Foam,Trash,Other_				1: (RB / LB / BB / US / DS / ##)
DOMINANT SUBSTRATE:	Bedrock, Concrete, Cobble, Boulder, Gravel, Sand, Mud, Unk, Other_________				
WATERCLARITY:	Clear (see bottom), Cloudy (>4" vis), Murky (<4" vis)	PRECIPITATION:	None, Fog, Drizzle, Rain, Snow		2: (RB / LB / BB / US / DS / ##)
WATERODOR:	None, Sulfides, Sewage, Petroleum, Mixed, Other___	PRECIPITATION (last 24 hrs):	Unknown, <1", >1", None		
WATERCOLOR:	Colorless, Green, Yellow, Brown				3: (RB / LB / BB / US / DS / ##)
OVERLAND RUNOFF (Last 24 hrs):	none, light, moderate / heavy, unknown				
OBSERVED FLOW:	NA, Dry Waterbody Bed, No Obs Flow, Isolated Pool, Trickle (<0.1cfs), 0.1-1cfs, 1-5cfs, 5-20cfs, 20-50cfs, 50-200cfs, >200cfs				

Field Samples (Record Time Sample Collected)

Carboy ID #	Start Sample Time	End Sample Time	Sample Type (Grab=G; Integrated = I)	Collection Depth (m)	Field Dup (Yes/No)	Indiv bottle (by hand, by pole, by bucket); Teflon tubing; Kemmer; Pole & Beaker; Other

COMMENTS:

Stormwater Influent Samples – Office of Water Programs

Sample Receiving							
Date (mm/dd/yy):		Time (24 hr) :			Team Member's Initial:		
Carboy	Temperature	pH	Observations				
1							
2							
3							
4							
5							
6							
7							

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID:

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

25. Appendix B: Laboratory Standard Operating Procedures (SOPs)

APPENDIX C: PROPOSED BIOCHAR SELECTION FACTORS

The primary goal of this study is to select a biochar and bioretention soil mix (BSM) for field testing which will be conducted to assess improved removal of PCBs and mercury. The selection for field tests will be informed by column tests performed by this study. This memorandum contains a review of known biochar available in the Western United States. Five biochars are needed for column tests; nine biochars will be obtained and mixed with BSM at a ratio of 75 percent BSM and 25 percent biochar. These mixes will be tested hydraulically according to the alternative BSM specification to see which mixes pass the hydraulic requirement of an infiltration rate of 5-12 inches per hour. If more than five biochar mixes pass the hydraulic test then five will be chosen based on probable treatment efficiency and cost. Factors that will be used to determine probable treatment efficiency are pH, surface area, source material, pyrolysis method, and hydrophobicity.

Feasibility Criteria

Three criteria were chosen to screen potential biochars for sample gathering. All nine of the biochars selected for initial hydraulic testing have met reasonable expectations of cost, availability, and consistency.

Cost

Generally, biochar is a byproduct of the lumber industry or more recently household yard waste and tree trimmings. This byproduct is cheap and plentiful in certain regions especially when compared to more costly adsorbents commonly used to treat stormwater such as zeolite, activated alumina, activated carbon, or proprietary engineered media. Because even a relatively expensive biochar can be considered inexpensive when compared to other soil additives, biochars will not be excluded based solely on cost.

Availability

The selection process for the different biochars ensures that local soil suppliers have consistent access to the tested biochar in commercial quantities. To ensure availability, producers that are well established and offer biochar in commercial quantities in stock year round were prioritized.

Consistency

Biochar can be made from a variety of feedstocks and processed at various temperatures, which will produce biochars with varying properties and treatment capacities. To ensure that the biochars tested in this study will be available with the same properties, only suppliers who use a consistent feedstock and process will be considered.

Performance Criteria

Hydraulic Conductivity

A current requirement of alternative BSM is to have an infiltration rate between 5 and 12 inches per hour with a long-term infiltration rate of at least 5 inches per hour. In a previous study, the hydraulic conductivity of a biochar was studied before and after having the fines removed by sieving. The sample with fines removed had a hydraulic conductivity nearly four times higher than the one with fines (Yargicoglu et al., 2015). Any biochar amended BSM that does not achieve 5 to 12 inches per hour infiltration rate will be removed from the study.

Soil pH

There is a correlation between increased pyrolysis temperatures and increased pH, though there is a large variation between feedstocks (Cantrell et al., 2012). If the pH is raised enough it could affect plant health as several key nutrients required by plants can be immobilized in high pH soils. Ideally the biochars chosen should have a pH as close to seven as possible.

Surface Area

Surface area is arguably the most important characteristic for treatment performance. Adsorption capacity is directly related to available surface area of the adsorbent. Some biochars have been lab tested to measure surface area via N_2 adsorption but not many. From literature, a correlation between pyrolysis temperature and surface area is established, pyrolysis temperatures of 600-700 C show much higher surface areas than those produced at 500 C or less (Ahmad et al., 2014).

Hydrophobicity

Hydrophobicity is important to our study because hydrophobic substances, like PCBs, in a water solution are attracted to hydrophobic surfaces like biochar where they are adsorbed and removed from the water. Hydrophobicity is a difficult characteristic to measure, requiring either specialized equipment or lengthy experimentation. However, it has been well documented that hydrophobicity in biochar decreases as pyrolysis temperature increases (Zimmerman, 2010). The hydrophobicity in biochar is likely due to hydrophobic substances that are not completely volatilized at lower temperatures (Gray et al., 2014). Hydrophobicity in biochar will decline over time as these hydrophobic substances are consumed by microbes or oxidized, eventually making the biochar hydrophilic (Zimmerman, 2010). This is a concern for long-term treatment effectiveness if treatment depends on hydrophobicity.

Source Material and Pyrolysis Method

Many studies have compared the physical and chemical properties of biochar produced using different feedstocks and different methods of pyrolysis. However, because we have chosen to only study biochars that meet our availability requirements we do not have the option to make source material a primary selection criteria. Most of the biochars that meet our selection requirements are produced from woodchips and other industrial forestry residues. Consequently, biochars will be ordered by pyrolysis temperature. A range of pyrolysis temperatures are recommended since low temperatures tend to produce more hydrophobic biochars and higher temperatures produce biochars with more surface area (Zimmerman, 2010).

Probable Treatment Efficiency

From literature there are many factors that will affect overall treatment efficiency in a biochar. To simplify the selection process, pyrolysis temperature was chosen as the factor to represent treatment efficiency. Because pyrolysis temperature affects both surface area and hydrophobicity directly, biochars will be chosen that are produced at a wide range of temperatures. This will ensure biochars with the greatest surface area, the greatest hydrophobicity, and combinations of the two will be tested.

Table 1. Biochar Selection Table

Biochar Name	Cost ($/yd^3)	Pyrolysis Temp (Degrees C)
1. Pacific	$ 90.00	700
2. Sonoma Biochar	$ 240.00	1315
3. Rogue Biochar	$ 249.50	700
4. BioChar Now - Medium	$ 350.00	600
5. Sunriver High Porosity Biochar	$ 500.00	500
6. Biochar Solutions (CW4CB)	$ 225.00	700
7. Agrosorb	$ 250.00	900
8. BlackSorb	$ 250.00	900
9. Cool Terra CF-11	$ 700.00	600
10. Phoenix	$ 254.00	700

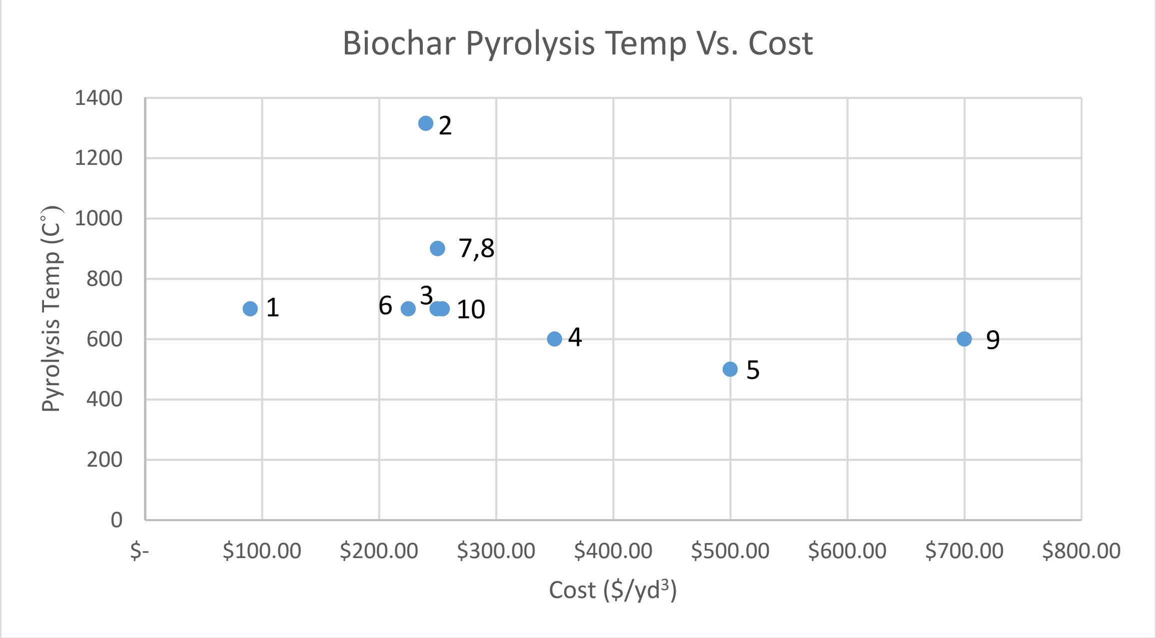

Figure 1. Biochar Pyrolysis Temperature Vs. Cost

References

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Gray, M., Johnson, M.G., Dragila, M.I., Kleber, M., Water Uptake in Biochars: The Roles of Porosity and Hydrophobicity, In Biomass and Bioenergy, Volume 61, 2014, Pages 196-205, ISSN 0961-9534, https://doi.org/10.1016/j.biombioe.2013.12.010.

APPENDIX D: HYDRAULIC TEST RESULTS

Blacksorb biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
43.7	35.1	8.6	46	240	0.001051	0.565789	19.9	0.001858	0.00186303	2.640514
42.75	27.6	15.15	49.5	150	0.00181	0.996711	19.9	0.001816	0.00182084	2.580724
42.3	24.7	17.6	49.5	135	0.002011	1.157895	19.9	0.001737	0.00174153	2.468306
									Average K	2.563181

Sonoma biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
43.98	37.1	6.88	48.8	165	0.001622	0.452632	20	0.003584	0.00358473	5.080723
43.25	32.3	10.95	48	100	0.002633	0.720395	20	0.003655	0.00365541	5.1809
42.65	28.05	14.6	47	75	0.003437	0.960526	20	0.003578	0.00357926	5.072965
									Average K	5.111529

Pacific biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
42.2	38.1	4.1	43.5	225	0.00106	0.269737	20.5	0.003931	0.0038846	5.505762
42.1	38	4.1	43	225	0.001048	0.269737	20.5	0.003886	0.00384	5.442478
40.4	34.2	6.2	43	150	0.001572	0.407895	20.5	0.003855	0.003809	5.398587
35.2	24.15	11.05	45	90	0.002742	0.726974	20.5	0.003772	0.0037276	5.283264
									Average K	5.407523

Sunriver biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
43.2	40.7	2.5	47	280	0.000921	0.164474	21.5	0.005598	0.005399934	7.65345
42.8	39.6	3.2	47.5	210	0.001241	0.210526	21.5	0.005893	0.005684771	8.057156
41.7	36.6	5.1	46	128	0.001971	0.335526	21.5	0.005875	0.005667171	8.032211
39.85	32.2	7.65	48	90	0.002925	0.503289	21.5	0.005812	0.00560694	7.946844
39.4	31.8	7.6	46.5	90	0.002834	0.5	21.5	0.005668	0.005467458	7.749154
34.5	22.5	12	200	255	0.004302	0.789474	21.5	0.005449	0.005256507	7.450167
33.4	22.3	11.1	200	255	0.004302	0.730263	21.5	0.005891	0.00568271	8.054234
33.1	22.2	10.9	200	305	0.003597	0.717105	21.5	0.005015	0.004838294	6.857425
32.5	22.15	10.35	200	305	0.003597	0.680921	21.5	0.005282	0.005095402	7.221829
									Average K	7.669163

Rogue biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm		viscosity at 20		1.0034
Area	182.3222	cm2		viscosity at 22		0.955
				Ratio		0.951764

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.65	42.5	2.15	40	270	0.000813	0.141447	22	0.005745	0.005476319	7.761713
43.5	35.75	7.75	48.5	90	0.002956	0.509868	22	0.005797	0.005526225	7.832444
43.3	34.75	8.55	45	75	0.003291	0.5625	22	0.00585	0.005577199	7.904691
42.6	31.5	11.1	46.5	60	0.004251	0.730263	22	0.005821	0.005548936	7.864634
42	28.75	13.25	41.7	45	0.005083	0.871711	22	0.005831	0.005558258	7.877845
43	34.95	8.05	50.5	90	0.003078	0.529605	22	0.005811	0.005539671	7.851503
									Average K	7.848805

Phoenix biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
42.58	39.9	2.68	49	210	0.00128	0.176316	19.5	0.007258	0.007349893	10.41717
40.3	34.9	5.4	47.5	100	0.002605	0.355263	19.5	0.007333	0.007425726	10.52465
38.9	31.65	7.25	49.2	80	0.003373	0.476974	19.5	0.007072	0.007161041	10.14951
									Average K	10.36378

Voss Compacted to 85% MDD of Standard Proctor

Length	15.2	cm		viscosity at 20		1.0034
Area	182.3222	cm2		viscosity at 21		0.979
				Ratio		0.975683

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
40.2	37.35	2.85	44.5	165	0.001479	0.1875	21	0.007889	0.007702247	10.91657
39.81	33.45	6.36	43	75	0.003145	0.418421	21	0.007515	0.007337301	10.39932
39.55	30.8	8.75	46	58	0.00435	0.575658	21	0.007557	0.00737748	10.45627
39	27.5	11.5	203	176	0.006326	0.756579	21	0.008362	0.008163413	11.57019
									Average K	10.83559

BioChar Solutions biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.2	41.7	2.5	49.5	220	0.001234	0.164474	20	0.007503	0.00750502	10.63704
43.5	39.05	4.45	49.5	120	0.002262	0.292763	20	0.007728	0.00772989	10.95575
42.7	36.48	6.22	49.5	85	0.003194	0.409211	20	0.007805	0.00780738	11.06558
42.3	35.4	6.9	46.5	70	0.003643	0.453947	20	0.008026	0.00802814	11.37847
41.45	32.7	8.75	47.8	58	0.00452	0.575658	20	0.007852	0.00785419	11.13192
									Average K	11.03375

Agrosorb biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm		viscosity at 20		1.0034
Area	182.3222	cm2		viscosity at 22		0.955
				Ratio		0.951764

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.23	40.58	3.65	47	100	0.002578	0.240132	20.4	0.010735	0.0106337	15.07137
43.09	36.4	6.69	45.2	50	0.004958	0.440132	20.4	0.011265	0.0111589	15.81576
43.05	36.3	6.75	45.4	50	0.00498	0.444079	20.4	0.011215	0.0111086	15.74453
41.82	32.2	9.62	51.2	40	0.007021	0.632895	20.4	0.011093	0.0109879	15.57337
41.82	32.09	9.73	38	30	0.006947	0.640132	20.4	0.010853	0.0107505	15.23692
40.85	28.58	12.27	39.1	25	0.008578	0.807237	20.4	0.010627	0.0105262	14.91901
40.85	28.5	12.35	39	25	0.008556	0.8125	20.4	0.010531	0.0104313	14.78446
44	39.9	4.1	41.8	85	0.002697	0.269737	20.4	0.009999	0.009905	14.03852
									Average K	15.14799

Biochar Now biochar-amended BSM Compacted to 85% MDD of Standard Proctor

Length	15.2	cm
Area	182.3222	cm2

Manometers										
H1	H2	head	Q	t	Q/At	h/L	Temp	k cm/s	k corrected	k in/hr
44.3	40.8	3.5	48	90	0.002925	0.230263	21	0.012704	0.01240272	17.57866
44	39.3	4.7	49	70	0.003839	0.309211	21	0.012417	0.01212234	17.18127
43.5	36.85	6.65	49.5	50	0.00543	0.4375	21	0.012411	0.01211713	17.17389
42.85	34.25	8.6	45.1	35	0.007068	0.565789	21	0.012491	0.01219541	17.28483
42.15	31.35	10.8	200	128	0.00857	0.710526	21	0.012061	0.01177559	16.68981
									Average K	17.18169

APPENDIX E: BIOCHAR PARTICLE SIZE DISTRIBUTION

Sieve Analysis Data Sheet

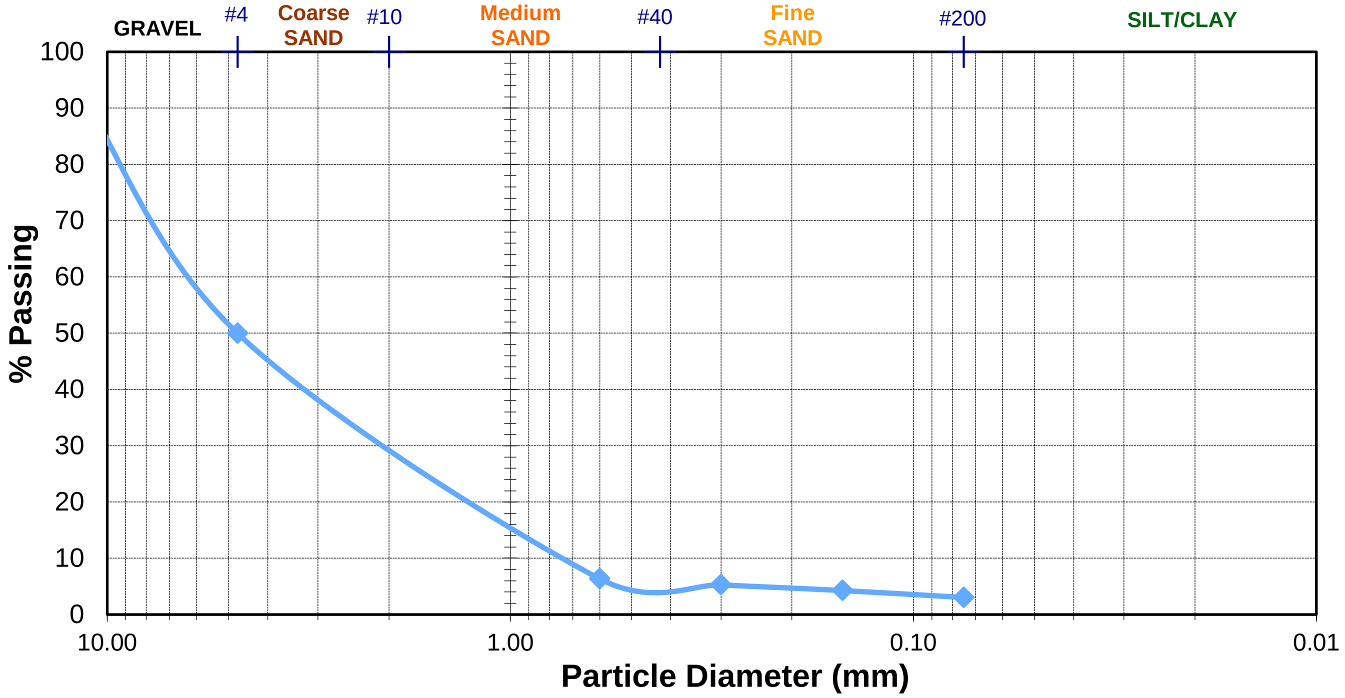
ASTM D422-63(2007)

Project Name:
Tested By: RH & JB
Date: 7/10/2018
Location:
Checked By:
Date:
Boring No:
Test Number:
Sample Depth:
Gnd Elev.:

Biochar Type: BioChar Solutions

Weight of Container (g): 52.4
Weight of Container & Soil (g): 97.0
Weight of Dry Sample (g): 44.6

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	13.9837	15.1551	1.2	2.6	97.4
4	4.75	13.9837	35.5409	21.6	47.4	50.0
30	0.60	13.9837	33.8176	19.8	43.6	6.4
50	0.30	13.9837	14.4764	0.5	1.1	5.3
100	0.15	13.9837	14.4401	0.5	1.0	4.3
200	0.075	0.7018	1.2622	0.6	1.2	3.0
Pan		0.7018	2.0797	1.4	3.0	0.0
			TOTAL:	**45.4**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: 2.6
D_{10}: 0.72
C_u: 8.61
% Sand: 94.4
D_{30}: 2.05
$C_{c:}$ 0.94
% Fines: 3
D_{60}: 6.2

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name: ________ **Tested By:** RH & JB **Date:** 7/10/2018

Location: ________ **Checked By:** ________ **Date:** ________

Boring No: ________ **Test Number:** ________

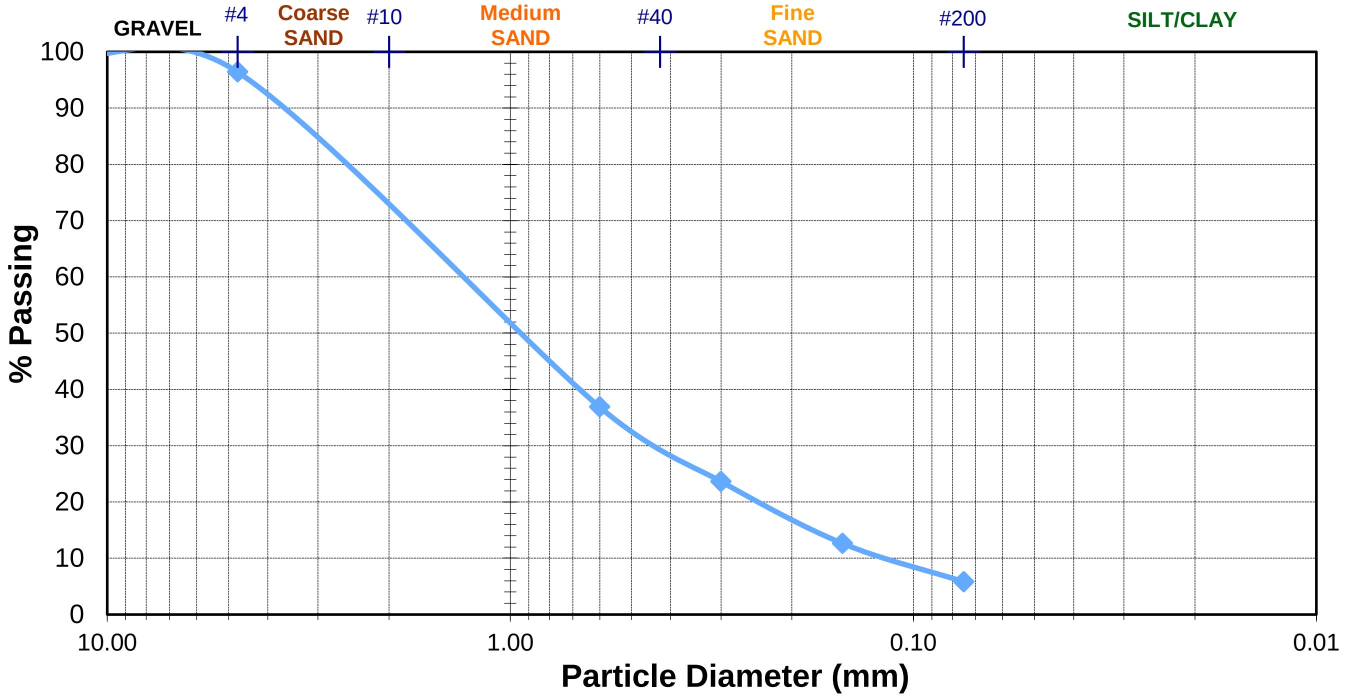
Sample Depth: ________ **Gnd Elev.:** ________

Biochar Type: Agrosorb

Weight of Container (g): 3.2 **Weight of Container & Soil (g):** 175.3

Weight of Dry Sample (g): 172.1

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	1.5896	3.1261	1.5	0.9	99.1
4	4.75	1.5896	6.1437	4.6	2.7	96.4
30	0.60	3.1792	104.6093	101.4	59.6	36.9
50	0.30	1.5896	24.1144	22.5	13.2	23.6
100	0.15	1.5896	20.3184	18.7	11.0	12.7
200	0.075	1.5896	13.1978	11.6	6.8	5.8
Pan		1.5896	11.5284	9.9	5.8	0.0
			TOTAL:	**170.3**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: 0.9 **D_{10}:** 0.11 **C_u:** 10.9

% Sand: 93.3 **D_{30}:** 0.43 **C_c:** 1.40

% Fines: 5.8 **D_{60}:** 1.2

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name: ______ **Tested By:** RH & JB **Date:** 7/10/2018

Location: ______ **Checked By:** ______ **Date:** ______

Boring No: ______ **Test Number:** ______

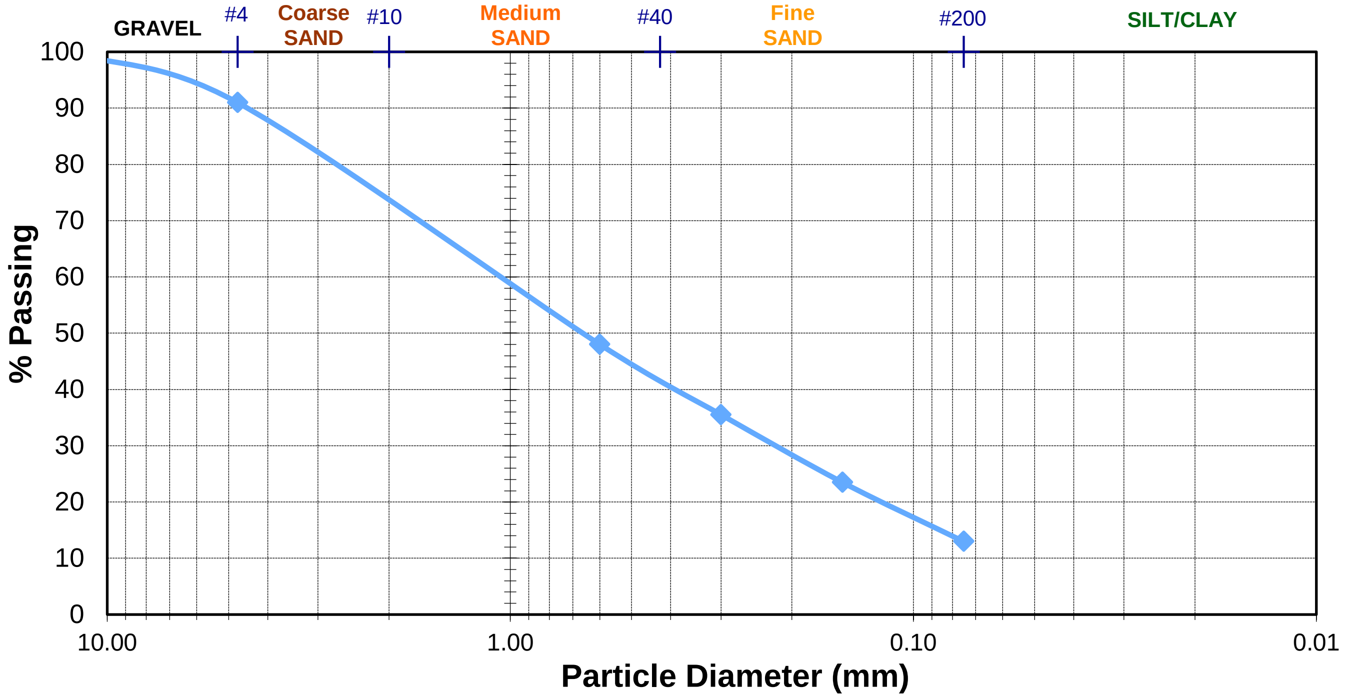
Sample Depth: ______ **Gnd Elev.:** ______

Biochar Type: Phoenix

Weight of Container (g): 2.8 **Weight of Container & Soil (g):** 241.2

Weight of Dry Sample (g): 238.4

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	0.7018	0.7018	0.0	0.0	100.0
4	4.75	0.7018	23.5505	22.8	9.0	91.0
30	0.60	13.9837	122.8911	108.9	43.0	48.0
50	0.30	1.5896	33.2888	31.7	12.5	35.5
100	0.15	1.5896	32.0522	30.5	12.0	23.5
200	0.075	1.5896	28.2517	26.7	10.5	13.0
Pan		1.5896	34.4933	32.9	13.0	0.0
			TOTAL:	**253.5**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: 0 **D_{10}:** ______ **C_u:** ______

% Sand: 87 **D_{30}:** 0.21 **C_c:** ______

% Fines: 13 **D_{60}:** 1.03

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name: ________ **Tested By:** RH & JB **Date:** 7/10/2018

Location: ________ **Checked By:** ________ **Date:** ________

Boring No: ________ **Test Number:** ________

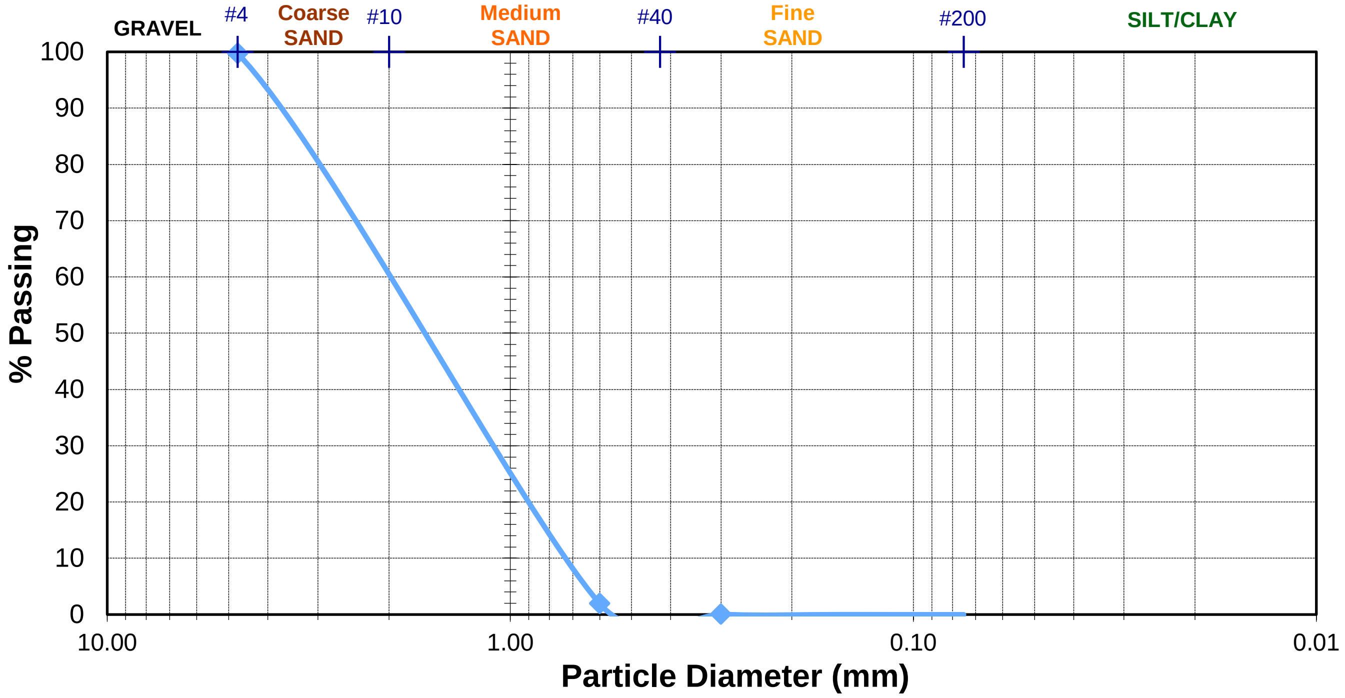
Sample Depth: ________ **Gnd Elev.:** ________

Biochar Type: Rogue

Weight of Container (g): 52.3 **Weight of Container & Soil (g):** 173.8

Weight of Dry Sample (g): 121.5

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	1.5896	1.5896	0.00	0.00	100.00
4	4.75	1.5896	1.9089	0.32	0.27	99.73
30	0.60	3.1792	119.5292	116.35	97.79	1.94
50	0.30	1.5896	3.8304	2.24	1.88	0.05
100	0.15	1.5896	1.6583	0.07	0.06	0.00
200	0.075	1.5896	1.6115	0.02	0.02	-0.02
Pan		1.5896	1.5635	-0.03	-0.02	0.00
			TOTAL:	**119.0**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: ________ **D_{10}:** ________ **C_u:** ________

% Sand: ________ **D_{30}:** ________ **C_c:** ________

% Fines: ________ **D_{60}:** ________

Sieve Analysis Data Sheet

ASTM D422-63(2007)

Project Name:

Tested By: RH & JB

Date: 7/10/2018

Location:

Checked By:

Date:

Boring No:

Test Number:

Sample Depth:

Gnd Elev.:

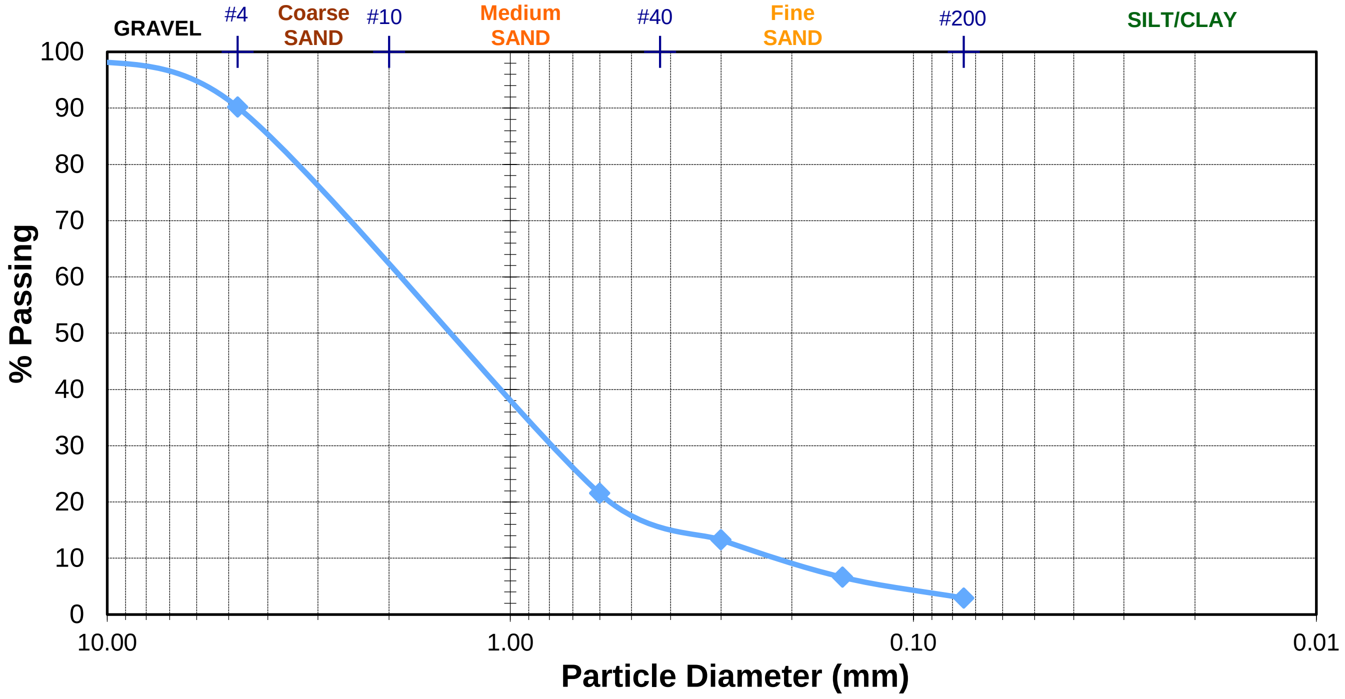
Biochar Type: **Sun River**

Weight of Container (g): 52.3

Weight of Container & Soil (g): 153.2

Weight of Dry Sample (g): 100.9

Sieve Number	Diameter (mm)	Mass of Container (g)	Mass of Container & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
0.5	12.70	1.5896	2.4228	0.8	0.8	99.2
4	4.75	1.5896	10.6182	9.0	9.0	90.2
30	0.60	1.5896	70.5872	69.0	68.7	21.5
50	0.30	1.5896	9.8777	8.3	8.2	13.3
100	0.15	1.5896	8.2566	6.7	6.6	6.6
200	0.075	1.5896	5.3083	3.7	3.7	2.9
Pan		1.5896	4.5286	2.9	2.9	0.0
			TOTAL:	**100.5**	**100.0**	



Grain Size Distribution Curve Results:

% Gravel: 0.8

% Sand: 96.3

% Fines: 2.9

D_{10}: 0.22

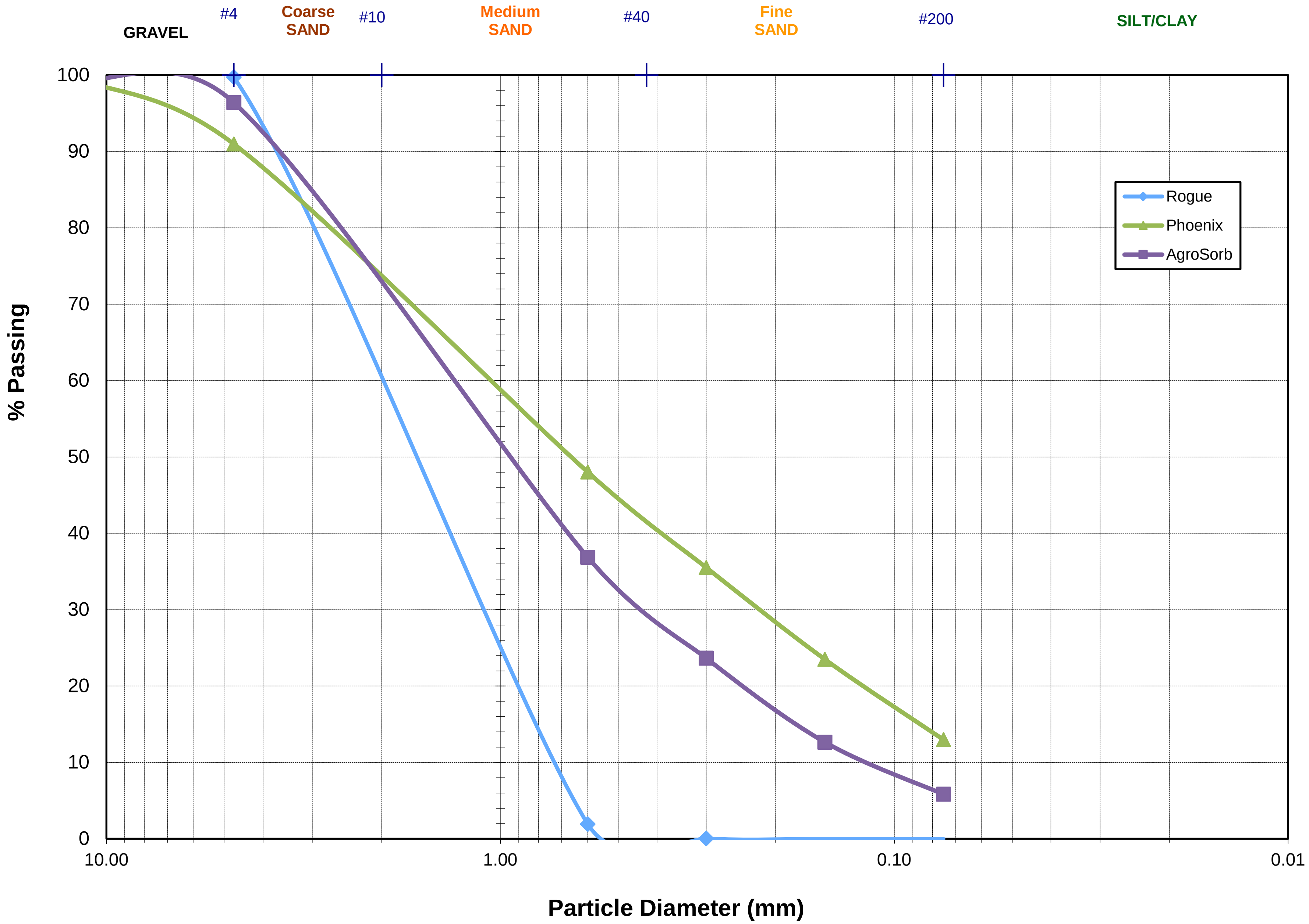
D_{30}: 0.78

D_{60}: 1.8

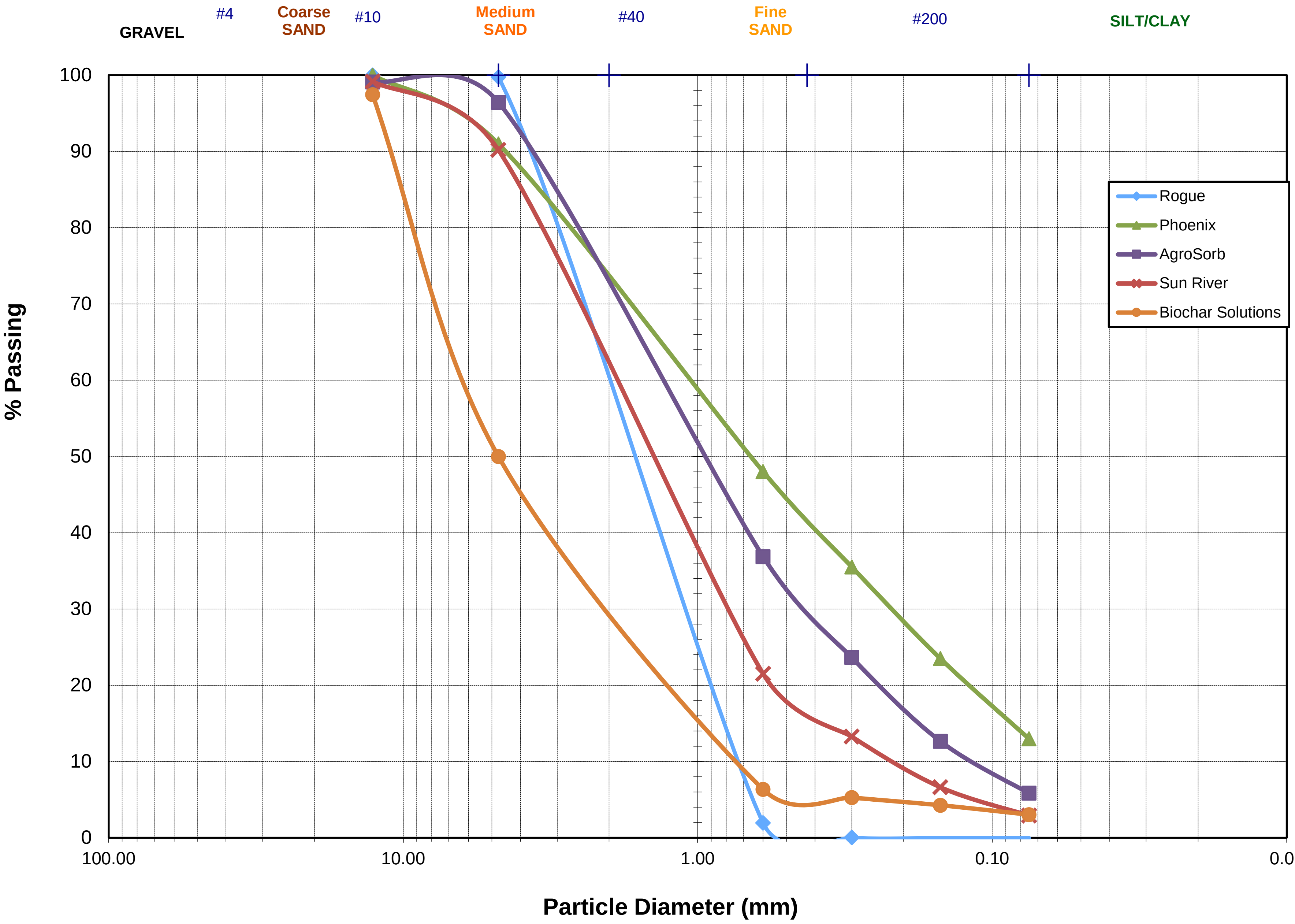
C_u: 8.18

C_c: 1.54

Appendix E: Biochar Particle Size Distribution



Appendix E: Biochar Particle Size Distribution



APPENDIX F: COLUMN TEST OBSERVATION FORMS

OCC 13.7

4/10/18 First Run

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: CO

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:25	2"	20.6			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:49	2"	18.7			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C02

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:23	9"	210			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:49	9"	204			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C05

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:26	1"	138			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:41	4"	181			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C2C1

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4:28	0"	289			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:42	1"	212			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C05

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
4.31	2"	283			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5.52	2"	234			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: C06

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
1028	1"	212			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:55	3"	335			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Stormwater Column Tests – Office of Water Programs

Sampling Run			
Date (mm/dd/yy):	Time (24 hr) :	Team Member's Initials:	Column ID: IN Fluent

During Test - Timed Measurements

Time	Water Depth	Media Condition	Other Observations

Grab Sample - Beginning of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
9:18	–	24.			

Grab Sample - Middle of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations
5:56	–	21.4			

Grab Sample - End of Run

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Grab Sample - Mercury

Time	Water Depth	Turbidity (NTU)	Temp	pH	Other Observations

Technician____________________ **Sampling Sheet** Column ID: TW2 Date: 4/10/18

Column Description Influent

Sample Run 1

Water 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	X			
2	X			
3	X	→ Start of Sampling		
4	X			
5	X			
6	X			
7	X			
8	3:46			
9	3:58			
10	4:18	Turb		
11	4:46			
12	5:02			
13	6:29			
14	X			
15	5:36			
16	5:[illegible]			
17	5:46			
18	5:55			

Observations:

Technician________________

Sampling Sheet

Column ID: C02 Date: 4/10/18

Column Description Rogue

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	3:45			
2	3:48			
3	3:20			
4	3:27			
5	3:30			
6	3:34			
7	3:41			
8	3:44			
9	3:48			
10	4:15			
11	4:20	Turb		
12	4:42			
13	4:50	Mercury		
14	5:21			
15	5:31			
16	5:37	.5?		
17	5:41			
18	5:51			

Observations:

Technician____________________

Sampling Sheet

Column ID: C01 Date: 4/10/18

Column Description Gun River

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	3:45			
2	2:48			
3	3:19			
4	3:26	Shorter lengths of		
5	3:30	4" →	dry before	next pour
6	3:33	2"	"	
7	3:40	1"		
8	3:44	.75"		
9	3:47	.4" →	dry before	next pour
10	4:15			
11	4:19	Turb		
12	4:41			
13	4:48	Mercury	grab	
14	5:20			
15	5:30			
16	5:36	.75		
17	5:40			
18	5:50			

Observations:

Technician____________________ **Sampling Sheet** Column ID: C03 Date: 6/10/18

Column Description Phoenix

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	2:45			
2	2:49			
3	3:20	Ponding		
4	3:27			
5	3:30	1.5"		
6	3:34	2.0"		
7	3:41	2.0"		
8	3:45	2.5		
9	3:49	2.75		
10	4:15	1"		
11	4:20	1.5	Turb	
12	4:43	1"		
13	4:52	[illegible]		
14	5:25	1"		
15	5:32	1"		
16	5:38	1		
17	5:41	1.5"		
18	5:51			

Observations:

Sampling Sheet

Technician____________________ Column ID: C04 Date: 4/10/18

Column Description: Biochar Solutions

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	2:45			
2	2:49			
3	3:21			
4	3:28			
5	3:31	1"		
6	3:34	1.5"		
7	3:42	1"		
8	3:45	1.5"		
9	3:50	2"		
10	4:16	.75"		
11	4:21	Turb		
12	4:44	.5"		
13	4:58	murky		
14	5:26	1"		
15	5:33	.5"		
16	5:38			
17	5:42	2"		
18	5:51			

Observations:

Technician ____________________ **Sampling Sheet** Column ID: C05 Date: 4/10/18

Column Description Black Sorb

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	2:45			
2	2:50			
3	3:22	Ponding		
4	3:28	1"		
5	3:31	1.25		
6	3:34	1.75"		
7	3:42	1.5		
8	3:46	2"		
9	3:50	2.75		
10	4:17	1"		
11	4:22	1.5"	Turb	
12	4:44	1"		
13	5:02	1"		
14	5:26	.75"		
15	5:34	1.5"		
16	5:38			
17	5:43	3"		
18	5:53	1.5"		

Observations:

Sampling Sheet

Technician____________________ Column ID: C06 Date: 4/10/18

Column Description control

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	2:45			
2	2:51			
3	3:22	Yandr 17		
4	3:28			
5	3:32	1.75"		
6	3:35	2.5"		
7	3:43	2.75"		
8	3:46	3.5"		
9	3:50	4"		
10	4:18	1.75"		
11	4:22	2"	Turb →	dropped to 0" before next sample
12	4:45	4"		
13	5:03	1"		
14	5:29	1		
15	5:34	1.5"		
16	5:40			
17	5:42	2.5"		
18	5:54	3.5"		

Observations:

Technician Michelle

Sampling Sheet

Column ID: 6

Date: 4/11/18

Column Description

Media flushing w/2-2 & 2-1

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	1:06	1		
2	/	1		
3	/	1		
4	/	2		
5	/	2.5		
6	/	2		88.5
7	2:02	1		
8	/	2		
9	/	2.5		
10	/	3		
11	/	4		
12	/	5		
13	/	3.5		
14	3:08	1		
15	/	2		
16	/	2.5		
17	3:31	2.5		
18	3:40	2		155

site 2 storm 1

Break @ 2:35

Mix of 2-1 & 2-2 half dose

9 X

Observations:

Technician Michelle

Sampling Sheet

Column ID: 5

Date: 4/11/18

Column Description

Media flushing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	1:05	0		
2	/	1		
3	/	1		
4	/	1.5		
5	/	2		
6	/	2		91.1
7	2:01	1		
8	/	2		
9	/	2.5		
10	/	3		
11	/	4		
12	/	4.5		
13	/	3		
14	3:07	0		
15	/	1		
16	/	2		
17	3:29	1		
18	3:39	0		160

19 X

Site 2 Storm 1

Break @ 2:35

Mix of 2-1 & 2-2
half dose

Observations:

Technician Michelle

Sampling Sheet

Column ID: 4

Date: 4/11/18

Column Description

Media flushing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	1:04	0		
2	/	1		
3	/	1		
4	/	1		
5	/	1		
6	/	1		105
7	2:00	1		
8	-	1.5		
9	-	2.5		
10	/	3		
11	/	4		
12	/	5		
13	/	5		
14	3:06	1		
15	/	1.5		
16	/	2		
17	3:28	1		
18	3:38	0.5		122

19 X

site 2 storm 1

Break @ 2:35

Mix of 2-1 $ 2-2

half dose

Observations:

Technician Michelle **Sampling Sheet** Column ID: 3 Date: 4/11/18

Column Description

Media Fishing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:56	0		
2	–	1		
3	/	1		
4	/	1.5		
5	/	1.5		
6	/	1		75.4
7	2:00	1		
8	/	1.5		
9	/	2.5		
10	–	3		
11	/	4		
12	/	5		
13	/	5		
14	3:05	1		
15	/	1.5		
16	/	2.5		
17	3:27	2		
18	3:38	1.5		96.1

Site 2 Storm 1

Break @ 2:35

Mix of 2-1 & 2-2 half dose

Observations:

Technician Michelle

Sampling Sheet

Column ID: 2 Date: 4/11/18

Column Description

Site 2 Flushing w/ 2-2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:35	8		
2	—	1		
3	/	1		
4	/	1		
5	/	1		
6	/	1		105
7	1:59	1		
8	/	1		
9	/	2		
10	/	2.5		
11	/	3		
12	/	4		
13	/	4		
14	3:05	1		
15	/	1		
16	/	1		
17	3:27	1		
18	3:37	0		143

Site R storm 1

Break @ 2:35

Mix of 2-1 & 2-2 half dose

17 X

Observations:

Technician Michelle **Sampling Sheet** Column ID: 1 Date: 4/11/18

Column Description

Media flushing w/ 2-2 Site 2 Storm 2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:54	0		
2	/	0		
3	/	0		
4	/			
5	/			
6	/			87.5
7	1:58	0		
8	/	0		
9	/			
10	/			
11	/			
12	/	0		
13	/			
14	3:05	0		
15	/	0		
16	/	~~3~~ 1		
17	3:25	0		
18	3:34	0		~~98.5~~ 1024

Site 2 Storm 1

Break @ 2:35

Mix of 2-1 & 2-2
half dose

Observations:

Technician Jessica/Audrey **Sampling Sheet** **Column ID:** C01 **Date:** 4/12/18

Column Description Media flushing

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	[illegible]			
3	/	1		
4	/	2		
5	/	2.2		
6	1:14	2.8		16.5
7	1:33	1.9		
8	/	2.8		
9	/	3		
10	/	4		
11	/	4.4		21.6
12	2:31	[illegible]		
13	—	1		
14	—	1		
15	—	2		
16	—	2.4		
17	—	2.4		
18	—	4		47.7

3:14

Break

Observations:

Technician Jessica/Audrey **Sampling Sheet** **Column ID:** C02 **Date:** 4/10/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2		1		
3	/	1.5		
4	/	2.2		
5	/	2.5		
6	1:15	3		15.4
7	1:34	2		
8	/	2.2		
9	/	3		
10	/	4		
11	/	4.3		28.3
12	2:31			
13	—	1.75		
14	—	2.5		
15	—	3.4		
16	—	4.0		
17	—	4.9		
18	3:14	4		45.6

BREAK

Observations:

Technician Jessica/Aubrey **Sampling Sheet** Column ID: CD 3 Date: 4/10/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	/	1		
3	/	1		
4	/	1		
5	/	1.5		
6	1:15	1.6		34.4
7	1:34	1		
8	/	1.8		
9	/	1.5		
10	/	1.8		
11	/	2.2		61.1
12	2:31	1		
13	—	1.5		
14	—	2		
15	—	3		
16	—	3.4		
17	—	3.4		
18	3:14	1.7		63.7

BREAK

Observations:

Technician Jessica/Audrey **Sampling Sheet** **Column ID:** C04 **Date:** 4/10/19

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	/			
3	/	1		
4	/	1.2		
5	/	1.7		
6	1:16	2		33.1
7	1:36	2		
8	/	1.2		
9	/	2		
10	/	2.5		
11	/	2.9		48.0
12	2:32	–		
13	–	1		
14	–	1.3		
15	–	2		
16	–	2.8		
17	–	2.8		
18	3:14	1		67.2

BREAK

Observations:

Technician Jessica/Andrey **Sampling Sheet** Column ID: C05 Date: 4/11/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	/			
3	/	1.5		
4	/	2		
5	/	2.8		
6	1:16	3.3		32.4
7	1:36	2		
8	/	2.5		
9	/	3		
10	/	3.8		
11	/	4.2		48.3
12	2:32	←		
13	—	1.2		
14	—	1.8		
15	—	2.3		
16	—	2.5		
17	—	3		
18	3:16	1		80.5

BREAK

Observations:

Technician Jessica/Audrey **Sampling Sheet** Column ID: C06 Date: 4/11/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	12:45			
2	/	1		
3	/	1.5		
4	/	1.75		
5	/	2		
6	1:17	2.75		29.3
7	1:37	1		
8	/	1.8		
9	/	2.1		
10	/	3		
11	1:53	3.6		76.5
12	2:32	1		
13	—	1.75		
14	—	2		
15	—	3		
16	—	3.5		
17	—	4		
18	—	2.8		102

— BREAK

Observations:

Technician Joel **Sampling Sheet** **Column ID:** Inf **Date:** 9/13/18

Appendix F: Column Test Observation Forms

Column Description

Sample Run 2

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:05			
2	9:10			✓
3	9:30			
4	9:40		21	
5	9:48			
6	9:51			
7	10:30			
8	10:37			✓
9	10:42			
10	10:56			
11	11:38			
12	11:49			
13	11:53			
14	11:57			
15	[illegible]			
16	12:03			
17	1:09			
18	4:12		20°C	

→ ponding

Observations: pH: 6.80 temp: 20.2°c

Technician______ **Sampling Sheet** Column ID: C01 Date: 4/13/18

Appendix F: Column Test Observation Forms

Column Description ______________________

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:01			
2	9:08			✓
3	9:27			
4	9:38			
5	9:46			
6	9:49	.5"		
7	10:29			
8	10:31			✓
9	10:40			
10	10:46			
11	11:15			
12	11:42			
13	11:50			
14	11:55			
15	12:06			
16	12:59			
17	1:04			
18	1:11	1.25		

no ponding

Observations: 19.2°C c̄ pH = 7.66

Technician Dave f **Sampling Sheet** Column ID: C02 Date: 4/13/18

Appendix F: Column Test Observation Forms

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:05			
2	9:09	1"		Stopped draining, no turb sample
3	9:25	1.25"		✓
4	9:38	2"		
5	9:46	2.75		
6	9:49	3.25"		→ removed 3 screws → flow Started again
7	10:29	1.1"		
8	10:35	1.75		
9	10:40	2.5		✓
10	10:49	2.75		
11	11:30			
12	11:42			
13	11:50			
14	11:55			
15	12:00p			→ pending
16	1:00			
17	1:05	1.5"		
18	1:17	2.25		

Observations: Very Slow this run, Very Clear effluent

pH=7.97 Temp=19.2°C

Technician JDC/ **Sampling Sheet** Column ID: C03 Date: 4/13/18

C03

Appendix F: Column Test Observation Forms

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:04			
2	9:09			✓
3	9:28			
4	9:39	1"		
5	9:47	1.25"		
6	9:49	1.75		
7	10:31			
8	10:35	?		
9	10:41	1.75		✓
10	10:50	2.1		
11	11:31			
12	11:43			
13	11:51			
14	11:55			
15	12:00			
16	1:09			
17	1:04	1.25"		
18	1:13	1.75"		

→ ponding

Observations:

pH= 7.65 Temp: 19.2°C

Technician Joel

Sampling Sheet

Column ID: CC1 Date: 9/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:21			
2	9:04			~~e~~
3	9:28			
4	9:34	0.75		
5	9:48	— ?		
6	9:49	1.5		
7	10:31			
8	10:52			
9	10:41	1		✓
10	10:53	1"		
11	11:32			
12	11:43			
13	11:51			
14	11:56			
15	12:02e			
16	1:01			
17	1:06			
18	1:14	~~#~~ .20		

→ ponding

Observations: pH= ~~[illegible]~~ 7.78 temp: 19.2°C

Technician Joel

Sampling Sheet

Column ID: C05 Date: 9/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:01			
2	9:10			✓
3	9:28			
4	9:40			
5	9:48	1"		
6	9:50	1.75		
7	10:31			
8	10:36	1"		
9	10:48	1.75		✓
10	10:55	1.75		
11	11:35			
12	11:44			
13	11:52			
14	11:56			
15	12:02			
16	1:02			
17	1:07	1"		
18	1:15	2"		

→ remove 3 screws

→ Ponding

Observations: pH = 7.77 Temp: 19.5°C

Technician Joel

Sampling Sheet

Column ID: C06 Date: 4/13/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:14			
2	9:10			✓
3	9:29			
4	9:40	.75"		
5	9:48	1.5"		
6	9:50	2"		
7	10.32			
8	10:36	1"		
9	10.42	1.5		✓
10	10:56	1.5"		
11	11:26			
12	11:44			
13	11:53			
14	11:57			
15	12:03p			
16	1:03			
17	1:08	1"		
18	1:16	1.5"		

Observations: pH: 7.94 Temp: 19.5°C

Technician: Joel

Sampling Sheet

Column ID: C01 Date: 4/17/18

Column Description

Sample Run 5

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:14			
2	10:16			
3	10:20	0.50		10.5
4	10:36			
5	10:45			
6	11:27			
7	11:32	0.50		
8	11:35	1.25		✓
9	11:40	1.75	✓	✓
10	12:18			
11	12:25	0.75		
12	12:35	1.25		
13	12:39	2.25		
14	12:47	2.75		
15	12:50	3.50		
16	12:53	4.25		
17	1:02	4.00		
18	1:06	4.50		

12

20

Observations:

Technician Joel

Sampling Sheet

Column ID: C02 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:14	0.25		
2	10:16	0.75		
3	10:20	1.5		
4	10:36	1.75		
5	10:45	2.50		2.27
6	11:27	0.75		
7	11:32	1.5		
8	11:35	2.25		
9	11:41	2.75	✓	✓
10	12:18	1.50		
11	12:25	2.00		
12	12:36	2.50		
13	12:39	3.25		
14	12:47	3.75		
15	12:50	4.00		
16	12:54	5.25		
17	1:02	5.25		
18	1:06	5.75		

4

21

Observations:

Technician Joel

Sampling Sheet

Column ID: C03 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:14			
2	10:17			
3	10:20	0.25		14.5
4	10:42			
5	10:45			
6	11:27			
7	11:33	0.50		
8	11:35	1.00		/
9	11:42	1.25	\	/
10	12:18			
11	12:25	0.25		
12	12:36	0.50		
13	12:40	1.50		
14	12:47	2.50		
15	12:50	3.50		
16	12:54	4.00		
17	1:03	3.75		
18	1:06	4.50		

27

57

Observations:

Technician Seel **Sampling Sheet** Column ID C04 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:17	0.25		
3	10:20	0.50		8.02
4	10:42			
5	10:46	0.50		
6	11:28	0.25		
7	11:33	0.75		
8	11:36	1.75		
9	11:44	2.00	✓	✓
10	12:19	0.25		
11	12:26	0.50		
12	12:37	0.75		
13	12:40	1.75		
14	12:48	2.25		
15	12:50	3.00		
16	12:54	3.75		
17	1:03	4.00		
18	1:07	4.75		

14

36

Observations:

Technician Joel

Sampling Sheet

Column ID: C05 Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:18	0.5		
3	10:21	1		6.27
4	10:42			
5	10:46	0.50		
6	11:28			
7	11:33	0.25		
8	11:36	0.75		
9	11:44	0.75	✓	✓
10	12:19	0.25		
11	12:26	0.50		
12	12:37	1.00		
13	12:40	1.75		
14	12:48	2.25		
15	12:50	3.00		
16	12:55	4.00		
17	1:03	4.00		
18	1:07	4.50		

22

22

Observations:

Technician Joel
Sampling Sheet
Column ID: C06
Date: 4/17/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:18	0.25		
3	10:21	0.25		11.7
4	10:43			
5	10:46	0.50		
6	11:29	0.50		
7	11:34	1.00		
8	11:37	1.75		
9	11:45	2.00	✓	✓
10	12:19	0.50		
11	12:27	0.50		
12	12:38	0.75		
13	12:40	1.75		
14	12:48	2.25		
15	12:52	3.00		
16	12:55	4.00		
17	1:04	4.00		
18	1:07	4.75		

26

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Observations:

Technician Joel

Sampling Sheet

Column ID: INF TW6

Date: 4/17/18

Column Description Storm 2

12:27

shift down

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:15			
2	10:18			
3	10:22			5.51
4	10:43			
5	10:46			
6	11:28			
7	11:34			
8	11:37			
9	11:41		✓	✓
10	12:20			
11	12:38			
12	12:40			
13	12:48			
14	12:52			
15	12:55			
16	1:04			
17	1:08			
18				

Observations: Missed 12:27 time record
shift Dose 11 through Dose 17 down
one cell & insert 12:27 for Dose 11

Technician Joel **Sampling Sheet** Column ID: TW2 Date: 4/19/18

Column Description

Dillution Run

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:41			
2	9:42			
3	9:46			
4	9:55			
5	9:56		✓	✓
6	10:15			
7	10:17			
8	10:19			
9	10:22			
10	10:24			
11	10:26		✓	✓
12	11:04			
13	11:05			
14	11:06			
15	11:07			
16	11:08			
17	11:10			
18	11:16			

Observations:

Technician Joel **Sampling Sheet** Column ID: C06 Date: 4/19/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	9:41			
2	9:43	0.5		
3	9:46	0.75		
4	9:54	1.0		
5	9:56	1.5	✓	✓
6	10:15	.5		
7	10:16	1.5		
8	10:18	2.25		
9	10:22	3.00		
10	10:23	4.		
11	10:26	5	✓	✓
12	11:04	1		
13	11:05	2		
14	11:06	2.5		
15	11:07	3.75		
16	11:08	4.85		
17	11:10	5.5		
18	11:16	5.8		

→ Start effluent collection

Grab Merc

Observations:

Technician Joel **Sampling Sheet** Column ID: C04 Date: 4/19/18

Column Description

Dose	**Time**	**Height of water (in)**	**Temp (C)**	**Turbidity (NTU)**
1	9:40			
2	9:42	1		
3	9:45	1.75		
4	9:54	20		
5	9:56	2.75	✓	✓
6	10:14	1		
7	10:15	2		
8	10:18	2.75		
9	10:21	3.5		
10	10:23	4.25		
11	10:25	5	✓	✓
12	11:04			
13	11:05	2		
14	11:06	2.75		
15	11:07	3.75		
16	11:08	4.75		
17	11:10	5.5		
18	11:16	5.9		

→ Start Effluent Collecting

Grab Merc

Observations:

4/19/18 FOC Columns

SampLE ID	Turb	Time	pH	Temp
OCC	13.6	10:02	6.99	18.7
CO4	6.46	10:03	7.09	19.3
CO6	7.75	10:06	6.96	18.9
Influent	2.02	10:10	7.63	19.1
CO4	9.75	1029	6.89	19.4
CO6	13.8	1034	7.08	19.2
Influent	1.93	1036	7.77	19.3
Co6	21.8	11:18	6.55	19.1°C
Co4	21.7	11:22	6.93	19.2°C
Influent	2.08	11:24	7.68	18.8°C

Technician Joel S.

Sampling Sheet

Column ID: INF Date: 5/9/18

Retest

Column Description TW2 influent

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)
1	10:02a			
2	10:03a			
3	10:04a			
4	10:05a			
5	10:17a			
6	10:18a			
7	10:19a			
8	10:20a			
9	10:29a			
10	10:30a			
11	10:31a			
12	10:32a			
13	10:41a			
14	10:42a			
15	10:43a			
16	10:45a			
17	10:46a			
18	10:56a			

replacement Storm.
2-1 used for majority of influent,
2-2 mixed in for last part

→ Turb

→ Mercury Grab

→ Grab taken

→ Grab taken

Observations:

Technician Joel G.

Sampling Sheet

Column ID: C01 Date: 5/9/18

Column Description

Dose	Time	Height of water (in)	Temp (C)	Turbidity (NTU)	
1	10:02a				
2	10:03a				
3	10:04a				
4	10:05a			✓	→ grab taken
5	10:17a				
6	10:18a				
7	10:19a				
8	10:19a	3"			→ mercury grab
9	10:29a				
10	10:29a				
11	10:31a	3.5			
12	10:32a			✓	→ Grab taken
13	10:41a				
14	10:42a				
15	10:43a				
16	10:45a				
17	10:46a				
18	10:50a	6"			

Observations:

Toe 1

4/13/18	Turb/POC	Column
OOC	13.6	9:11
Influent	17.1	9:13
CO1	27.0	9:14
CO3	69.5	9:15
CO4	48.9	9:17
CO5	55.3	9:17
CO6	46.0	9:20
CO2	63.3	9:36

Round 2

CO1	59.8	10:44am
CO2	22.5	10:44am
CO3	52.3	10:46am
CO4	47.8	10:47am
CO5	54.9	10:51am
CO6	82.8	10:54am
Influent	13.2	10:55am

Round 3

CO1	56.9	1:14pm
CO2	74.3	1:20pm
CO3	84.2	1:21pm
CO4	82.4	1:22pm
CO5	81.9	1:23pm
CO6	122	1:24pm
Influent	18.0	

4/17/18 POC Columns

	Sample ID	Turb	Time	pH	temp
	COC	13.6	9:47		
	Tw6	5.51	10:23am	6.10	19°C
	C06	11.7	10:24am	6.86	19.2°C
	C03	14.5	10:27am	7.01	19.1°C
	C04	8.02	10:28am	6.83	19.3°C
	C05	6.27	10:30am	7.05	18.9°C
	C01	10.5	10:36am	6.95	19.2°C
	C02 (Dose 5)	2.27	10:57am	7.26	18.7°C
Round 2 (Dose 4)	Tw6	7.95	11:46am	6.04	20.1°C
	C01	13.0	11:56am	6.88	19.4°C
	C02	4.05	12:00p.m	7.23	19.3°C
	C03	27.6	11:58am	6.98	19.1°C
	C04	14.9	12:01pm	7.16	19.2°C
	C05	22.8	12:11pm	7.02	19.1°C
	C06	26.1	12:15p.m	7.03	19.4°C
Round 3	TW6	6.60	1:27pm	6.40	20.2°C
	C01	20.0	1:42pm	7.13	19.2°C
	C02	21.5	1:38pm	7.30	19.3°C
	C03	57.7	1:32	7.06	19.6°C
	C04	36.4	1:35	7.19	19.5°C
	C05	22.2	1:28	6.90	19.5°C
	C06	61.4	1:25pm	6.90	19.4°C

4/19/18 POC Columns

Sample ID	Turb	Time	pH	Temp
OCC	15.6	10:02	6.99	18.7
CO4	6.46	10:03	7.09	19.3
CO6	7.75	10:06	6.96	18.9
Influent	2.02	10:10	7.63	19.1
CO4	9.75	1029	6.89	19.4
CO6	13.8	1034	7.08	19.2
Influent	1.93	1036	7.77	19.3
CO6	21.8	11:18	6.55	19.1°C
CO4	21.7	11:22	6.93	19.2°C
Influent	2.08	11:24	7.68	18.8°C

5/9/18

①

	Turb	time	pH	temp
OCV	14.5	10:09		22.8 °C
Col	14.0	10:15	7.54	
Influent	16.8	10:10	6.59	22.0 °C

②

Col	22.0	10:35a	6.84	22.7 °C
Influent	16.0	10:34a	6.08	22 °C

Col	24.3	10:54am	6.59	22.3 °C
Influent	18.4	10:54am	6.28	22 °C

APPENDIX G: WATER QUALITY Data

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04102018-01	PCB 008	pg/L	76.2	18.3	48	NBC,VIL,VJ
CO2-EF-04102018-01	PCB 018/30	pg/L	69.5	28.6	48	NBC
CO2-EF-04102018-01	PCB 020/28	pg/L	90	42.2	48	JA,NBC
CO2-EF-04102018-01	PCB 021/33	pg/L	69.1	44.7	48	NBC
CO2-EF-04102018-01	PCB 031	pg/L	87.8	40.1	48	NBC
CO2-EF-04102018-01	PCB 044/47/65	pg/L	206	38.5	97	NBC,VIU
CO2-EF-04102018-01	PCB 049/69	pg/L	167	35.9	97	NBC,VIU
CO2-EF-04102018-01	PCB 052	pg/L	370	36.1	48	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 056	pg/L		35.5	48	NBC
CO2-EF-04102018-01	PCB 060	pg/L		34.6	48	NBC
CO2-EF-04102018-01	PCB 066	pg/L	67.3	30.5	48	NBC,VIU
CO2-EF-04102018-01	PCB 070/61/74/76	pg/L	131	32.9	193	J,NBC,VIL,VIU,VJ
CO2-EF-04102018-01	PCB 083/99	pg/L	519	23.3	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	209	20.3	193	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 090/101/113	pg/L	424	20.3	193	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 093/95/100	pg/L	362	23.2	193	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 105	pg/L	63.6	27.7	28	NBC,VIU
CO2-EF-04102018-01	PCB 110/115	pg/L	162	18.4	97	NBC
CO2-EF-04102018-01	PCB 118	pg/L	191	25.8	26	NBC,VIL
CO2-EF-04102018-01	PCB 128/166	pg/L	113	14.4	97	JA,NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 129/138/163	pg/L	1440	19.6	193	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 132	pg/L	116	17.8	48	NBC,VIL,VIU
CO2-EF-04102018-01	PCB 135/151/154	pg/L	1050	10.6	97	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 141	pg/L	116	15.1	48	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 147/149	pg/L	670	15.1	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 153/168	pg/L	5360	12.9	97	VIP,NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 156/157	pg/L	62	18	39	NBC,VIU
CO2-EF-04102018-01	PCB 158	pg/L	78.2	11.2	48	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 170	pg/L	525	29.1	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 174	pg/L	163	23.8	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 177	pg/L	262	25.6	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 180/193	pg/L	1960	22.8	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 183/185	pg/L	626	24.3	97	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 187	pg/L	2270	14.1	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 194	pg/L	734	28.4	48	NBC,VIL,VJ
CO2-EF-04102018-01	PCB 195	pg/L	172	25.9	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	PCB 201	pg/L	79.1	14.9	48	VRIU,NBC,VIL,VJ
CO2-EF-04102018-01	PCB 203	pg/L	317	22.3	48	NBC,VIL,VJ,VIU
CO2-EF-04102018-01	Total DiCB	pg/L	76.2	18.3	19	NBC,VIL,VJ
CO2-EF-04102018-01	Total HeptaCB	pg/L	5170	14.1	19	NBC,VIL,VJ
CO2-EF-04102018-01	Total HexaCB	pg/L	9000	10.6	19	VIP,NBC,VIL,VJ
CO2-EF-04102018-01	Total MonoCB	pg/L		19.3	19	NBC
CO2-EF-04102018-01	Total NonaCB	pg/L		19.3	19	NBC
CO2-EF-04102018-01	Total OctaCB	pg/L	1300	14.9	19	NBC,VIL,VJ
CO2-EF-04102018-01	Total PCBs	pg/L	19400	10.6	193	VIP,NBC,VIL,VJ
CO2-EF-04102018-01	Total PentaCB	pg/L	1930	18.4	193	NBC,VIL

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04102018-01	Total TetraCB	pg/L	941	30.5	193	NBC,VIL
CO2-EF-04102018-01	Total TriCB	pg/L	316	28.6	48	NBC,VIL
CO3-EF-04102018-01	PCB 008	pg/L	76.3	2.87	49	NBC,VIL,VJ
CO3-EF-04102018-01	PCB 018/30	pg/L	62.3	6.37	49	NBC
CO3-EF-04102018-01	PCB 020/28	pg/L	114	7.02	49	NBC
CO3-EF-04102018-01	PCB 021/33	pg/L	56.1	7	49	NBC
CO3-EF-04102018-01	PCB 031	pg/L	91.5	6.49	49	NBC
CO3-EF-04102018-01	PCB 044/47/65	pg/L	78.7	6.23	98	J,NBC,VIU
CO3-EF-04102018-01	PCB 049/69	pg/L	41.8	5.86	98	J,NBC,VIU
CO3-EF-04102018-01	PCB 052	pg/L	107	6.17	49	NBC,VIL,VIU
CO3-EF-04102018-01	PCB 056	pg/L	23.8	7.96	49	J,JA,NBC
CO3-EF-04102018-01	PCB 060	pg/L	16.8	7.8	49	J,NBC
CO3-EF-04102018-01	PCB 066	pg/L	47.5	4.83	49	J,NBC,VIU
CO3-EF-04102018-01	PCB 070/61/74/76	pg/L	108	5.19	197	J,NBC,VIL,VIU,VJ
CO3-EF-04102018-01	PCB 083/99	pg/L	50.1	4.37	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	63.1	3.83	197	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 090/101/113	pg/L	91.5	3.78	197	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 093/95/100	pg/L	66.3	3	197	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 105	pg/L	37.2	3.04	20	NBC,VIU
CO3-EF-04102018-01	PCB 110/115	pg/L	102	3.49	98	NBC
CO3-EF-04102018-01	PCB 118	pg/L	68.4	2.83	20	NBC,VIL
CO3-EF-04102018-01	PCB 128/166	pg/L	14.6	2.84	98	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 129/138/163	pg/L	133	3.7	197	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 132	pg/L	29.6	3.38	49	J,NBC,VIL,VIU
CO3-EF-04102018-01	PCB 135/151/154	pg/L	28.9	2.59	98	VRIU,J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 141	pg/L	18.5	2.85	49	VRIU,J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 147/149	pg/L	60.1	2.8	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 153/168	pg/L	92.8	2.44	98	VIP,J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 156/157	pg/L	11.1	8.04	39	J,JA,NBC,VIU
CO3-EF-04102018-01	PCB 158	pg/L	10.3	2.14	49	VRIU,J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 170	pg/L	28.8	5.59	49	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 174	pg/L	25.8	4.2	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 177	pg/L	16.3	4.54	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 180/193	pg/L	81	4.19	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 183/185	pg/L	21.7	4.11	98	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 187	pg/L	45.1	3.29	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 194	pg/L	36	4.35	49	J,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 195	pg/L	11.9	3.71	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	PCB 201	pg/L	3.28	1.86	49	VRIU,J,JA,NBC,VIL,VJ
CO3-EF-04102018-01	PCB 203	pg/L	28.2	3.07	49	J,NBC,VIL,VJ,VIU
CO3-EF-04102018-01	Total DiCB	pg/L	76.3	2.87	20	NBC,VIL,VJ
CO3-EF-04102018-01	Total HeptaCB	pg/L	197	3.29	20	NBC,VIL,VJ
CO3-EF-04102018-01	Total HexaCB	pg/L	399	2.14	20	VIP,NBC,VIL,VJ
CO3-EF-04102018-01	Total MonoCB	pg/L		19.7	20	NBC
CO3-EF-04102018-01	Total NonaCB	pg/L		19.7	20	NBC
CO3-EF-04102018-01	Total OctaCB	pg/L	79.4	1.86	20	NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO3-EF-04102018-01	Total PCBs	pg/L	2000	1.86	197	VIP,NBC,VIL,VJ
CO3-EF-04102018-01	Total PentaCB	pg/L	479	2.83	197	NBC,VIL
CO3-EF-04102018-01	Total TetraCB	pg/L	424	4.83	197	NBC,VIL
CO3-EF-04102018-01	Total TriCB	pg/L	324	6.37	49	NBC,VIL
CO4-EF-04102018-01	PCB 008	pg/L	104	4.41	48	NBC,VIL,VJ
CO4-EF-04102018-01	PCB 018/30	pg/L	105	8.46	48	NBC
CO4-EF-04102018-01	PCB 020/28	pg/L	162	10.8	48	NBC
CO4-EF-04102018-01	PCB 021/33	pg/L	98.2	10.8	48	NBC
CO4-EF-04102018-01	PCB 031	pg/L	130	9.97	48	NBC
CO4-EF-04102018-01	PCB 044/47/65	pg/L	127	6.12	96	NBC,VIU
CO4-EF-04102018-01	PCB 049/69	pg/L	75.6	5.75	96	J,NBC,VIU
CO4-EF-04102018-01	PCB 052	pg/L	161	6.05	48	NBC,VIL,VIU
CO4-EF-04102018-01	PCB 056	pg/L	44.7	8.87	48	J,JA,NBC
CO4-EF-04102018-01	PCB 060	pg/L	29.9	8.69	48	J,NBC
CO4-EF-04102018-01	PCB 066	pg/L	80.2	4.74	48	NBC,VIU
CO4-EF-04102018-01	PCB 070/61/74/76	pg/L	185	5.09	192	J,NBC,VIL,VIU,VJ
CO4-EF-04102018-01	PCB 083/99	pg/L	84.1	5.33	96	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	130	4.67	192	J,NBC,VIL,VIU
CO4-EF-04102018-01	PCB 090/101/113	pg/L	146	4.61	192	J,NBC,VIL,VIU
CO4-EF-04102018-01	PCB 093/95/100	pg/L	112	5.15	192	J,NBC,VIL,VIU
CO4-EF-04102018-01	PCB 105	pg/L	64.5	8.66	19	NBC,VIU
CO4-EF-04102018-01	PCB 110/115	pg/L	186	4.26	96	NBC
CO4-EF-04102018-01	PCB 118	pg/L	114	8.16	19	NBC,VIL
CO4-EF-04102018-01	PCB 128/166	pg/L	34.1	4.91	96	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 129/138/163	pg/L	226	6.41	192	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 132	pg/L	54.8	5.85	48	NBC,VIL,VIU
CO4-EF-04102018-01	PCB 135/151/154	pg/L	50.3	3.6	96	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 141	pg/L	31.8	4.94	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 147/149	pg/L	104	4.85	96	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 153/168	pg/L	138	4.22	96	VIP,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 156/157	pg/L	28.1	9.81	38	J,NBC,VIU
CO4-EF-04102018-01	PCB 158	pg/L	20.2	3.7	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 170	pg/L	45	8.2	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 174	pg/L	45.6	6.17	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 177	pg/L	24.3	6.65	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 180/193	pg/L	118	6.15	96	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 183/185	pg/L	38.6	6.03	96	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 187	pg/L	65.4	3.19	48	NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 194	pg/L	49.5	6.04	48	NBC,VIL,VJ
CO4-EF-04102018-01	PCB 195	pg/L	16.3	5.15	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	PCB 201	pg/L	9.17	2.59	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04102018-01	PCB 203	pg/L	34.6	4.26	48	J,NBC,VIL,VJ,VIU
CO4-EF-04102018-01	Total DiCB	pg/L	104	4.41	19	NBC,VIL,VJ
CO4-EF-04102018-01	Total HeptaCB	pg/L	298	3.19	19	NBC,VIL,VJ
CO4-EF-04102018-01	Total HexaCB	pg/L	687	3.6	19	VIP,NBC,VIL,VJ
CO4-EF-04102018-01	Total MonoCB	pg/L		19.2	19	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04102018-01	Total NonaCB	pg/L		19.2	19	NBC
CO4-EF-04102018-01	Total OctaCB	pg/L	110	2.59	19	NBC,VIL,VJ
CO4-EF-04102018-01	Total PCBs	pg/L	3270	2.59	192	VIP,NBC,VIL,VJ
CO4-EF-04102018-01	Total PentaCB	pg/L	837	4.26	192	NBC,VIL
CO4-EF-04102018-01	Total TetraCB	pg/L	704	4.74	192	NBC,VIL
CO4-EF-04102018-01	Total TriCB	pg/L	496	8.46	48	NBC,VIL
CO5-EF-04102018-01	PCB 008	pg/L	135	48	48	NBC,VIL,VJ
CO5-EF-04102018-01	PCB 018/30	pg/L	117	97.6	98	JA,NBC
CO5-EF-04102018-01	PCB 020/28	pg/L	206	116	116	NBC
CO5-EF-04102018-01	PCB 021/33	pg/L		116	116	NBC
CO5-EF-04102018-01	PCB 031	pg/L	149	107	107	JA,NBC
CO5-EF-04102018-01	PCB 044/47/65	pg/L	137	80.3	96	NBC,VIU
CO5-EF-04102018-01	PCB 049/69	pg/L	129	75.4	96	NBC,VIU
CO5-EF-04102018-01	PCB 052	pg/L	306	79.4	79	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 056	pg/L		89.9	90	NBC
CO5-EF-04102018-01	PCB 060	pg/L		88	88	NBC
CO5-EF-04102018-01	PCB 066	pg/L		62.2	62	NBC,VIU
CO5-EF-04102018-01	PCB 070/61/74/76	pg/L	139	66.8	191	J,NBC,VIL,VIU,VJ
CO5-EF-04102018-01	PCB 083/99	pg/L		70.6	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L		61.8	191	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 090/101/113	pg/L		61	191	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 093/95/100	pg/L		87.1	191	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 105	pg/L		57.5	58	NBC,VIU
CO5-EF-04102018-01	PCB 110/115	pg/L	121	56.4	96	NBC
CO5-EF-04102018-01	PCB 118	pg/L	78.3	53.8	54	NBC,VIL
CO5-EF-04102018-01	PCB 128/166	pg/L		44	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 129/138/163	pg/L	182	57.4	191	J,NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 132	pg/L		52.4	52	NBC,VIL,VIU
CO5-EF-04102018-01	PCB 135/151/154	pg/L		48.9	96	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 141	pg/L		44.2	48	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 147/149	pg/L	76.7	43.4	96	J,NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 153/168	pg/L	219	37.7	96	VIP,NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 156/157	pg/L		78.7	79	NBC,VIU
CO5-EF-04102018-01	PCB 158	pg/L		33.1	48	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 170	pg/L		129	129	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 174	pg/L		96.7	97	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 177	pg/L		105	105	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 180/193	pg/L	103	96.4	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 183/185	pg/L		94.5	96	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 187	pg/L	61.8	46	48	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 194	pg/L		106	106	NBC,VIL,VJ
CO5-EF-04102018-01	PCB 195	pg/L		89.9	90	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	PCB 201	pg/L		45.1	48	VRIU,NBC,VIL,VJ
CO5-EF-04102018-01	PCB 203	pg/L		74.4	74	NBC,VIL,VJ,VIU
CO5-EF-04102018-01	Total DiCB	pg/L	135	48	48	NBC,VIL,VJ
CO5-EF-04102018-01	Total HeptaCB	pg/L	165	46	46	NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO5-EF-04102018-01	Total HexaCB	pg/L	478	33.1	33	VIP,NBC,VIL,VJ
CO5-EF-04102018-01	Total MonoCB	pg/L		19.1	19	NBC
CO5-EF-04102018-01	Total NonaCB	pg/L		19.1	19	NBC
CO5-EF-04102018-01	Total OctaCB	pg/L		45.1	45	NBC,VIL,VJ
CO5-EF-04102018-01	Total PCBs	pg/L	2160	33.1	191	VIP,NBC,VIL,VJ
CO5-EF-04102018-01	Total PentaCB	pg/L	199	53.8	191	NBC,VIL
CO5-EF-04102018-01	Total TetraCB	pg/L	711	62.2	191	NBC,VIL
CO5-EF-04102018-01	Total TriCB	pg/L	473	97.6	98	NBC,VIL
CO6-EF-04102018-01	PCB 008	pg/L	99.7	1.26	48	NBC,VIL,VJ
CO6-EF-04102018-01	PCB 018/30	pg/L	125	5.01	48	NBC
CO6-EF-04102018-01	PCB 020/28	pg/L	164	7.93	48	NBC
CO6-EF-04102018-01	PCB 021/33	pg/L	86.3	7.9	48	NBC
CO6-EF-04102018-01	PCB 031	pg/L	130	7.33	48	NBC
CO6-EF-04102018-01	PCB 044/47/65	pg/L	133	3.68	96	NBC,VIU
CO6-EF-04102018-01	PCB 049/69	pg/L	70.8	3.46	96	J,NBC,VIU
CO6-EF-04102018-01	PCB 052	pg/L	169	3.64	48	NBC,VIL,VIU
CO6-EF-04102018-01	PCB 056	pg/L	40.8	7.08	48	J,NBC
CO6-EF-04102018-01	PCB 060	pg/L	24.5	6.93	48	J,NBC
CO6-EF-04102018-01	PCB 066	pg/L	74.2	2.85	48	NBC,VIU
CO6-EF-04102018-01	PCB 070/61/74/76	pg/L	167	3.07	192	J,NBC,VIL,VIU,VJ
CO6-EF-04102018-01	PCB 083/99	pg/L	67.3	2.9	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 086/87/97/109/119/125	pg/L	102	2.54	192	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 090/101/113	pg/L	135	2.51	192	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 093/95/100	pg/L	113	2.35	192	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 105	pg/L	49.3	4.61	19	NBC,VIU
CO6-EF-04102018-01	PCB 110/115	pg/L	159	2.32	96	NBC
CO6-EF-04102018-01	PCB 118	pg/L	106	4.17	19	NBC,VIL
CO6-EF-04102018-01	PCB 128/166	pg/L	23.3	2.94	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 129/138/163	pg/L	187	3.84	192	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 132	pg/L	45.1	3.5	48	J,NBC,VIL,VIU
CO6-EF-04102018-01	PCB 135/151/154	pg/L	42	2.57	96	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 141	pg/L	24.2	2.96	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 147/149	pg/L	96.5	2.91	96	NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 153/168	pg/L	115	2.52	96	VIP,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 156/157	pg/L	16.9	5.34	39	J,NBC,VIU
CO6-EF-04102018-01	PCB 158	pg/L	15.3	2.22	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 170	pg/L	35.9	5.28	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 174	pg/L	33.8	3.97	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 177	pg/L	21.2	4.29	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 180/193	pg/L	84.8	3.96	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 183/185	pg/L	27.2	3.88	96	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 187	pg/L	51.6	2.29	48	NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 194	pg/L	35.8	4.57	48	J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 195	pg/L	14.6	3.9	48	J,NBC,VIL,VJ,VIU
CO6-EF-04102018-01	PCB 201	pg/L	5.85	1.96	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04102018-01	PCB 203	pg/L	27.3	3.23	48	J,JA,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO6-EF-04102018-01	Total DiCB	pg/L	99.7	1.26	19	NBC,VIL,VJ
CO6-EF-04102018-01	Total HeptaCB	pg/L	227	2.29	19	NBC,VIL,VJ
CO6-EF-04102018-01	Total HexaCB	pg/L	565	2.22	19	VIP,NBC,VIL,VJ
CO6-EF-04102018-01	Total MonoCB	pg/L		19.2	19	NBC
CO6-EF-04102018-01	Total NonaCB	pg/L		19.2	19	NBC
CO6-EF-04102018-01	Total OctaCB	pg/L	83.6	1.96	19	NBC,VIL,VJ
CO6-EF-04102018-01	Total PCBs	pg/L	2920	1.26	192	VIP,NBC,VIL,VJ
CO6-EF-04102018-01	Total PentaCB	pg/L	732	2.32	192	NBC,VIL
CO6-EF-04102018-01	Total TetraCB	pg/L	680	2.85	192	NBC,VIL
CO6-EF-04102018-01	Total TriCB	pg/L	506	5.01	48	NBC,VIL
TW2-IN-04102018-01	PCB 008	pg/L	130	10.7	49	NBC,VIL,VJ
TW2-IN-04102018-01	PCB 018/30	pg/L	218	37.4	49	NBC
TW2-IN-04102018-01	PCB 020/28	pg/L	489	44.4	49	NBC
TW2-IN-04102018-01	PCB 021/33	pg/L	337	47	49	NBC
TW2-IN-04102018-01	PCB 031	pg/L	397	42.2	49	NBC
TW2-IN-04102018-01	PCB 044/47/65	pg/L	545	52.3	98	NBC,VIU
TW2-IN-04102018-01	PCB 049/69	pg/L	275	48.7	98	NBC,VIU
TW2-IN-04102018-01	PCB 052	pg/L	508	49	49	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 056	pg/L	223	32.4	49	NBC
TW2-IN-04102018-01	PCB 060	pg/L	128	31.6	49	NBC
TW2-IN-04102018-01	PCB 066	pg/L	322	41.4	49	NBC,VIU
TW2-IN-04102018-01	PCB 070/61/74/76	pg/L	717	44.7	195	NBC,VIL,VIU,VJ
TW2-IN-04102018-01	PCB 083/99	pg/L	367	27.3	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 086/87/97/109/119/125	pg/L	443	23.8	195	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 090/101/113	pg/L	527	23.8	195	JA,NBC,VIL,VIU
TW2-IN-04102018-01	PCB 093/95/100	pg/L	470	31.8	195	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 105	pg/L	325	21.3	21	NBC,VIU
TW2-IN-04102018-01	PCB 110/115	pg/L	822	21.5	98	NBC
TW2-IN-04102018-01	PCB 118	pg/L	554	19.5	20	NBC,VIL
TW2-IN-04102018-01	PCB 128/166	pg/L	186	23.9	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 129/138/163	pg/L	1690	32.5	195	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 132	pg/L	368	29.6	49	NBC,VIL,VIU
TW2-IN-04102018-01	PCB 135/151/154	pg/L	584	16.6	98	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 141	pg/L	213	25	49	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 147/149	pg/L	963	25.1	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 153/168	pg/L	1710	21.3	98	VIP,NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 156/157	pg/L	145	44.6	45	NBC,VIU
TW2-IN-04102018-01	PCB 158	pg/L	110	18.6	49	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 170	pg/L	540	36.4	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 174	pg/L	608	29.8	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 177	pg/L	361	32	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 180/193	pg/L	1550	28.6	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 183/185	pg/L	529	30.4	98	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 187	pg/L	1100	17.1	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	PCB 194	pg/L	560	35.7	49	NBC,VIL,VJ
TW2-IN-04102018-01	PCB 195	pg/L	192	32.6	49	JA,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04102018-01	PCB 201	pg/L	69.4	18.8	49	VRIU,NBC,VIL,VJ
TW2-IN-04102018-01	PCB 203	pg/L	365	28	49	NBC,VIL,VJ,VIU
TW2-IN-04102018-01	Total DiCB	pg/L	130	10.7	20	NBC,VIL,VJ
TW2-IN-04102018-01	Total HeptaCB	pg/L	4160	17.1	20	NBC,VIL,VJ
TW2-IN-04102018-01	Total HexaCB	pg/L	5970	16.6	20	VIP,NBC,VIL,VJ
TW2-IN-04102018-01	Total MonoCB	pg/L		19.5	20	NBC
TW2-IN-04102018-01	Total NonaCB	pg/L		19.5	20	NBC
TW2-IN-04102018-01	Total OctaCB	pg/L	1190	18.8	20	NBC,VIL,VJ
TW2-IN-04102018-01	Total PCBs	pg/L	19600	10.7	195	VIP,NBC,VIL,VJ
TW2-IN-04102018-01	Total PentaCB	pg/L	3510	19.5	195	NBC,VIL
TW2-IN-04102018-01	Total TetraCB	pg/L	2720	31.6	195	NBC,VIL
TW2-IN-04102018-01	Total TriCB	pg/L	1440	37.4	49	NBC,VIL
CO1-EF-04132018-01	PCB 008	pg/L	74.8	2.31	48	NBC,VIL,VJ
CO1-EF-04132018-01	PCB 018/30	pg/L	60.3	5.02	48	NBC
CO1-EF-04132018-01	PCB 020/28	pg/L	84.8	12	48	NBC
CO1-EF-04132018-01	PCB 021/33	pg/L	50.6	12	48	NBC
CO1-EF-04132018-01	PCB 031	pg/L	65.8	11.1	48	NBC
CO1-EF-04132018-01	PCB 044/47/65	pg/L	105	5.15	96	NBC,VIU
CO1-EF-04132018-01	PCB 049/69	pg/L	74.9	4.84	96	J,NBC,VIU
CO1-EF-04132018-01	PCB 052	pg/L	160	5.09	48	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 056	pg/L	38.2	27.4	48	J,NBC
CO1-EF-04132018-01	PCB 060	pg/L		26.8	48	NBC
CO1-EF-04132018-01	PCB 066	pg/L	52.8	3.99	48	NBC,VIU
CO1-EF-04132018-01	PCB 070/61/74/76	pg/L	111	4.28	192	J,NBC,VIL,VIU,VJ
CO1-EF-04132018-01	PCB 083/99	pg/L	531	4.87	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	184	4.26	192	J,NBC,VIL,VIU
CO1-EF-04132018-01	PCB 090/101/113	pg/L	405	4.21	192	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 093/95/100	pg/L	211	3.39	192	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 105	pg/L	82.7	12	19	NBC,VIU
CO1-EF-04132018-01	PCB 110/115	pg/L	147	3.89	96	NBC
CO1-EF-04132018-01	PCB 118	pg/L	277	10.9	19	NBC,VIL
CO1-EF-04132018-01	PCB 128/166	pg/L	224	5.47	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 129/138/163	pg/L	2450	7.14	192	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 132	pg/L	142	6.51	48	NBC,VIL,VIU
CO1-EF-04132018-01	PCB 135/151/154	pg/L	1360	3.39	96	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 141	pg/L	176	5.5	48	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 147/149	pg/L	980	5.4	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 153/168	pg/L	9440	4.69	96	VIP,NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 156/157	pg/L	115	14.9	38	NBC,VIU
CO1-EF-04132018-01	PCB 158	pg/L	125	4.12	48	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 170	pg/L	1160	8.02	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 174	pg/L	308	6.03	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 177	pg/L	520	6.5	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 180/193	pg/L	4090	6.01	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 183/185	pg/L	1250	5.89	96	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 187	pg/L	4380	3.23	48	NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04132018-01	PCB 194	pg/L	1480	6.25	48	NBC,VIL,VJ
CO1-EF-04132018-01	PCB 195	pg/L	348	5.33	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	PCB 201	pg/L	152	2.68	48	VRIU,NBC,VIL,VJ
CO1-EF-04132018-01	PCB 203	pg/L	622	4.41	48	NBC,VIL,VJ,VIU
CO1-EF-04132018-01	Total DiCB	pg/L	74.8	2.31	19	NBC,VIL,VJ
CO1-EF-04132018-01	Total HeptaCB	pg/L	10500	3.23	19	NBC,VIL,VJ
CO1-EF-04132018-01	Total HexaCB	pg/L	15000	3.39	19	VIP,NBC,VIL,VJ
CO1-EF-04132018-01	Total MonoCB	pg/L		19.2	19	NBC
CO1-EF-04132018-01	Total NonaCB	pg/L		19.2	19	NBC
CO1-EF-04132018-01	Total OctaCB	pg/L	2610	2.68	19	NBC,VIL,VJ
CO1-EF-04132018-01	Total PCBs	pg/L	32000	2.31	192	VIP,NBC,VIL,VJ
CO1-EF-04132018-01	Total PentaCB	pg/L	1840	3.39	192	NBC,VIL
CO1-EF-04132018-01	Total TetraCB	pg/L	542	3.99	192	NBC,VIL
CO1-EF-04132018-01	Total TriCB	pg/L	261	5.02	48	NBC,VIL
CO2-EF-04132018-01	PCB 008	pg/L	19.4	1.28	48	J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 018/30	pg/L	21.6	3.12	48	J,NBC
CO2-EF-04132018-01	PCB 020/28	pg/L	33.3	3.86	48	J,NBC
CO2-EF-04132018-01	PCB 021/33	pg/L	21.6	3.94	48	J,NBC
CO2-EF-04132018-01	PCB 031	pg/L	28.7	3.6	48	J,NBC
CO2-EF-04132018-01	PCB 044/47/65	pg/L	46.5	2.79	96	J,NBC,VIU
CO2-EF-04132018-01	PCB 049/69	pg/L	24.9	2.65	96	J,NBC,VIU
CO2-EF-04132018-01	PCB 052	pg/L	73.3	2.72	48	NBC,VIL,VIU
CO2-EF-04132018-01	PCB 056	pg/L	8.37	4.63	48	J,NBC
CO2-EF-04132018-01	PCB 060	pg/L	5.01	4.55	48	J,NBC
CO2-EF-04132018-01	PCB 066	pg/L	15	2.26	48	J,NBC,VIU
CO2-EF-04132018-01	PCB 070/61/74/76	pg/L	37.5	2.42	191	J,NBC,VIL,VIU,VJ
CO2-EF-04132018-01	PCB 083/99	pg/L	19.8	2.74	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	28.1	2.39	191	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 090/101/113	pg/L	39.5	2.36	191	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 093/95/100	pg/L	39.8	1.83	191	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 105	pg/L	11.3	3.41	19	J,JA,NBC,VIU
CO2-EF-04132018-01	PCB 110/115	pg/L	39.6	2.17	96	J,NBC
CO2-EF-04132018-01	PCB 118	pg/L	23.1	3.13	19	NBC,VIL
CO2-EF-04132018-01	PCB 128/166	pg/L	8.08	2.45	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 129/138/163	pg/L	69.7	3.24	191	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 132	pg/L	14.9	2.83	48	J,NBC,VIL,VIU
CO2-EF-04132018-01	PCB 135/151/154	pg/L	19.9	1.26	96	VRIU,J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 141	pg/L	8.4	2.45	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 147/149	pg/L	31.7	2.33	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 153/168	pg/L	60.6	2.07	96	VIP,J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 156/157	pg/L	9.15	5.15	38	J,JA,NBC,VIU
CO2-EF-04132018-01	PCB 158	pg/L	5.91	1.83	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 170	pg/L	18.2	4.4	48	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 174	pg/L	12.8	3.11	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 177	pg/L	9.24	3.44	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 180/193	pg/L	42.4	3.33	96	J,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04132018-01	PCB 183/185	pg/L	16.2	3.24	96	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 187	pg/L	26.9	1.6	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 194	pg/L	17.5	2.9	48	J,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 195	pg/L	6.09	2.5	48	J,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	PCB 201	pg/L	2.47	1.28	48	VRIU,J,JA,NBC,VIL,VJ
CO2-EF-04132018-01	PCB 203	pg/L	9.22	2.1	48	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04132018-01	Total DiCB	pg/L	19.4	1.28	19	NBC,VIL,VJ
CO2-EF-04132018-01	Total HeptaCB	pg/L	109	1.6	19	NBC,VIL,VJ
CO2-EF-04132018-01	Total HexaCB	pg/L	228	1.26	19	VIP,NBC,VIL,VJ
CO2-EF-04132018-01	Total MonoCB	pg/L		19.1	19	NBC
CO2-EF-04132018-01	Total NonaCB	pg/L		19.1	19	NBC
CO2-EF-04132018-01	Total OctaCB	pg/L	35.3	1.28	19	NBC,VIL,VJ
CO2-EF-04132018-01	Total PCBs	pg/L	926	1.26	191	VIP,NBC,VIL,VJ
CO2-EF-04132018-01	Total PentaCB	pg/L	201	1.83	191	NBC,VIL
CO2-EF-04132018-01	Total TetraCB	pg/L	211	2.26	191	NBC,VIL
CO2-EF-04132018-01	Total TriCB	pg/L	105	3.12	48	NBC,VIL
CO3-EF-04132018-01	PCB 008	pg/L	40.9	0.85	48	J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 018/30	pg/L	45.7	3.09	48	J,NBC
CO3-EF-04132018-01	PCB 020/28	pg/L	52.3	5.23	48	NBC
CO3-EF-04132018-01	PCB 021/33	pg/L	30.9	5.34	48	J,NBC
CO3-EF-04132018-01	PCB 031	pg/L	46.2	4.88	48	J,NBC
CO3-EF-04132018-01	PCB 044/47/65	pg/L	68	2.8	96	J,NBC,VIU
CO3-EF-04132018-01	PCB 049/69	pg/L	39.8	2.66	96	J,NBC,VIU
CO3-EF-04132018-01	PCB 052	pg/L	108	2.73	48	NBC,VIL,VIU
CO3-EF-04132018-01	PCB 056	pg/L	12.4	4.81	48	J,NBC
CO3-EF-04132018-01	PCB 060	pg/L	8.03	4.72	48	J,NBC
CO3-EF-04132018-01	PCB 066	pg/L	24.9	2.27	48	J,NBC,VIU
CO3-EF-04132018-01	PCB 070/61/74/76	pg/L	56.7	2.43	191	J,NBC,VIL,VIU,VJ
CO3-EF-04132018-01	PCB 083/99	pg/L	62.8	1.89	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	41.9	1.65	191	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 090/101/113	pg/L	70.9	1.63	191	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 093/95/100	pg/L	65.8	2.54	191	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 105	pg/L	17.5	3.94	19	J,JA,NBC,VIU
CO3-EF-04132018-01	PCB 110/115	pg/L	53.2	1.5	96	J,NBC
CO3-EF-04132018-01	PCB 118	pg/L	46.1	3.55	19	NBC,VIL
CO3-EF-04132018-01	PCB 128/166	pg/L	15.2	3.6	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 129/138/163	pg/L	169	4.77	191	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 132	pg/L	20.8	4.16	48	J,NBC,VIL,VIU
CO3-EF-04132018-01	PCB 135/151/154	pg/L	69.5	1.6	96	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 141	pg/L	17.7	3.6	48	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 147/149	pg/L	59.4	3.43	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 153/168	pg/L	427	3.05	96	VIP,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 156/157	pg/L	11	5.5	38	J,JA,NBC,VIU
CO3-EF-04132018-01	PCB 158	pg/L	9.79	2.69	48	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 170	pg/L	51.1	3.92	48	JA,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 174	pg/L	24.7	2.77	48	J,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO3-EF-04132018-01	PCB 177	pg/L	24.4	3.07	48	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 180/193	pg/L	166	2.96	96	NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 183/185	pg/L	53.5	2.88	96	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 187	pg/L	166	2.02	48	NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 194	pg/L	48.3	5	48	NBC,VIL,VJ
CO3-EF-04132018-01	PCB 195	pg/L	15.8	4.31	48	J,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	PCB 201	pg/L	6.08	2.21	48	VRIU,J,NBC,VIL,VJ
CO3-EF-04132018-01	PCB 203	pg/L	22.3	3.63	48	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04132018-01	Total DiCB	pg/L	40.9	0.85	19	NBC,VIL,VJ
CO3-EF-04132018-01	Total HeptaCB	pg/L	432	2.02	19	NBC,VIL,VJ
CO3-EF-04132018-01	Total HexaCB	pg/L	799	1.6	19	VIP,NBC,VIL,VJ
CO3-EF-04132018-01	Total MonoCB	pg/L		19.1	19	NBC
CO3-EF-04132018-01	Total NonaCB	pg/L		19.1	19	NBC
CO3-EF-04132018-01	Total OctaCB	pg/L	92.4	2.21	19	NBC,VIL,VJ
CO3-EF-04132018-01	Total PCBs	pg/L	2270	0.85	191	VIP,NBC,VIL,VJ
CO3-EF-04132018-01	Total PentaCB	pg/L	358	1.5	191	NBC,VIL
CO3-EF-04132018-01	Total TetraCB	pg/L	318	2.27	191	NBC,VIL
CO3-EF-04132018-01	Total TriCB	pg/L	175	3.09	48	NBC,VIL
CO4-EF-04132018-01	PCB 008	pg/L	47.3	1.41	50	J,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 018/30	pg/L	65.4	3.95	50	NBC
CO4-EF-04132018-01	PCB 020/28	pg/L	75	4.57	50	NBC
CO4-EF-04132018-01	PCB 021/33	pg/L	42.4	4.67	50	J,NBC
CO4-EF-04132018-01	PCB 031	pg/L	59.7	4.27	50	NBC
CO4-EF-04132018-01	PCB 044/47/65	pg/L	82.9	2.72	101	J,NBC,VIU
CO4-EF-04132018-01	PCB 049/69	pg/L	40.7	2.57	101	J,NBC,VIU
CO4-EF-04132018-01	PCB 052	pg/L	108	2.64	50	NBC,VIL,VIU
CO4-EF-04132018-01	PCB 056	pg/L	18.8	7.34	50	J,NBC
CO4-EF-04132018-01	PCB 060	pg/L	11.4	7.21	50	J,NBC
CO4-EF-04132018-01	PCB 066	pg/L	38	2.2	50	J,NBC,VIU
CO4-EF-04132018-01	PCB 070/61/74/76	pg/L	79.6	2.36	201	J,NBC,VIL,VIU,VJ
CO4-EF-04132018-01	PCB 083/99	pg/L	36.2	4.47	101	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	58.2	3.91	201	J,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 090/101/113	pg/L	78.9	3.86	201	J,JA,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 093/95/100	pg/L	76.2	2.89	201	J,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 105	pg/L	25.4	8.33	20	JA,NBC,VIU
CO4-EF-04132018-01	PCB 110/115	pg/L	88.3	3.55	101	J,NBC
CO4-EF-04132018-01	PCB 118	pg/L	52.6	7.21	20	NBC,VIL
CO4-EF-04132018-01	PCB 128/166	pg/L	15.3	3.12	101	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 129/138/163	pg/L	202	4.13	201	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 132	pg/L	43.2	3.6	50	J,NBC,VIL,VIU
CO4-EF-04132018-01	PCB 135/151/154	pg/L	57	2.64	101	VRIU,J,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 141	pg/L	36	3.12	50	VRIU,J,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 147/149	pg/L	126	2.97	101	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 153/168	pg/L	151	2.64	101	VIP,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 156/157	pg/L	17.2	6.85	40	J,NBC,VIU
CO4-EF-04132018-01	PCB 158	pg/L	15.7	2.33	50	VRIU,J,NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04132018-01	PCB 170	pg/L	66.3	5.84	50	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 174	pg/L	65.4	4.13	50	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 177	pg/L	39	4.57	50	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 180/193	pg/L	166	4.41	101	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 183/185	pg/L	51.6	4.29	101	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 187	pg/L	80.7	2.88	50	NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 194	pg/L	41.1	8.32	50	J,JA,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 195	pg/L	19.2	7.16	50	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	PCB 201	pg/L	5.22	3.67	50	VRIU,J,JA,NBC,VIL,VJ
CO4-EF-04132018-01	PCB 203	pg/L	32.6	6.03	50	J,NBC,VIL,VJ,VIU
CO4-EF-04132018-01	Total DiCB	pg/L	47.3	1.41	20	NBC,VIL,VJ
CO4-EF-04132018-01	Total HeptaCB	pg/L	417	2.88	20	NBC,VIL,VJ
CO4-EF-04132018-01	Total HexaCB	pg/L	663	2.33	20	VIP,NBC,VIL,VJ
CO4-EF-04132018-01	Total MonoCB	pg/L		20.1	20	NBC
CO4-EF-04132018-01	Total NonaCB	pg/L		20.1	20	NBC
CO4-EF-04132018-01	Total OctaCB	pg/L	98.1	3.67	20	NBC,VIL,VJ
CO4-EF-04132018-01	Total PCBs	pg/L	2310	1.41	201	VIP,NBC,VIL,VJ
CO4-EF-04132018-01	Total PentaCB	pg/L	416	2.89	201	NBC,VIL
CO4-EF-04132018-01	Total TetraCB	pg/L	379	2.2	201	NBC,VIL
CO4-EF-04132018-01	Total TriCB	pg/L	243	3.95	50	NBC,VIL
CO5-EF-04132018-01	PCB 008	pg/L	32.3	0.6	49	J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 018/30	pg/L	53.6	2.72	49	NBC
CO5-EF-04132018-01	PCB 020/28	pg/L	75.2	2.82	49	NBC
CO5-EF-04132018-01	PCB 021/33	pg/L	38	2.88	49	J,NBC
CO5-EF-04132018-01	PCB 031	pg/L	60.8	2.63	49	NBC
CO5-EF-04132018-01	PCB 044/47/65	pg/L	71.9	1.68	98	J,NBC,VIU
CO5-EF-04132018-01	PCB 049/69	pg/L	39.3	1.59	98	J,NBC,VIU
CO5-EF-04132018-01	PCB 052	pg/L	98	1.63	49	NBC,VIL,VIU
CO5-EF-04132018-01	PCB 056	pg/L	15.5	4.5	49	J,JA,NBC
CO5-EF-04132018-01	PCB 060	pg/L	12.6	4.42	49	J,NBC
CO5-EF-04132018-01	PCB 066	pg/L	37	1.36	49	J,NBC,VIU
CO5-EF-04132018-01	PCB 070/61/74/76	pg/L	82.3	1.45	196	J,NBC,VIL,VIU,VJ
CO5-EF-04132018-01	PCB 083/99	pg/L	58.8	2.74	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	55.3	2.39	196	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 090/101/113	pg/L	82.6	2.36	196	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 093/95/100	pg/L	69.7	1.64	196	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 105	pg/L	27.8	3.43	20	NBC,VIU
CO5-EF-04132018-01	PCB 110/115	pg/L	80.2	2.17	98	J,NBC
CO5-EF-04132018-01	PCB 118	pg/L	61	3.07	20	NBC,VIL
CO5-EF-04132018-01	PCB 128/166	pg/L	22.6	1.78	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 129/138/163	pg/L	215	2.36	196	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 132	pg/L	28.4	2.06	49	J,NBC,VIL,VIU
CO5-EF-04132018-01	PCB 135/151/154	pg/L	84.6	1.64	98	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 141	pg/L	21.7	1.78	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 147/149	pg/L	93.2	1.7	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 153/168	pg/L	507	1.51	98	VIP,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO5-EF-04132018-01	PCB 156/157	pg/L	13.5	5.87	39	J,NBC,VIU
CO5-EF-04132018-01	PCB 158	pg/L	12.6	1.33	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 170	pg/L	80.7	4.59	49	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 174	pg/L	31.4	3.25	49	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 177	pg/L	33.7	3.59	49	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 180/193	pg/L	252	3.47	98	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 183/185	pg/L	73.2	3.38	98	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 187	pg/L	221	1.71	49	NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 194	pg/L	98.8	6.97	49	NBC,VIL,VJ
CO5-EF-04132018-01	PCB 195	pg/L	24.7	6	49	J,JA,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	PCB 201	pg/L	8.22	3.08	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04132018-01	PCB 203	pg/L	45	5.06	49	J,NBC,VIL,VJ,VIU
CO5-EF-04132018-01	Total DiCB	pg/L	32.3	0.6	20	NBC,VIL,VJ
CO5-EF-04132018-01	Total HeptaCB	pg/L	618	1.71	20	NBC,VIL,VJ
CO5-EF-04132018-01	Total HexaCB	pg/L	999	1.33	20	VIP,NBC,VIL,VJ
CO5-EF-04132018-01	Total MonoCB	pg/L		19.6	20	NBC
CO5-EF-04132018-01	Total NonaCB	pg/L		19.6	20	NBC
CO5-EF-04132018-01	Total OctaCB	pg/L	177	3.08	20	NBC,VIL,VJ
CO5-EF-04132018-01	Total PCBs	pg/L	2920	0.6	196	VIP,NBC,VIL,VJ
CO5-EF-04132018-01	Total PentaCB	pg/L	435	1.64	196	NBC,VIL
CO5-EF-04132018-01	Total TetraCB	pg/L	357	1.36	196	NBC,VIL
CO5-EF-04132018-01	Total TriCB	pg/L	228	2.63	49	NBC,VIL
CO6-EF-04132018-01	PCB 008	pg/L	52.5	1.12	48	NBC,VIL,VJ
CO6-EF-04132018-01	PCB 018/30	pg/L	82.9	3.3	48	NBC
CO6-EF-04132018-01	PCB 020/28	pg/L	105	5.3	48	NBC
CO6-EF-04132018-01	PCB 021/33	pg/L	54.1	5.41	48	NBC
CO6-EF-04132018-01	PCB 031	pg/L	80.7	4.94	48	NBC
CO6-EF-04132018-01	PCB 044/47/65	pg/L	145	3.11	97	NBC,VIU
CO6-EF-04132018-01	PCB 049/69	pg/L	96.4	2.95	97	J,NBC,VIU
CO6-EF-04132018-01	PCB 052	pg/L	264	3.03	48	NBC,VIL,VIU
CO6-EF-04132018-01	PCB 056	pg/L	22.8	4.1	48	J,NBC
CO6-EF-04132018-01	PCB 060	pg/L	14	4.03	48	J,NBC
CO6-EF-04132018-01	PCB 066	pg/L	43.1	2.52	48	J,NBC,VIU
CO6-EF-04132018-01	PCB 070/61/74/76	pg/L	94	2.7	193	J,NBC,VIL,VIU,VJ
CO6-EF-04132018-01	PCB 083/99	pg/L	146	2.94	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 086/87/97/109/119/125	pg/L	74.2	2.57	193	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 090/101/113	pg/L	157	2.54	193	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 093/95/100	pg/L	175	2.24	193	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 105	pg/L	30.1	5.13	19	NBC,VIU
CO6-EF-04132018-01	PCB 110/115	pg/L	87.3	2.33	97	J,NBC
CO6-EF-04132018-01	PCB 118	pg/L	72.4	4.41	19	NBC,VIL
CO6-EF-04132018-01	PCB 128/166	pg/L	26.6	3.31	97	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 129/138/163	pg/L	284	4.39	193	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 132	pg/L	33.2	3.82	48	J,NBC,VIL,VIU
CO6-EF-04132018-01	PCB 135/151/154	pg/L	221	1.5	97	VRIU,NBC,VIL,VJ
CO6-EF-04132018-01	PCB 141	pg/L	28.2	3.32	48	VRIU,J,NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO6-EF-04132018-01	PCB 147/149	pg/L	157	3.15	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 153/168	pg/L	926	2.81	97	VIP,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 156/157	pg/L	17.7	5.92	39	J,NBC,VIU
CO6-EF-04132018-01	PCB 158	pg/L	16.6	2.48	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04132018-01	PCB 170	pg/L	93	4.17	48	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 174	pg/L	36.3	2.95	48	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 177	pg/L	45.7	3.26	48	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 180/193	pg/L	328	3.15	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 183/185	pg/L	104	3.06	97	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 187	pg/L	357	1.75	48	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 194	pg/L	113	5.23	48	NBC,VIL,VJ
CO6-EF-04132018-01	PCB 195	pg/L	28.4	4.5	48	J,NBC,VIL,VJ,VIU
CO6-EF-04132018-01	PCB 201	pg/L	13.9	2.31	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04132018-01	PCB 203	pg/L	51.9	3.79	48	NBC,VIL,VJ,VIU
CO6-EF-04132018-01	Total DiCB	pg/L	52.5	1.12	19	NBC,VIL,VJ
CO6-EF-04132018-01	Total HeptaCB	pg/L	859	1.75	19	NBC,VIL,VJ
CO6-EF-04132018-01	Total HexaCB	pg/L	1710	1.5	19	VIP,NBC,VIL,VJ
CO6-EF-04132018-01	Total MonoCB	pg/L		19.3	19	NBC
CO6-EF-04132018-01	Total NonaCB	pg/L		19.3	19	NBC
CO6-EF-04132018-01	Total OctaCB	pg/L	207	2.31	19	NBC,VIL,VJ
CO6-EF-04132018-01	Total PCBs	pg/L	4680	1.12	193	VIP,NBC,VIL,VJ
CO6-EF-04132018-01	Total PentaCB	pg/L	742	2.24	193	NBC,VIL
CO6-EF-04132018-01	Total TetraCB	pg/L	680	2.52	193	NBC,VIL
CO6-EF-04132018-01	Total TriCB	pg/L	323	3.3	48	NBC,VIL
TW2-IN-04132018-01	PCB 008	pg/L	81.6	1.5	48	NBC,VIL,VJ
TW2-IN-04132018-01	PCB 018/30	pg/L	111	3.77	48	NBC
TW2-IN-04132018-01	PCB 020/28	pg/L	311	7.05	48	NBC
TW2-IN-04132018-01	PCB 021/33	pg/L	214	7.23	48	NBC
TW2-IN-04132018-01	PCB 031	pg/L	252	6.63	48	NBC
TW2-IN-04132018-01	PCB 044/47/65	pg/L	340	9.11	96	NBC,VIU
TW2-IN-04132018-01	PCB 049/69	pg/L	173	8.61	96	NBC,VIU
TW2-IN-04132018-01	PCB 052	pg/L	330	8.88	48	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 056	pg/L	167	3.54	48	NBC
TW2-IN-04132018-01	PCB 060	pg/L	92.1	3.37	48	NBC
TW2-IN-04132018-01	PCB 066	pg/L	302	7.66	48	NBC,VIU
TW2-IN-04132018-01	PCB 070/61/74/76	pg/L	664	8.02	192	NBC,VIL,VIU,VJ
TW2-IN-04132018-01	PCB 083/99	pg/L	351	4.32	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 086/87/97/109/119/125	pg/L	529	3.77	192	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 090/101/113	pg/L	641	3.75	192	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 093/95/100	pg/L	401	4.01	192	NBC,VIL,VIU
TW2-IN-04132018-01	PCB 105	pg/L	356	3.83	19	NBC,VIU
TW2-IN-04132018-01	PCB 110/115	pg/L	906	3.42	96	NBC
TW2-IN-04132018-01	PCB 118	pg/L	728	3.52	19	NBC,VIL
TW2-IN-04132018-01	PCB 128/166	pg/L	219	2.04	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 129/138/163	pg/L	2070	2.81	192	VIP,NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 132	pg/L	388	2.49	48	NBC,VIL,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04132018-01	PCB 135/151/154	pg/L	445	1.95	96	VRIU,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 141	pg/L	256	2.15	48	VRIU,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 147/149	pg/L	860	2.12	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 153/168	pg/L	2170	1.82	96	VIP,NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 156/157	pg/L	175	6.64	38	NBC,VIU
TW2-IN-04132018-01	PCB 158	pg/L	142	1.57	48	VRIU,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 170	pg/L	548	3.84	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 174	pg/L	380	3.19	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 177	pg/L	271	3.44	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 180/193	pg/L	1490	3.02	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 183/185	pg/L	434	3.3	96	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 187	pg/L	1030	1.76	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 194	pg/L	367	3.01	48	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 195	pg/L	107	3.16	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	PCB 201	pg/L	46.2	2.03	48	VRIU,J,NBC,VIL,VJ
TW2-IN-04132018-01	PCB 203	pg/L	227	2.87	48	NBC,VIL,VJ,VIU
TW2-IN-04132018-01	Total DiCB	pg/L	81.6	1.5	19	NBC,VIL,VJ
TW2-IN-04132018-01	Total HeptaCB	pg/L	3720	1.76	19	NBC,VIL,VJ
TW2-IN-04132018-01	Total HexaCB	pg/L	6720	1.57	19	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	Total MonoCB	pg/L		19.2	19	NBC
TW2-IN-04132018-01	Total NonaCB	pg/L		19.2	19	NBC
TW2-IN-04132018-01	Total OctaCB	pg/L	747	2.03	19	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	Total PCBs	pg/L	18600	1.5	192	VIP,NBC,VIL,VJ
TW2-IN-04132018-01	Total PentaCB	pg/L	3910	3.42	192	NBC,VIL
TW2-IN-04132018-01	Total TetraCB	pg/L	2070	3.37	192	NBC,VIL
TW2-IN-04132018-01	Total TriCB	pg/L	889	3.77	48	NBC,VIL
BLNK-EF-04172018-01	PCB 008	pg/L	13.7	1.82	48	J,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 018/30	pg/L	10.7	5.11	48	J,JA,NBC
BLNK-EF-04172018-01	PCB 020/28	pg/L	17.4	6.17	48	J,NBC
BLNK-EF-04172018-01	PCB 021/33	pg/L	12.8	6.3	48	J,NBC
BLNK-EF-04172018-01	PCB 031	pg/L	14.9	5.76	48	J,NBC
BLNK-EF-04172018-01	PCB 044/47/65	pg/L	37.3	4.52	95	J,NBC,VIU
BLNK-EF-04172018-01	PCB 049/69	pg/L	14.7	4.28	95	J,NBC,VIU
BLNK-EF-04172018-01	PCB 052	pg/L	52.6	4.39	48	NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 056	pg/L		4.76	48	NBC
BLNK-EF-04172018-01	PCB 060	pg/L		4.68	48	NBC
BLNK-EF-04172018-01	PCB 066	pg/L	5.97	3.65	48	J,JA,NBC,VIU
BLNK-EF-04172018-01	PCB 070/61/74/76	pg/L	14.9	3.92	190	J,NBC,VIL,VIU,VJ
BLNK-EF-04172018-01	PCB 083/99	pg/L	10.9	6.88	95	J,JA,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L		6.01	190	NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 090/101/113	pg/L	22.7	5.93	190	J,NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 093/95/100	pg/L	26.9	5.98	190	J,NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 105	pg/L		5.78	19	NBC,VIU
BLNK-EF-04172018-01	PCB 110/115	pg/L	13.8	5.45	95	J,JA,NBC
BLNK-EF-04172018-01	PCB 118	pg/L		5.31	19	NBC,VIL
BLNK-EF-04172018-01	PCB 128/166	pg/L		5.28	95	NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
BLNK-EF-04172018-01	PCB 129/138/163	pg/L	17.1	6.99	190	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 132	pg/L		6.08	48	NBC,VIL,VIU
BLNK-EF-04172018-01	PCB 135/151/154	pg/L	10.1	3.04	95	VRIU,J,JA,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 141	pg/L		5.28	48	VRIU,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 147/149	pg/L	13.6	5.02	95	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 153/168	pg/L	20.6	4.47	95	IP,J,JA,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 156/157	pg/L		6.97	38	NBC,VIU
BLNK-EF-04172018-01	PCB 158	pg/L		3.94	48	VRIU,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 170	pg/L		8.48	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 174	pg/L		5.99	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 177	pg/L		6.63	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 180/193	pg/L	13.7	6.41	95	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 183/185	pg/L		6.23	95	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 187	pg/L	8.14	4.81	48	J,NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 194	pg/L		8.64	48	NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 195	pg/L		7.44	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	PCB 201	pg/L		3.81	48	VRIU,NBC,VIL,VJ
BLNK-EF-04172018-01	PCB 203	pg/L		6.26	48	NBC,VIL,VJ,VIU
BLNK-EF-04172018-01	Total DiCB	pg/L	13.7	1.82	19	J,NBC,VIL,VJ
BLNK-EF-04172018-01	Total HeptaCB	pg/L	21.9	4.81	19	NBC,VIL,VJ
BLNK-EF-04172018-01	Total HexaCB	pg/L	61.4	3.04	19	VIP,NBC,VIL,VJ
BLNK-EF-04172018-01	Total MonoCB	pg/L		19	19	NBC
BLNK-EF-04172018-01	Total NonaCB	pg/L		19	19	NBC
BLNK-EF-04172018-01	Total OctaCB	pg/L		3.81	19	NBC,VIL,VJ
BLNK-EF-04172018-01	Total PCBs	pg/L	353	1.82	190	VIP,NBC,VIL,VJ
BLNK-EF-04172018-01	Total PentaCB	pg/L	74.4	5.31	190	J,NBC,VIL
BLNK-EF-04172018-01	Total TetraCB	pg/L	126	3.65	190	J,NBC,VIL
BLNK-EF-04172018-01	Total TriCB	pg/L	55.7	5.11	48	NBC,VIL
CO1-EF-04172018-01	PCB 008	pg/L		61.9	62	NBC,VIL,VJ
CO1-EF-04172018-01	PCB 018/30	pg/L		84.4	84	NBC
CO1-EF-04172018-01	PCB 020/28	pg/L		103	103	NBC
CO1-EF-04172018-01	PCB 021/33	pg/L		106	106	NBC
CO1-EF-04172018-01	PCB 031	pg/L		96.5	97	NBC
CO1-EF-04172018-01	PCB 044/47/65	pg/L		96.1	99	NBC,VIU
CO1-EF-04172018-01	PCB 049/69	pg/L		90.9	99	NBC,VIU
CO1-EF-04172018-01	PCB 052	pg/L		93.7	94	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 056	pg/L		44.9	50	NBC
CO1-EF-04172018-01	PCB 060	pg/L		42.7	50	NBC
CO1-EF-04172018-01	PCB 066	pg/L		80.8	81	NBC,VIU
CO1-EF-04172018-01	PCB 070/61/74/76	pg/L		84.6	199	NBC,VIL,VIU,VJ
CO1-EF-04172018-01	PCB 083/99	pg/L		32.4	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L		28.3	199	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 090/101/113	pg/L	47.8	28.1	199	J,NBC,VIL,VIU
CO1-EF-04172018-01	PCB 093/95/100	pg/L		40.1	199	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 105	pg/L		23	23	NBC,VIU
CO1-EF-04172018-01	PCB 110/115	pg/L	49.6	25.7	99	J,NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04172018-01	PCB 118	pg/L		24.1	24	NBC,VIL
CO1-EF-04172018-01	PCB 128/166	pg/L		14.8	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 129/138/163	pg/L	95.2	20.3	199	IP,J,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 132	pg/L		18	50	NBC,VIL,VIU
CO1-EF-04172018-01	PCB 135/151/154	pg/L		15.2	99	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 141	pg/L		15.5	50	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 147/149	pg/L		15.3	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 153/168	pg/L	92	13.2	99	IP,J,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 156/157	pg/L		26.3	40	NBC,VIU
CO1-EF-04172018-01	PCB 158	pg/L		11.4	50	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 170	pg/L		38.5	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 174	pg/L		31.9	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 177	pg/L		34.5	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 180/193	pg/L	61.2	30.3	99	J,JA,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 183/185	pg/L		33	99	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 187	pg/L	36.9	16.1	50	J,NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 194	pg/L		22.2	50	VRIP,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 195	pg/L		23.4	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	PCB 201	pg/L		15	50	VRIU,NBC,VIL,VJ
CO1-EF-04172018-01	PCB 203	pg/L		21.2	50	NBC,VIL,VJ,VIU
CO1-EF-04172018-01	Total DiCB	pg/L		61.9	62	NBC,VIL,VJ
CO1-EF-04172018-01	Total HeptaCB	pg/L	98.1	16.1	20	NBC,VIL,VJ
CO1-EF-04172018-01	Total HexaCB	pg/L	187	11.4	20	VIP,NBC,VIL,VJ
CO1-EF-04172018-01	Total MonoCB	pg/L		19.9	20	NBC
CO1-EF-04172018-01	Total NonaCB	pg/L		19.9	20	NBC
CO1-EF-04172018-01	Total OctaCB	pg/L		15	20	VRIP,NBC,VIL,VJ
CO1-EF-04172018-01	Total PCBs	pg/L	383	11.4	199	VIP,NBC,VIL,VJ
CO1-EF-04172018-01	Total PentaCB	pg/L	97.4	23	199	J,NBC,VIL
CO1-EF-04172018-01	Total TetraCB	pg/L		42.7	199	NBC,VIL
CO1-EF-04172018-01	Total TriCB	pg/L		84.4	84	NBC,VIL
CO2-EF-04172018-01	PCB 008	pg/L	35.5	3.22	48	J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 008	pg/L	10.9	1.78	49	J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 018/30	pg/L	14.9	5.25	48	J,NBC
CO2-EF-04172018-D	PCB 018/30	pg/L	9.84	5.62	49	J,NBC
CO2-EF-04172018-01	PCB 020/28	pg/L	20	13.2	48	J,JA,NBC
CO2-EF-04172018-D	PCB 020/28	pg/L	15.6	8.61	49	J,NBC
CO2-EF-04172018-01	PCB 021/33	pg/L		13.5	48	NBC
CO2-EF-04172018-D	PCB 021/33	pg/L		8.54	49	NBC
CO2-EF-04172018-01	PCB 031	pg/L	14.4	12.4	48	J,NBC
CO2-EF-04172018-D	PCB 031	pg/L		8.22	49	NBC
CO2-EF-04172018-01	PCB 044/47/65	pg/L	34.6	8.19	96	J,NBC,VIU
CO2-EF-04172018-D	PCB 044/47/65	pg/L	27.7	6.27	98	J,NBC,VIU
CO2-EF-04172018-01	PCB 049/69	pg/L	20.2	7.75	96	J,JA,NBC,VIU
CO2-EF-04172018-D	PCB 049/69	pg/L	9.7	6.09	98	J,NBC,VIU
CO2-EF-04172018-01	PCB 052	pg/L	38.7	7.98	48	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 052	pg/L	20	6.72	49	J,NBC,VIL,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04172018-01	PCB 056	pg/L		17.3	48	NBC
CO2-EF-04172018-D	PCB 056	pg/L		4.36	49	NBC
CO2-EF-04172018-01	PCB 060	pg/L		16.5	48	NBC
CO2-EF-04172018-D	PCB 060	pg/L		4.03	49	NBC
CO2-EF-04172018-01	PCB 066	pg/L	15.4	6.89	48	J,NBC,VIU
CO2-EF-04172018-D	PCB 066	pg/L	7.41	4.39	49	J,NBC,VIU
CO2-EF-04172018-01	PCB 070/61/74/76	pg/L	32.3	7.21	192	J,NBC,VIL,VIU,VJ
CO2-EF-04172018-D	PCB 070/61/74/76	pg/L	18.2	4.76	195	J,JA,NBC,VIL,VIU,VJ
CO2-EF-04172018-01	PCB 083/99	pg/L	73.6	4.1	96	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 083/99	pg/L	11.3	3.35	98	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	38.1	3.58	192	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 086/87/97/109/119/125	pg/L	22.2	2.87	195	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 090/101/113	pg/L	60.7	3.56	192	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 090/101/113	pg/L	22.1	2.95	195	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 093/95/100	pg/L	44.5	3.08	192	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 093/95/100	pg/L	15.9	3.61	195	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 105	pg/L		12.7	19	NBC,VIU
CO2-EF-04172018-D	PCB 105	pg/L	7.29	4.52	20	J,JA,NBC,VIU
CO2-EF-04172018-01	PCB 110/115	pg/L	34	3.25	96	J,NBC
CO2-EF-04172018-D	PCB 110/115	pg/L	25.8	2.55	98	J,NBC
CO2-EF-04172018-01	PCB 118	pg/L	42.7	12	19	NBC,VIL
CO2-EF-04172018-D	PCB 118	pg/L	14.8	4.15	20	J,NBC,VIL
CO2-EF-04172018-01	PCB 128/166	pg/L	33	2.49	96	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 128/166	pg/L	5.12	1.81	98	J,JA,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 129/138/163	pg/L	367	3.43	192	VIP,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 129/138/163	pg/L	36.1	2.6	195	IP,J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 132	pg/L	22.5	3.04	48	J,NBC,VIL,VIU
CO2-EF-04172018-D	PCB 132	pg/L	10.2	2.43	49	J,NBC,VIL,VIU
CO2-EF-04172018-01	PCB 135/151/154	pg/L	149	2.25	96	VRIU,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 135/151/154	pg/L	11.8	2.28	98	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 141	pg/L	30.6	2.62	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 141	pg/L	5.88	1.98	49	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 147/149	pg/L	120	2.59	96	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 147/149	pg/L	20.5	2.13	98	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 153/168	pg/L	1190	2.22	96	VIP,NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 153/168	pg/L	24	1.71	98	VRIP,IP,J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 156/157	pg/L	19.1	8.29	38	J,NBC,VIU
CO2-EF-04172018-D	PCB 156/157	pg/L	5.08	3.9	39	J,JA,NBC,VIU
CO2-EF-04172018-01	PCB 158	pg/L	19.8	1.92	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 158	pg/L	3.24	1.4	49	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 170	pg/L	185	3.98	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 170	pg/L	6.79	3.44	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 174	pg/L	48.3	3.3	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 174	pg/L	7.59	3.29	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 177	pg/L	78	3.57	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 177	pg/L	4.44	3.32	49	J,NBC,VIL,VJ,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO2-EF-04172018-01	PCB 180/193	pg/L	608	3.13	96	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 180/193	pg/L	17.2	2.84	98	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 183/185	pg/L	174	3.42	96	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 183/185	pg/L	7.22	3.3	98	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 187	pg/L	585	2.28	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 187	pg/L	9.87	2.25	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 194	pg/L	203	2.9	48	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 194	pg/L	5.75	2.75	49	VRIP,IP,J,JA,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 195	pg/L	51.3	3.04	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 195	pg/L	3.92	2.79	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	PCB 201	pg/L	20.8	1.95	48	VRIU,J,NBC,VIL,VJ
CO2-EF-04172018-D	PCB 201	pg/L		1.99	49	VRIU,NBC,VIL,VJ
CO2-EF-04172018-01	PCB 203	pg/L	87.7	2.76	48	NBC,VIL,VJ,VIU
CO2-EF-04172018-D	PCB 203	pg/L	5.23	2.57	49	J,NBC,VIL,VJ,VIU
CO2-EF-04172018-01	Total DiCB	pg/L	35.5	3.22	19	NBC,VIL,VJ
CO2-EF-04172018-D	Total DiCB	pg/L	10.9	1.78	20	J,NBC,VIL,VJ
CO2-EF-04172018-01	Total HeptaCB	pg/L	1500	2.28	19	NBC,VIL,VJ
CO2-EF-04172018-D	Total HeptaCB	pg/L	45.9	2.25	20	NBC,VIL,VJ
CO2-EF-04172018-01	Total HexaCB	pg/L	1950	1.92	19	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	Total HexaCB	pg/L	122	1.4	20	VIP,NBC,VIL,VJ
CO2-EF-04172018-01	Total MonoCB	pg/L		19.2	19	NBC
CO2-EF-04172018-D	Total MonoCB	pg/L		19.5	20	NBC
CO2-EF-04172018-01	Total NonaCB	pg/L		19.2	19	NBC
CO2-EF-04172018-D	Total NonaCB	pg/L		19.5	20	NBC
CO2-EF-04172018-01	Total OctaCB	pg/L	362	1.95	19	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	Total OctaCB	pg/L	14.9	1.99	20	VRIP,J,NBC,VIL,VJ
CO2-EF-04172018-01	Total PCBs	pg/L	4510	1.92	192	VIP,NBC,VIL,VJ
CO2-EF-04172018-D	Total PCBs	pg/L	429	1.4	195	VIP,NBC,VIL,VJ
CO2-EF-04172018-01	Total PentaCB	pg/L	294	3.08	192	NBC,VIL
CO2-EF-04172018-D	Total PentaCB	pg/L	119	2.55	195	J,NBC,VIL
CO2-EF-04172018-01	Total TetraCB	pg/L	141	6.89	192	J,NBC,VIL
CO2-EF-04172018-D	Total TetraCB	pg/L	83	4.03	195	J,NBC,VIL
CO2-EF-04172018-01	Total TriCB	pg/L	49.3	5.25	48	NBC,VIL
CO2-EF-04172018-D	Total TriCB	pg/L	25.4	5.62	49	J,NBC,VIL
CO3-EF-04172018-01	PCB 008	pg/L		25.7	48	NBC,VIL,VJ
CO3-EF-04172018-01	PCB 018/30	pg/L		42.9	48	NBC
CO3-EF-04172018-01	PCB 020/28	pg/L		54.9	55	NBC
CO3-EF-04172018-01	PCB 021/33	pg/L		56.4	56	NBC
CO3-EF-04172018-01	PCB 031	pg/L		51.6	52	NBC
CO3-EF-04172018-01	PCB 044/47/65	pg/L		53.2	97	NBC,VIU
CO3-EF-04172018-01	PCB 049/69	pg/L		50.4	97	NBC,VIU
CO3-EF-04172018-01	PCB 052	pg/L		51.9	52	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 056	pg/L		26.5	48	NBC
CO3-EF-04172018-01	PCB 060	pg/L		25.2	48	NBC
CO3-EF-04172018-01	PCB 066	pg/L		44.8	48	NBC,VIU
CO3-EF-04172018-01	PCB 070/61/74/76	pg/L		46.9	194	NBC,VIL,VIU,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO3-EF-04172018-01	PCB 083/99	pg/L		15.9	97	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L		13.9	194	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 090/101/113	pg/L	37.1	13.8	194	J,JA,NBC,VIL,VIU
CO3-EF-04172018-01	PCB 093/95/100	pg/L		23.4	194	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 105	pg/L		16.9	19	NBC,VIU
CO3-EF-04172018-01	PCB 110/115	pg/L	54.1	12.6	97	J,NBC
CO3-EF-04172018-01	PCB 118	pg/L	38.7	17	19	NBC,VIL
CO3-EF-04172018-01	PCB 128/166	pg/L		8.58	97	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 129/138/163	pg/L	69.9	11.9	194	IP,J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 132	pg/L		10.5	48	NBC,VIL,VIU
CO3-EF-04172018-01	PCB 135/151/154	pg/L	15.1	8.16	97	VRIU,J,JA,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 141	pg/L		9.02	48	VRIU,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 147/149	pg/L	17.9	8.91	97	J,JA,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 153/168	pg/L	41.4	7.65	97	IP,J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 156/157	pg/L		11.9	39	NBC,VIU
CO3-EF-04172018-01	PCB 158	pg/L		6.6	48	VRIU,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 170	pg/L	26	16	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 174	pg/L	17.5	13.2	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 177	pg/L		14.3	48	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 180/193	pg/L	48.9	12.6	97	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 183/185	pg/L		13.7	97	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 187	pg/L	19.4	8.47	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 194	pg/L	15.4	7.39	48	VRIP,IP,J,JA,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 195	pg/L		7.77	48	NBC,VIL,VJ,VIU
CO3-EF-04172018-01	PCB 201	pg/L		4.98	48	VRIU,NBC,VIL,VJ
CO3-EF-04172018-01	PCB 203	pg/L	10	7.05	48	J,NBC,VIL,VJ,VIU
CO3-EF-04172018-01	Total DiCB	pg/L		25.7	26	NBC,VIL,VJ
CO3-EF-04172018-01	Total HeptaCB	pg/L	112	8.47	19	NBC,VIL,VJ
CO3-EF-04172018-01	Total HexaCB	pg/L	144	6.6	19	VIP,NBC,VIL,VJ
CO3-EF-04172018-01	Total MonoCB	pg/L		19.4	19	NBC
CO3-EF-04172018-01	Total NonaCB	pg/L		19.4	19	NBC
CO3-EF-04172018-01	Total OctaCB	pg/L	25.4	4.98	19	VRIP,NBC,VIL,VJ
CO3-EF-04172018-01	Total PCBs	pg/L	411	4.98	194	VIP,NBC,VIL,VJ
CO3-EF-04172018-01	Total PentaCB	pg/L	130	12.6	194	J,NBC,VIL
CO3-EF-04172018-01	Total TetraCB	pg/L		25.2	194	NBC,VIL
CO3-EF-04172018-01	Total TriCB	pg/L		42.9	48	NBC,VIL
CO4-EF-04172018-01	PCB 008	pg/L	27.9	2.36	48	J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 018/30	pg/L	35.8	5.41	48	J,NBC
CO4-EF-04172018-01	PCB 020/28	pg/L	34.3	7.76	48	J,NBC
CO4-EF-04172018-01	PCB 021/33	pg/L	19.5	7.96	48	J,NBC
CO4-EF-04172018-01	PCB 031	pg/L	27.9	7.29	48	J,NBC
CO4-EF-04172018-01	PCB 044/47/65	pg/L	37.8	8.16	97	J,NBC,VIU
CO4-EF-04172018-01	PCB 049/69	pg/L	16.9	7.72	97	J,NBC,VIU
CO4-EF-04172018-01	PCB 052	pg/L	33.8	7.96	48	J,JA,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 056	pg/L	12.1	6.33	48	J,NBC
CO4-EF-04172018-01	PCB 060	pg/L		6.02	48	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04172018-01	PCB 066	pg/L	19.7	6.86	48	J,NBC,VIU
CO4-EF-04172018-01	PCB 070/61/74/76	pg/L	43.3	7.19	193	J,NBC,VIL,VIU,VJ
CO4-EF-04172018-01	PCB 083/99	pg/L	17.8	2.99	97	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	31.6	2.61	193	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 090/101/113	pg/L	38.5	2.59	193	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 093/95/100	pg/L	29.1	4.92	193	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 105	pg/L	16	4.73	19	J,NBC,VIU
CO4-EF-04172018-01	PCB 110/115	pg/L	49.7	2.37	97	J,NBC
CO4-EF-04172018-01	PCB 118	pg/L	29.7	4.35	19	NBC,VIL
CO4-EF-04172018-01	PCB 128/166	pg/L	6.79	3.24	97	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 129/138/163	pg/L	63.2	4.46	193	IP,J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 132	pg/L	14	3.95	48	J,NBC,VIL,VIU
CO4-EF-04172018-01	PCB 135/151/154	pg/L	15.2	2.51	97	VRIU,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 141	pg/L	8.6	3.4	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 147/149	pg/L	31.1	3.36	97	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 153/168	pg/L	51.6	2.89	97	IP,J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 156/157	pg/L	7.15	6.26	39	J,NBC,VIU
CO4-EF-04172018-01	PCB 158	pg/L	4.99	2.49	48	VRIU,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 170	pg/L	11.9	4.86	48	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 174	pg/L	10.8	4.03	48	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 177	pg/L	6.01	4.35	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 180/193	pg/L	33.1	3.82	97	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 183/185	pg/L	12.6	4.17	97	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 187	pg/L	23.7	3.17	48	J,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 194	pg/L	10.6	3.59	48	VRIP,IP,J,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 195	pg/L		3.77	48	NBC,VIL,VJ,VIU
CO4-EF-04172018-01	PCB 201	pg/L		2.42	48	VRIU,NBC,VIL,VJ
CO4-EF-04172018-01	PCB 203	pg/L	6.36	3.42	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04172018-01	Total DiCB	pg/L	27.9	2.36	19	NBC,VIL,VJ
CO4-EF-04172018-01	Total HeptaCB	pg/L	85.6	3.17	19	NBC,VIL,VJ
CO4-EF-04172018-01	Total HexaCB	pg/L	203	2.49	19	VIP,NBC,VIL,VJ
CO4-EF-04172018-01	Total MonoCB	pg/L		19.3	19	NBC
CO4-EF-04172018-01	Total NonaCB	pg/L		19.3	19	NBC
CO4-EF-04172018-01	Total OctaCB	pg/L	16.9	2.42	19	VRIP,J,NBC,VIL,VJ
CO4-EF-04172018-01	Total PCBs	pg/L	839	2.36	193	VIP,NBC,VIL,VJ
CO4-EF-04172018-01	Total PentaCB	pg/L	212	2.37	193	NBC,VIL
CO4-EF-04172018-01	Total TetraCB	pg/L	164	6.02	193	J,NBC,VIL
CO4-EF-04172018-01	Total TriCB	pg/L	117	5.41	48	NBC,VIL
CO5-EF-04172018-01	PCB 008	pg/L	19.6	1.35	49	J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 018/30	pg/L	27.1	2.91	49	J,NBC
CO5-EF-04172018-01	PCB 020/28	pg/L	33.9	3.59	49	J,NBC
CO5-EF-04172018-01	PCB 021/33	pg/L	16	3.69	49	J,JA,NBC
CO5-EF-04172018-01	PCB 031	pg/L	24.3	3.38	49	J,NBC
CO5-EF-04172018-01	PCB 044/47/65	pg/L	30.5	5.41	98	J,NBC,VIU
CO5-EF-04172018-01	PCB 049/69	pg/L	14.2	5.12	98	J,NBC,VIU
CO5-EF-04172018-01	PCB 052	pg/L	29.9	5.28	49	J,NBC,VIL,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO5-EF-04172018-01	PCB 056	pg/L	8.04	5	49	J,NBC
CO5-EF-04172018-01	PCB 060	pg/L		4.76	49	NBC
CO5-EF-04172018-01	PCB 066	pg/L	15.1	4.55	49	J,NBC,VIU
CO5-EF-04172018-01	PCB 070/61/74/76	pg/L	33.1	4.76	197	J,NBC,VIL,VIU,VJ
CO5-EF-04172018-01	PCB 083/99	pg/L	13.6	2.87	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	23.9	2.51	197	J,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 090/101/113	pg/L	28.1	2.49	197	J,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 093/95/100	pg/L	19.9	2.66	197	J,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 105	pg/L	11.6	4.63	20	J,NBC,VIU
CO5-EF-04172018-01	PCB 110/115	pg/L	30.8	2.28	98	J,NBC
CO5-EF-04172018-01	PCB 118	pg/L	20.6	4.24	20	JA,NBC,VIL
CO5-EF-04172018-01	PCB 128/166	pg/L	5.1	2.12	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 129/138/163	pg/L	38.2	2.92	197	IP,J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 132	pg/L	8.85	2.58	49	J,JA,NBC,VIL,VIU
CO5-EF-04172018-01	PCB 135/151/154	pg/L	7.19	1.59	98	VRIU,J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 141	pg/L	4.64	2.23	49	VRIU,J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 147/149	pg/L	20	2.2	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 153/168	pg/L	24.8	1.89	98	VRIP,IP,J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 156/157	pg/L	4.32	3.83	39	J,NBC,VIU
CO5-EF-04172018-01	PCB 158	pg/L	2.76	1.63	49	VRIU,J,JA,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 170	pg/L	6.83	2.82	49	J,JA,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 174	pg/L	7.9	2.34	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 177	pg/L	4.04	2.52	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 180/193	pg/L	20.6	2.22	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 183/185	pg/L	7.29	2.42	98	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 187	pg/L	12	1.63	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 194	pg/L	6.34	2.15	49	VRIP,IP,J,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 195	pg/L		2.25	49	NBC,VIL,VJ,VIU
CO5-EF-04172018-01	PCB 201	pg/L		1.45	49	VRIU,NBC,VIL,VJ
CO5-EF-04172018-01	PCB 203	pg/L	5.01	2.05	49	J,NBC,VIL,VJ,VIU
CO5-EF-04172018-01	Total DiCB	pg/L	19.6	1.35	20	J,NBC,VIL,VJ
CO5-EF-04172018-01	Total HeptaCB	pg/L	51.4	1.63	20	NBC,VIL,VJ
CO5-EF-04172018-01	Total HexaCB	pg/L	116	1.59	20	VIP,NBC,VIL,VJ
CO5-EF-04172018-01	Total MonoCB	pg/L		19.7	20	NBC
CO5-EF-04172018-01	Total NonaCB	pg/L		19.7	20	NBC
CO5-EF-04172018-01	Total OctaCB	pg/L	11.3	1.45	20	VRIP,J,NBC,VIL,VJ
CO5-EF-04172018-01	Total PCBs	pg/L	586	1.35	197	VIP,NBC,VIL,VJ
CO5-EF-04172018-01	Total PentaCB	pg/L	149	2.28	197	J,NBC,VIL
CO5-EF-04172018-01	Total TetraCB	pg/L	131	4.55	197	J,NBC,VIL
CO5-EF-04172018-01	Total TriCB	pg/L	101	2.91	49	NBC,VIL
CO6-EF-04172018-01	PCB 008	pg/L	43.7	3.44	48	J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 018/30	pg/L	49.8	7.74	48	NBC
CO6-EF-04172018-01	PCB 020/28	pg/L	48.2	11.1	48	NBC
CO6-EF-04172018-01	PCB 021/33	pg/L	27.8	11.4	48	J,NBC
CO6-EF-04172018-01	PCB 031	pg/L	37.8	10.5	48	J,NBC
CO6-EF-04172018-01	PCB 044/47/65	pg/L	47.9	13.9	96	J,NBC,VIU

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO6-EF-04172018-01	PCB 049/69	pg/L	20.2	13.2	96	J,JA,NBC,VIU
CO6-EF-04172018-01	PCB 052	pg/L	49.5	13.6	48	NBC,VIL,VIU
CO6-EF-04172018-01	PCB 056	pg/L	14.5	11.4	48	J,NBC
CO6-EF-04172018-01	PCB 060	pg/L		10.9	48	NBC
CO6-EF-04172018-01	PCB 066	pg/L	23.7	11.7	48	J,NBC,VIU
CO6-EF-04172018-01	PCB 070/61/74/76	pg/L	53.5	12.3	192	J,NBC,VIL,VIU,VJ
CO6-EF-04172018-01	PCB 083/99	pg/L	23.4	6.28	96	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 086/87/97/109/119/125	pg/L	37.7	5.49	192	J,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 090/101/113	pg/L	47.3	5.45	192	J,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 093/95/100	pg/L	29.5	8.33	192	J,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 105	pg/L	15	7.25	19	J,NBC,VIU
CO6-EF-04172018-01	PCB 110/115	pg/L	53.5	4.98	96	J,NBC
CO6-EF-04172018-01	PCB 118	pg/L	35	6.82	19	NBC,VIL
CO6-EF-04172018-01	PCB 128/166	pg/L	8.2	3.23	96	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 129/138/163	pg/L	71.8	4.45	192	IP,J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 132	pg/L	14	3.94	48	J,JA,NBC,VIL,VIU
CO6-EF-04172018-01	PCB 135/151/154	pg/L	16.5	3.43	96	VRIU,J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 141	pg/L	10.9	3.4	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 147/149	pg/L	34.4	3.36	96	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 153/168	pg/L	44.2	2.88	96	IP,J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 156/157	pg/L		7.1	39	NBC,VIU
CO6-EF-04172018-01	PCB 158	pg/L	5.53	2.49	48	VRIU,J,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 170	pg/L	10.7	7.54	48	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 174	pg/L	11.6	6.25	48	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 177	pg/L	6.75	6.75	48	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 180/193	pg/L	33.5	5.93	96	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 183/185	pg/L	8.35	6.47	96	J,JA,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 187	pg/L	17	3.17	48	J,NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 194	pg/L	8.43	5.44	48	VRIP,IP,J,JA,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 195	pg/L		5.71	48	NBC,VIL,VJ,VIU
CO6-EF-04172018-01	PCB 201	pg/L		3.66	48	VRIU,NBC,VIL,VJ
CO6-EF-04172018-01	PCB 203	pg/L		5.18	48	NBC,VIL,VJ,VIU
CO6-EF-04172018-01	Total DiCB	pg/L	43.7	3.44	19	NBC,VIL,VJ
CO6-EF-04172018-01	Total HeptaCB	pg/L	79.6	3.17	19	NBC,VIL,VJ
CO6-EF-04172018-01	Total HexaCB	pg/L	206	2.49	19	VIP,NBC,VIL,VJ
CO6-EF-04172018-01	Total MonoCB	pg/L		19.2	19	NBC
CO6-EF-04172018-01	Total NonaCB	pg/L		19.2	19	NBC
CO6-EF-04172018-01	Total OctaCB	pg/L	8.43	3.66	19	VRIP,J,NBC,VIL,VJ
CO6-EF-04172018-01	Total PCBs	pg/L	960	2.49	192	VIP,NBC,VIL,VJ
CO6-EF-04172018-01	Total PentaCB	pg/L	241	4.98	192	NBC,VIL
CO6-EF-04172018-01	Total TetraCB	pg/L	209	10.9	192	NBC,VIL
CO6-EF-04172018-01	Total TriCB	pg/L	164	7.74	48	NBC,VIL
TW6-IN-04172018-01	PCB 008	pg/L	35.9	3.61	55	J,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 018/30	pg/L	47	6.31	55	J,NBC
TW6-IN-04172018-01	PCB 020/28	pg/L	176	8.1	55	NBC
TW6-IN-04172018-01	PCB 021/33	pg/L	71	8.31	55	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW6-IN-04172018-01	PCB 031	pg/L	107	7.61	55	NBC
TW6-IN-04172018-01	PCB 044/47/65	pg/L	222	10.5	109	NBC,VIU
TW6-IN-04172018-01	PCB 049/69	pg/L	107	9.88	109	J,NBC,VIU
TW6-IN-04172018-01	PCB 052	pg/L	282	10.2	55	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 056	pg/L	91	6.89	55	NBC
TW6-IN-04172018-01	PCB 060	pg/L	43.4	6.56	55	J,NBC
TW6-IN-04172018-01	PCB 066	pg/L	172	8.78	55	NBC,VIU
TW6-IN-04172018-01	PCB 070/61/74/76	pg/L	377	9.19	218	NBC,VIL,VIU,VJ
TW6-IN-04172018-01	PCB 083/99	pg/L	205	5.09	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 086/87/97/109/119/125	pg/L	338	4.44	218	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 090/101/113	pg/L	437	4.42	218	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 093/95/100	pg/L	302	4.61	218	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 105	pg/L	228	2.88	22	NBC,VIU
TW6-IN-04172018-01	PCB 110/115	pg/L	630	4.03	109	NBC
TW6-IN-04172018-01	PCB 118	pg/L	454	2.64	22	NBC,VIL
TW6-IN-04172018-01	PCB 128/166	pg/L	138	2.47	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 129/138/163	pg/L	1180	3.41	218	VIP,NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 132	pg/L	256	3.01	55	NBC,VIL,VIU
TW6-IN-04172018-01	PCB 135/151/154	pg/L	193	2.25	109	VRIU,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 141	pg/L	166	2.6	55	VRIU,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 147/149	pg/L	512	2.57	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 153/168	pg/L	664	2.21	109	VIP,NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 156/157	pg/L	109	6.21	44	NBC,VIU
TW6-IN-04172018-01	PCB 158	pg/L	87.7	1.9	55	VRIU,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 170	pg/L	285	6.02	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 174	pg/L	246	4.99	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 177	pg/L	150	5.39	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 180/193	pg/L	668	4.73	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 183/185	pg/L	188	5.17	109	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 187	pg/L	321	2.6	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 194	pg/L	160	3.94	55	IP,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 195	pg/L	55.9	4.15	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	PCB 201	pg/L	22.9	2.66	55	VRIU,J,NBC,VIL,VJ
TW6-IN-04172018-01	PCB 203	pg/L	134	3.76	55	NBC,VIL,VJ,VIU
TW6-IN-04172018-01	Total DiCB	pg/L	35.9	3.61	22	NBC,VIL,VJ
TW6-IN-04172018-01	Total HeptaCB	pg/L	1670	2.6	22	NBC,VIL,VJ
TW6-IN-04172018-01	Total HexaCB	pg/L	3310	1.9	22	VIP,NBC,VIL,VJ
TW6-IN-04172018-01	Total MonoCB	pg/L		21.8	22	NBC
TW6-IN-04172018-01	Total NonaCB	pg/L		21.8	22	NBC
TW6-IN-04172018-01	Total OctaCB	pg/L	373	2.66	22	VIP,NBC,VIL,VJ
TW6-IN-04172018-01	Total PCBs	pg/L	9860	1.9	218	VIP,NBC,VIL,VJ
TW6-IN-04172018-01	Total PentaCB	pg/L	2590	2.64	218	NBC,VIL
TW6-IN-04172018-01	Total TetraCB	pg/L	1300	6.56	218	NBC,VIL
TW6-IN-04172018-01	Total TriCB	pg/L	401	6.31	55	NBC,VIL
CO4-EF-04192018-01	PCB 008	pg/L	37.8	1.74	48	J,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 018/30	pg/L	38	4.44	48	J,NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO4-EF-04192018-01	PCB 020/28	pg/L	36.1	8.56	48	J,NBC
CO4-EF-04192018-01	PCB 021/33	pg/L	24.1	8.53	48	J,JA,NBC
CO4-EF-04192018-01	PCB 031	pg/L	33.5	7.91	48	J,NBC
CO4-EF-04192018-01	PCB 044/47/65	pg/L	47.2	4.23	96	J,NBC,VIU
CO4-EF-04192018-01	PCB 049/69	pg/L	24.9	3.97	96	J,NBC,VIU
CO4-EF-04192018-01	PCB 052	pg/L	66.1	4.18	48	NBC,VIL,VIU
CO4-EF-04192018-01	PCB 056	pg/L		12.3	48	NBC
CO4-EF-04192018-01	PCB 060	pg/L		12.1	48	NBC
CO4-EF-04192018-01	PCB 066	pg/L	17.7	3.27	48	J,NBC,VIU
CO4-EF-04192018-01	PCB 070/61/74/76	pg/L	45.9	3.52	192	J,NBC,VIL,VIU,VJ
CO4-EF-04192018-01	PCB 083/99	pg/L	21.5	4.34	96	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 086/87/97/109/119/125	pg/L	30.2	3.8	192	J,JA,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 090/101/113	pg/L	43	3.75	192	J,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 093/95/100	pg/L	36.4	3.18	192	J,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 105	pg/L	10	6.39	19	J,NBC,VIU
CO4-EF-04192018-01	PCB 110/115	pg/L	41.8	3.47	96	J,NBC
CO4-EF-04192018-01	PCB 118	pg/L	22.9	5.91	19	JA,NBC,VIL
CO4-EF-04192018-01	PCB 128/166	pg/L	6.91	4.6	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 129/138/163	pg/L	47.5	5.99	192	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 132	pg/L	11	5.47	48	J,NBC,VIL,VIU
CO4-EF-04192018-01	PCB 135/151/154	pg/L	15	2.55	96	VRIU,J,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 141	pg/L	5.69	4.62	48	VRIU,J,JA,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 147/149	pg/L	24.5	4.54	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 153/168	pg/L	36	3.94	96	IP,J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 156/157	pg/L		6.32	38	NBC,VIU
CO4-EF-04192018-01	PCB 158	pg/L		3.46	48	VRIU,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 170	pg/L		5.97	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 174	pg/L	8.3	4.49	48	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 177	pg/L		4.84	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 180/193	pg/L	20.4	4.47	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 183/185	pg/L	9.78	4.39	96	J,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 187	pg/L	11.1	2.53	48	J,JA,NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 194	pg/L	8.43	5.4	48	J,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 195	pg/L		4.61	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	PCB 201	pg/L		2.31	48	VRIU,NBC,VIL,VJ
CO4-EF-04192018-01	PCB 203	pg/L		3.81	48	NBC,VIL,VJ,VIU
CO4-EF-04192018-01	Total DiCB	pg/L	37.8	1.74	19	NBC,VIL,VJ
CO4-EF-04192018-01	Total HeptaCB	pg/L	39.8	2.53	19	NBC,VIL,VJ
CO4-EF-04192018-01	Total HexaCB	pg/L	147	2.55	19	VIP,NBC,VIL,VJ
CO4-EF-04192018-01	Total MonoCB	pg/L		19.2	19	NBC
CO4-EF-04192018-01	Total NonaCB	pg/L		19.2	19	NBC
CO4-EF-04192018-01	Total OctaCB	pg/L	8.43	2.31	19	J,NBC,VIL,VJ
CO4-EF-04192018-01	Total PCBs	pg/L	782	1.74	192	VIP,NBC,VIL,VJ
CO4-EF-04192018-01	Total PentaCB	pg/L	206	3.18	192	NBC,VIL
CO4-EF-04192018-01	Total TetraCB	pg/L	202	3.27	192	NBC,VIL
CO4-EF-04192018-01	Total TriCB	pg/L	132	4.44	48	NBC,VIL

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04192018-01	PCB 008	pg/L	19.9	2.59	48	J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 018/30	pg/L	49.1	7.77	48	NBC
TW2-IN-04192018-01	PCB 020/28	pg/L	91.5	6.35	48	NBC
TW2-IN-04192018-01	PCB 021/33	pg/L	37.1	6.33	48	J,NBC
TW2-IN-04192018-01	PCB 031	pg/L	74.5	5.87	48	NBC
TW2-IN-04192018-01	PCB 044/47/65	pg/L	115	5.83	96	NBC,VIU
TW2-IN-04192018-01	PCB 049/69	pg/L	55.8	5.47	96	J,NBC,VIU
TW2-IN-04192018-01	PCB 052	pg/L	125	5.76	48	NBC,VIL,VIU
TW2-IN-04192018-01	PCB 056	pg/L	39.2	5.48	48	J,NBC
TW2-IN-04192018-01	PCB 060	pg/L	20.6	5.37	48	J,JA,NBC
TW2-IN-04192018-01	PCB 066	pg/L	63.3	4.51	48	NBC,VIU
TW2-IN-04192018-01	PCB 070/61/74/76	pg/L	136	4.85	192	J,NBC,VIL,VIU,VJ
TW2-IN-04192018-01	PCB 083/99	pg/L	50.3	5.21	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 086/87/97/109/119/125	pg/L	67.6	4.56	192	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 090/101/113	pg/L	74.4	4.51	192	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 093/95/100	pg/L	58.4	5.1	192	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 105	pg/L	35.6	4.34	19	NBC,VIU
TW2-IN-04192018-01	PCB 110/115	pg/L	105	4.16	96	NBC
TW2-IN-04192018-01	PCB 118	pg/L	66.3	4.03	19	NBC,VIL
TW2-IN-04192018-01	PCB 128/166	pg/L	17.8	4.24	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 129/138/163	pg/L	150	5.53	192	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 132	pg/L	29.4	5.05	48	J,NBC,VIL,VIU
TW2-IN-04192018-01	PCB 135/151/154	pg/L	34.3	3.07	96	VRIU,J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 141	pg/L	15.7	4.26	48	VRIU,J,JA,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 147/149	pg/L	52.2	4.19	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 153/168	pg/L	171	3.64	96	VIP,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 156/157	pg/L	13.9	6.31	38	J,NBC,VIU
TW2-IN-04192018-01	PCB 158	pg/L	8.3	3.2	48	VRIU,J,JA,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 170	pg/L	38	7.21	48	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 174	pg/L	18.1	5.42	48	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 177	pg/L	16.2	5.85	48	J,JA,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 180/193	pg/L	88.8	5.4	96	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 183/185	pg/L	24.5	5.3	96	J,JA,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 187	pg/L	73.2	3.48	48	NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 194	pg/L	32.7	6.48	48	J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 195	pg/L	8.1	5.53	48	J,JA,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	PCB 201	pg/L	3.5	2.78	48	VRIU,J,NBC,VIL,VJ
TW2-IN-04192018-01	PCB 203	pg/L	17.9	4.57	48	J,NBC,VIL,VJ,VIU
TW2-IN-04192018-01	Total DiCB	pg/L	19.9	2.59	19	NBC,VIL,VJ
TW2-IN-04192018-01	Total HeptaCB	pg/L	234	3.48	19	NBC,VIL,VJ
TW2-IN-04192018-01	Total HexaCB	pg/L	493	3.07	19	VIP,NBC,VIL,VJ
TW2-IN-04192018-01	Total MonoCB	pg/L		19.2	19	NBC
TW2-IN-04192018-01	Total NonaCB	pg/L		19.2	19	NBC
TW2-IN-04192018-01	Total OctaCB	pg/L	62.2	2.78	19	NBC,VIL,VJ
TW2-IN-04192018-01	Total PCBs	pg/L	2100	2.59	192	VIP,NBC,VIL,VJ
TW2-IN-04192018-01	Total PentaCB	pg/L	458	4.03	192	NBC,VIL

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-04192018-01	Total TetraCB	pg/L	556	4.51	192	NBC,VIL
TW2-IN-04192018-01	Total TriCB	pg/L	252	5.87	48	NBC,VIL
CO1-EF-05092018-01	PCB 008	pg/L	31.9	7.11	48	J,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 018/30	pg/L	18.9	9.26	48	J,NBC
CO1-EF-05092018-01	PCB 020/28	pg/L	23.1	10.9	48	J,JA,NBC
CO1-EF-05092018-01	PCB 021/33	pg/L	27.4	11.1	48	J,NBC
CO1-EF-05092018-01	PCB 031	pg/L		10.2	48	NBC
CO1-EF-05092018-01	PCB 044/47/65	pg/L	23.3	12.4	96	J,JA,NBC,VIU
CO1-EF-05092018-01	PCB 049/69	pg/L		11.7	96	NBC,VIU
CO1-EF-05092018-01	PCB 052	pg/L	21	12.1	48	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 056	pg/L		19.4	48	NBC
CO1-EF-05092018-01	PCB 060	pg/L		19.4	48	NBC
CO1-EF-05092018-01	PCB 066	pg/L		10.5	48	NBC,VIU
CO1-EF-05092018-01	PCB 070/61/74/76	pg/L	105	43.6	191	J,NBC,VIL,VIU,VJ
CO1-EF-05092018-01	PCB 083/99	pg/L	13.3	6.37	96	J,JA,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 086/87/97/109/119/125	pg/L	25.5	5.66	191	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 090/101/113	pg/L	27.1	5.52	191	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 093/95/100	pg/L	32.6	4.44	191	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 105	pg/L		11.8	19	NBC,VIU
CO1-EF-05092018-01	PCB 110/115	pg/L	48.9	5.19	96	J,NBC
CO1-EF-05092018-01	PCB 118	pg/L	12.5	10.8	19	J,NBC,VIL
CO1-EF-05092018-01	PCB 128/166	pg/L	9.24	4.56	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 129/138/163	pg/L	50	4.98	191	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 132	pg/L	14.1	5.15	48	J,NBC,VIL,VIU
CO1-EF-05092018-01	PCB 135/151/154	pg/L	14.6	3.33	96	VRIU,J,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 141	pg/L	7.76	4.62	48	VRIU,J,JA,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 147/149	pg/L	26.6	4.19	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 153/168	pg/L	32.7	3.92	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 156/157	pg/L		7.24	38	NBC,VIU
CO1-EF-05092018-01	PCB 158	pg/L	7.17	3.45	48	VRIU,J,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 170	pg/L	11.9	8.21	48	J,JA,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 174	pg/L	13.3	6.26	48	J,JA,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 177	pg/L		6.69	48	NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 180/193	pg/L	34.2	6.4	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 183/185	pg/L	12.5	6.13	96	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 187	pg/L	17.6	3.55	48	J,NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 194	pg/L		10.4	48	NBC,VIL,VJ
CO1-EF-05092018-01	PCB 195	pg/L		9.39	48	NBC,VIL,VJ,VIU
CO1-EF-05092018-01	PCB 201	pg/L		5.12	48	VRIU,NBC,VIL,VJ
CO1-EF-05092018-01	PCB 203	pg/L		8.14	48	NBC,VIL,VJ,VIU
CO1-EF-05092018-01	Total DiCB	pg/L	31.9	7.11	19	NBC,VIL,VJ
CO1-EF-05092018-01	Total HeptaCB	pg/L	77	3.55	19	NBC,VIL,VJ
CO1-EF-05092018-01	Total HexaCB	pg/L	162	3.33	19	NBC,VIL,VJ
CO1-EF-05092018-01	Total MonoCB	pg/L		19.1	19	NBC
CO1-EF-05092018-01	Total NonaCB	pg/L		19.1	19	NBC
CO1-EF-05092018-01	Total OctaCB	pg/L		5.12	19	NBC,VIL,VJ

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-05092018-01	Total PCBs	pg/L	662	3.33	191	NBC,VIL,VJ
CO1-EF-05092018-01	Total PentaCB	pg/L	160	4.44	191	J,NBC,VIL
CO1-EF-05092018-01	Total TetraCB	pg/L	149	10.5	191	J,NBC,VIL
CO1-EF-05092018-01	Total TriCB	pg/L	69.5	9.26	48	NBC,VIL
TW2-IN-05092018-01	PCB 008	pg/L	37.8	2.15	48	J,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 018/30	pg/L	29.2	4.43	48	J,NBC
TW2-IN-05092018-01	PCB 020/28	pg/L	93.6	4.35	48	NBC
TW2-IN-05092018-01	PCB 021/33	pg/L	44.8	4.45	48	J,NBC
TW2-IN-05092018-01	PCB 031	pg/L	62.1	4.08	48	NBC
TW2-IN-05092018-01	PCB 044/47/65	pg/L	123	5.66	96	NBC,VIU
TW2-IN-05092018-01	PCB 049/69	pg/L	52	5.33	96	J,NBC,VIU
TW2-IN-05092018-01	PCB 052	pg/L	247	5.5	48	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 056	pg/L	26.9	10.1	48	J,JA,NBC
TW2-IN-05092018-01	PCB 060	pg/L	17.3	10.2	48	J,NBC
TW2-IN-05092018-01	PCB 066	pg/L	85.3	4.8	48	NBC,VIU
TW2-IN-05092018-01	PCB 070/61/74/76	pg/L	501	20	192	NBC,VIL,VIU,VJ
TW2-IN-05092018-01	PCB 083/99	pg/L	204	3.25	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 086/87/97/109/119/125	pg/L	310	2.89	192	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 090/101/113	pg/L	414	2.82	192	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 093/95/100	pg/L	410	3.36	192	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 105	pg/L	191	5.48	19	NBC,VIU
TW2-IN-05092018-01	PCB 110/115	pg/L	795	2.65	96	NBC
TW2-IN-05092018-01	PCB 118	pg/L	401	5.03	19	NBC,VIL
TW2-IN-05092018-01	PCB 128/166	pg/L	166	3.43	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 129/138/163	pg/L	914	3.75	192	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 132	pg/L	270	3.87	48	NBC,VIL,VIU
TW2-IN-05092018-01	PCB 135/151/154	pg/L	159	2.21	96	VRIU,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 141	pg/L	132	3.47	48	VRIU,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 147/149	pg/L	437	3.15	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 153/168	pg/L	520	2.95	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 156/157	pg/L	101	6.26	38	NBC,VIU
TW2-IN-05092018-01	PCB 158	pg/L	87.8	2.6	48	VRIU,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 170	pg/L	178	5.62	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 174	pg/L	142	4.28	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 177	pg/L	84.6	4.58	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 180/193	pg/L	372	4.38	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 183/185	pg/L	107	4.19	96	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 187	pg/L	185	2.73	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 194	pg/L	110	8.51	48	NBC,VIL,VJ
TW2-IN-05092018-01	PCB 195	pg/L	35.9	7.71	48	J,NBC,VIL,VJ,VIU
TW2-IN-05092018-01	PCB 201	pg/L	18.1	4.2	48	VRIU,J,NBC,VIL,VJ
TW2-IN-05092018-01	PCB 203	pg/L	93.2	6.68	48	NBC,VIL,VJ,VIU
TW2-IN-05092018-01	Total DiCB	pg/L	37.8	2.15	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total HeptaCB	pg/L	962	2.73	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total HexaCB	pg/L	2790	2.21	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total MonoCB	pg/L		19.2	19	NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
TW2-IN-05092018-01	Total NonaCB	pg/L		19.2	19	NBC
TW2-IN-05092018-01	Total OctaCB	pg/L	257	4.2	19	NBC,VIL,VJ
TW2-IN-05092018-01	Total PCBs	pg/L	8160	2.15	192	NBC,VIL,VJ
TW2-IN-05092018-01	Total PentaCB	pg/L	2730	2.65	192	NBC,VIL
TW2-IN-05092018-01	Total TetraCB	pg/L	1050	4.8	192	NBC,VIL
TW2-IN-05092018-01	Total TriCB	pg/L	230	4.08	48	NBC,VIL
QA Codes	http://www.ceden.org/CEDEN_Checker/Checker/DisplayCEDENLookUp.php?List=QALookUp					

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04102018-01	Mercury	ng/L	24.4	0.06	0.5	VIP,NBC
CO1-EF-04102018-01	Suspended Sediment Concentration	mg/L	116	0.91	0.9	NBC
CO1-EF-04102018-01	Total Organic Carbon	mg/L	26.7	0.3	2	D,NBC
CO2-EF-04102018-01	Mercury	ng/L	16.3	0.06	0.5	VIP,NBC
CO2-EF-04102018-01	Suspended Sediment Concentration	mg/L	104	0.9	0.9	NBC
CO2-EF-04102018-01	Total Organic Carbon	mg/L	11	0.07	0.5	NBC
CO3-EF-04102018-01	Mercury	ng/L	6.77	0.06	0.5	VIP,NBC
CO3-EF-04102018-01	Suspended Sediment Concentration	mg/L	50.3	0.92	0.9	NBC
CO3-EF-04102018-01	Total Organic Carbon	mg/L	42	0.3	2	D,NBC
CO4-EF-04102018-01	Mercury	ng/L	15.2	0.06	0.5	VIP,NBC
CO4-EF-04102018-01	Suspended Sediment Concentration	mg/L	89.1	0.96	1	NBC
CO4-EF-04102018-01	Total Organic Carbon	mg/L	28.9	0.3	2	D,NBC
CO5-EF-04102018-01	Mercury	ng/L	7.57	0.06	0.5	VIP,NBC
CO5-EF-04102018-01	Suspended Sediment Concentration	mg/L	78	0.92	0.9	NBC
CO5-EF-04102018-01	Total Organic Carbon	mg/L	27.7	0.3	2	D,NBC
CO6-EF-04102018-01	Mercury	ng/L	14	0.06	0.5	VIP,NBC
CO6-EF-04102018-01	Suspended Sediment Concentration	mg/L	118	0.91	0.9	NBC
CO6-EF-04102018-01	Total Organic Carbon	mg/L	32.9	0.3	2	D,NBC
TW2-IN-04102018-01	Mercury	ng/L	9.99	0.06	0.5	VIP,NBC
TW2-IN-04102018-01	Suspended Sediment Concentration	mg/L	19.4	0.9	0.9	NBC
TW2-IN-04102018-01	Total Organic Carbon	mg/L	5.39	0.07	0.5	NBC
CO1-EF-04132018-01	Mercury	ng/L	9.68	0.06	0.5	VIP,NBC
CO1-EF-04132018-01	Suspended Sediment Concentration	mg/L	21.9	0.89	0.9	NBC
CO1-EF-04132018-01	Total Organic Carbon	mg/L	12.3	0.3	2	D,NBC
CO2-EF-04132018-01	Mercury	ng/L	8.58	0.06	0.5	VIP,NBC
CO2-EF-04132018-01	Suspended Sediment Concentration	mg/L	13.3	0.9	0.9	NBC
CO2-EF-04132018-01	Total Organic Carbon	mg/L	5.72	0.07	0.5	NBC
CO3-EF-04132018-01	Mercury	ng/L	5.69	0.06	0.5	VIP,NBC
CO3-EF-04132018-01	Suspended Sediment Concentration	mg/L	14.5	0.89	0.9	NBC
CO3-EF-04132018-01	Total Organic Carbon	mg/L	19.1	0.3	2	D,NBC
CO4-EF-04132018-01	Mercury	ng/L	11.2	0.06	0.5	VIP,NBC
CO4-EF-04132018-01	Suspended Sediment Concentration	mg/L	17	0.93	0.9	NBC
CO4-EF-04132018-01	Total Organic Carbon	mg/L	13.8	0.3	2	D,NBC
CO5-EF-04132018-01	Mercury	ng/L	4.53	0.06	0.5	VIP,NBC
CO5-EF-04132018-01	Suspended Sediment Concentration	mg/L	17.3	0.92	0.9	NBC
CO5-EF-04132018-01	Total Organic Carbon	mg/L	12.5	0.3	2	D,NBC
CO6-EF-04132018-01	Mercury	ng/L	13.1	0.06	0.5	VIP,NBC
CO6-EF-04132018-01	Suspended Sediment Concentration	mg/L	35	0.93	0.9	NBC
CO6-EF-04132018-01	Total Organic Carbon	mg/L	15.9	0.3	2	D,NBC
TW2-IN-04132018-01	Mercury	ng/L	10.2	0.06	0.5	VIP,NBC
TW2-IN-04132018-01	Suspended Sediment Concentration	mg/L	40.2	0.89	0.9	NBC
TW2-IN-04132018-01	Total Organic Carbon	mg/L	1.71	0.07	0.5	NBC
BLNK-EF-04172018-01	Mercury	ng/L	1.96	0.06	0.5	VIP,NBC
BLNK-EF-04172018-01	Suspended Sediment Concentration	mg/L	1.4	0.9	0.9	NBC
BLNK-EF-04172018-01	Total Organic Carbon	mg/L	0.19	0.07	0.5	J,NBC

Sample ID	Analyte Name	Unit Name	Result	MDL	RL	QA Code
CO1-EF-04172018-01	Mercury	ng/L	9.74	0.06	0.5	VIP,NBC
CO1-EF-04172018-01	Suspended Sediment Concentration	mg/L	12.5	0.93	0.9	NBC
CO1-EF-04172018-01	Total Organic Carbon	mg/L	12.1	0.07	0.5	NBC
CO2-EF-04172018-01	Mercury	ng/L	2.17	0.06	0.5	VIP,NBC
CO2-EF-04172018-01	Suspended Sediment Concentration	mg/L	8.4	0.91	0.9	NBC
CO2-EF-04172018-01	Total Organic Carbon	mg/L	5.12	0.07	0.5	NBC
CO2-EF-04172018-D	Suspended Sediment Concentration	mg/L	9.1	0.92	0.9	NBC
CO2-EF-04172018-D	Total Organic Carbon	mg/L	5.15	0.07	0.5	NBC
CO3-EF-04172018-01	Mercury	ng/L	6.02	0.06	0.5	VIP,NBC
CO3-EF-04172018-01	Suspended Sediment Concentration	mg/L	19.3	0.96	1	NBC
CO3-EF-04172018-01	Total Organic Carbon	mg/L	21.6	0.3	2	D,NBC
CO4-EF-04172018-01	Mercury	ng/L	7.58	0.06	0.5	VIP,NBC
CO4-EF-04172018-01	Suspended Sediment Concentration	mg/L	16.5	0.94	0.9	NBC
CO4-EF-04172018-01	Total Organic Carbon	mg/L	14.4	0.3	2	D,NBC
CO5-EF-04172018-01	Mercury	ng/L	7.36	0.06	0.5	VIP,NBC
CO5-EF-04172018-01	Suspended Sediment Concentration	mg/L	11.7	0.92	0.9	NBC
CO5-EF-04172018-01	Total Organic Carbon	mg/L	12	0.3	2	D,NBC
CO6-EF-04172018-01	Mercury	ng/L	11.3	0.06	0.5	VIP,NBC
CO6-EF-04172018-01	Suspended Sediment Concentration	mg/L	26.7	0.95	1	NBC
CO6-EF-04172018-01	Total Organic Carbon	mg/L	17.2	0.3	2	D,NBC
TW6-IN-04172018-01	Mercury	ng/L	9.86	0.06	0.5	VIP,NBC
TW6-IN-04172018-01	Suspended Sediment Concentration	mg/L	16.3	0.89	0.9	NBC
TW6-IN-04172018-01	Total Organic Carbon	mg/L	1.64	0.07	0.5	NBC
CO4-EF-04192018-01	Mercury	ng/L	5.26	0.06	0.5	VIP,NBC
CO4-EF-04192018-01	Suspended Sediment Concentration	mg/L	9.7	0.9	0.9	NBC
CO6-EF-04192018-01	Mercury	ng/L	7.41	0.06	0.5	VIP,NBC
CO6-EF-04192018-01	Suspended Sediment Concentration	mg/L	11.1	0.94	0.9	NBC
CO6-EF-04192018-01	Total Organic Carbon	mg/L	10.9	0.3	2	D,NBC
TW2-IN-04192018-01	Mercury	ng/L	3	0.06	0.5	VIP,NBC
TW2-IN-04192018-01	Suspended Sediment Concentration	mg/L	1.9	0.89	0.9	NBC
QA Codes	http://www.ceden.org/CEDEN_Checker/Checker/DisplayCEDENLookUp.php?List=QALookUp					

Appendix E

Evaluation of Mercury and PCBs Removal Effectiveness of Full Trash Capture HDS Units

Appendix F

RMP STLS POC Reconnaissance Monitoring Progress Report, Water Years 2015 - 2018

RMP
REGIONAL MONITORING
PROGRAM FOR WATER QUALITY
IN SAN FRANCISCO BAY

sfei.org/rmp

Pollutants of Concern Reconnaissance Monitoring Progress Report, Water Years 2015 - 2018

Prepared by

Alicia Gilbreath, Jennifer Hunt and Lester McKee

SFEI

CONTRIBUTION NO. XXX / DECEMBER 2018

Preface

Reconnaissance monitoring for water years 2015, 2016, 2017 and 2018 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 (2019) is planned for this study. This initial full draft report was prepared for the Bay Area Stormwater Management Agencies Association (BASMAA) in support of materials submitted on or before March 31st 2019 in compliance with the Municipal Regional Stormwater Permit (MRP) Order No. R2-2015-0049. This draft report may undergo updates following review by members of the Sources, Pathways, and Loadings Workgroup of the RMP in May 2019.

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 RMP 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, 2017, and 2018. 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). RMP field and logistical support provided by San Francisco Estuary Institute (SFEI) over the first winter of the project included Patrick Kim, Carolyn Doehring, and Phil Trowbridge, in the second winter of the project included Patrick Kim, Amy Richey, and Jennifer Sun, in the winter of WY 2017 included Ila Shimabuku, Amy Richey, Steven Hagerty, Diana Lin, Margaret Sedlak, Jennifer Sun, Katie McKnight, Emily Clark, Don Yee, and Jennifer Hunt, and in the winter of WY 2018 included Ila Shimabuku, Margaret Sedlak, Jennifer Sun, Micha Salomon, and Don Yee. The RMP 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, 2017 and 2018. Helpful written reviews of this report were provided by members of BASMAA (Bonnie de Berry, EOA Inc. on behalf of the San Mateo Countywide Water Pollution Prevention Program; Lucile Paquette, Contra Costa Clean Water Program; Jim Scanlin, Alameda Countywide Clean Water Program); Barbara Mahler (USGS) and Richard Looker (SFBRWQCB).

Suggested citation:

Gilbreath, A.N., Hunt, J.A., and McKee, L.J., in preparation. Pollutants of Concern Reconnaissance Monitoring Progress Report, Water Years 2015-2018. A Technical Report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Contribution No. XXX. San Francisco Estuary Institute, Richmond, California.

Executive Summary

The San Francisco Bay polychlorinated biphenyl (PCB) and mercury (Hg) total maximum daily loads (TMDLs) call for implementation of control measures to reduce PCB and Hg loads entering the Bay via stormwater. In 2009, the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) issued the first Municipal Regional Stormwater Permit (MRP). This 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 the 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 reconnaissance monitoring field protocol was developed and implemented in water years (WYs) 2015, 2016, 2017 and 2018. Most of the sites monitored were in Alameda, Santa Clara, and San Mateo Counties, with a few sites in Contra Costa and Solano Counties. At the 60 sampling sites, time-weighted composite water samples were collected during individual storm events and analyzed for 40 PCB congeners, total Hg (HgT), and suspended sediment concentration (SSC). At a subset of sites, additional samples were analyzed for selected trace metals, organic carbon (OC), and grain size. Where possible, sampling efficiency was increased by sampling two or three sites during a single storm if the sites were near enough to one another that alternating between them was safe and rapid. This same field protocol is being implemented in the winter of WY 2019 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 sampling protocol with their own funding.

During this study beginning in WY 2015, the RMP began piloting the use of un-staffed “remote” suspended sediment samplers (Hamlin samplers and Walling Tube samplers). These remote samplers were designed to enhance settling and capture of suspended sediment from the water column. At 10 of the manual sampling sites, a remote sample was collected using a Hamlin suspended sediment sampler in parallel with the manual sample, and at 9 sites a remote sample was collected using a Walling Tube suspended sediment sampler in parallel with the manual sample.

Key Findings

Based on the WY 2015–18 monitoring, a number of sites with elevated PCB and Hg stormwater concentrations and estimated concentrations on particles were identified. Including RMP sampling prior to WY 2015, now 24 sites with estimated particle concentrations of PCBs greater than 200 ng/g and 31 sites with estimated particle concentrations of Hg greater than 0.5 µg/g have been identified. Total PCB concentrations measured in the composite water samples collected from the 83 sites ranged 840-fold, from 533 to 448,000 pg/L (excluding one sample where PCBs were below the detection limit). The three highest ranking sites for PCB whole-water concentrations were Pulgas Pump Station South (448,000 pg/L), Santa Fe Channel (198,000 pg/L), and Industrial Rd Ditch in San Carlos (160,000 pg/L). When normalized by SSC to generate estimated particle concentrations, the three sites with highest estimated

particle concentrations were Pulgas Pump Station South (8,222 ng/g), Industrial Rd Ditch in San Carlos (6,139 ng/g), and Line 12H at Coliseum Way in Oakland (2,601 ng/g).

Total Hg concentrations in samples collected in water years since 2003 ranged 112-fold, from 5.4 to 603 ng/L. The lower variation in HgT concentrations relative 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, the concentrations and mass used in industrial applications were relatively much smaller compared to industrial use of PCBs, and Hg has a larger atmospheric component to its cycle. The greatest HgT concentrations were measured at the Guadalupe River at Hwy 101 (603 ng/L), Guadalupe River at Foxworthy Road/Almaden (529 ng/L), and Zone 5 Line M (505 ng/L). The greatest estimated particle concentrations were measured at Guadalupe River at Foxworthy Road/Almaden (4.1 µg/g), Guadalupe River at Hwy 101 (3.6 µg/g), and the Outfall at Gilman St. in Berkeley (2.8 µg/g). Two of these stations are downstream of the historic New Almaden Mining District.

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 ranked 45th, 27th, 19th, 22nd, 51st, 39th, 65th, 36th, 14th, and 10th, respectively, for 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 in the sediment collected by the remote samplers were the same as those with higher concentrations in the composite samples. Therefore, the remote samplers will be used in WY 2019 for preliminary screening of new sites to support decisions about further sampling.

In comparing the remote versus manual sampling methods, generally speaking, it is estimated that remote sampling methods are more cost-effective because they allow for many sites to be monitored during a single storm event without actually being present on site during the storm event. However, similar to manual sampling methods, there are initial costs to purchase the equipment, and labor is required to deploy and process samples. In addition, there will always be logistical constraints (such as turbulence, tidal influences, or hardened channels) that complicate use of the remote devices and require manual monitoring at a particular site. The data collected using the remote sampling methodologies are generally useful for ranking sites for different pollutants but cannot be used 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 a cost-effective site screening field monitoring protocol to support decisions about further 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 since WY 2003, PCB particle concentrations positively correlate with impervious cover (r_s = 0.53), old industrial land use (r_s = 0.59), and HgT particle concentrations (r_s = 0.36). PCB particle concentrations inversely correlate with watershed area and particle concentrations for arsenic, cadmium, copper, lead, and zinc. HgT particle concentrations do not correlate with those of other trace metals and had similar but weaker relationships to impervious cover, old industrial land use, and watershed area than did PCBs. In contrast, the trace metals arsenic, cadmium, copper, lead, and zinc were all correlated with one another. Overall, the data collected to date do not support the use of any of the trace metals analyzed as a proxy for either PCB or HgT pollution sources.

Old industrial land use is believed to have both the greatest yields as well as total mass of PCB loads in the region. The watersheds for the 83 sites that have been sampled with RMP and grant funding since WY 2003 cover about 26% of the old industrial area in the region. The largest proportion of old industrial area sampled to date in each county has been in Santa Clara County (61% of old industrial area in this county is in the watershed of a sampling site), followed by Alameda (30%), San Mateo (27%), and Contra Costa (9%) counties. Coverage in Santa Clara County is highest because a number of large watersheds have been sampled and old industrial areas are prevalent upstream in two of the watersheds sampled (Coyote Creek and Guadalupe River). Of the remaining areas in the region with old industrial land use yet to be sampled (78 km^2), 49% of it lies within 1 km of the Bay and 63% is within 2 km of the Bay. These areas are more likely to be tidal and to include heavy industrial areas that were historically serviced by rail and ship-based transport, and are often very difficult to sample because of a lack of public rights-of-way and tidal-related constraints. It may also be reasonable to suggest that these areas may have relatively high concentrations compared to industrial areas further from the Bay margin due to a longer use period and the nature of heavy machinery associated with rail and ship transport. A different sampling strategy may be needed to effectively estimate what mass of pollution is associated with these areas. In the short term, this Pollutants of Concern Reconnaissance Monitoring study will continue at least into WY 2019 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 will occur at some sites to verify initial sampling results.

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Introduction

The San Francisco Bay polychlorinated biphenyl (PCB) and mercury total maximum daily loads (TMDLs) (SFBRWQCB, 2006; 2007) call 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 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.) and 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 that contribute disproportionately high concentrations or loads to sensitive Bay margins. This work was funded by the RMP and the Bay Area Stormwater Management Agencies Association (BASMAA)[1]. Sufficient pollutant data were collected at 11 urban sites to estimate pollutant loads from these sites with varying degrees of certainty (McKee et al., 2015, Gilbreath et al., 2015a). Also during the first MRP term, a Regional Watershed Spreadsheet Model (RWSM) was 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; 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 source properties that are more polluted, and that are located upstream of sensitive Bay margin areas.

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

Specifically, the permit adds a stipulation that calls for 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 to refine information to address Management Questions, the Sources, Pathways, and Loadings Work Group (SPLWG) and the Small Tributaries Loading Strategy Team developed and implemented a stormwater reconnaissance field monitoring protocol in WYs 2015, 2016, 2017 and 2018 to provide data, as part of multiple lines of evidence, for the identification of potential high-leverage areas. The monitoring protocol was adapted from the one first implemented in WY 2011 (McKee et al., 2012) and benefited from lessons learned from that effort. This same field monitoring protocol was also implemented in WYs 2016 - 2018 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, 2017 and 2018. The data collected and presented here contribute 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 existing stormwater PCB data. The primary goals of that analysis are to develop more methods for identifying and ranking watersheds of management interest for further investigation, and to guide future sampling design (McKee et al., in review). In addition, the STLS team is evaluating sampling protocols for monitoring stormwater loading trends in response to management efforts (Melwani et al., 2018) and has developed a trends strategy that outlines key elements including modeling needs (Wu, et. al., 2018). Reconnaissance data collected in WYs 2011, 2015, 2016, 2017 and 2018 may provide “baseline” data for identifying concentration or particle concentration trends over time, with the understanding that management actions to control PCB and Hg loads are increasingly being implemented throughout this period.

The report is designed to be updated annually and will be updated again in approximately 12 months to include WY 2019 sampling data currently being collected.

Methods

Sampling locations

Four objectives were used as a basis 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 allow for the continuing reevaluation of our conceptual understanding of relationships between land uses, source areas and pollutant concentrations and loads)

The majority of samples during WYs 2015-2017 (60-80% of the effort) were dedicated to identifying potential high-leverage watersheds and subwatersheds. The remaining resources were allocated to addressing the other three objectives. In WY 2018, 50% of the resources were allocated to identifying potential high-leverage watersheds while the other 50% was allocated to resampling watersheds previously measured in reconnaissance sampling in order to validate concentrations previously measured. RMP SPLWG staff worked with the respective Countywide Programs to identify priority drainages for monitoring including storm drains, ditches/culverts, tidally influenced areas, and natural areas. During the summers of 2014, 2015, 2016 and 2017, approximately 100 sites were visited, and each was surveyed for safety, logistical constraints, and feasible drainage-line entry points. From this larger set, a final set of about 15-25 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, 2017 and 2018 (Figure 1 and Table 1). Of these sites, 19 were in Santa Clara County, 19 in San Mateo County, 17 in Alameda County, 9 in Contra Costa County[2] and 1 site in Solano County. The drainage area for each sampling location ranged from 0.02 to 233 km^2 and imperviousness based on the National Land Cover Database (Homer et al., 2015) ranged from 2%-88%. Typically, however, the reconnaissance watersheds were characterized as small (75% were smaller than 5.2 sq km) with a high degree of imperviousness (75% of watersheds were greater than 60% impervious). The percentage of the watersheds designated as old industrial[3] ranged from 0 to 87% (mean 24%) (dataset used included the land use dataset input to the Regional Watershed Spreadsheet Model (https://www.sfei.org/projects/regional-watershed-spreadsheet-model#sthash.bUGyXA2x.dpbs)). Although most of the sampling sites were selected primarily to 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 for PCBs in WY 2017 as a piggyback opportunity during a large and rare storm sampled primarily to assess trends for mercury (McKee et al., 2018). And in WY 2018, five sites (including: Gull Dr. Outfall, Gull Dr. Stormdrain, Kirker Ck at Pittsburgh Antioch Hwy, Meeker Slough and the Outfall at Gilman St.) were resampled to verify stormwater concentrations previously measured. A matrix of site characteristics for sampling strategic larger watersheds was also developed (Appendix A), but no larger watersheds 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 at EBRPD Bridge at Quarry Lakes,

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

[3] Note that 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).

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.

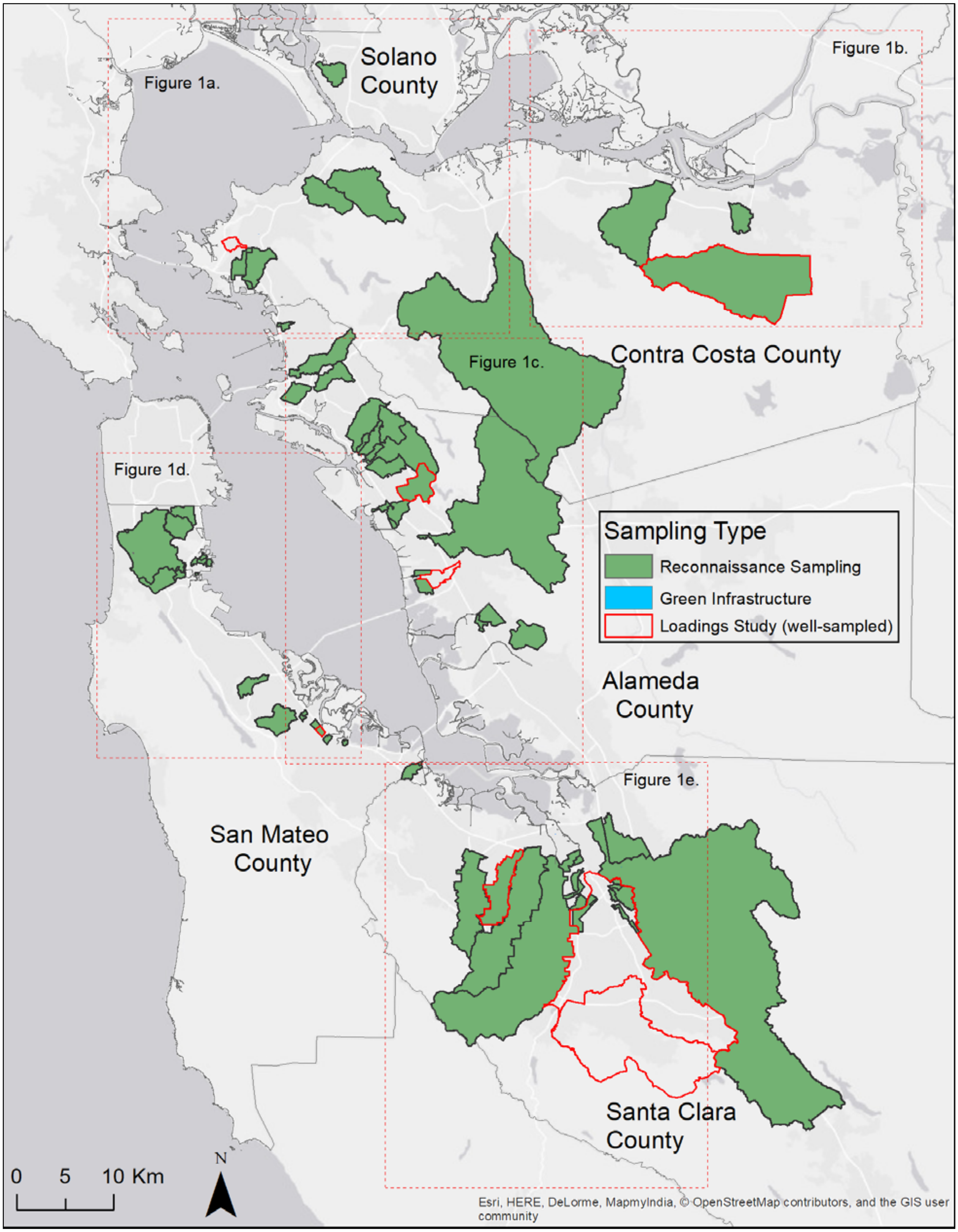

Figure 1. Watersheds sampled to date.

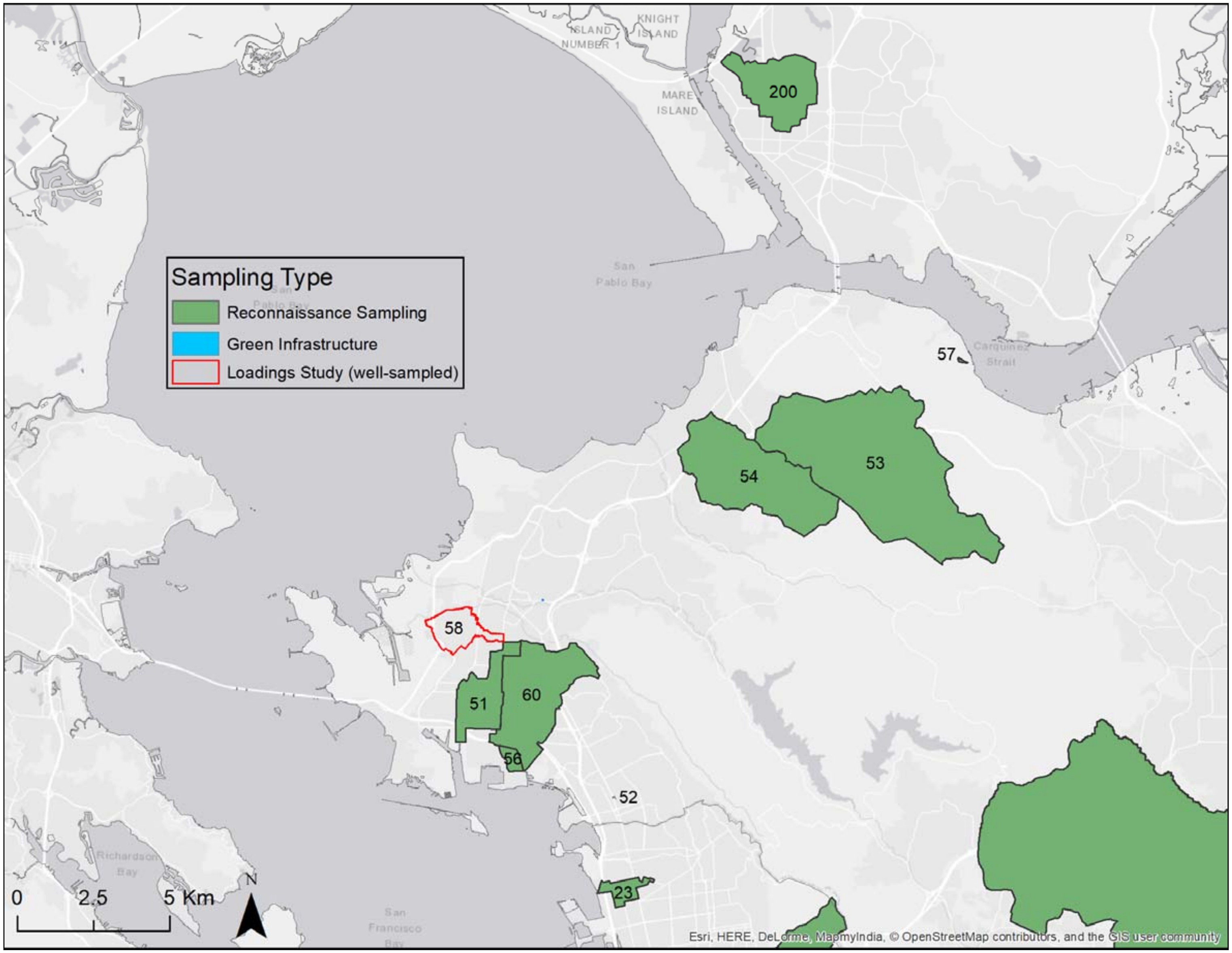

Figure 1a. Watershed boundaries of sites sampled in western Contra Costa County and Solano County.

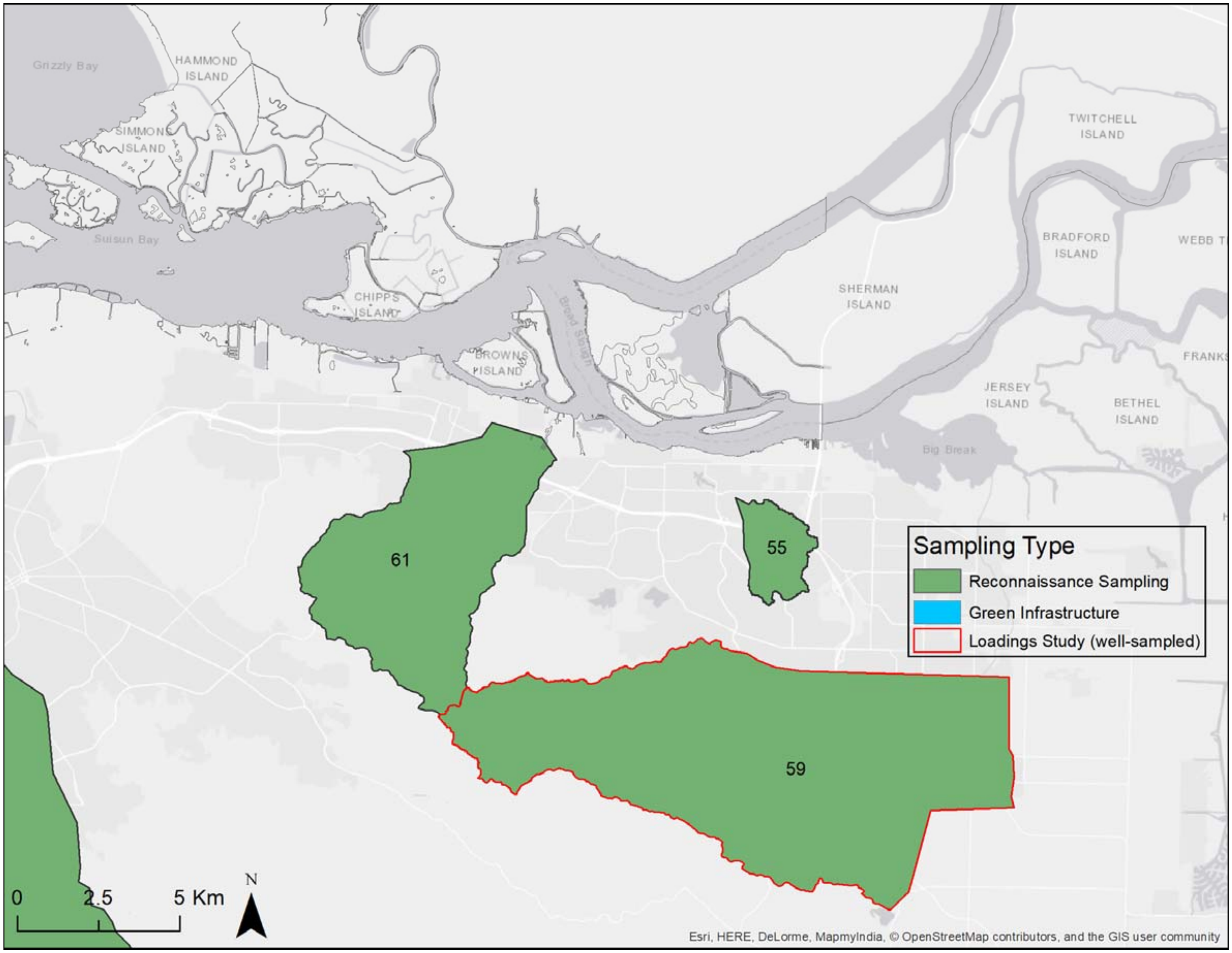

Figure 1b. Watershed boundaries of sites sampled in eastern Contra Costa County.

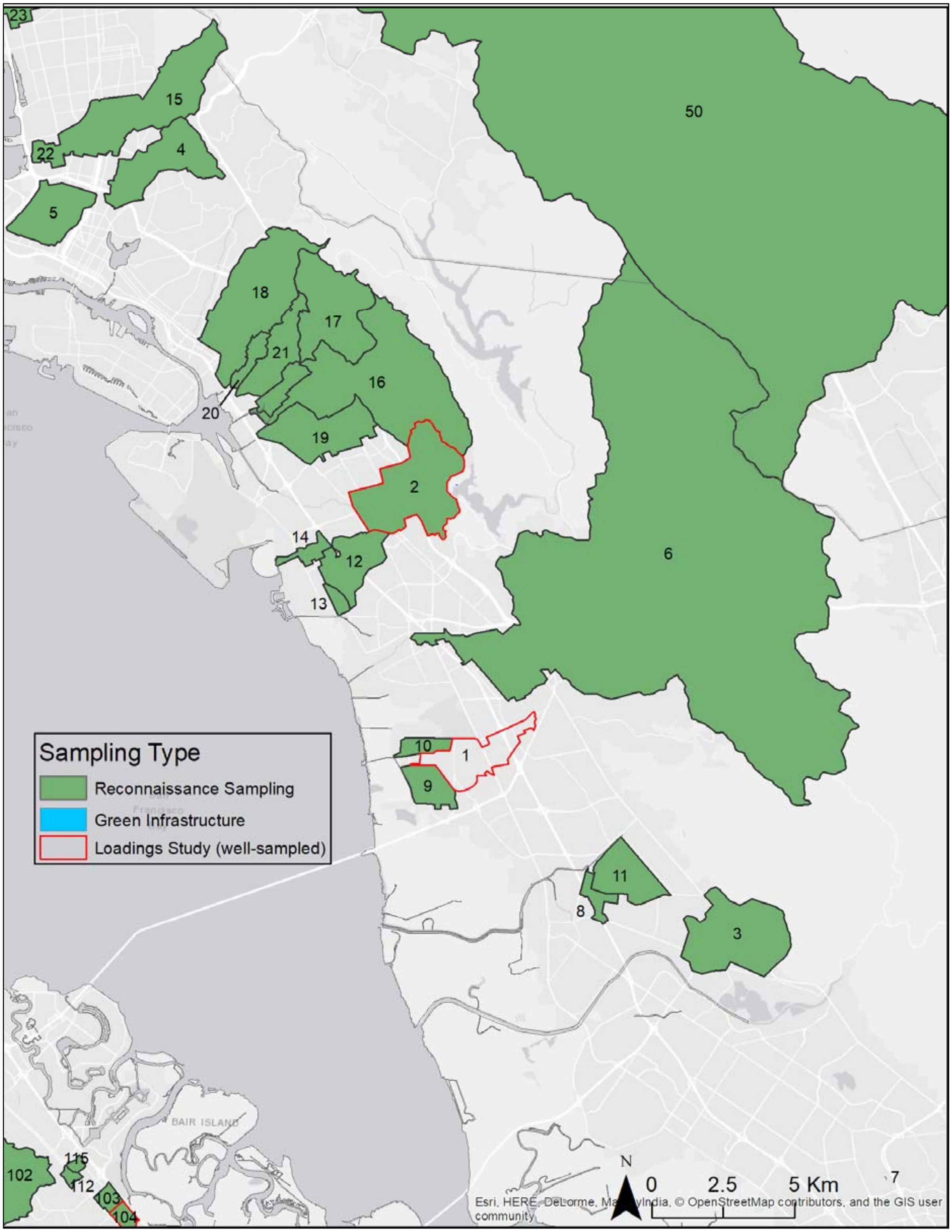

Figure 1c. Watershed boundaries of sites sampled in Alameda County.

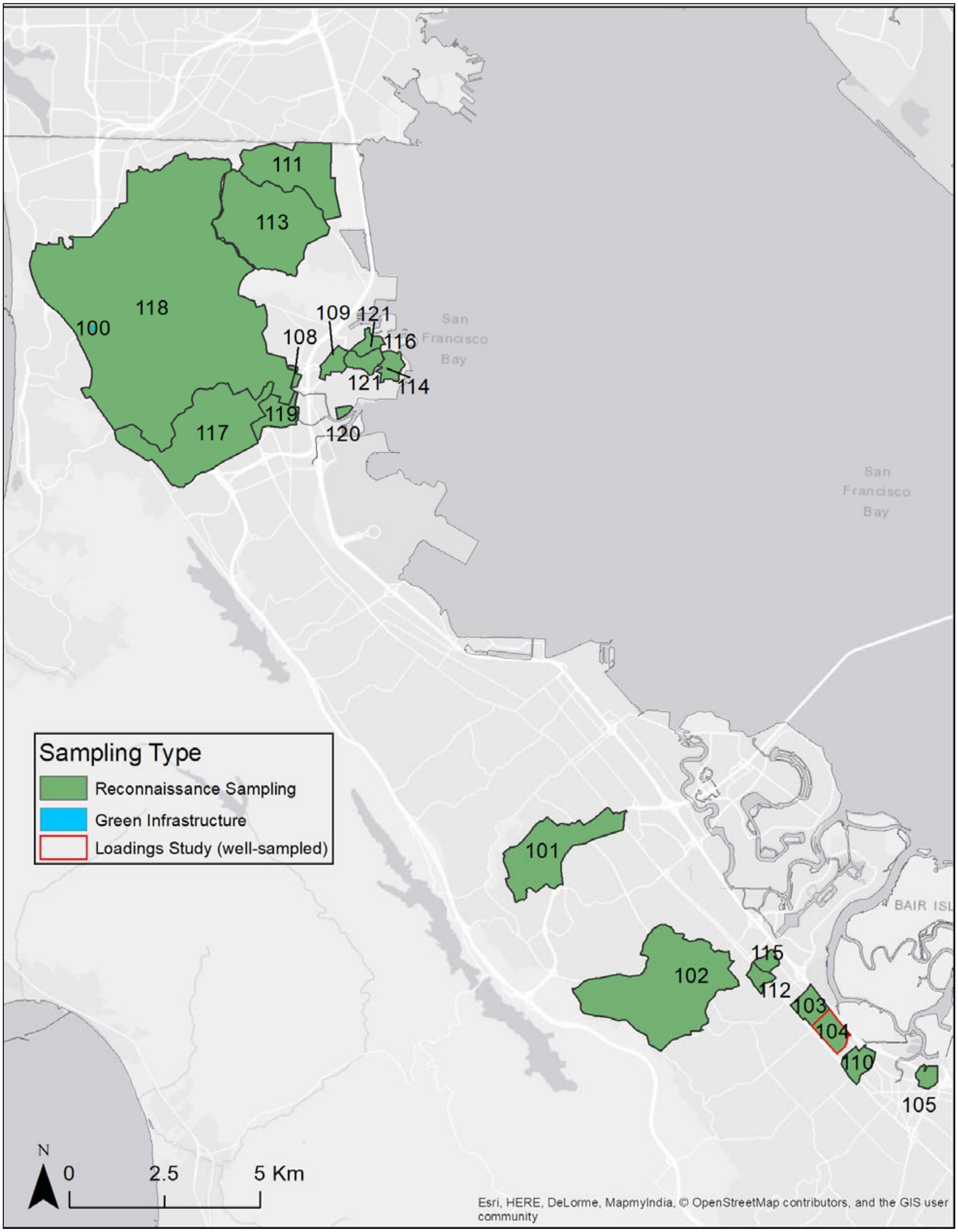

Figure 1d. Watershed boundaries of sites sampled in northern San Mateo County.

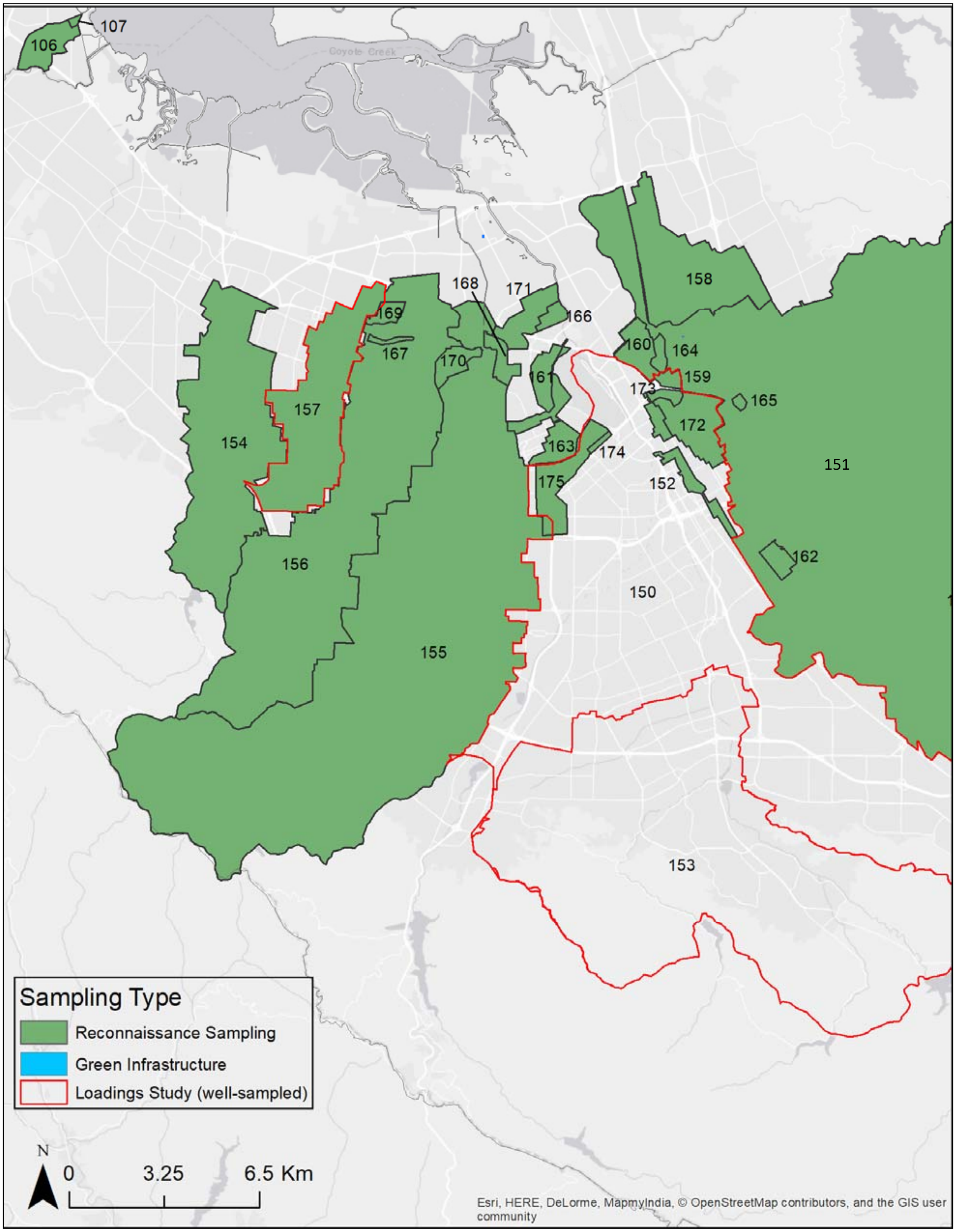

Figure 1e. Watershed boundaries of sites sampled in Santa Clara County.

Table 1. Key characteristics of the 83 sampling locations. Note gaps in continuous numbering allow for the addition of locations in the future so that the unique identifying numbers for each county remain in the same 50-count.

Map Key	County	City	Watershed Name	Catchment Code	MS4 or Receiving Water	Latitude	Longitude	Sample Date	Area (sq km)	Impervious Cover (%)	Old Industrial (%)
1	Alameda	Hayward	Zone 4 Line A	Z4LA	MS4	37.645328	-122.137364	WY 2007-2010	4.2	68%	12%
2	Alameda	San Leandro	San Leandro Creek	SLC	MS4	37.726119	-122.162696	12/5/10 & 12/19/10; WYs 2012-14	8.9	38%	0%
3	Alameda	Union City	Zone 5 Line M	Z5LM	MS4	37.586476	-122.028427	12/17/10 & 3/19/11	8.1	34%	5%
4	Alameda	Oakland	Glen Echo Creek	Glen Echo Creek	MS4	37.818271	-122.260326	2/15/11	5.5	39%	0%
5	Alameda	Oakland	Ettie Street Pump Station	ESPS	MS4	37.826043	-122.288942	2/17/11	4.0	75%	22%
6	Alameda	San Leandro	San Lorenzo Creek	San Lorenzo Creek	MS4	37.684836	-122.138599	12/17/10 & 12/19/10	125	13%	0%
7	Alameda	Fremont	Fremont Osgood Road Bioretention Influent	Fremont Osgood Road Bioretention Influent	Bioretention Influent	37.518394	-121.945225	2012, 2013	0.00	76%	0%
8	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%
9	Alameda	Hayward	Line 4-E	AC-Line 4-E	MS4	37.64415	-122.14127	12/16/14	2.00	81%	27%
10	Alameda	Hayward	Line 4-B-1	AC-Line 4-B-1	MS4	37.64752	-122.14362	12/16/14	0.96	85%	28%
11	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%
12	Alameda	San Leandro	Line 9-D	AC-Line 9-D	MS4	37.69383	-122.16248	4/7/15	3.59	78%	46%
13	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%
14	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%
15	Alameda	Emeryville	Zone 12 Line A under Temescal Ck Park	AC-2016-3	MS4	37.83450	-122.29159	1/6/16	9.41	42%	0.6%
16	Alameda	Oakland	Line 12K at Coliseum Entrance	Line12KEntrance	MS4	37.75446	-122.20431	2/9/17	16.40	31%	1%
17	Alameda	Oakland	Line 12J at mouth to 12K	Line12J	MS4	37.75474	-122.20136	12/15/16	8.81	30%	2%
18	Alameda	Oakland	Line 12F below PG&E station	Line12F	MS4	37.76218	-122.21431	12/15/16	10.18	56%	3%
19	Alameda	Oakland	Line 12M at Coliseum Way	Line12MColWay	MS4	37.74689	-122.20069	2/9/17	5.30	69%	22%
20	Alameda	Oakland	Line 12H at Coliseum Way	Line12H	MS4	37.76238	-122.21217	12/15/16	0.97	71%	10%
21	Alameda	Oakland	Line 12I at Coliseum Way	Line12I	MS4	37.75998	-122.21020	12/15/16	3.41	63%	9%

WYs 2015 through 2018 POC Reconnaissance Monitoring

Map Key	County	City	Watershed Name	Catchment Code	MS4 or Receiving Water	Latitude	Longitude	Sample Date	Area (sq km)	Impervious Cover (%)	Old Industrial (%)
22	Alameda	Emeryville	Zone 12 Line A at Shellmound	Line12AShell	MS4	37.83424	-122.29352	1/8/18	10.48	41%	6%
23	Alameda	Berkeley	Outfall at Gilman St.	AC-2016-1	MS4	37.87761	-122.30984	12/21/15 & 1/9/18	0.84	76%	32%
50	Contra Costa	Concord	Walnut Creek	Walnut Creek	Receiving Water	37.96962	-122.053778	12/28/10	232	15%	0%
51	Contra Costa	Richmond	Santa Fe Channel	Santa Fe Channel	MS4	37.92118056	-122.3619972	12/05/10	3.3	69%	3%
52	Contra Costa	El Cerrito	El Cerrito Bioretention Influent	ELC	Bioretention Influent	37.905884	-122.304929	WY 2012, 2014-15, 2017	0.00	74%	0%
53	Contra Costa	Rodeo	Rodeo Creek at Seacliff Ct. Pedestrian Br.	RodeoCk	Receiving Water	38.01604	-122.25381	1/18/17	23.41	2%	3%
54	Contra Costa	Hercules	Refugio Ck at Tsushima St	RefugioCk	Receiving Water	38.01775	-122.27710	1/18/17	10.73	23%	0%
55	Contra Costa	Antioch	East Antioch nr Trembath	EAntioch	Receiving Water	38.00333	-121.78106	1/8/17	5.26	26%	3%
56	Contra Costa	Richmond	MeekerWest	MeekerWest	Receiving Water	37.91313	-122.33871	1/9/18	0.41	70%	69%
57	Contra Costa	Port Costa	Little Bull Valley	Little Bull Valley	Receiving Water	38.03680	-122.17662	3/1/18	0.02	67%	2%
58	Contra Costa	Richmond	North Richmond Pump Station	NRPS	MS4	37.953903	-122.373997	WY 2011, 2013-14	2.0	62%	18%
59	Contra Costa	Oakley	Lower Marsh Creek	LMC	Receiving Water	37.990723	-121.696118	3/24/11; WYs 2012-14	84	10%	0%
60	Contra Costa	Richmond	Meeker Slough	Meeker Slough	Receiving Water	37.91786	-122.33838	12/3/14 & 1/9/18	7.34	64%	6%
61	Contra Costa	Pittsburg	Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	KirkerCk	Receiving Water	38.01275	-121.84345	1/8/17 & 4/6/18	36.67	18%	5%
100	San Mateo	Daly City	Gellert Park Daly City Library Bioretention Influent	Gellert Park	Bioretention Influent	37.663037	-122.470585	WY 2009	0.02	40%	0%
101	San Mateo	San Mateo	Borel Creek	Borel Creek	MS4	37.551273	-122.309424	3/18/11	3.2	31%	0%
102	San Mateo	Belmont	Belmont Creek	Belmont Creek	MS4	37.517328	-122.276109	3/18/11	7.2	27%	0%
103	San Mateo	San Carlos	Pulgas Pump Station-North	Pulgas Pump Station-North	MS4	37.5045833	-122.2490056	2/17/11 & 3/18/11	0.55	84%	52%
104	San Mateo	San Carlos	Pulgas Pump Station-South	Pulgas Pump Station-South	MS4	37.5045833	-122.2490056	2/17/11 & 3/18/11; WYs 2013-14	0.58	87%	54%
105	San Mateo	Redwood City	Oddstad PS	SM-267	MS4	37.49172	-122.21886	12/2/14	0.28	74%	11%
106	San Mateo	East Palo Alto	Runnymede Ditch	SM-70	MS4	37.46883	-122.12701	2/6/15	2.05	53%	2%
107	San Mateo	East Palo Alto	SD near Cooley Landing	SM-72	MS4	37.47492	-122.12640	2/6/15	0.11	73%	39%

WYs 2015 through 2018 POC Reconnaissance Monitoring

Map Key	County	City	Watershed Name	Catchment Code	MS4 or Receiving Water	Latitude	Longitude	Sample Date	Area (sq km)	Impervious Cover (%)	Old Industrial (%)
108	San Mateo	South San Francisco	South Linden PS	SM-306	MS4	37.65018	-122.41127	2/6/15	0.14	83%	22%
109	San Mateo	South San Francisco	Gateway Ave SD	SM-293	MS4	37.65244	-122.40257	2/6/15	0.36	69%	52%
110	San Mateo	Redwood City	Veterans PS	SM-337	MS4	37.49723	-122.23693	12/15/14	0.52	67%	7%
111	San Mateo	Brisbane	Tunnel Ave Ditch	SM-350/368/more	Receiving Water	37.69490	-122.39946	3/5/16	3.02	47%	8%
112	San Mateo	San Carlos	Taylor Way SD	SM-32	MS4	37.51320	-122.26466	3/11/16	0.27	67%	11%
113	San Mateo	Brisbane	Valley Dr SD	SM-17	MS4	37.68694	-122.40215	3/5/16	5.22	21%	7%
114	San Mateo	South San Francisco	Forbes Blvd Outfall	SM-319	MS4	37.65889	-122.37996	3/5/16	0.40	79%	0%
115	San Mateo	San Carlos	Industrial Rd Ditch	SM-75	MS4	37.51831	-122.26371	3/11/16	0.23	85%	79%
116	San Mateo	South San Francisco	Gull Dr SD	SM-314	MS4	37.66033	-122.38510	3/5/16 & 1/9/18	0.30	78%	54%
117	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%
118	San Mateo	South San Francisco	Colma Ck at S. Linden Blvd	ColmaCk	MS4	37.65017	-122.41189	2/7/17	35.07	41%	3%
119	San Mateo	South San Francisco	S Linden Ave SD (291)	SLinden	MS4	37.64420	-122.41390	1/8/17	0.78	88%	57%
120	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%
121	San Mateo	South San Francisco	Gull Dr Outfall	SM-315	MS4	37.66033	-122.38502	3/5/16 & 1/9/18	0.43	75%	42%
150	Santa Clara	San Jose	Guadalupe River at Hwy 101	Guad 101	Receiving Water	37.37355	-121.93269	WYs 2003-2006, 2010, 2012-2014; 1/8/17	233.00	39%	3%
151	Santa Clara	Milpitas	Lower Coyote Creek	Lower Coyote Creek	Receiving Water	37.421814	-121.928153	2005	327	22%	1%
152	Santa Clara	San Jose	San Pedro Storm Drain	San Pedro Storm Drain	MS4	37.343769	-121.900781	2006	1.3	72%	16%
153	Santa Clara	San Jose	Guadalupe River at Foxworthy Road/ Almaden Expressway	GRFOX	Receiving Water	37.278396	-121.877944	2010	107	22%	0%
154	Santa Clara	Mountain View	Stevens Creek	Stevens Creek	Receiving Water	37.391306	-122.069586	2/18/11	26	38%	1%
155	Santa Clara	Santa Clara	San Tomas Creek	San Tomas Creek	Receiving Water	37.388992	-121.968634	12/28/10	108	33%	0%

WYs 2015 through 2018 POC Reconnaissance Monitoring

Map Key	County	City	Watershed Name	Catchment Code	MS4 or Receiving Water	Latitude	Longitude	Sample Date	Area (sq km)	Impervious Cover (%)	Old Industrial (%)
156	Santa Clara	Santa Clara	Calabazas Creek	Calabazas Creek	Receiving Water	37.4034556	-121.9867056	12/28/10	50	44%	3%
157	Santa Clara	Sunnyvale	Sunnyvale East Channel	SunCh	Receiving Water	37.394728	-122.010441	3/19/11; WYs 2012-14	15	59%	4%
158	Santa Clara	Milpitas	Lower Penitencia Ck	Lower Penitencia	Receiving Water	37.42985	-121.90913	WY 2011; 12/11/14	11.50	65%	2%
159	Santa Clara	San Jose	E. Gish Rd SD	SC-066GAC550	MS4	37.36632	-121.90203	12/11/14	0.44	84%	71%
160	Santa Clara	San Jose	Charcot Ave SD	SC-051CTC275	MS4	37.38413	-121.91076	4/7/15	1.79	79%	25%
161	Santa Clara	Santa Clara	Seabord Ave SD SC-050GAC580	SC-050GAC580	MS4	37.37637	-121.93793	12/11/14	1.35	81%	68%
162	Santa Clara	San Jose	Rock Springs Dr SD	SC-084CTC625	MS4	37.31751	-121.85459	2/6/15	0.83	80%	10%
163	Santa Clara	Santa Clara	Seabord Ave SD SC-050GAC600	SC-050GAC600	MS4	37.37636	-121.93767	12/11/14	2.80	62%	18%
164	Santa Clara	San Jose	Ridder Park Dr SD	SC-051CTC400	MS4	37.37784	-121.90302	12/15/14	0.50	72%	57%
165	Santa Clara	San Jose	Outfall to Lower Silver Ck	SC-067SCL080	MS4	37.35789	-121.86741	2/6/15	0.17	79%	78%
166	Santa Clara	Santa Clara	Victor Nelo PS Outfall	SC-050GAC190	MS4	37.38991	-121.93952	1/19/16	0.58	87%	4%
167	Santa Clara	Santa Clara	Lawrence & Central Expwys SD	SC-049CZC800	MS4	37.37742	-121.99566	1/6/16	1.20	66%	1%
168	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%
169	Santa Clara	Santa Clara	Duane Ct and Ave Triangle SD	SC-049CZC200	MS4	37.38852	-121.99901	12/13/15 & 1/6/2016	1.00	79%	23%
170	Santa Clara	Santa Clara	Condensa St SD	SC-049STA710	MS4	37.37426	-121.96918	1/19/16	0.24	70%	32%
171	Santa Clara	Santa Clara	Haig St SD	SC-050GAC030	MS4	37.38664	-121.95223	3/6/16	2.12	72%	10%
172	Santa Clara	San Jose	Rosemary St SD 066GAC550C	Rosemary	MS4	37.36118	-121.90594	1/8/17	3.67	64%	11%
173	Santa Clara	San Jose	North Fourth St SD 066GAC550B	NFourth	MS4	37.36196	-121.90535	1/8/17	1.01	68%	27%
174	Santa Clara	San Jose	GR outfall 066GAC900	GR outfall 066GAC900	MS4	37.35392	-121.91223	4/7/18	0.17	66%	1%
175	Santa Clara	San Jose	GR outfall 066GAC850	GR outfall 066GAC850	MS4	37.35469	-121.91279	4/7/18	3.35	61%	6%
200	Solano	Vallejo	Austin Ck at Hwy 37	AustinCk	Receiving Water	38.12670	-122.26791	3/24/17	4.88	61%	2%

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[4] over 6 hours was forecast, sampling teams were deployed, ideally reaching the sampling site about 1 hour before the onset of rainfall[5]. 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) were reached before the storm's end. Because the minimum volume requirements were less than the size of the 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 laboratory (see Yee et al. (2017)) for information about bottles, preservatives and holding times).

Remote suspended sediment sampling procedures

Two remote samplers, the Hamlin (Lubliner, 2012) and the Walling Tube (Phillips et al., 2000), were deployed at approximately mid-channel/storm drain to collect suspended sediment samples. To date, ten locations have been sampled with the Hamlin sampler and nine locations with the Walling Tube sampler (Table 2). Due to both samplers being trialed at five sites, a total of 14 sites of differing characteristics have now been sampled. During deployment, the Hamlin sampler[6] was stabilized on the bed of the stormdrain or concrete channel either by its own weight (approximately 25 lbs) or by attaching barbell weight plates to the bottom of the sampler (Figure 2b). The Walling Tube could not be deployed in storm drains because of its size and the requirement that it be horizontal, and therefore

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

[5] 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.

[6] In future years, if the Hamlin is deployed within a natural bed channel, elevating the sampler a greater distance from the bed may be considered but was not done in WYs 2015-2018.

Walling Tube samplers were only used in open channels and secured either by barbell weights attached by hose clamps to a concrete bed, or to a natural bed with hose clamps 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 sediment 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 shipped to the laboratory for analysis. Most samples were analyzed as whole-water samples (because of insufficient solid mass to analyze as a sediment sample); a sample from 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 dionized water (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 2. Locations where remote sediment samplers were pilot tested.

Site	Date	Sampler(s) deployed	Comments
Meeker Slough	11/2015	Hamlin and Walling Tube	Sampling effort was unsuccessful because of 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 Tube	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 Tube	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 Tuber	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 Tube	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 Tube	Sampling effort was successful. This sample was analyzed as a water sample.
Refugio Creek	1/18/2017	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.
Rodeo Creek	1/18/2017	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.
Outfall at Gilman St.	1/9/2018	Hamlin and Walling Tube	Sampling effort was successful; however, Hamlin sampler could not be gently lowered into place on the bed and instead was dropped from approximately 1.5 ft above the bed; it is possible, therefore, that the sampler did not lay horizontal along the bed. This sample was analyzed as a water sample.
Meeker West	1/9/2018	Walling Tube	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 3. 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, including method detection limits, accuracy and precision, and costs (BASMAA, 2011; 2012) (Table 3). For some sites where remote samplers were deployed, both particulate and dissolved phases of Hg, PCBs and organic carbon (OC) were analyzed for comparison with whole-water concentrations and particulate-only concentrations from manually collected water samples.

Table 3. Laboratory analysis methods.

Analysis	Matrix	Analytical Method	Lab	Filtered	Field Preservation	Contract Lab / Preservation Hold Time
PCBs (40)[7]-Total	Water	EPA 1668	AXYS	No	NA	NA
PCBs (40)[7]-Dissolved	Water	EPA 1668	AXYS	Yes	NA	NA
PCBs (40)[7]	Sediment	EPA 1668	AXYS	NA	NA	NA
Mercury-Total	Water	EPA 1631E	BRL	No	BrCl	BRL preservation with BrCl within 28 days
Mercury-Dissolved	Water	EPA 1631E	BRL	Yes	BrCl	BRL preservation with BrCl within 28 days
Mercury	Sediment	EPA 1631E, Appendix	BRL	NA	NA	7 days
Metals-Total (As, Cd, Pb, Cu, Zn)	Water	EPA 1638 mod	BRL	No	HNO_3	BRL preservation with Nitric acid within 14 days
SSC	Water	ASTM D3977	USGS	No	NA	NA
Grain size	Water	USGS GS method	USGS	No	NA	NA
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 2016-2018)	Water	EPA 9060A	ALS	No	HCL	NA
Organic carbon-Dissolved (WY 2016, 2017)	Water	EPA 9060A	ALS	Yes	HCL	NA
Organic carbon (WY 2016, 2017)	Particulate	EPA 440.0	ALS	NA	NA	NA

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[7] 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 field protocol is designed to collect one composite sample during a single storm at each site to characterize concentrations found during storm flow. Measured PCB and Hg concentrations at a site could have large inter-storm variability related to storm size and intensity and antecedent conditions, as observed from previous studies when a large number of storms were sampled (Gilbreath et al., 2015a); this variability cannot be captured in a single composite sample. However, variability can be reduced if concentrations are normalized to SSC, which produces an estimate of the pollutant concentration associated with particles in the sample. The estimated particle concentration (EPC) has been demonstrated to have less inter-storm variability than whole-water concentrations, and it was therefore reasoned that the EPC is likely a better characterization of water quality at a site than water concentration alone and therefore a better metric for comparison between sites (McKee et al., 2012; Rügner et al., 2013; McKee et al., 2015).EPCs were used as the primary index to compare sites without regard to climate or rainfall intensity. For each analyte at each site the estimated particle concentration (ratio of mass of a given pollutant of concern to mass of suspended sediment) was computed for each composite water sample (Equation 1):

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

Although normalizing PCB and Hg concentrations to SSC provides an improved metric to compare sites, climatic conditions can nonetheless 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 and there is little dilution of contaminant concentrations 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 small storm or dry year. Only with many years of data during many types of storms can such processes be identified.

Because of concerns regarding inter-storm variability, relative ranking of sites based on EPC data from only one or two storms should be interpreted with caution and added to a broad set of evidence. 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 more rigorous sampling campaign targeting many storms over many years would be required (c.f. the Guadalupe River study: McKee et al., 2017; McKee et al., 2018, or the Zone 4 Line A study: Gilbreath and McKee, 2015; McKee and Gilbreath 2015). Alternatively, a more advanced data analysis would need to be performed 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 a project in CY 2018 to complete this type of investigation (McKee et al., in review).

Derivations of central tendency for comparisons with past data

A mean, median, geometric mean, time-weighted mean, or flow-weighted mean can all 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. However, to best compare composite data from WY 2015-2018 monitoring with previously collected discrete sample data, a slightly different approach was used to re-compute the central tendency of the discrete stormwater samples. 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):

$$EPCcomp\ \left(\frac{ng}{mg}\right) = \frac{\Sigma POCdis\left(\frac{ng}{L}\right)}{\Sigma SSCdis\left(\frac{mg}{L}\right)} \qquad (2)$$

where EPC_{comp} is the estimated composite particle concentration for a site with discrete sampling, POC_{dis} is the pollutant concentration of the discrete sample at a site, and SSC_{dis} 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

This report presents data from all available stormwater data collected since 2002 when stormwater studies first began through SFEI contracts or RMP projects, not just the data collected for this WY 2015-18 reconnaissance monitoring study. The additional data primarily includes data collected in intensive loadings studies from WYs 2003-2010 and 2012-2014, a similar reconnaissance study done in WY 2011, and studies of green infrastructure done between 2010 and the present. The data are presented in the context of three 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 for composite water samples compare to EPCs derived from samples collected by the remote suspended-sediment samplers?
c) How do concentrations and EPCs relate to other trace contaminant concentrations and land use?

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, the relative rankings of particular sites have changed, but the highest-ranking sites have generally remained in the top quarter of sites.

SSC stormwater concentrations

Suspended sediment concentrations from the 84 sampling locations ranged from 16 to 2626 mg/L, with a median of 93 mg/L. These statistics include about a quarter of watersheds with agricultural and uncompacted open spaces at percentages greater than 5%. When those watersheds are removed, 61 remain that are nearly wholly urban (maximum agricultural plus uncompacted open space equals 2.1%). Summary statistics for these urban watersheds are presented below in Table 4 as a whole, as well as broken down by county.

Table 4. Summary statistics of SSC for urban watersheds with agricultural and uncompacted open space <2.2%.

	All Counties	Alameda	Contra Costa	San Mateo	Santa Clara
n	61	18	6	16	20
Minimum	16	60	41	16	27
10%	26	68	49	20	34
25%	44	81	53	25	45
50%	73	111	60	43	65
75%	132	178	110	62	119
90%	182	388	123	183	149
Maximum	671	671	151	265	250

PCBs stormwater concentrations and estimated particle concentrations

Total PCB concentrations from the 83 sampling sites[8] ranged from 533 to 448,000 pg/L excluding one sample that was <MDL (Table 5). 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, Pulgas Pump Station-North, Ettie Street Pump Station, Ridder Park Dr Storm Drain, Gull Dr. Outfall, and Outfall to Lower Silver Creek (Table 5, Figure 3). We often associate high PCB concentrations with old industrial land use, but these results suggest there is not a perfect correlation; the old industrial land use for these top-10 sites ranges from 3-79% (mean 40%, median 47%), highlighting the challenge of using land use alone as a guide to identify high leverage areas. Rather, localized sources are likely the most important factor controlling PCB concentrations, and these sources frequently are located in old industrial areas.

Using PCB EPCs, the highest-ranking sites are: Pulgas Pump Station-South, Industrial Rd Ditch, Line 12H at Coliseum Way, Santa Fe Channel, Gull Dr SD, Pulgas Pump Station-North, Outfall to Colma Ck on service road near Littlefield Ave., Outfall to Lower Silver Creek, Ettie Street Pump Station, and South

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[8] There are 84 sites in Table 5 but one site, San Pedro Stormdrain, only analyzed samples for Hg, not PCBs.

Linden Ave. SD. There was good correspondence between the sites ranked highest based on stormwater concentrations and those ranked highest based on EPCs. Seven sampling sites are on both of the lists of the top-10 highest-ranking sites (Figure 4); most sites in the top-10 for either concentrations or EPCs were within the top-20 of the other list, while only one site (South Linden Ave. SD) was ranked high (10th) in EPCs but low on water concentration (35th) because of very low suspended sediment concentration. Figure 3 shows how each year, one or more sites of interest were identified through this sampling effort. Of the 10 sites added, WY 2018 sampling identified one more PCB site of interest.

The fact that there are watersheds that rank high in water concentration but low in EPC suggests that there are PCB sources present but that the EPC is diluted by relatively high loading of clean sediment (e.g. >75% of SSC, Table 5). Examples include Line 13A at end of slough (357 mg/L) and Line 12K at Coliseum Entrance (671 mg/L). Conversely, that there are watersheds that rank high in EPC but not high in water concentration suggests that mobilization of PCBs is high relative to sediment mobilization, often with samples having a relatively low SSC. In addition to South Linden Ave. SD (16 mg/L), other examples of this include Austin Ck at Hwy 37 (20 mg/L) and Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Circle (27 mg/L). This latter scenario is more likely to occur in watersheds that are highly impervious with little erosion and transport of clean sediment from rural areas.

Most of the sites investigated 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 1,330 pg/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 (Wu et al., 2017) and an average annual suspended sediment load of 1.4 million metric tons (McKee et al., 2013). Only five sampling locations investigated to date (Gellert Park bioretention influent stormwater, Duane Ct. and Triangle Ave., East Antioch nr Trembath, Refugio Ck at Tsushima St. and Little Bull Valley) have a composite averaged PCB water concentration of <1,330 pg/L (Table 5) and none of 83 sampling locations have composite averaged PCB EPCs of <1.4 ng/g (Table 5; Figure 3). The lowest PCB EPC measured to date is for Marsh Creek (2.9 ng/g).

Table 5. PCB and total mercury (HgT) water concentrations and estimated particle concentrations (EPCs) measured in the Bay Area based on all RMP data collected in stormwater since water year 2003 (83 sites in total for PCBs and 84 sites for HgT). The data are sorted from high-to-low for PCB EPC to provide preliminary information on potential leverage. Note: Ranks with a half number (.5) are the result of two watersheds with the same rank.

Watershed/ Catchment	County	Water Year sampled	Area(km2)	Impervious cover(%)	Old Industrial land use (%)	Polychlorinated biphenyls (PCBs)				Total Mercury (HgT)				Suspended Sediment Concentration (SSC)	
						Estimated Particle Concentration		Composite /mean water concentration		Estimated Particle Concentration		Composite /mean water concentration		Composite /mean water concentration	
						(ng/g)	Rank	(ng/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(mg/L)	Rank
Pulgas Pump Station-South	San Mateo	2011-2014	0.58	87%	54%	8222	1	448	1	350	45.5	19	58	54	62
Industrial Rd Ditch	San Mateo	2016	0.23	85%	79%	6139	2	160	3	535	27	14	68	26	79
Line 12H at Coliseum Way	Alameda	2017	0.97	71%	10%	2601	3	156	4	602	19	36	43	60	55
Santa Fe Channel	Contra Costa	2011	3.3	69%	3%	1295	4	198	2	570	22.5	86	12.5	151	22
Gull Dr SD	San Mateo	2016	0.30	78%	54%	903	5	39.8	11	320	51	5.4	81	43	70
Pulgas Pump Station-North	San Mateo	2011	0.55	84%	52%	893	6	60.3	6	400	39	24	54.5	60	55
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	San Mateo	2017	0.09	88%	87%	788	7	33.9	16	210	65	9	78	43	68
Outfall to Lower Silver Creek	Santa Clara	2015	0.17	79%	78%	783	8	44.6	10	420	36	24	54.5	57	60
Ettie Street Pump Station	Alameda	2011	4.0	75%	22%	759	9	59.0	7	690	14	55	24.5	80	48
S Linden Ave SD (291)	San Mateo	2017	0.78	88%	57%	736	10	11.8	35	775	10	12	74	16	84
Gull Dr Outfall	San Mateo	2016 & 2018	0.43	75%	42%	599	11	49.5	9	180	70.5	7.6	79	62	53
Austin Ck at Hwy 37	Solano	2017	4.9	61%	2%	573	12	11.5	37	640	17	13	72.5	20	83
Ridder Park Dr Storm Drain	Santa Clara	2015	0.50	72%	57%	488	13	55.5	8	330	49	37	42	114	32
MeekerWest	Contra Costa	2018	0.41	70%	69%	458	14	28.0	20	530	29	32	46	61	54

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Watershed/ Catchment	County	Water Year sampled	Area(km2)	Impervious cover(%)	Old Industrial land use (%)	Polychlorinated biphenyls (PCBs)				Total Mercury (HgT)				Suspended Sediment Concentration (SSC)	
						Estimated Particle Concentration		Composite /mean water concentration		Estimated Particle Concentration		Composite /mean water concentration		Composite /mean water concentration	
						(ng/g)	Rank	(ng/L)	Rank	(ng/g)	Rank	(ng/L)	Rank	(mg/L)	Rank
Outfall at Gilman St.	Alameda	2016 & 2018	0.84	76%	32%	451	15	37.2	13	2820	3	233	5	81	47
Line 12I at Coliseum Way	Alameda	2017	3.4	63%	9%	398	16	37.0	14	129	76	12	76	93	43
Sunnyvale East Channel	Santa Clara	2011	15	59%	4%	343	17	96.6	5	200	67	50	28	250	13
Line 3A-M at 3A-D	Alameda	2015	0.88	73%	12%	337	18	24.8	21	1170	4	86	12.5	74	49
North Richmond Pump Station	Contra Costa	2011-2014	2.0	62%	18%	241	19	13.2	33	810	9	47	29.5	58	58
Seabord Ave Storm Drain SC-050GAC580	Santa Clara	2015	1.4	81%	68%	236	20	19.9	26	550	25	47	29.5	85	44
Line 12M at Coliseum Way	Alameda	2017	5.3	69%	22%	222	21	24.1	22	365	42	40	38	109	36
Line 4-E	Alameda	2015	2.0	81%	27%	219	22	37.4	12	350	45.5	59	21	170	19
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	Contra Costa	2017 & 2018	36.67	18%	5%	219	23	5.64	55	540	26	16	62	27	77
Glen Echo Creek	Alameda	2011	5.5	39%	0%	191	24	31.1	18	210	66	73	17	348	11
Seabord Ave Storm Drain SC-050GAC600	Santa Clara	2015	2.8	62%	18%	186	25	13.5	32	530	28	38	40.5	73	50
Line 12F below PG&E station	Alameda	2017	10	56%	3%	184	26	21.0	25	373	40	43	35	114	32
South Linden Pump Station	San Mateo	2015	0.14	83%	22%	182	27	7.81	49	680	15	29	50	43	68
Taylor Way SD	San Mateo	2016	0.27	67%	11%	169	28	4.23	60	1156	5	29	51	25	80
Line 9-D	Alameda	2015	3.6	78%	46%	153	29	10.5	40	240	59.5	17	60.5	69	52
Meeker Slough	Contra Costa	2015 & 2018	7.3	64%	6%	140	30	7.91	48	770	11	45	32	57	61
Rock Springs Dr Storm Drain	Santa Clara	2015	0.83	80%	10%	128	31	5.25	56	930	7	38	40.5	41	71
GR outfall 066GAC900	Santa Clara	2018	0.17	66%	1%	125	32	3.36	65	644	16	17	59	27	77

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Watershed/ Catchment	**County**	**Water Year sampled**	**Area(km2)**	**Impervious cover(%)**	**Old Industrial land use (%)**	**Polychlorinated biphenyls (PCBs)**				**Total Mercury (HgT)**				**Suspended Sediment Concentration (SSC)**	
						Estimated Particle Concentration		**Composite /mean water concentration**		**Estimated Particle Concentration**		**Composite /mean water concentration**		**Composite /mean water concentration**	
						(ng/g)	**Rank**	**(ng/L)**	**Rank**	**(ng/g)**	**Rank**	**(ng/L)**	**Rank**	**(mg/L)**	**Rank**
Charcot Ave Storm Drain	Santa Clara	2015	1.8	79%	24%	123	33	14.9	29	560	24	67	19	121	31
Veterans Pump Station	San Mateo	2015	0.52	67%	7%	121	34	3.52	64	470	32	14	67	29	76
Gateway Ave Storm Drain	San Mateo	2015	0.36	69%	52%	117	35	5.24	57	440	33	20	57	45	66
Guadalupe River at Hwy 101	Santa Clara	2003-2006, 2010, 2012-2014	233	39%	3%	115	36	23.7	23	3600	2	603	1	560	5
Line 9D1 PS at outfall to Line 9D	Alameda	2016	0.48	88%	62%	110	37	18.1	28	720	13	118	8.5	164	20
Tunnel Ave Ditch	San Mateo	2016	3.0	47%	8%	109	38	10.5	39	760	12	73	18	96	39
Valley Dr SD	San Mateo	2016	5.2	21%	7%	109	39	10.4	41	276	57	27	53	96	39
Runnymede Ditch	San Mateo	2015	2.1	53%	2%	108	40	28.5	19	190	69	52	27	265	12
E Gish Rd Storm Drain	Santa Clara	2015	0.45	84%	70%	99	41	14.4	30	590	21	85	14	145	25
Line 3A-M-1 at Industrial Pump Station	Alameda	2015	3.4	78%	26%	96	42	8.92	43	340	47	31	47	93	42
Line 13A at end of slough	Alameda	2016	0.83	84%	68%	96	43	34.3	15	331	48	118	8.5	357	9
Line 12A at Shellmound	Alameda	2018	10.48	41%	6%	95	44	10.8	38	406	37	46	31	114	32
Rosemary St SD 066GAC550C	Santa Clara	2017	3.7	64%	11%	89	45	4.11	62	591	20	27	52	46	65
North Fourth St SD 066GAC550B	Santa Clara	2017	1.0	68%	27%	87	46	4.17	61	477	31	23	56	48	63
Zone 4 Line A	Alameda	2007-2010	4.2	68%	12%	82	47	18.4	27	170	72	30	49	176	18
Forbes Blvd Outfall	San Mateo	2016	0.40	79%	0%	80	48	1.84	73	637	18	15	66	23	81

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Watershed/ Catchment	**County**	**Water Year sampled**	**Area(km2)**	**Impervious cover(%)**	**Old Industrial land use (%)**	**Polychlorinated biphenyls (PCBs)**				**Total Mercury (HgT)**				**Suspended Sediment Concentration (SSC)**	
						Estimated Particle Concentration		**Composite /mean water concentration**		**Estimated Particle Concentration**		**Composite /mean water concentration**		**Composite /mean water concentration**	
						(ng/g)	**Rank**	**(ng/L)**	**Rank**	**(ng/g)**	**Rank**	**(ng/L)**	**Rank**	**(mg/L)**	**Rank**
Storm Drain near Cooley Landing	San Mateo	2015	0.11	73%	39%	79	49	6.47	53	430	34	35	44	82	46
Lawrence & Central Expwys SD	Santa Clara	2016	1.2	66%	1%	78	50	4.51	59	226	61	13	69.5	58	59
Condensa St SD	Santa Clara	2016	0.24	70%	32%	74	51	2.60	71	329	50	12	77	35	74
San Leandro Creek	Alameda	2011-2014	8.9	38%	0%	66	52	8.61	46	860	8	117	10	136	29
Oddstad Pump Station	San Mateo	2015	0.28	74%	11%	62	53	9.20	42	370	41	55	24.5	148	24
Line 4-B-1	Alameda	2015	1.0	85%	28%	57	54	8.67	45	280	55.5	43	34	152	21
Line 12A under Temescal Ck Park	Alameda	2016	9.4		1%	54	55	7.80	50	290	54	42	36	143	26
Victor Nelo PS Outfall	Santa Clara	2016	0.58	87%	4%	51	56	2.29	72	351	43	16	64	45	66
Line 12K at Coliseum Entrance	Alameda	2017	16	31%	1%	48	57	32.0	17	429	35	288	4	671	4
GR outfall 066GAC850	Santa Clara	2018	3.35	61%	6%	45	58	6.63	51	107	79	16	63	149	23
Haig St SD	Santa Clara	2016	2.1	72%	10%	43	59	1.45	75	194	68	7	80	34	75
Colma Ck at S. Linden Blvd	San Mateo	2017	35	41%	3%	37	60	2.65	70	215	64	15	65	71	51
Line 12J at mouth to 12K	Alameda	2017	8.8	30%	2%	35	61	6.48	52	401	38	73	16	183	17
S Spruce Ave SD at Mayfair Ave (296)	San Mateo	2017	5.1	39%	1%	30	62	3.36	66	350	44	39	39	111	35
Lower Coyote Creek	Santa Clara	2005	327	22%	1%	30	63	4.58	58	240	59.5	34	45	142	28
Calabazas Creek	Santa Clara	2011	50	44%	3%	29	64	11.5	36	150	75	59	21	393	7
E Outfall to San Tomas at Scott Blvd	Santa Clara	2016	0.67	66%	31%	27	65	2.80	69	127	77	13	69.5	103	38
San Lorenzo Creek	Alameda	2011	125	13%	0%	25	66	12.9	34	180	70.5	41	37	228	15

WYs 2015 through 2018 POC Reconnaissance Monitoring

Watershed/ Catchment	**County**	**Water Year sampled**	**Area(km2)**	**Impervious cover(%)**	**Old Industrial land use (%)**	**Polychlorinated biphenyls (PCBs)**				**Total Mercury (HgT)**				**Suspended Sediment Concentration (SSC)**	
						Estimated Particle Concentration		**Composite /mean water concentration**		**Estimated Particle Concentration**		**Composite /mean water concentration**		**Composite /mean water concentration**	
						(ng/g)	**Rank**	**(ng/L)**	**Rank**	**(ng/g)**	**Rank**	**(ng/L)**	**Rank**	**(mg/L)**	**Rank**
Stevens Creek	Santa Clara	2011	26	38%	1%	23	67	8.16	47	220	62.5	77	15	350	10
Guadalupe River at Foxworthy Road/ Almaden Expressway	Santa Clara	2010	107	22%	0%	19	68	3.12	67	4090	1	529	2	129	30
Duane Ct and Ave Triangle SD	Santa Clara	2016	1.0	79%	23%	17	69	0.832	77	268	58	13	71	48	63
Lower Penitencia Creek	Santa Clara	2011, 2015	12	65%	2%	16	70	1.59	74	160	73.5	17	60.5	106	37
Borel Creek	San Mateo	2011	3.2	31%	0%	15	71	6.13	54	160	73.5	58	23	363	8
San Tomas Creek	Santa Clara	2011	108	33%	0%	14	72	2.83	68	280	55.5	59	21	211	16
Little Bull Valley	Contra Costa	2018	0.02	67%	2%	13	73	0.543	78	312	53	13	72.5	41	71
Zone 5 Line M	Alameda	2011	8.1	34%	5%	13	74.5	21.1	24	570	22.5	505	3	886	3
Belmont Creek	San Mateo	2011	7.2	27%	0%	13	74.5	3.60	63	220	62.5	53	26	241	14
Refugio Ck at Tsushima St	Contra Costa	2017	11	23%	0%	9	76	0.533	79	509	30	30	48	59	57
Walnut Creek	Contra Costa	2011	232	15%	0%	7	77	8.83	44	70	80	94	11	1343	2
Rodeo Creek at Seacliff Ct. Pedestrian Br.	Contra Costa	2017	23	2%	3%	5	78	13.9	31	45	81	119	7	2626	1
Lower Marsh Creek	Contra Costa	2011-2014	84	10%	0%	3	79	1.45	76	110	78	44	33	400	6
San Pedro Storm Drain	Santa Clara	2006	1.3	72%	16%	No data	No data	No data	No data	1120	6	160	6	143	27
East Antioch nr Trembath	Contra Costa	2017	5.3	26%	3%	NR[a]	NR[a]	<MDL	NR[a]	313	52	12	75	39	73
El Cerrito Bioretention Influent	Contra Costa	2012, 2014-15, 2017	0.00	74%	0%	310	NR[a]	29.7	NR[a]	196	NR[a]	19	NR[a]	96	41

WYs 2015 through 2018 POC Reconnaissance Monitoring

Watershed/ Catchment	**County**	**Water Year sampled**	**Area(km2)**	**Impervious cover(%)**	**Old Industrial land use (%)**	**Polychlorinated biphenyls (PCBs)**				**Total Mercury (HgT)**				**Suspended Sediment Concentration (SSC)**	
						Estimated Particle Concentration		**Composite /mean water concentration**		**Estimated Particle Concentration**		**Composite /mean water concentration**		**Composite /mean water concentration**	
						(ng/g)	**Rank**	**(ng/L)**	**Rank**	**(ng/g)**	**Rank**	**(ng/L)**	**Rank**	**(mg/L)**	**Rank**
Fremont Osgood Road Bioretention Influent	Alameda	2012, 2013	0.00	76%	0%	45	NR[a]	2.906	NR[a]	120	NR[a]	10	NR[a]	83	45
Gellert Park Daly City Library Bioretention Influent	San Mateo	2009	0.02	40%	0%	36	NR[a]	0.725	NR[a]	1010	NR[a]	22	NR[a]	22	82

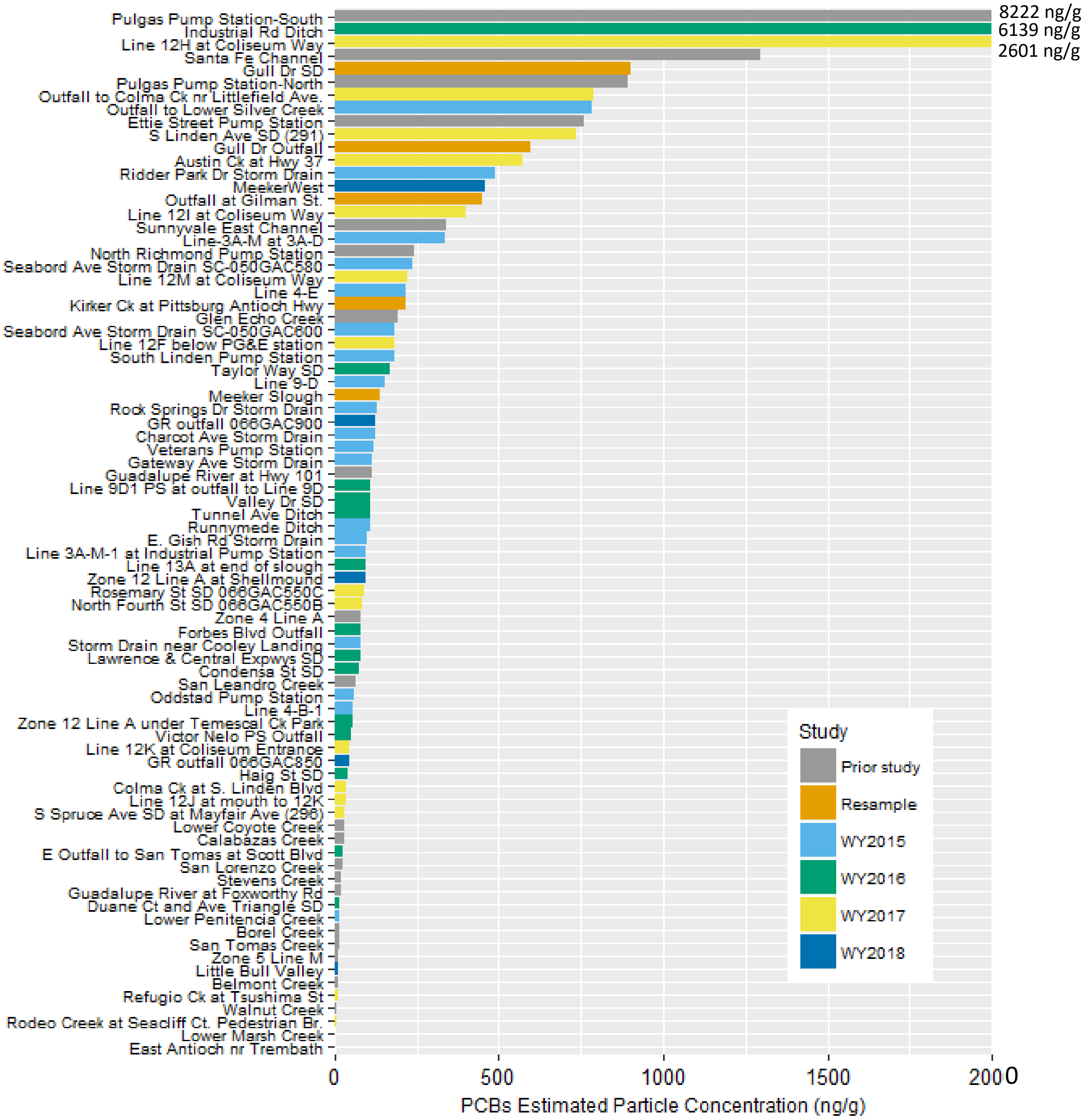

Figure 3. PCB estimated particle concentrations (EPCs) for watershed sampling sites measured to date (water years 2003-2018; where more than one storm is sampled at a site, the reported value is the average of the storm composite samples). Note that PCB EPCs for Pulgas Pump Station-South (8,222 ng/g), Industrial Road Ditch (6,139 ng/g), and 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 D.

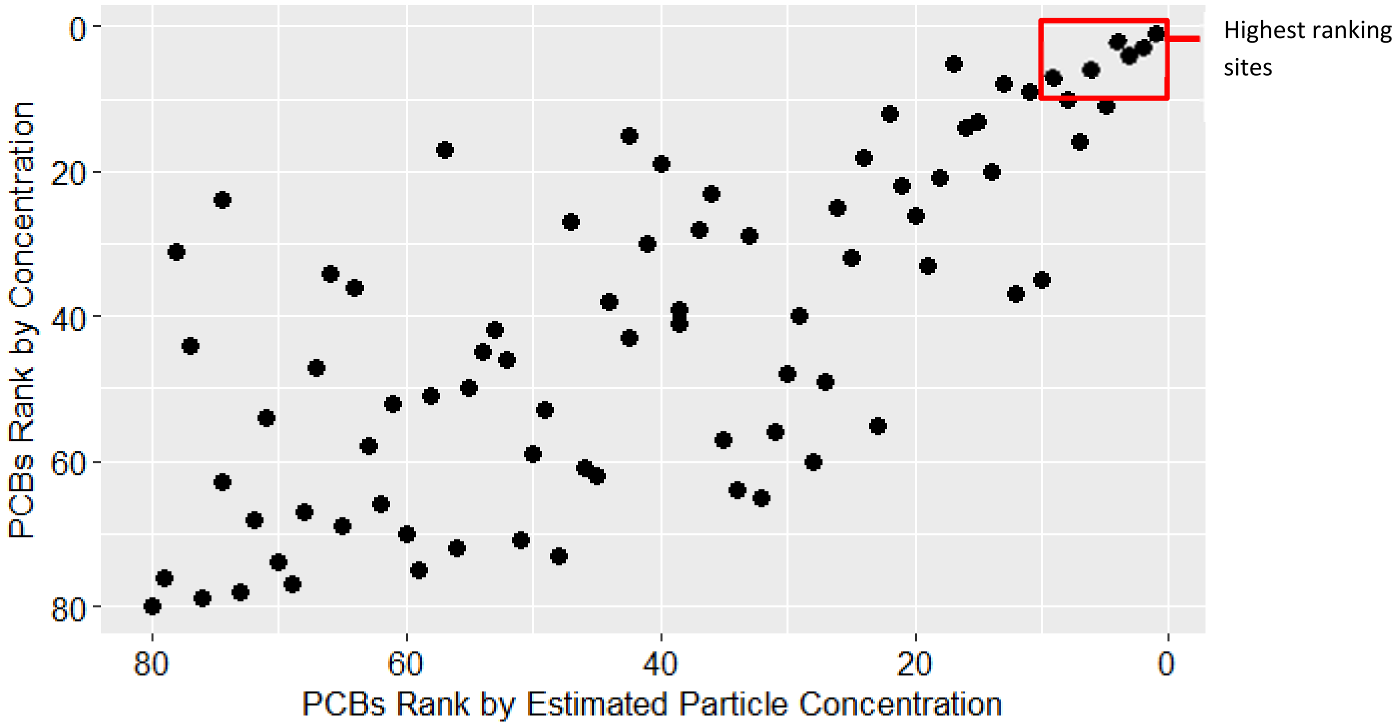

Figure 4. Comparison of site rankings for PCBs based on estimated particle concentrations (EPCs) versus water concentrations. 1 = highest rank; 80 = lowest rank.

Mercury stormwater concentrations and estimated particle concentrations

Total mercury concentrations in composite water samples ranged 110-fold from 5.4 to 603 ng/L, among the 84 sites sampled to date (Table 4). Based on water concentrations, the 10 highest ranking sites for HgT are the Guadalupe River at Hwy 101 (3% old industrial and with the legacy New Almaden Mining District upstream), Guadalupe River at Foxworthy Road/ Almaden Expressway (0% old industrial and with the legacy New Almaden Mining District upstream), Zone 5 Line M (5% old industrial), Line 12K at the Coliseum Entrance (1% old industrial), Outfall at Gilman St. (32% old industrial), San Pedro Storm Drain (16% old industrial), Rodeo Creek at Seacliff Ct. Pedestrian Br. (3% old industrial), Line 13-A at end of slough (68% old industrial), Line 9-D-1 PS at outfall to Line 9-D (62% old industrial) and San Leandro Creek (0% old industrial) (Table 4). These results suggest that there is no direct or strong positive relationship between mercury concentrations[9] and old industrial land use, in contrast to the weak and positive relationship between concentrations measured in water and industrial land use for PCBs. None of these sites ranked among the 10 most highly-ranked sites for PCBs, also suggesting there is no direct relationship between mercury and PCBs in stormwater runoff in the Bay Area. Thus management of highly polluted PCB sites will not necessarily lead to multiple benefits that include similarly large reductions in Hg load.

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[9] There is a weak and negative relationship between old industrial land use and Hg concentrations in water.

There are several watersheds that have relatively low Hg concentrations. The HgT load allocation of 82 kg from the TMDL (SFBRWQCB, 2006) 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 (Wu et al., 2017). Fifty-eight of 84 sampling locations have composite HgT water concentrations below this concentration (Table 4). There are likely few Hg sources in these watersheds besides atmospheric deposition[10].

Estimated particle concentrations ranged between 45 and 4090 ng/g. The 10 most polluted sites for HgT based on EPCs are Guadalupe River at Foxworthy Road/ Almaden Expressway, Guadalupe River at Hwy 101, Outfall at Gilman St., Line 3A-M at 3A-D, Taylor Way SD, San Pedro Storm Drain, Rock Springs Dr. Storm Drain, San Leandro Creek, North Richmond Pump Station and South Linden Ave. SD (Table 4; Figure 5). Management action in these watersheds might be most cost effective for reducing HgT loads. Only one of these 10 sites was among the 10 most highly-ranked sites for PCBs (South Linden Ave. SD), but 6 additional watersheds rank in the 20 most highly-ranked sites for both pollutants (Figure 6), providing the opportunity to address both PCBs and HgT. Twenty-five sites sampled to date have EPCs <250 ng/g, which, given a reasonable expectation of error of 25% around the measurements, could be considered equivalent to or less than 200 ng/g of Hg on suspended solids (the particulate Hg concentration specified in the Bay and Guadalupe River TMDLs (SFBRWQCB, 2006; 2008)).

Site ranking for HgT presents a different picture from PCBs. Sites ranking high based on water concentration are not necessarily ranked high for EPC (Figure 7). Given 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 (one of the highest) for stormwater composite HgT concentrations but 80th (nearly the lowest) on the basis of EPC. Therefore, ranking of sites for HgT should be approached more cautiously than for PCBs.

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[10] 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).

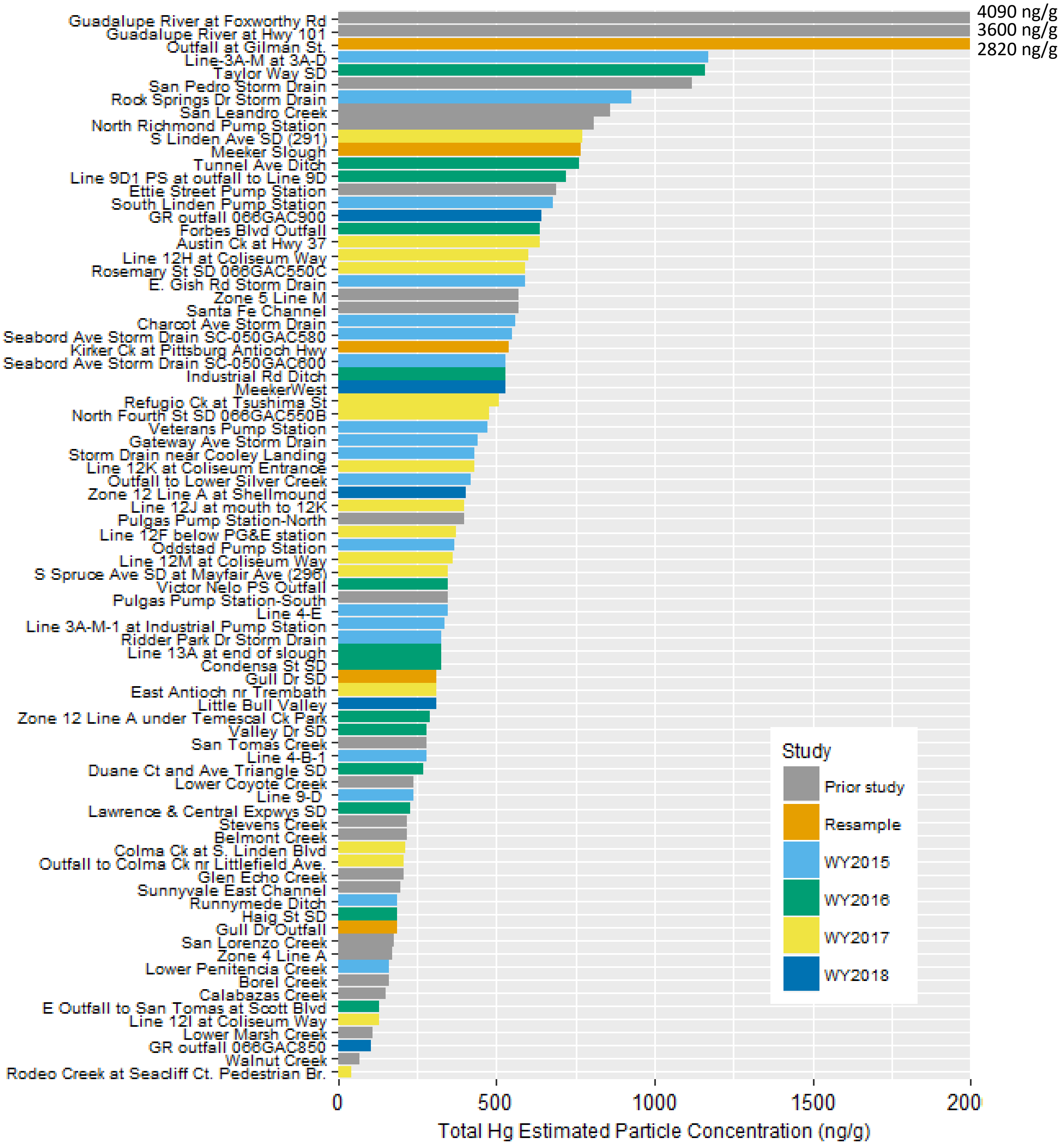

Figure 5. All watershed sampling locations measured to date (water years 2003-2018) ranked by total mercury (HgT) estimated particle concentrations (EPCs). The sample count represented by each bar in the graph is provided in Appendix D.

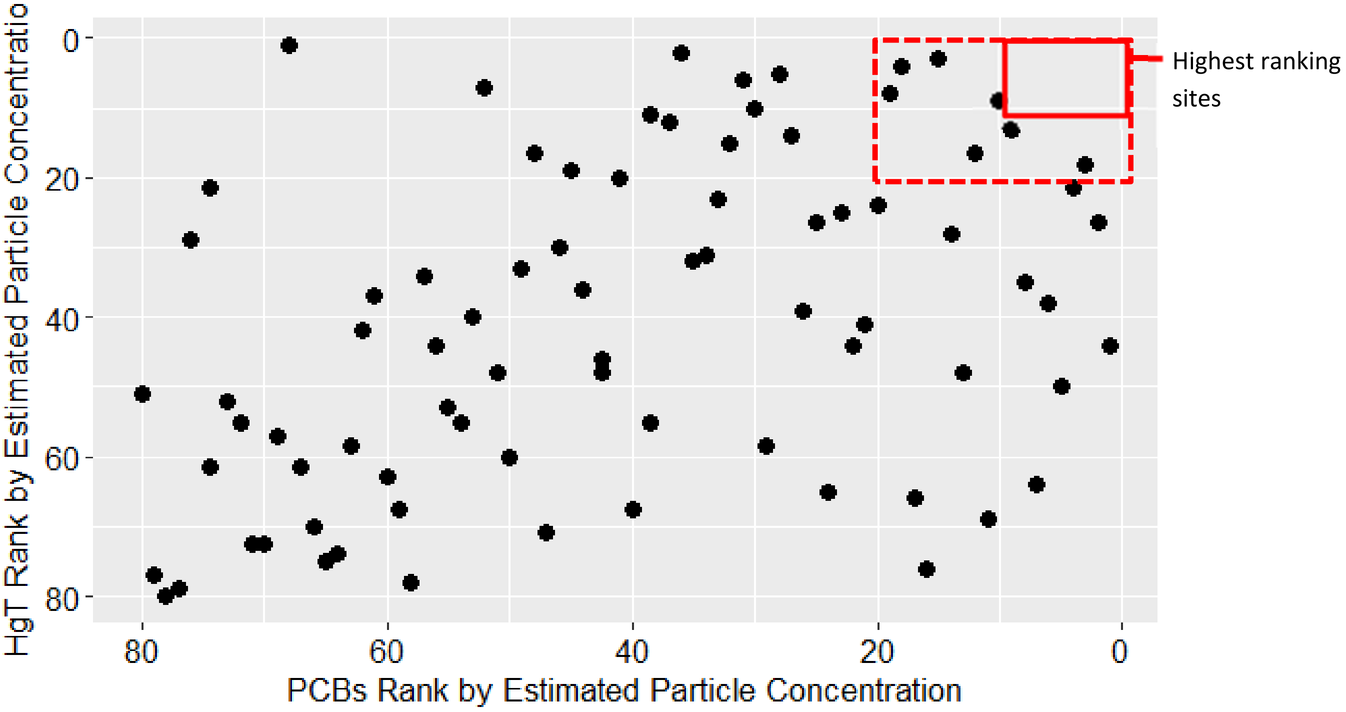

Figure 6. Comparison of site rankings for PCB and total mercury (HgT) estimated particle concentrations (EPCs). 1 = highest rank; 80 = lowest rank. One watershed ranks in the top 10 for both PCBs and HgT (in the solid red box), and seven watersheds rank in the top 20 for both pollutants (in the dashed red box).

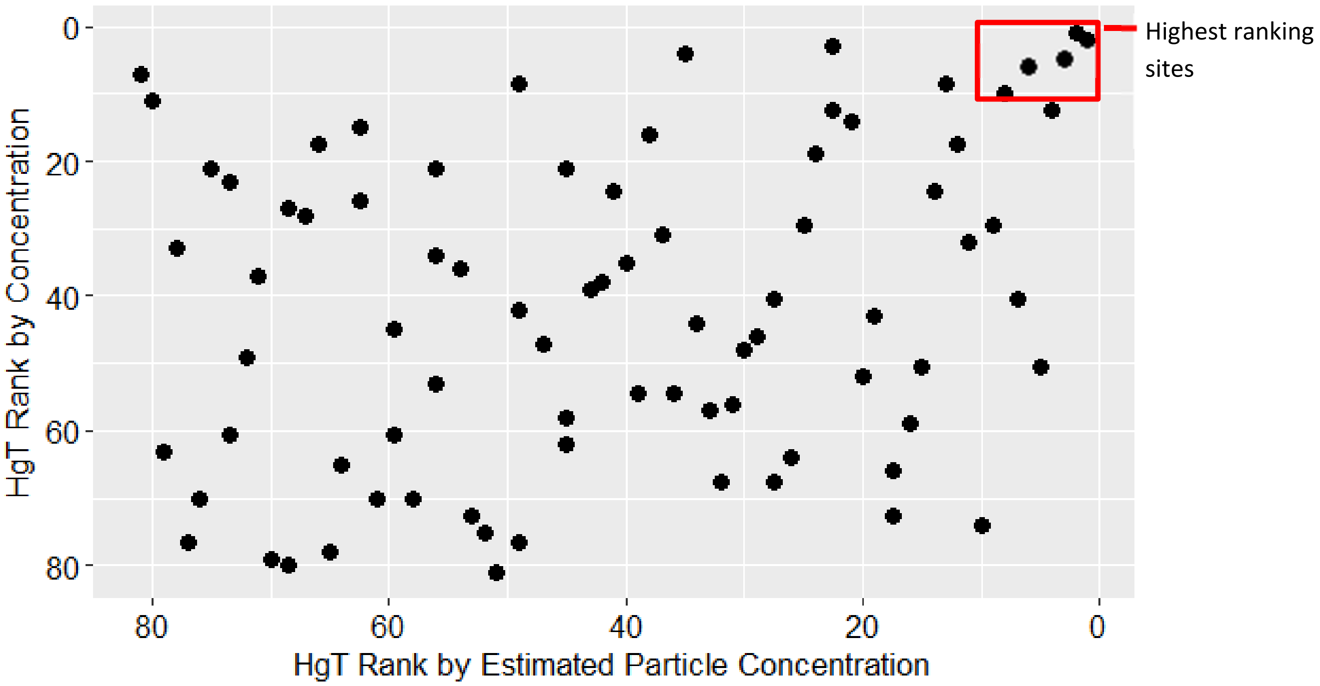

Figure 7. Comparison of site rankings for total mercury (HgT) estimated particle concentrations and water concentrations. 1 = highest rank; 81 = lowest rank.

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

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

- Arsenic (As): Arsenic concentrations ranged from less than the MDL (0.34 µg/L for that sample) to 2.66 µg/L (Table 6). Total As concentrations of this magnitude have been measured in the Bay Area previously (Guadalupe River at Hwy 101: mean=1.9 µg/L; Zone 4 Line A: mean=1.6 µg/L) but are much lower than those 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 (mean = 0.32 µg/L), and Zone 4 Line A (mean = 0.25 µg/L) (Appendix A3 in McKee et al., 2015).
- Copper (Cu): Copper concentrations ranged from 3.63 to 52.7 µg/L (Table 6). These concentrations are typical of those measured in other Bay Area watersheds (mean concentrations for all of the following: 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): Lead concentrations ranged from 0.910 to 21.3 µg/L (Table 6). Total Pb concentrations of this magnitude have been measured in the Bay Area previously (mean concentrations for all of the following: 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 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 (<MDL-0.39 µg/L) were added to the list of analytes. Both Mg and Se 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 end 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 the inverse correlated with flow (David et al., 2015; McKee and Gilbreath, 2015; McKee et al., 2017), it is reasonable that the current sampling protocol, with a focus on high flow, 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/). Because of this sampling bias, care should be taken if the Se concentrations reported from this study were to be used in the future to estimate regional loads.

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 in bold.

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	**<MDL**	246
Gateway Ave SD	2/6/2015	1.18	0.053	24.3	1.04			78.8
Gull Dr SD	3/5/2016	**<MDL**	**0.023**	3.63	1.18	**528**	**<MDL**	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	**<MDL**	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		<MDL	0.023	3.53	0.91	528	<MDL	36.3
Maximum		2.66	0.552	52.7	21.3	11,100	0.67	337

Relationships between PCBs and Hg and other trace substances and land-cover attributes

Beginning in WY 2003, numerous sites have been evaluated for selected trace elements in addition to HgT. These sites include the fixed station loads monitoring sites on Guadalupe River at Hwy 101 (McKee et al., 2017, Zone 4 Line A (Gilbreath and McKee, 2015; McKee and Gilbreath, 2015), North Richmond Pump Station (Hunt et al., 2012) and four sites at 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., 2012; 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 5). The pooled data comprise 39 sites for Cu; 33 for Cd, Pb, and Zn; and 32 for As. Data for Mg and Se were not included because of small sample size. Organic carbon has been collected at 28 locations in this study and an additional 21 locations in previous studies.

Spearman rank correlation analysis[11] was used to investigate relationships between EPCs of PCBs, HgT, and trace elements, and impervious land cover and old industrial land use (Table 6). Since the focus was on learning about pollutant covariance associated with urban land uses, HgT data associated with the main channel of the Guadalupe River were removed from the analysis because of historic mining influence in the watershed[12]. Estimated particle concentrations were chosen for this analysis for the same reasons as 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, and old industrial land use, and correlate inversely with watershed area (Table 6). 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 versus the smaller watersheds that are more urbanized and more industrialized. There was also a positive but relatively weak correlation between PCBs and HgT, which is logical given the general relationships between impervious cover and old industrial land use and both PCBs and HgT. This observation contrasts with the conclusions drawn from the WY 2011 dataset, where there appeared to be more of a general correlation between PCBs and HgT (McKee et al., 2012). The difference between the studies might reflect a stronger focus on PCBs during the WY 2015-2018 sampling campaigns, which included more drainage-line outfalls to creeks with higher imperviousness and old industrial land use, or it might be an artifact of small sample size without sample representation along all environmental gradients. The weakness of the relationship may also partly be associated with

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[11] The rank correlation was preferred because it makes no assumption of the type of relationship (linear or other) or the data distribution (normal data distribution is a requirement of a Pearson Product Moment correlation); in the Spearman correlation, every data pair has an equal influence on the coefficient.

[12] Historic mining in the Guadalupe River watershed caused a unique positive relationship between Hg, Cr, and Ni, and unique inverse correlations between Hg and other typically urban metals such as Cu and Pb (McKee et al., 2017).

the larger role of atmospheric recirculation in the mercury cycle than the PCB cycle and large differences between the use history of each pollutant. PCBs are legacy contaminants that were used as dielectrics, plasticizers, and oils. Mercury was used in electronic devices, pressure and heat sensors, pigments, mildewcides, and dentistry, and has contemporary uses[13] in addition to legacy use. Total Hg also has statistical relationships to the geospatial variables 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 are strongly correlated with other trace metals. Based on the analysis that uses 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 relationships between PCBs, other pollutants, landscape and sediment characteristics, the PCB data were examined graphically (Figure 8). The graphs illustrate 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 stronger 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.

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[13] Some button-type batteries, cleansers, fireworks, folk medicines, grandfather clocks, pesticides, and skin-lightening creams and soaps still contain mercury, but domestic mercury consumption will continue to decline owing to increased use of LED lighting and consequent reduced use of conventional fluorescent tubes and compact fluorescent bulbs, and continued substitution of non-mercury-containing products, such as digital thermometers, and in measuring, control, and dental applications.

Table 6. Spearman Rank correlation matrix based on estimated particle concentrations (EPCs) 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* value <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)	0.357												
Arsenic (ug/mg)	-0.61	-0.07											
Cadmium (ug/mg)	-0.28	0.23	0.67										
Copper (ug/mg)	-0.08	0.162	0.56	0.743									
Lead (ug/mg)	-0.25	0.179	0.583	0.863	0.711								
Zinc (ug/mg)	-0.25	0.266	0.497	0.801	0.894	0.691							
Area (sq km)	-0.41	-0.25	0.00	-0.23	-0.43	-0.08	-0.41						
% Imperviousness	0.529	0.25	-0.35	0.00	0.185	-0.10	0.173	-0.75					
% Old Industrial	0.588	0.233	-0.48	-0.2	-0.21	-0.25	-0.14	-0.52	0.735				
% Clay (<0.0039 mm)	0.272	0.135	-0.12	0.038	-0.23	-0.04	-0.16	-0.23	0.037	0.115			
% Silt (0.0039 to <0.0625 mm)	-0.13	0.07	-0.14	-0.18	0.274	0.00	0.168	0.206	-0.05	-0.06	-0.37		
% Sands (0.0625 to <2.0 mm)	-0.19	-0.24	0.094	0.008	-0.02	0.086	-0.02	0.285	-0.14	-0.11	-0.84	-0.05	
TOC (mg/mg)	0.258	0.427	0.70	0.60	0.875	0.466	0.756	-0.48	0.441	0.173	-0.13	0.118	-0.06

p value <0.05

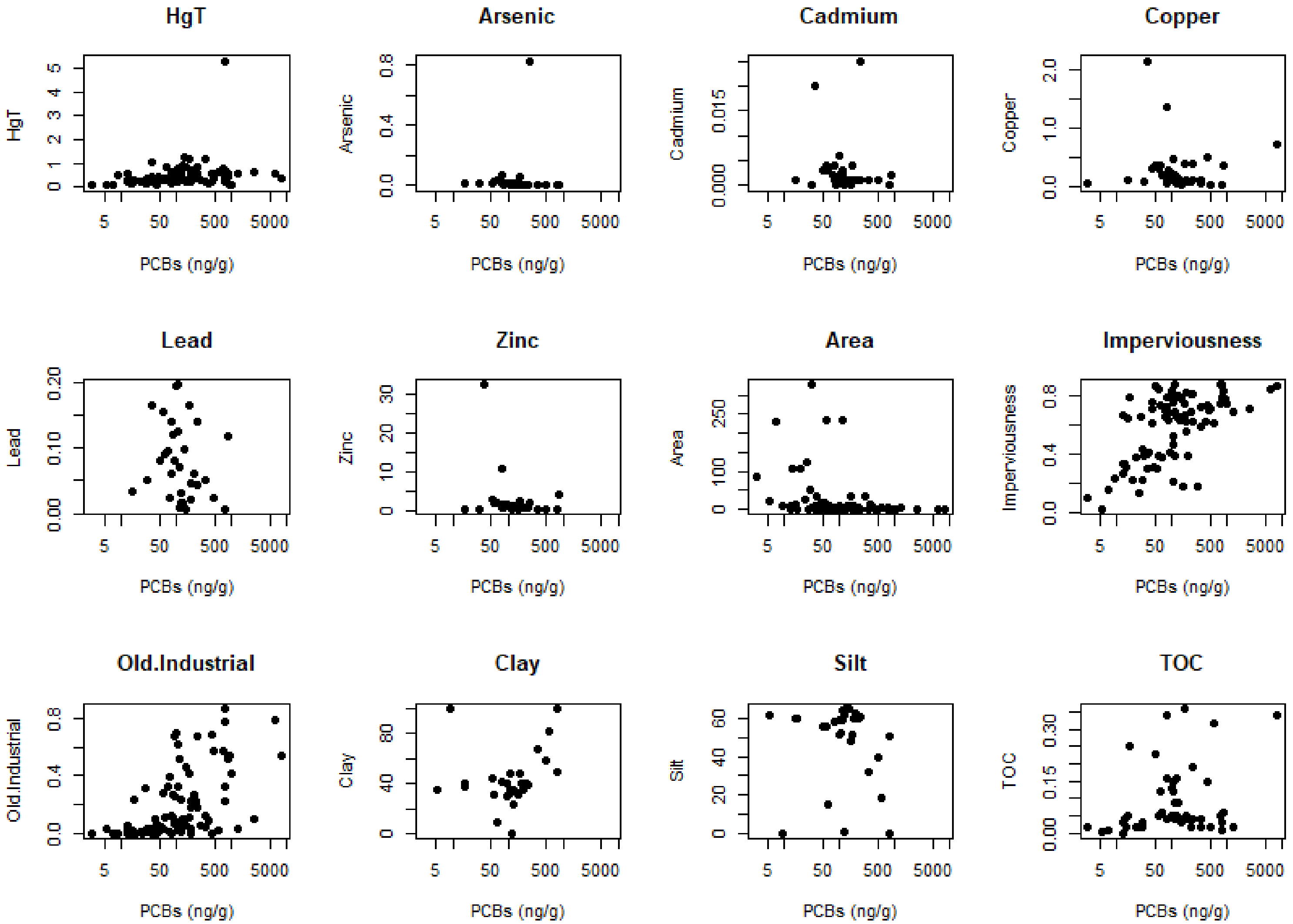

Figure 8. Relationships between observed estimated particle concentrations (EPCs) of PCBs and total mercury (HgT), trace elements, and impervious land cover and old industrial land use.

Comparison between remote and composite 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). PCB EPCs in these manual water composite samples ranged widely from 5 to 788 ng/g. SSC for these same samples was generally below 100 mg/L, with the exception of one sample that was 121 mg/L and one sample that was a high outlier at 2626 mg/L. This outlier SSC sample is from a watershed with 67% agricultural and uncompacted open space, and was collected during a period in which the watershed was fully saturated (collected on 1/18/2017 after a large storm even approximately one week prior); therefore, the high SSC was not unexpected. Due to the high magnitude SSC, and relatively lesser mobilized PCBs in the watershed, the EPC at this site was only 5 ng/g. Conversely the site with the highest EPC (788 ng/g; Outfall to Colma Creek on service road near Littlefield Ave.) had a relatively low SSC at just 43 mg/L.

Mercury EPCs in the manual water composite samples in which remote samples were collected in parallel ranged three orders of magnitude from 45 to 1156 ng/g. Similar to the case for PCBs, the highest SSC sample also had the lowest Hg EPC, and the highest Hg EPC was measured in a sample with relatively low SSC (25 mg/L).

In addition to data shown in the tables, grain size was analyzed for the remote suspended sediment samples and the manual water composite samples collected in parallel. The grain-size distribution for the Walling tube samples agreed well with the manual water-composite samples (Figure 10). The grain-size distribution for the Hamlin samples typically was coarser than for the Walling tube or manual water composite samples. The results as they relate to grain size are discussed further below.

The EPCs for the samples from the remote samplers and manual water composites were compared to determine similarity of the results between the three differing field sampling techniques. The level of resemblance was determined following previously developed techniques (Bland and Altman, 1986; Dallal, 2012). The data were first plotted against one another for a basic visual inspection of scatter about the 1:1 line, and then the differences between concentrations measured in samples collected by the two 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 indicate that the Walling Tube samples were close to the 1:1 line with the stormwater samples (Figure 11A, B), and have no obvious bias (four samples are lower than the 1:1 line and two are higher). The Hamlin samples, however, were generally lower than the 1:1 line. The mean deviation of the paired sample differences (remote sample concentrations minus the water-composite sample concentrations) for the for Walling Tube sampler was -25 ng/g with a standard deviation of 170, whereas for the Hamlin sampler, the mean deviation was -241 ng/g and standard deviation was 275 ng/g. The smallest difference in Hg EPCs between the remote samplers and the composite water samples was at Rodeo Creek at Seacliff Ct. Pedestrian Br using a Walling Tube (RPD 9%); a difference this low could be entirely attributed to subsampling and analytical variation. However, at other sites the differences were as much as 5-fold and cannot be easily explained by subsampling or analytical variation. Instead, a possible explanation is that the manual water composite sample is collected using just 2 to 9 sub-samples whereas the remote sampler is a continuous time-integrated sample that reduces the influence of momentary spikes in concentrations. That the remote sampler Hg EPCs are typically lower than the manual composites is conceptually in concordance with the findings in Yee and McKee (2010), with significant proportions of Hg in dissolved and slower settling fractions. This is consistent with the data (Table 7b), which indicate that, on average, 26% of the HgT was in the dissolved form (range 10-38%). Thus, these composited stormwater samples would be expected to have higher EPCs than would the remote samplers, resulting from lower sediment content and thus a greater relative proportion of Hg in the dissolved phase or on fine particles.

There is better agreement between PCB EPCs measured by the remote and manual sampling methods (Figure 11C, D). Those sites with high EPCs from composite samples also had high EPCs as 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 relative to a remote sample that has an insignificant dissolved phase contribution. 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 more similar to the manual water composite EPC (783 ng/g). One hypothesis is 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 samples, 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 slightly larger particles, which the Hamlin is more likely to capture than the Walling Tube.

The percentage dissolved phase in the PCB samples, where measured (n=9), ranged from 0 to 34% and did not correlate with the PCB EPC; the more polluted a site was did not translate into a larger percentage in dissolved phase. However, the disparity between the manual water composite and remote sampling methods (indicated in the far right hand column of the table titled “Comparative Ratio between Remote Sampler and Manual Water Composites”) was well correlated with the percentage dissolved in the manual water composite for each sampler (Figure 12). In other words, when more of a sample that was in the dissolved phase, the match between the manual water composite samples and the remote sampler samples was worse.

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 (ng/L)	PCBs Particulate (ng/L)	PCBs Dissolved (ng/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	0.8	0.55	0.28	34%	11	17	151%	43	246%
Victor Nelo PS Outfall	Hamlin	45	2.3	2.0	0.28	12%	45	51	114%	70	137%
Taylor Way SD	Hamlin	25	4.2	3.5	0.76	18%	139	169	122%	237	140%
Tunnel Ave Ditch	Hamlin	96	10	9.9	0.60	6%	103	109	106%	150	137%
Forbes Blvd Outfall	Hamlin	23	1.8	1.8	0.047	3%	78	80	103%	42	53%
Charcot Ave SD	Hamlin	121	15	No data				123	No data	142	115%
Outfall to Lower Silver Ck	Hamlin	57	45					783		1767	226%
SD near Cooley Landing	Hamlin	82	6.5					79		68	87%
Austin Ck at Hwy 37	Hamlin	20	11					573		700	122%
Outfall at Gilman St	Hamlin	81	8.6					107		64	60%
Outfall at Gilman St	Walling	81	8.6					107		144	135%
MeekerWest	Walling	61	28					458		522	114%
Outfall to Lower Silver Ck	Walling	57	45					783		956	122%
Austin Ck at Hwy 37	Walling	20	11					573		362	63%
Rodeo Creek at Seacliff Ct. Pedestrian Br.	Walling	2626	14					5		10	195%
Victor Nelo PS Outfall	Walling	45	2.3	2.0	0.28	12%	45	51	114%	100	197%
Tunnel Ave Ditch	Walling	96	10	10	0.60	6%	103	109	106%	96	88%
Refugio Ck at Tsushima St	Walling	59	0.5	0.53	<MDL	0%	0	9	100000%	8	86%
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	Walling	43	34	37	1.0	3%	1	788	90428%	1172	149%
Median						6%			122%		122%
Mean						11%			27289%		130%

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	1.9	15%	229	268	117%	99	37%
Victor Nelo PS Outfall	Hamlin	45	16	12	3.7	23%	269	351	131%	447	127%
Taylor Way SD	Hamlin	25	29	18	11	38%	716	1156	161%	386	33%
Tunnel Ave Ditch	Hamlin	96	73	66	7.2	10%	685	760	111%	530	70%
Forbes Blvd Outfall	Hamlin	23	15	12	2.5	17%	530	637	120%	125	20%
Charcot Ave SD	Hamlin	121	67	No data				557	No data	761	137%
Outfall to Lower Silver Ck	Hamlin	57	24					423		150	36%
SD near Cooley Landing	Hamlin	82	35					427		101	24%
Austin Ck at Hwy 37	Hamlin	20	13					640		459	72%
Outfall at Gilman St	Hamlin	81	27					333		82	25%
Outfall at Gilman St	Walling	81	27					333		408	123%
MeekerWest	Walling	61	32					530		772	146%
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 B	Walling	2626	119					45		50	110%
Victor Nelo PS Outfall	Walling	45	16	12	3.7	23%	269	351	131%	483	138%
Tunnel Ave Ditch	Walling	96	73	66	7.2	10%	685	760	111%	577	76%
Refugio Ck at Tsushima St	Walling	59	30	22	8.4	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%		72%
Mean						26%			125%		78%

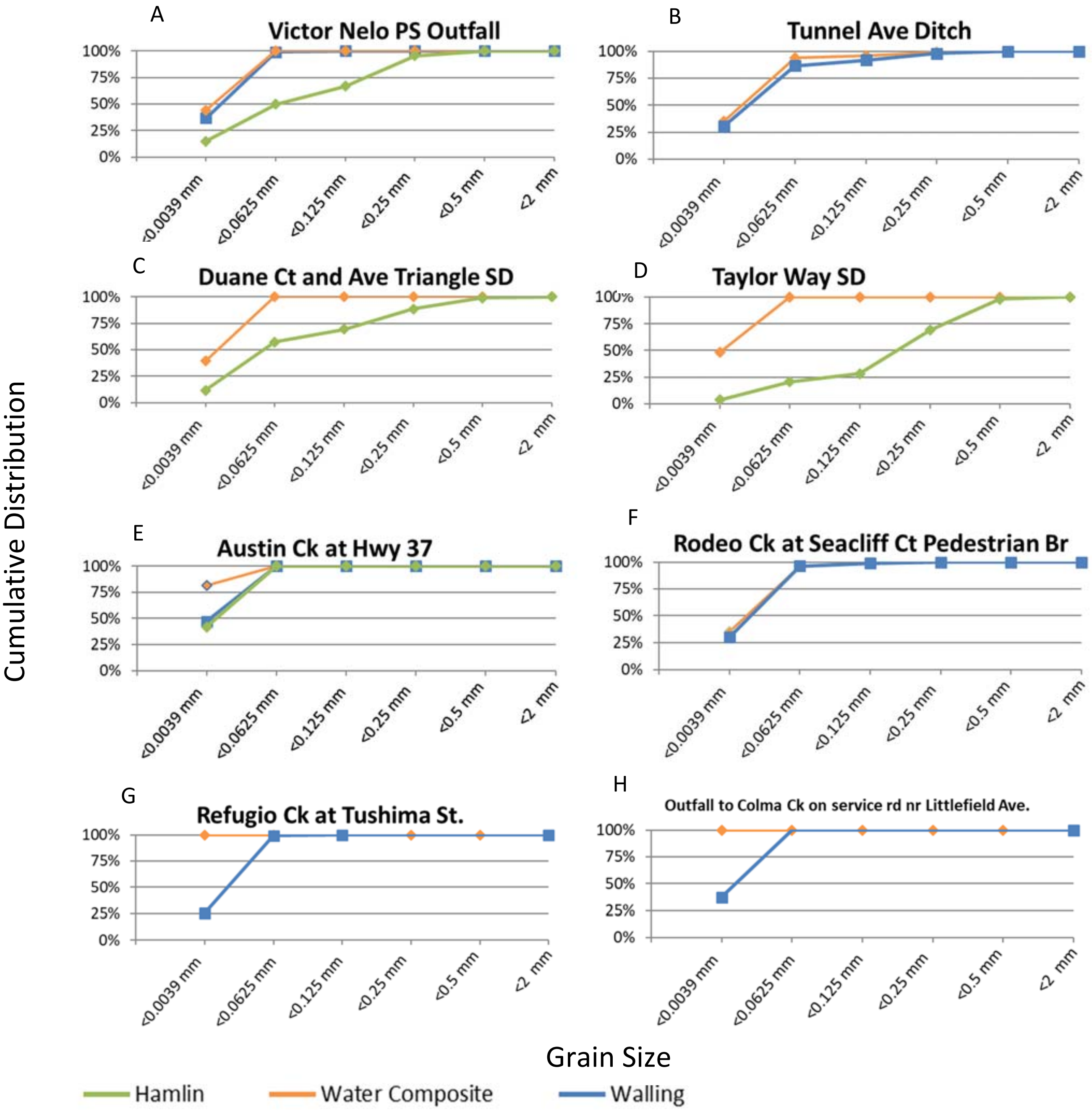

Figure 10. Cumulative grain size distribution in the Hamlin suspended-sediment sampler, Walling Tube suspended-sediment sampler, and water composite samples at eight of the sampling locations. Note that the two samplers were deployed together at only two of these eight sites.

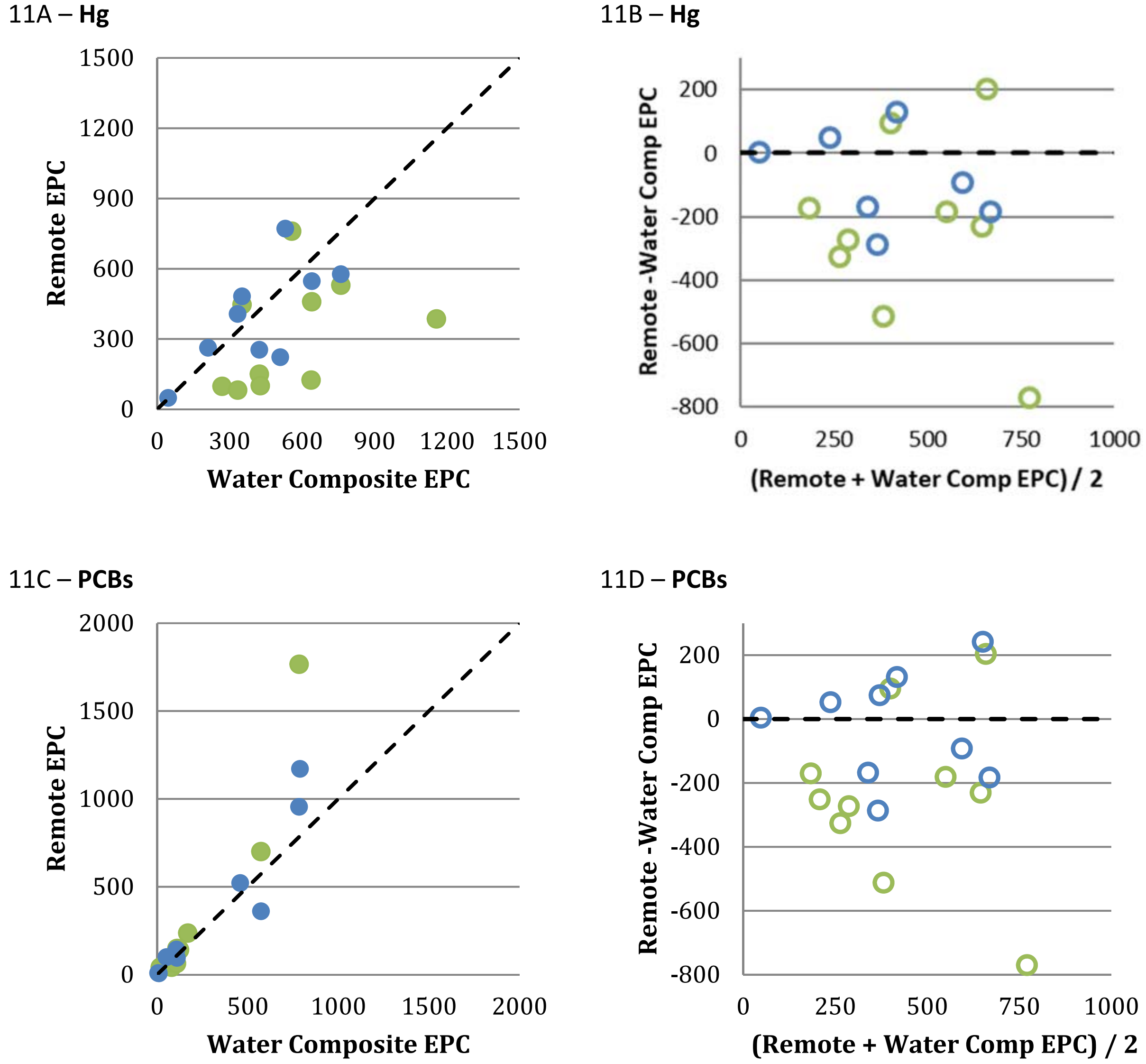

Figure 11. Estimated particle concentration comparisons between remote suspended-sediment samples versus manually collected composite samples, and comparisons of the differences between the methods against their means. Figures 11A and 11C show the 1:1 line (dashed black line), and Figures 11B and 11D 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.

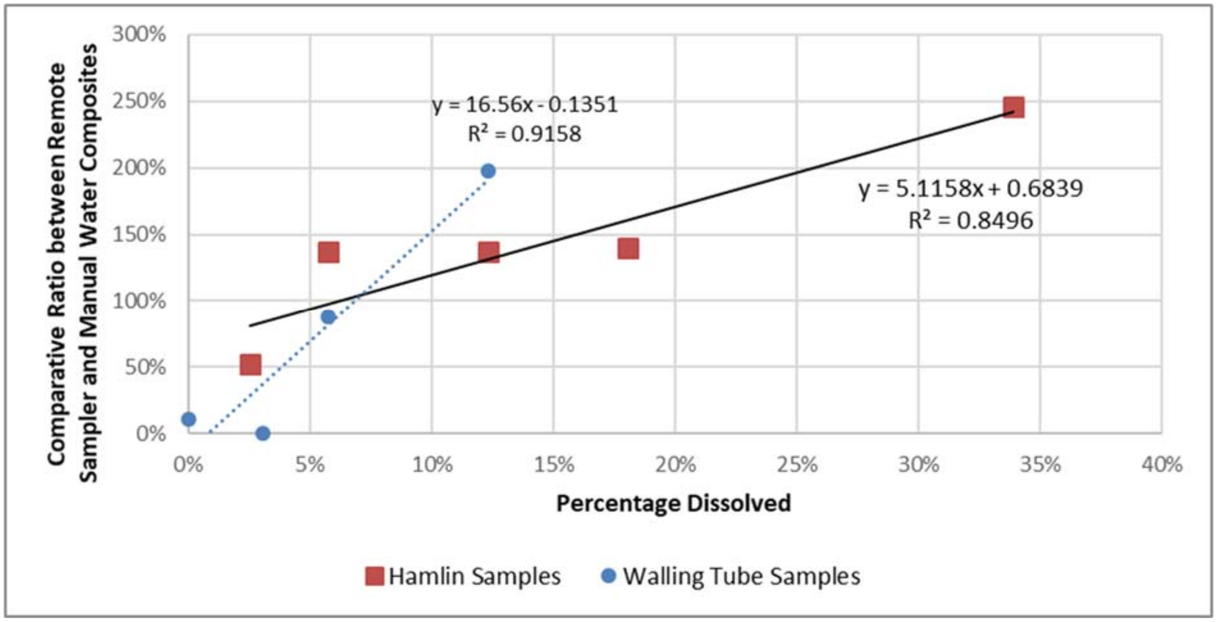

Figure 12. Comparative ratio between remote sampler and manual water composites as a function of the percentage dissolved in the manual water composite for each sampler.

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 water samples remains challenging. Whereas the remote methods collect primarily a concentrated, whole-storm-integrated suspended sediment sample, the manually composited water samples include a proportion of dissolved concentration, which confounds the metric of comparison (EPC) between the methods. In addition, although the Walling Tube does not, the data collected thus far from the Hamlin sampler has a different grain-size distribution than for data collected by the manual water composite method. Another challenge with the remote sampling data is that they cannot be used to estimate loads without corresponding sediment load estimates, which are not readily available.

In summary, remote samplers have shown promise as a screening tool based on data collected to date. The SPLWG has decided that the pilot phase of this study is now complete and recommended that the remote samplers are now ready for use as a low-cost screening tool to identify watersheds where greater investment in manual sampling and other methods of investigation may be needed. Reconnaissance characterization monitoring will continue into WY 2019, during which time remote samplers will be used for a portion of the effort, allowing the project to gather information at more sites for the same budget allocation.

Pros and cons of the remote sampling method

The pilot study to assess effectiveness of remote samplers is now complete. The samplers have been successfully deployed at 14 locations; the Hamlin sampler tested at ten locations and the Walling Tube sampler tested at nine locations. A comparison between remote sampling and manual sampling methods is described below and presented in Table 8a and 8b.

Cost: 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. Manual sampling requires more labor 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 using the manual storm characterization protocol. Laboratory analytical costs are equivalent. See additional details in Table 8b below.

Sampling Feasibility: 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 logistically difficult locations such as 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.

Data Quality: Comparison between the remote sampler and manual sampling results were assessed in this study. Both methods appear to reproduce similar trends – the highly polluted sites have high concentrations using both methods, and the lesser polluted sites have low concentrations for both methods. Although a more direct comparison of absolute measurements has not been studied, there does not seem to be a consistent systematic bias between the field protocols. It is not entirely clear which sampling method is superior for data quality because the remote samplers arguably miss the very finest fraction of sediments and dissolved phase portion, which is achieved in the manual water composite sampling. Yet the remote samplers have the benefit of sampling continuously throughout the storm and not missing any important pulses of pollutants through the flow path, versus manual water composite sampling in which only 3[14] to 9 discrete aliquots are collected throughout a storm event. Additionally, if remote samplers are deployed over multiple storm events, it is reasonable to think that the extended sample collection would improve the representativeness of the sample. Because of these challenges in direct comparison, we suggest that the data quality for both methods is good for characterization, although for absolute comparison, the assessment is incomplete and would require a different study design to adequately compare.

Data Uses: At this time, the particle concentration data being collected using the remote sedimentation sampler methods will be used as a screening method for proposing further sampling at sites with elevated concentrations. We will continue to use data collected by the manual composite water sampling techniques for comparing sites. The water concentration data from the manual water

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[14] There were two exceptions in which only 2 aliquots were collected, Little Bull Valley and Outfall to Colma Ck on service rd nr Littlefield Ave. (359). At Little Bull Valley, flow was so minimal that 2 aliquots were sufficient to adequately characterize the runoff. At Out to Colma Ck on service rd nr Littlefield Ave. (359), a high tide cycle prevented collection during the middle of the storm; one aliquot was collected before and after the high tide cycle.

composites may also be used to estimate single storm loads if the volume is known or can be estimated (e.g., using the RWSM). Particle concentration data from remote samplers cannot be used for this purpose.

Human Stresses and Risks Associated with Sampling Protocol: 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).

Table 8a. Comparison of the advantages and disadvantages of the remote sampling method for screening sites for further investigation by sampling versus the manual sampling method ranking sites relative to each other to support management decisions.

Category	Remote Sampling Relative to Manual Sampling	Notes
Cost	Less	• Less labor during storms when labor is the limiting factor. (See table 8b. below for additional details.)
Sampling Feasibility	Some advantages	• Minimized cleaning time between storms • Can be deployed over multiple storms • Samplers composite more evenly over a storm • Could be deployed by municipalities • No advantage in tidal location
Data Quality	Good for characterization; for absolute comparison, assessment incomplete	• Both methods appear to reproduce similar trends – the highly polluted sites have high concentrations using both methods, and the lesser polluted sites have low concentrations for both methods. • May underrepresent the finest fractions, but sample continuously and do not miss any pulses.
Data Uses	Equivalent or slightly lower	• Successful as a site screening tool. • Unlike with manually collected samples, cannot be combined with volume (if known) to estimate loads.
Human stresses and risks associated with sampling protocol	Much less	• Greatly reduced stress associated with storm planning and storm timing.

Table 8b. Labor and cost comparison between the remote sampling method for screening sites for further investigation by sampling versus the manual composite sampling method for the ranking sites relative to each other to support management decisions.

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 twice
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)

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 coverage to date has occurred in Santa Clara County (61% of old industrial land use in the county is in watersheds that have been sampled), followed by Alameda County (30%) and San Mateo County (27%). In Contra Costa County, only 9% 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 a result of 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 relatively large proportions of older industrial land use upstream from their sampling points. Of the remaining older industrial land use yet to be sampled, 49% of it lies within 1 km and 63% within 2 km of the Bay. These areas are more likely to be tidal and are 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 because of a lack of public rights-of-way and tidal conditions. A different sampling strategy may be required to effectively assess what pollution might be associated with these areas to better identify areas for potential management.

Summary and Recommendations

During WYs 2015-2018, composite water samples were collected at 65 sites during at least one storm event and analyzed for PCBs, HgT, and SSC, and, for a subset of samples, trace metals, organic carbon, and grain size. Sampling efficiency was increased, when possible, by sampling two nearby sites during a single storm. In parallel, a second sample was collected at 10 of the sampling sites using a Hamlin remote sedimentation sampler, and at nine sites using a Walling Tube sedimentation 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 positive results and beginning in WY 2019, the remote samplers will be used as a low-cost screening tool, for the first time unaccompanied by manual water composite sampling. Based on the WY 2015-2018 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 identifying potential high leverage areas with high unit area loads (yields) or concentrations/EPCs. Selecting sites by focusing on older industrial and highly impervious landscapes appears to be successful in identifying high leverage areas.
- Continue to use the composite sampling field protocol as developed and applied during WYs 2015-2018 without further modifications. In the event of a higher rainfall wet season, when there is a greater likelihood that more storm events will fall within the required tidal windows, it may be possible to sample tidally influenced sites.
- Develop a procedure for identifying sites that return lower-than-expected concentrations or EPCs and consider re-sampling those sites. This method is being developed currently in an advanced data analysis project.
- Positive results from the remote sampler study indicate that the samplers show promise as a screening tool. It is therefore recommended that future sampling can include the use of remote samplers as a low-cost screening tool to support decisions about possible further sampling using the reconnaissance characterization monitoring protocol.
- Develop an advanced data analysis method for identifying and ranking watersheds of management interest for further characterization or investigation. This recommendation will be implemented during the 2018 calendar year and possibly be ready to influence site selection in WY 2019.

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Appendices

Appendix A: Characteristics of Larger Watersheds

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, 2016 or 2018 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 on 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

Appendix B – Sampling Method Development

The monitoring protocol implemented in WYs 2015-2018 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.

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[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 C – Quality assurance

The sections below report quality assurance reviews on WYs 2015-18 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 monitoring protocols, however, for the RMP the underlying data were never discarded. Because the results for "censored" data were maintained, the effects of applying different QA protocols can be assessed by a future analyst if desired.

Suspended Sediment Concentration and Particle Size Distribution

In WY 2015, the SSC and particle size distribution (PSD)[16] data from USGS-PCMSC were acceptable, aside from failing hold-time targets. SSC samples were all analyzed outside of hold time (between 9 and 93 days after collection, exceeding the 7-day hold time specified in the RMP QAPP); hold times are not specified in the RMP QAPP for PSD. Minimum detection limits (MDLs) were generally sufficient, with <20% non-detects (NDs) reported for SSC and the more abundant Clay and Silt fractions. Extensive NDs (>50%) were generally reported for the sand fractions starting as fine as 0.125 mm and larger, with 100% NDs for the coarsest (Granule + Pebble/2.0 to <64 mm) fraction. Method blanks and spiked samples are not typically reported for SSC and PSD. Blind field replicates were used to evaluate precision in the absence of any other replicates. The relative standard deviation (RSD) for two field blind replicates of SSC were well below the 10% target. Particle size fractions had average RSDs ranging from 12% for Silt to 62% for Fine Sand. Although some individual fractions had average relative percent difference (RPD) or RSDs >40%, suspended sediments in runoff (and particle size distributions within that SSC) can be highly variable, even when collected by minutes, so results were flagged as estimated values rather than rejected. Fines (clay and silt) represented the largest proportion (~89% average) of the mass.

In 2016 samples, SSC and PSD was analyzed beyond the specified 7-day hold time (between 20 and 93 days after collection) and qualified for holding-time violation but not censored. No hold time is specified for grain-size analysis. Method detection limits were sufficient to have some reportable results for nearly all the finer fractions, with extensive NDs (> 50%) for many of the coarser fractions. No method blanks or spiked samples were analyzed/reported, common with SSC and PSD. Precision for PSD could not be evaluated as no replicates were analyzed for 2016. Precision of the SSC analysis was evaluated using the field blind replicates and the average RSD of 2.12% was well within the 10% target Method Quality Objective (MQO). PSD results were similar to other years, dominated by around 80% Fines.

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[16] Particle size data were captured for % Clay (<0.0039 mm), % Silt (0.0039 to <0.0625 mm), % V. Fine Sand (0.0625 to <0.125 mm), % Fine Sand (0.125 to <0.25 mm), % Medium Sand (0.25 to <0.5 mm), % Coarse Sand (0.5 to <1.0 mm), % V. Coarse Sand (1.0 to <2.0 mm), and % Granule + Pebble (>2.0 mm).

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.

In WY 2015, the SSC and particle size distribution (PSD)[17] data from USGS-PCMSC were acceptable, aside from failing hold-time targets. SSC samples were all analyzed outside of hold time (between 25 and 62 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 zero 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 the field blind replicate of SSC was 8.22%, below the 10% target. Particle size fractions had average RSDs ranging from 10.6% - 10.7% for Fine, Clay and Silt fractions.

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

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[17] 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).

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.

In WY 2018, all TOC samples were censored. Accuracy was evaluated using the matrix spikes. The average %error for TOC in the matrix spikes of 47.68% (average recovery 147.68%) was above the 10% target MQO.

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.

In WY 2018, AXYS analyzed total water samples for PCBs (no samples for dissolved or particulate fractions were submitted for analysis). Method detection limits were acceptable with non-detects (NDs) reported for a single PCB 170 result (7.14%; 1 out of 14 PCB 170 results). PCB 008, PCB 018, PCB 028, PCB 031, PCB 033, PCB 044, PCB 049, PCB 052, PCB 056, PCB 066, PCB 070, PCB 087, PCB 095, PCB 099,

PCB 101, PCB 105, PCB 110, PCB 118, PCB 138, PCB 149, PCB 151, and PCB 174 were found in at least one and often both method blanks at concentrations above the method detection limits. Two PCB 008 results (14.29%; 2 out of 14 results) were flagged with the censoring qualifier VRIP; other blank contaminated results were flagged by the laboratory and did not need to be censored. Contamination was found in the field blank for PCB 008, PCB 018, PCB 028, PCB 031, PCB 033, PCB 044, PCB 049, PCB 052, PCB 056, PCB 060, PCB 066, PCB 070, PCB 087, PCB 095, PCB 099, PCB 101, PCB 110, PCB 118, PCB 138, PCB 151, PCB 153, and PCB187 at concentrations generally less than 1% of the average concentrations found in the field samples (the only exception was PCB 008 which was found in the field blank at a concentration representing ~2% of the average field sample concentration). Accuracy was evaluated using the laboratory control samples (LCSs); the only spiked samples reported. PCB 105, PCB 118, and PCB 156 were the only target congeners included in the LCS samples with an average %error of 8.35%, 9.25%, and 13.63%, respectively, all well below the 35% target MQO. No qualifiers were needed. Precision was evaluated using the blind field replicates. The average RSD ranged from 0.10% to 17.99% for the 40 target PCB congeners; all below the target MQO of 35% target. Laboratory control sample replicates were examined, but not used in the evaluation. The respective RSD's for PCB 105, PCB 118, and PCB 156 were 11.07%, 12.25%, and 3.27%, respectively. No qualification was necessary.

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).

In WY 2018, samples were only analyzed for mercury. Samples were all measured well within hold time. Method detection limits were acceptable as no non-detects (NDs) were reported for mercury. Mercury was not found in the method blanks at concentrations above the method detection limits. All method blank results were NDs. The single field blank contained mercury at a low concentration (0.00015 ug/L) equal to ~0.1% of the average mercury concentration measured in the field samples. Accuracy was evaluated using the matrix spikes. The average %error for mercury in the matrix spikes of 4% was well below the 35% target MQO. Laboratory control material samples were examined, but not used in the evaluation. The average %error of 6% was also well below the target MQO of 35%. No qualifiers were needed. Precision was evaluated using the lab replicates. The average RSD for Mercury was 3% well below the target MQO of 35% target (average RSD for lab replicates and field replicates combined was 6%). Matrix spike replicates were examined, but not used in the evaluation. The average RSD of 2% was also below the 35% target MQO. The laboratory control materials were not used because they had different though similar target values. No additional qualifiers were added.

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 D – Figures 7 and 10 Supplementary Info

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	Discrete Grabs	Composite Samples	Number of Aliquots per composite sample
Belmont Creek	Prior to WY2015	4	0	NA
Borel Creek	Prior to WY2015	5	0	NA
Calabazas Creek	Prior to WY2015	5	0	NA
Ettie Street Pump Station	Prior to WY2015	4	0	NA
Glen Echo Creek	Prior to WY2015	4	0	NA
Guadalupe River at Foxworthy Road/ Almaden Expressway	Prior to WY2015	14 PCB; 46 Hg	0	NA
Guadalupe River at Hwy 101	Prior to WY2015	119 PCB; 261 Hg	0	NA
Lower Coyote Creek	Prior to WY2015	5 PCB; 6 Hg	0	NA
Lower Marsh Creek	Prior to WY2015	28 PCB; 31 Hg	0	NA
Lower Penitencia Creek	Prior to WY2015	4	0	NA
North Richmond Pump Station	Prior to WY2015	38	0	NA
Pulgas Pump Station-North	Prior to WY2015	4	0	NA
Pulgas Pump Station-South	Prior to WY2015	29 PCB; 26 Hg	0	NA
San Leandro Creek	Prior to WY2015	39 PCB; 38 Hg	0	NA
San Lorenzo Creek	Prior to WY2015	5 PCB; 6 Hg	0	NA
San Pedro Storm Drain	Prior to WY2015	0 PCB; 3 Hg	0	NA
San Tomas Creek	Prior to WY2015	5	0	NA
Santa Fe Channel	Prior to WY2015	5	0	NA
Stevens Creek	Prior to WY2015	6	0	NA
Sunnyvale East Channel	Prior to WY2015	42 PCB; 41 Hg	0	NA
Walnut Creek	Prior to WY2015	6 PCB; 5 Hg	0	NA
Zone 4 Line A	Prior to WY2015	69 PCB; 94 Hg	0	NA
Zone 5 Line M	Prior to WY2015	4	0	NA
Charcot Ave Storm Drain	WY2015	0	1	6
E. Gish Rd Storm Drain	WY2015	0	1	5
Gateway Ave Storm Drain	WY2015	0	1	6
Line 3A-M-1 at Industrial Pump Station	WY2015	0	1	6
Line 4-B-1	WY2015	0	1	5
Line 9-D	WY2015	0	1	8
Line-3A-M at 3A-D	WY2015	0	1	5
Line4-E	WY2015	0	1	6
Lower Penitencia Creek	WY2015	0	1	7
Meeker Slough	WY2015	0	1	6
Oddstad Pump Station	WY2015	0	1	6
Outfall to Lower Silver Creek	WY2015	0	1	5
Ridder Park Dr Storm Drain	WY2015	0	1	5
Rock Springs Dr Storm Drain	WY2015	0	1	5
Runnymede Ditch	WY2015	0	1	6
Seabord Ave Storm Drain SC-050GAC580	WY2015	0	1	5
Seabord Ave Storm Drain SC-050GAC600	WY2015	0	1	5
South Linden Pump Station	WY2015	0	1	5
Storm Drain near Cooley Landing	WY2015	0	1	6

Catchment	Year Sampled	Discrete Grabs	Composite Samples	Number of Aliquots per composite sample
Veterans Pump Station	WY2015	0	1	5
Condensa St SD	WY2016	0	1	6
Duane Ct and Ave Triangle SD	WY2016	0	1	5
Duane Ct and Ave Triangle SD	WY2016	0	1	3
E Outfall to San Tomas at Scott Blvd	WY2016	0	1	6
Forbes Blvd Outfall	WY2016	0	1	5
Gull Dr Outfall	WY2016	0	1	5
Gull Dr SD	WY2016	0	1	5
Haig St SD	WY2016	0	1	6
Industrial Rd Ditch	WY2016	0	1	4
Lawrence & Central Expwys SD	WY2016	0	1	3
Line 13A at end of slough	WY2016	0	1	7
Line 9D1 PS at outfall to Line 9D	WY2016	0	1	8
Outfall at Gilman St.	WY2016	0	1	9
Taylor Way SD	WY2016	0	1	5
Tunnel Ave Ditch	WY2016	0	1	6
Valley Dr SD	WY2016	0	1	6
Victor Nelo PS Outfall	WY2016	0	1	9
Zone 12 Line A under Temescal Ck Park	WY2016	0	1	8
Line 12H at Coliseum Way	WY2017	0	1	3
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	WY2017	0	1	2
S Linden Ave SD (291)	WY2017	0	1	7
Austin Ck at Hwy 37	WY2017	0	1	6
Line 12I at Coliseum Way	WY2017	0	1	3
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	WY2017	0	1	4
Line 12M at Coliseum Way	WY2017	0	1	4
Line 12F below PG&E station	WY2017	0	1	3
Rosemary St SD 066GAC550C	WY2017	0	1	5
North Fourth St SD 066GAC550B	WY2017	0	1	5
Line 12K at Coliseum Entrance	WY2017	0	1	4
Colma Ck at S. Linden Blvd	WY2017	0	1	5
Line 12J at mouth to 12K	WY2017	0	1	3
S Spruce Ave SD at Mayfair Ave (296)	WY2017	0	1	8
Guadalupe River at Hwy 101	WY2017	0	0	7
Refugio Ck at Tsushima St	WY2017	0	1	6
Rodeo Creek at Seacliff Ct. Pedestrian Br.	WY2017	0	1	7
East Antioch nr Trembath	WY2017	0	1	6
Outfall at Gilman St.	WY2018	0	1	5
Zone 12 Line A at Shellmound	WY2018	0	1	6
Meeker Slough	WY2018	0	1	5
MeekerWest	WY2018	0	1	5
Little Bull Valley	WY2018	0	1	2
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	WY2018	0	1	5
Gull Dr Outfall	WY2018	0	1	6
Gull Dr SD	WY2018	0	1	5
GR outfall 066GAC850	WY2018	0	1	4
GR outfall 066GAC900	WY2018	0	1	4

Appendix G

PCBs from Electrical Utilities in San Francisco Bay Area Watersheds. Stressor/Source Identification (SSID) Project Work Plan

PCBs from Electrical Utilities in San Francisco Bay Area Watersheds
Stressor/Source Identification (SSID)

Prepared in support of provision C.8.e.iii of
NPDES Permit # CAS612008

Project Work Plan

BASMAA
Bay Area
Stormwater Management
Agencies Association

Prepared for:
Bay Area Stormwater Management Agencies Association (BASMAA)

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FINAL March 2019

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1.0 Introduction

This work plan supports the requirement to implement a Stressor/Source Identification (SSID) Project as required by Provision C.8.e.iii of the San Francisco Bay (Bay) Region Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP) (Order No. R2-2015-0049, SFRWQCB 2015). Per MRP Provision C.8.e.ii, the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC)[1] members are working to initiate eight SSID projects during the five-year term of the MRP (i.e., 2016 – 2020). The RMC programs have agreed that seven SSID projects will be conducted to address local needs (for Santa Clara, Alameda, San Mateo, Contra Costa, Fairfield/Suisun and Vallejo counties), and one project (this project) will be conducted regionally (on behalf of all RMC members). SSID projects follow-up on monitoring conducted in compliance with MRP Provision C.8 (or monitoring conducted through other programs) with results that exceed trigger thresholds identified in the MRP. Trigger thresholds are not necessarily equivalent to Water Quality Objectives (WQOs) established in the San Francisco Bay Basin (Region 2) Water Quality Control Plan (Basin Plan) (SFRWQCB, 2017) by the San Francisco Bay Regional Water Quality Control Board (SF Bay Water Board); however, sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses.

This SSID work plan describes the steps that will be taken to investigate sources of polychlorinated biphenyls (PCBs) from electrical utility equipment in watersheds draining to the San Francisco Bay Basin. BASMAA will implement the work plan as a regional project. BASMAA retained EOA, Inc., of Oakland, CA to develop this work plan and implement the SSID project under the direction of a BASMAA Project Management Team (PMT). All work on this project is supported by funding provided by BASMAA.

1.1 Overview of SSID Project Requirements

SSID projects focus on taking action(s) to identify and reduce sources of pollutants, alleviate stressors, and address water quality problems. MRP Provision C.8.e.iii requires SSID projects to be conducted in a stepwise process, as described below.

Step 1: Develop a work plan that includes the following elements:

- Define the water quality problem (e.g., magnitude, temporal extent, and geographic extent) to the extent known;
- Describe the SSID project objectives, including the management context within which the results of the investigation will be used;
- Consider the problem within a watershed context and examine multiple types of related indicators, where possible (e.g., basic water quality data and biological assessment results);

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[1] The BASMAA RMC is a consortium of San Francisco Bay Area municipal stormwater programs that joined together to coordinate and oversee water quality monitoring and several other requirements of the MRP. Participating BASMAA members include the Alameda Countywide Clean Water Program (ACCWP), Contra Costa Clean Water Program (CCCWP), Fairfield-Suisun Urban Runoff Management Program (FSURMP), San Mateo Countywide Water Pollution Prevention Program (SMCWPPP), Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), and City of Vallejo and Vallejo Flood and Wastewater District (formerly Vallejo Sanitation and Flood Control District).

- List potential causes of the problem (e.g., biological stressors, pollutant sources, and physical stressors);
- Establish a schedule for investigating the cause(s) of the trigger stressor/source which begins upon completion of the work plan. Investigations may include evaluation of existing data, desktop analyses of land uses and management actions, and/or collection of new data; and
- Establish the methods and plan for conducting a site-specific study (or non-site specific if the problem is widespread) in a stepwise process to identify and isolate the cause(s) of the trigger stressor/source.

Step 2: Conduct SSID investigations according to the schedule in the work plan and report on the status of the SSID investigation annually in the Urban Creeks Monitoring Report (UCMR) that is submitted to the SF Bay Water Board on March 31 of each year.

Step 3: Follow-up actions:

- If it is determined that discharges to the municipal separate storm sewer system (MS4) contribute to an exceedance of a water quality standard (WQS) or an exceedance of a trigger threshold such that the water body’s beneficial uses are not supported, submit a report in the UCMR that describes Best Management Practices (BMPs) that are currently being implemented and additional BMPs that will be implemented to prevent or reduce the discharge of pollutants that are causing or contributing to the exceedance of WQS. The report must include an implementation schedule.
- If it is determined that MS4 discharges are not contributing to an exceedance of a WQS, the SSID project may end. The Executive Officer must concur in writing before an SSID project is determined to be completed.
- If the SSID investigation is inconclusive (e.g., the trigger threshold exceedance is episodic or reasonable investigations do not reveal a stressor/source), the Permittee may request that the Executive Officer consider the SSID project complete.

1.2 SSID Work Plan Organization

This work plan fulfills **Step 1** of the SSID process described above in Section 1.1. It describes the steps that will be conducted to investigate electrical utility equipment as a source of PCBs to the MS4 in watersheds draining to the Bay. The remainder of this work plan is organized according to the required elements described in Step 1:

Section 2.0	Problem Definition, Study Objectives, and Regulatory Background
Section 3.0	Study Area, Existing Data, and Potential Causes of Water Quality Problem
Section 4.0	SSID Investigation Approach and Schedule
Section 5.0	References

2.0 Problem Definition, Study Objectives, and Regulatory Background

2.1 Problem Definition

Fish tissue monitoring in the Bay has revealed the bioaccumulation of PCBs in Bay sportfish at levels thought to pose a health risk to people consuming these fish. As a result, in 1994, the state of California issued a sport fish consumption advisory cautioning people to limit their consumption of fish caught in the Bay. The advisory led to the Bay being designated as an impaired water body on the Clean Water Act (CWA) "Section 303(d) list" due to elevated levels of PCBs. In response, in 2008, the SF Bay Water Board adopted a Total Maximum Daily Load (TMDL) water quality restoration program targeting PCBs in the Bay[2]. The general goals of the TMDL are to identify sources of PCBs to the Bay, implement actions to control the sources, restore water quality, and protect beneficial uses. The PCBs TMDL estimates baseline loads to the Bay from various source categories. The largest source category, at 20 kilograms (kg) per year, was estimated to be stormwater runoff. This category includes all sources to small tributaries draining to the Bay. The PCBs TMDL indicates that a 90% reduction in PCBs from stormwater runoff to the Bay is needed to achieve water quality standards and restore beneficial uses. The TMDL states that the wasteload allocation for stormwater runoff of 2 kg per year shall be achieved within 20 years (i.e., by March 2030). The PCBs TMDL is being implemented through NPDES permits to discharge stormwater issued to municipalities and industrial facilities in the Bay Area (e.g. the MRP).

This SSID project was triggered by monitoring conducted over the past 15+ years by BASMAA members that demonstrates municipal stormwater runoff is a source of PCBs to the Bay. PCBs are a group of persistent organic pollutants that were historically used in many applications, including electrical utility equipment and caulks and sealants used in building materials. However, the greatest use by far was in electrical equipment such as transformers and capacitors (McKee et al. 2006). Existing electrical utility equipment, which is often located in public rights-of-way (ROWs), may still contain PCBs that can be released to the MS4 when spills and leaks occur. Due to past leaks or spills of PCBs oil from electrical equipment, properties owned and operated by electrical utilities may potentially have elevated concentrations of PCBs in surrounding surface soils that can be released to the MS4. Because the cumulative releases of PCBs-laden soils from these properties, and spills or leaks of PCBs oils from electrical equipment to MS4s across the Bay Area may occur at levels that exceed the 2 kg per year TMDL waste load allocation (see Section 3.2.3), this potential source of PCBs may limit the ability of municipalities to meet the goals of the PCBs TMDL for the Bay. Therefore, this potential source warrants further investigation.

Electrical utility applications present special challenges for source identification and abatement[3] due to the quantity of equipment and facilities, their dispersed nature, and difficulty in sampling discharges when they occur. In addition, municipalities lack control over these properties and

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[2] The PCBs TMDL was approved by the US Environmental Protection Agency (USEPA) on March 29, 2010 and became effective on March 1, 2010.

[3] Source identification and abatement is one type of stormwater control measure that Permittees use to reduce loads of PCBs in urban runoff. This control measure involves investigations of properties with elevated PCBs in stormwater or sediment to identify sources that contribute a disproportionate amount of PCBs to the MS4, and cause the properties to be abated, or refer the properties to the SF Bay Water Board or other regulatory authority for follow-up investigation and abatement. This control measure is described in more detail in the BASMAA Interim Accounting Methodology for TMDL Loads Reduced (BASMAA 2017).

equipment. Permittees have no jurisdiction over many large electrical utilities and therefore no control over the cleanup of PCBs-containing spills (e.g., dielectric fluids from transformers), or prompt notification when they happen. Release of PCBs from electrical utility applications has proved particularly difficult to document, quantify or control when private utility companies such as Pacific Gas and Electric, (PG&E) are involved. To date, neither Permittees nor the Region 2 Water Board have been able to verify that a sound and transparent cleanup protocol is used consistently by PG&E for PCBs spills from their electrical utility equipment and properties across Bay Area cities. Moreover, current state and federal regulatory levels for reporting and cleanup of PCBs spills (e.g., cleanup goals for soils) are higher than cleanup levels recommended by the SF Bay Water Board to meet the objectives of the PCBs TMDL (SFBRWQCB 2016). These differences create potential missed opportunities to cleanup spills to the more stringent levels that are more consistent with the PCBs TMDL requirements, and for Permittees to report the associated PCBs load reductions via the MRP load reduction tracking and reporting processes.

Due to these constraints, it is not feasible or appropriate for municipalities to develop and implement PCBs control and reporting programs for electrical utility companies. Therefore, municipalities will need to work with the SF Bay Water Board to investigate electrical utility operations. The overall goal of this project is to gather the information needed and provide justification for the SF Bay Water Board to compel the utilities to develop and implement improved procedures and practices that will reduce releases of PCBs to stormwater runoff.

2.2 SSID Project Objectives

The overall goal of this SSID project is to investigate electrical utility equipment as a source of PCBs to urban stormwater runoff and identify appropriate actions and control measures to reduce this source. Building on the information presented by SCVURPPP (2018), this project is designed to achieve the following three objectives:

1. Gather information from Bay Area utility companies to improve estimates of current PCBs loadings to MS4s from electrical utility equipment, and document current actions conducted by utility companies to reduce or prevent release of PCBs from their equipment;
2. Identify opportunities to improve spill response, cleanup protocols, or other programs designed to reduce or prevent releases of PCBs from electrical utility equipment to MS4s;
3. Develop an appropriate mechanism for municipalities to ensure adequate clean-up, reporting and control measure implementation to reduce urban stormwater loadings of PCBs from electrical utility equipment.

A possible outcome of this SSID project is a recommendation that Bay Area municipalities submit a referral to designate electrical utility equipment and properties as a *Categorical Source*, which is a type of source property as described in more detail in the BASMAA Interim Accounting Methodology for TMDL Loads Reduced (BASMAA, 2017). A *Categorical Source* designation would facilitate development of a regional approach to abate this source under the regulatory authority of the SF Bay Water Board. The *Categorical Source* designation was developed specifically to address potential sources of PCBs that are widespread and distributed across multiple jurisdictions, such as electrical utility applications. MRP Permittees, as a group, can refer an entire source category to the SF Bay Water Board. Although local agencies may still identify and refer individual electrical utility properties to the Water Board for abatement, addressing these facilities and equipment as a *Categorical Source* may prove to be a more effective and efficient way to reduce PCBs loads from this source category. The information gained during this project will also provide data that municipalities can use to develop a methodology to account for PCBs load reductions that can be achieved through implementation of a regional control measure program for electrical utilities.

2.3 Management Questions

This SSID project will address a number of key management questions regarding electrical utility applications as sources of PCBs to MS4s, including:

1. What is the current magnitude and extent of PCBs stormwater loadings from electrical utility equipment and operations in the San Francisco Bay Area region?
2. What aspects of equipment or operational procedures should electrical utilities be required to report to the SF Bay Water Board?
3. Are improvements to spill and cleanup control measures needed to reduce water quality impacts from the release of PCBs in electrical utility equipment?
4. Are additional proactive management practices needed to reduce releases of PCBs from electrical utility equipment?
5. What are the PCBs load reductions that can be achieved through implementation of a regional reporting and control measure program?

2.4 Regulatory Context of PCBs WQOs

To better understand the issues of PCBs in the Bay, it is important to understand the regulatory context of the PCBs WQOs and human health risks associated with PCBs. The State Water Resources Control Board (SWRCB) is part of the California Environmental Protection Agency and administers water rights, water pollution control, and water quality functions for the state. It shares authority for implementation of the federal CWA and the state Porter-Cologne Act with the nine Regional Water Quality Control Boards. The Regional Water Boards regulate surface water and groundwater quality through development and enforcement of WQOs and implementation of Basin Plans that will protect the beneficial uses of the State’s waters. These plans designate beneficial uses, WQOs that ensure the protection of those uses, and programs of implementation to achieve the WQOs.

The Basin Plan for the San Francisco Bay region (SFRWQCB 2017) provides the basis for water quality regulation in the San Francisco Bay region. It is implemented by the SWRCB and the SF Bay Water Board. The Basin Plan identifies beneficial uses of Bay waters, establishes narrative and numerical WQOs protective of those beneficial uses, identifies areas where discharges are prohibited, and sets forth a program of implementation to ensure that the Bay WQOs are achieved and beneficial uses are protected. Several beneficial uses are designated in the San Francisco Bay region including commercial and sport fishing (COMM), defined in the Basin Plan as:

- **COMM:** *“Uses of water for commercial or recreational collection of fish, shellfish, or other organisms, including, but not limited to, uses involving organisms intended for human consumption or bait purposes.”*

To protect this beneficial use, the narrative WQO for PCBs in the Bay states that “controllable water quality factors shall not cause a detrimental increase in toxic substances found in bottom sediments or aquatic life”. PCBs in Bay sportfish have been found at levels thought to pose a health risk to people consuming these fish. As a result, the COMM beneficial use of the Bay is not currently supported and the narrative WQO for PCBs has not been achieved.

3.0 Study Area, Existing Data, and Potential Causes of Water Quality Problem

3.1 Study Area

The study area for this SSID project is the portion of the San Francisco Bay Area region subject to the MRP. This section provides an overview of electrical utility systems and companies currently operating in the study area, and describes how and where PCBs are used within those systems.

Electrical utilities produce or buy electricity from generating sources, and then distribute that electricity to users through two networks: the transmission system and the distribution system. The **transmission system** carries bulk electricity at high voltages, often across long distances, directly from generation sources to substations via high voltage power lines. Substations connect the transmission and distribution systems. Substations may increase the voltage from nearby generating facilities for more efficient transmission over long distances or lower the voltage for transfer to the distribution system. Electricity at a typical substation flows from incoming transmission lines, to circuit breakers, to transformers (which step down the voltage), to voltage regulators and cut out switches (which protect the system from overvoltage), and finally to outgoing distribution lines.

The **distribution system** delivers lower voltage electricity from substations directly to homes and businesses over shorter distances. This system includes pole-mounted equipment, equipment in underground vaults, and aboveground equipment on cement pads that are often in green boxes in the public right-of-way (ROW). This equipment is smaller, but more numerous in terms of the number of units.

Electrical utility equipment and facilities in both the transmission and distribution systems are distributed across the entire Bay Area region. In the past, PCBs were routinely used in electrical utility equipment that contained dielectric fluid as an insulator. This is because prior to the 1979 PCBs ban, dielectric fluid was typically formulated with PCBs due to a number of desirable properties they have (e.g., high dielectric strength, thermal stability, chemical inertness, and non-flammability). Electrical equipment containing dielectric fluid is typically identified as Oil-Filled Electrical Equipment (OFEE). Any OFEE that contained PCBs in the past could still potentially be in use and contain PCBs today. The most common types of OFEE that may contain PCBs are transformers, capacitors, circuit breakers, reclosers, switches in vaults, substation insulators, voltage regulators, load tap changers, and synchronous condensers (PG&E 2000).

In the Bay Area, there are eight electric utility companies operating as of February 2015 (State Energy Commission 2015):

<u>Investor-Owned Utilities (IOUs)</u>

1. Pacific Gas and Electric Company (PG&E)
   77 Beale Street
   San Francisco, CA 94105
   (415) 973-7000 (tel)

Publicly Owned Load Serving Entities (LSEs) and Publicly Owned Utilities (POUs)

2. Alameda Municipal Power
   2000 Grand Street
   Alameda, CA 94501-0263
   510.748.3905 (tel)
3. CCSF (also called the Power Enterprise of the San Francisco Public Utilities Commission)
   1155 Market Street, 4th Floor
   San Francisco, CA 94103
   209.989.2063 (tel)
4. City of Palo Alto, Utilities Department
   P.O. Box 10250
   Palo Alto, CA 94303
   650.329.2161 (tel)
5. Pittsburg Power Company Island Energy-City of Pittsburg,
   65 Civic Drive
   Pittsburg, CA 94565-3814
   925.252.4180 (tel)
6. Port of Oakland
   530 Water Street, Ste 3
   Oakland, CA 94607-3814
   510.627.1100 (tel)
7. Silicon Valley Power (SVP) - City of Santa Clara
   1500 Warburton Avenue
   Santa Clara, CA 95050
   408.615.2300 (tel)

Community Choice Aggregators

8. Marin Clean Energy (MCE)
   781 Lincoln Ave Ste 320
   San Rafael, CA 94901-3379
   888.632.3674 (tel)

PG&E is by far the largest electrical utility company in the Bay Area. PG&E is an investor-owned company that is not under the jurisdiction of any Bay Area municipality[4]. Three small publicly-owned utilities in the Bay Area (Alameda Municipal Power, City of Palo Alto Utilities Department, and Silicon Valley Power owned by the City of Santa Clara) maintain their own substations and distribution lines. The other public utilities partner with PG&E to deliver energy through PG&E's equipment. PG&E owns and operates several hundred electrical substations in the Bay Area, in addition to the smaller electrical utility equipment that is widely disbursed throughout urbanized areas and along rural corridors (e.g., small transformers on utility poles or in utility boxes). The total number of pieces of equipment that is in use across the Bay Area and that contains PCBs is not known but is likely in the range of tens to hundreds of thousands (see Section 3.2.2).

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[4] PG&E is regulated by the California Public Utilities Commission (CPUC) and the Federal Energy Regulatory Commission (FERC).

3.2 Existing Data

This section presents an overview of the current state of knowledge about PCBs used by electrical utility companies in the Bay Area, the potential mass of PCBs released into the environment from this source over the past 50+ years, and the regulatory programs currently available for the purposes of managing PCBs and reporting and cleaning up spills. This information focuses on PG&E because this private company owns and operates the vast majority of electrical utility properties and equipment in the Bay Area. This information was originally reported by SCVURPPP (2018).

3.2.1 Regulatory Controls on PCBs in Electrical Utility Equipment

Existing federal and state regulations are primarily focused on controlling the management and handling of in-use PCBs and PCB-containing equipment when the concentrations are above the thresholds for hazardous waste. Under federal regulations, the hazardous waste threshold for PCBs is ≥ 50 parts per million (ppm). Under California regulations, the hazardous waste threshold for PCBs is ≥ 5 ppm in liquids (using the Waste Extraction Test, WET), and ≥ 50 ppm in solids. The allowable post-cleanup concentrations of remaining soils and other surface materials typically range from 10 to 25 ppm, depending on site-specific evaluations of human health risk. As a result, current efforts to control and cleanup PCB releases from electrical utility equipment are focused on these thresholds.

By comparison, Bay Area municipalities are concerned with much lower concentrations of PCBs. For example, currently Bay Area municipalities generally designate a site as a *potential* PCBs source to stormwater runoff if soil or sediment concentrations are ≥ 0.5 ppm and designate a site as a *confirmed* PCBs source to stormwater runoff if soil or sediment concentrations are ≥ 1.0 ppm. Control of PCBs sources at these substantially lower concentrations has been deemed necessary to make progress towards meeting the stringent stormwater runoff wasteload allocations called for in the PCBs TMDL.

3.2.2 PCBs Remaining in Electrical Utility Equipment

Although use of PCBs is highly restricted currently, McKee et al. (2006) estimated that 12.3 million kilograms of PCBs were used in the San Francisco Bay Area between 1950 and 1990. Roughly 65% (8 million kg) was used in electrical transformers and large capacitors (McKee et al. 2006). How much of this mass was released to the environment and how much remains in electrical equipment distributed across the Bay Area today is unknown. While the 1979 ban of PCBs did not require the immediate removal of PCBs from current applications, electrical utilities have made substantial efforts over the past 35+ years to reduce the amount of PCBs still used in their applications in the Bay Area. According to PG&E, the majority of OFEE containing PCBs in the Bay Area has already been removed or refurbished with dielectric fluids that do not contain PCBs through the following actions:

- Voluntary replacement programs;
- Ongoing removal of PCBs from OFEE as units are serviced or replaced due to routine maintenance programs; and
- OFEE replacement due to unplanned actions (e.g., transformer leaks and fires).

Voluntary actions conducted by PG&E, primarily in the mid-1980s, included the PCBs Distribution Capacitor Replacement Program and the PCBs Network Transformer Replacement Program (PG&E 2000). In addition, in the 1990s, PG&E implemented a program to remove oil-filled circuit breakers and replace them with equipment that contains sulfur hexafluoride gas

(PG&E 2000). Current ongoing PG&E efforts to remove PCBs-containing equipment are conducted primarily through maintenance programs. Past maintenance of older equipment may have included draining PCBs-containing oils and refilling the equipment with oils that did not contain PCBs. These refurbished OFEE may still contain PCBs at levels of concern to municipalities due to residual contamination from the original PCB-oil. Currently, as maintenance staff identify older equipment in-use, it is scheduled for replacement. However, PG&E has provided limited documentation of their past and current PCBs removal efforts. There remains much uncertainty on where PCBs transformers, PCBs capacitors, oil-filled circuit breakers, and PCBs-containing distribution system equipment were originally located, and which ones have already been removed or replaced.

Despite the removal efforts described above, PCBs may still be found in older and refurbished OFEE, and particularly OFEE located throughout the distribution system. In a recent meeting with SF Bay Water Board Staff, PG&E noted that any equipment installed prior to 1985 could contain PCBs, as it would have come from equipment stockpiled prior to the 1979 ban and was installed prior to the voluntary replacement programs (*personal communication*, Sanchez 2016). Because OFEE are not typically tested for PCBs until the fluid is removed during servicing or disposal, or in the event of a spill, the total number of PCBs-containing OFEE that remain in use is unknown. However, in a letter to the SF Bay Water Board in 2000, PG&E provided information that can be used to make some preliminary estimates, including the following (PG&E 2000):

- There are over 900,000 pieces of OFEE in service in the distribution system;
- In 1999, 22,000 pieces of equipment were serviced at the main PCBs-handling facilities in Emeryville;
- Approximately 10 percent of the units serviced and tested annually contain PCBs at concentrations of 50 parts per million (ppm) or greater, and fewer than 1 percent contained PCBs at concentrations of 500 ppm or greater; and
- The number of pieces of equipment containing PCBs concentrations > 50 ppm has declined over time.

The information above was used to calculate the following:

- Assuming the count of equipment processed in 1999 in Emeryville represents an average annual processing rate throughout the region and that there are at least 900,000 pieces of equipment in PG&E's distribution system it would take over 40 years at a minimum for all of this equipment to be replaced;
- Assuming the 1999 processing rate and 900,000 pieces of equipment in the distribution system in 1985, approximately 175,000 pieces would not yet have been serviced or replaced as of 2018; and
- Of the approximately 175,000 pieces of equipment remaining in-use in 2018, approximately 17,500 (10%) may contain PCBs concentrations > 50 ppm.

Although based on limited information, the above estimates demonstrate that a potentially large number of pieces of equipment containing PCBs over 50 ppm (i.e., 17,500 as of 2018) may remain in-use in the electrical utility distribution system. And the remaining 90% (roughly 157,000 pieces of equipment) may contain lower concentrations of PCBs that could still be of concern to Permittees in their efforts to meet TMDL requirements.

3.2.3 Estimated Loadings of PCBs from Electrical Utility Equipment to MS4s

Building upon their estimates of the total mass of PCBs used historically in the Bay Area, McKee et al. (2006) developed a transport and fate conceptual model that identified the major sources of PCBs to stormwater conveyances and described mass movement from these sources or source areas into the stormwater conveyance system. McKee et al. (2006) estimated the net mass input of PCBs to MS4s in the Bay Area in 2005 was approximately 28 kg per year.[5] Of this total, roughly 29% (8 kg/yr) was estimated to have originated from controlled closed systems (transformers and large capacitors) and 71% (20 kg/yr) was from dissipative uses (e.g., release of PCBs-containing building materials such as caulks and sealants during demolition and renovation). This includes both current and legacy uses that resulted in widespread distribution of PCBs across watershed surfaces. In other words, these estimates suggest that because of both current and past use, transformers and large capacitors, which are both electrical utility applications, may continue to contribute nearly one-third of the net PCBs mass to MS4s in the Bay Area. As noted earlier, such loadings would exceed the 2 kg per year TMDL waste load allocation for stormwater runoff (see Section 2.3.2) and limit the ability of municipalities to meet the goals of the PCBs TMDL for the Bay. Conversely, reduction of PCBs released to MS4s from electrical utility equipment may support attainment of TMDL goals.

3.2.4 Ongoing Release of PCBs from Electrical Utility Equipment

Although the bulk of PCBs remain contained within OFEE until the equipment is removed from use and transported to proper hazardous waste disposal facilities, releases of PCBs to the environment can and do occur. In order to document current spills, publicly available data in the California Office of Emergency Services (Cal OES) spill report database (Cal OES 2016), as well as internal spill records (PG&E 2000) supplied by PG&E to the SF Bay Water Board in September 2000 (that were provided pursuant to a California Water Code §13267 request for information) were reviewed. The Cal OES database and available PG&E spill records were searched for reports of spill releases related to OFEE in the Bay Area between 1994 and 2017. Over 1,200[6] reported release incidents from PG&E OFEE in the Bay Area were identified. The information provided by these records and a summary of the important issues identified for water quality concerns are summarized in the remainder of this section. It is important to note that current regulations do not require reporting of all releases from OFEE. The information provided below is based only on the reported releases for which records were available, and likely represents an underestimate of actual OFEE releases during the time period of review. However, these reports clearly demonstrate that PCBs may still be present in the electrical transmission and distribution systems in the Bay Area, and that releases from these systems can and do continue to occur.

Generally, the publicly available spill release records provide information about the spill release date, time, location, chemical, quantity released, actions taken, known or anticipated risks posed by the release, and additional comments. Other information that is sometimes reported for OFEE releases includes a description of the causes of the release and the equipment affected, and the concentrations of PCBs in that equipment (if known). Concentration information reported is likely assumed from equipment labels, as ranges are most often provided rather than specific values. Typically, the reports are limited to the information that was

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[5] The PCBs TMDL estimates a PCBs loading of 20 kg per year from stormwater runoff (see Section 2.1).

[6] The records span 24 years of spill reports, and include PG&E's own record of releases from 1994 thru 1999 and a portion of 2000. The number of reports PG&E submitted in 2000 represents less than half the number of reports for that year. Records did not include all the districts in the Bay Area. District documents submitted reported releases prior to June of 2000, with the exception of one district that submitted a June report. As a result, the number of additional reports from PG&E's records are assumed to be less than half the number of incidents for 2000.

available at the time the spill was initially reported. In some cases, follow-up information such as the results of analytical testing of the spilled materials is also provided, but this is not typical.

3.2.4.1 Number of Reported OFEE Releases

Between 1994 and 2017, over 1,000 spills from PG&E electrical equipment were reported to Cal OES. PG&E records contain information about 200 additional releases that were not reported to Cal OES between 1994 and 2000. A count of these reports by year is presented in Figure 1.

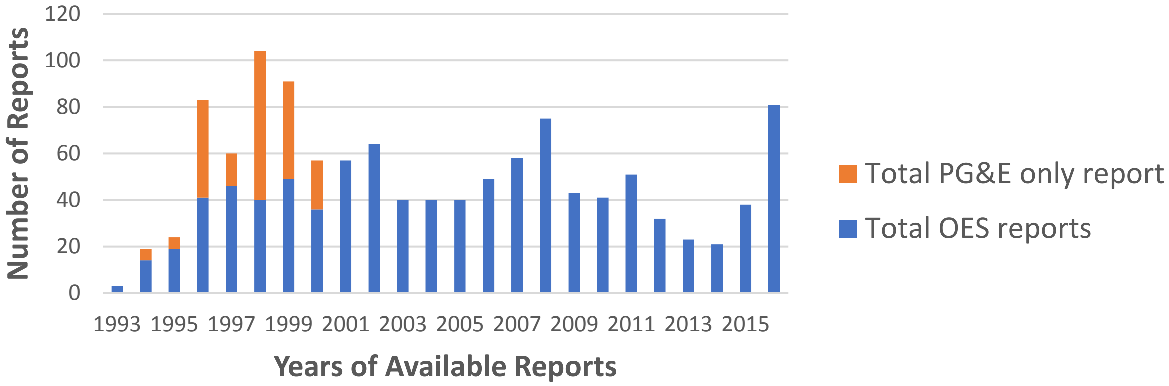

Figure 1. Oil-filled electric equipment spills reported to the California Office of Emergency Services (Cal OES) and/or identified through internal Pacific Gas & Electric (PG&E) reports between 1993 and 2017.

3.2.4.2 Volume of OFEE Releases

The total volume of material released from all reported OFEE spills in a given year in the Bay Area is presented in Figure 2. Mineral oil or transformer oil are the substances identified in over 99% of reported releases from OFEE in the Cal OES spill report database. In a phone conference with SF Bay Water Board staff in 2012, PG&E said they submit written reports to Cal OES for all PCBs spills that meet or exceed the mineral oil federal reportable quantities (RQ) of 42 gallons (*personal communication*, Jan O'Hara 2012). However, the reports reviewed indicate written reports are sometimes submitted for spills that are much less than 42 gallons.

The reported volumes of oil released during a single incident range from less than one gallon up to 5,000 gallons. Nearly half of all OFEE spill reports identify the volume of oil spilled as 5 gallons or less, and more than 90% of all spill reports identify the volume of fluid spilled as less than 100 gallons. Releases as large as 500 gallons from the distribution system and 5,000 gallons from the transmission system have been reported. Only five incidents reported releases that exceeded 1,000 gallons of oil. Nearly all (~99%) of reports provided information on the volume of oil released.

The reported volumes released do not necessarily equate to the volume of the oil that may have reached storm drains or local creeks. Estimates of those volumes were not available.

3.2.4.3 Location of OFEE Releases

Cal OES and PG&E records show releases occurred in all Bay Area counties. Leaks and spills of PCBs from electrical equipment have occurred onto roads, sidewalks, pervious areas, vegetation, structures, vehicles, and even people (Cal OES 2016). Most releases occurred in the distribution system, often from equipment installed in public ROWs such as pole-mounted transformers installed along roadways.

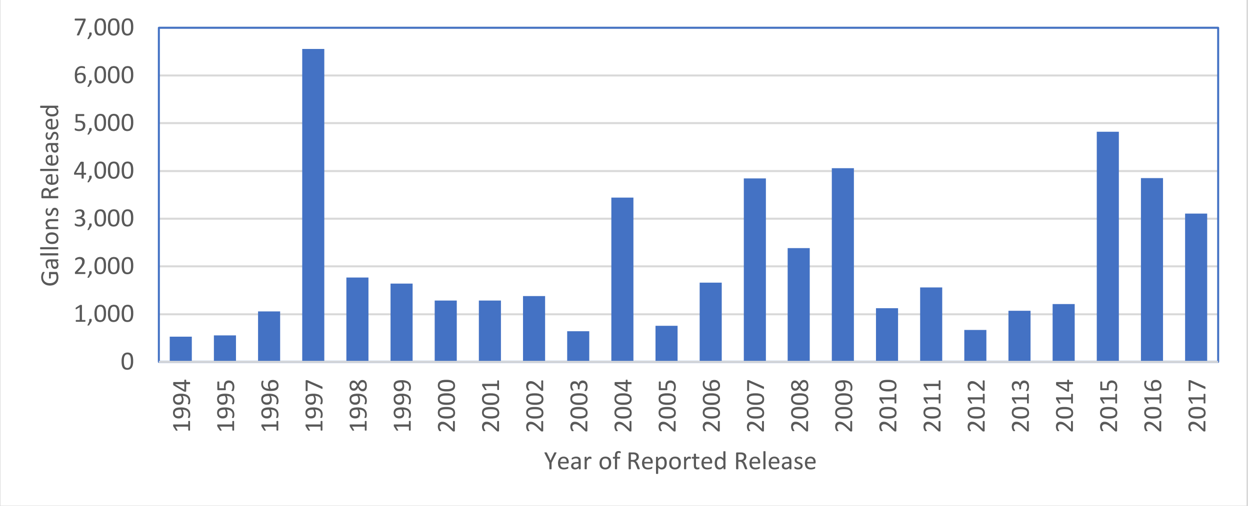

Figure 2. Total reported gallons of oil released each year (1994 – 2017) from spills from PG&E electrical utility equipment in the Bay Area.

A number of reports document direct releases from OFEE to the MS4, and potentially a downstream waterbody (e.g., creek). There are at least 17 incidents identified during the past 15 years that involved direct releases from PG&E OFEE directly to a waterbody or to storm drains that discharge to local creeks (Table 1). The majority of these releases were reported as having unknown PCBs concentrations, and no reports provide any follow-up information on the concentration of PCBs in the spilled materials based on chemical analysis.

It is important to note that in addition to the incidents identified in Table 1, materials spilled during any of the numerous other incidents may (or may not) have entered the MS4 and/or receiving waters such as local creeks directly or been washed into the MS4 and/or creeks by stormwater or irrigation runoff. Generally, the spill reports lack any details regarding this type of information.

Table 1. Examples of Information Reported on Releases of PCBs to Bay Area Storm Drains and Creeks.

Date	Gallons	Reported Concentration	Water Body	Municipality
1/24/2016	Unknown	<50 ppm	Coyote Creek	San José
2/17/2016	Up to 18	Unknown	Los Gatos Creek	Los Gatos
3/7/2016	10	Unknown	Culvert	Concord
8/16/2016	Unknown	<50 ppm	Guadalupe River	San José
11/17/2015	Unknown	Unknown	Cerrito Creek	Richmond
10/4/2015	5	Unknown	Creek	Los Gatos
5/3/2015	30	<2 ppm	Cerrito Creek	Richmond
3/2/2011	30	Unknown	Unknown Marsh	Menlo Park
6/2/2007	40	Unknown	Pond, Marsh Area	Vallejo
2/28/2006	20	<50 ppm	Calara Creek	Pacifica
5/27/2006	1	Unknown	Unknown Creek	Orinda
10/10/2005	Unknown	Unknown	Coyote Creek	San José
7/23/2005	<15	Unknown	Nearby Creek	Walnut Creek
12/8/2004	Small amount	<50 ppm	Moraga Creek	Orinda
3/7/2004	Unknown	Unknown	Blossom Creek	Calistoga
7/14/2003	8	< 50 ppm	Coyote Creek	San José
2/16/2002	15	Unknown	Napa River	Napa

3.2.4.4 Causes of OFEE Releases

Cal OES release reports and PG&E records document a number of causes of PCBs releases from OFEE. Most releases can be attributed to one of the following:

- **Equipment Failure**. This is the cause of the majority of the reported releases. Equipment failure in utility vaults has additional potential as an important source of PCBs because OFEE in these vaults may contain more than 100 gallons of oil. More than 50 release incidents were reported for equipment contained in electrical utility vaults during the time period reviewed. A number of these reports noted the presence of water in the vaults in addition to the PCBs oil released. Releases from equipment failure in utility vaults are mostly contained, but Cal OES spill reports document releases of PCBs oil that breached containment, including discharges that reached water bodies.

- **Accidents**. Approximately 20% of reported releases resulted from equipment knocked over by accident. In the distribution system, reports document 50 to 500 gallons released from poles knocked over during car accidents, by construction equipment, and during tree trimming. On rare occasion PCBs releases have occurred during accidents while equipment is in transport.
- **Storms, Fires, and Overheating from High Summer Temperatures**. These factors are the reported cause of more than 10% of the releases from the distribution system.
- **Field Repairs and Fluid Replacement**. The Cal OES database contains records that indicate draining fluids in the field may have been ongoing as recently as 2007, when a report documented that a valve left open from draining a transformer in the field caused a release. In 2016, Daniel Sanchez, who at the time was PG&E's Manager of Hazardous Materials and Water Quality Environmental Management Programs, informed SF Bay Water Board staff that PG&E does not drain and refill pole mounted PCB transformers in the field any longer; however, it is unclear when this practice ceased, and/or if it still occurs with equipment not mounted on poles.
- **Vandalism**. Between 1997 and 2015, there were at least 25 separate reported incidents of vandalism that resulted in PCBs releases. For example:
  - In 1997, gunshot damage caused the release of 5,000 gallons of oil from a substation transformer and regulators in San Mateo County;
  - In 2011, copper theft at a substation released 750 gallons of oil in Contra Costa County;
  - In 2013, vandalism of pad-mounted transformers resulted in the release of possibly 1,000s of gallons of oil before discovery in San José.

3.2.4.5 PCBs Concentrations in OFEE Releases

Of the more than 1,200 spill reports that were reviewed, approximately one-third identified the PCBs concentration as unknown or did not provide any information on the PCBs concentration of the spilled material (Figure 3). Releases with high PCBs concentrations (> 500 ppm) were infrequently reported, accounting for only 1% of reported spills. Concentrations above 50 ppm represent about 8% of the reported spills. As recently as 2016, failure of a PG&E pole-mounted transformer resulted in release of mineral oil with 280 ppm PCBs to surrounding soils and brick structures. For approximately 44% of the reported releases, the PCBs concentration was identified as less than 50 ppm, based primarily on assumptions associated with a "Non-PCB" label. According to labeling requirements, a "Non-PCB" label indicates the PCBs concentrations in the oil are assumed to be below hazardous waste thresholds of 50 ppm (federal regulations, see Section 3.2.1). However, in most cases, no additional information was provided in the spill reports to indicate how the "Non-PCB" category was arrived at, or whether the federal (> 50 ppm) or state (> 5 ppm in liquid) "Non-PCB" category was assumed. For the vast majority of these reports, no follow-up chemical analysis results were provided that confirmed the "Non-PCB" designations. In a limited number of reports, follow-up PCBs analysis results were provided for materials that were identified as "Non-PCB" during initial reporting. Generally, these results found PCBs concentrations between 5 and 49 ppm, suggesting that the labels were correctly applied. However, any concentration of PCBs in electrical equipment oils is potentially significant in terms of water quality impacts and implementation of the PCBs TMDL. These results clearly demonstrate that the "Non-PCB" designation represents a threshold that is far too high to necessarily be protective of water quality.

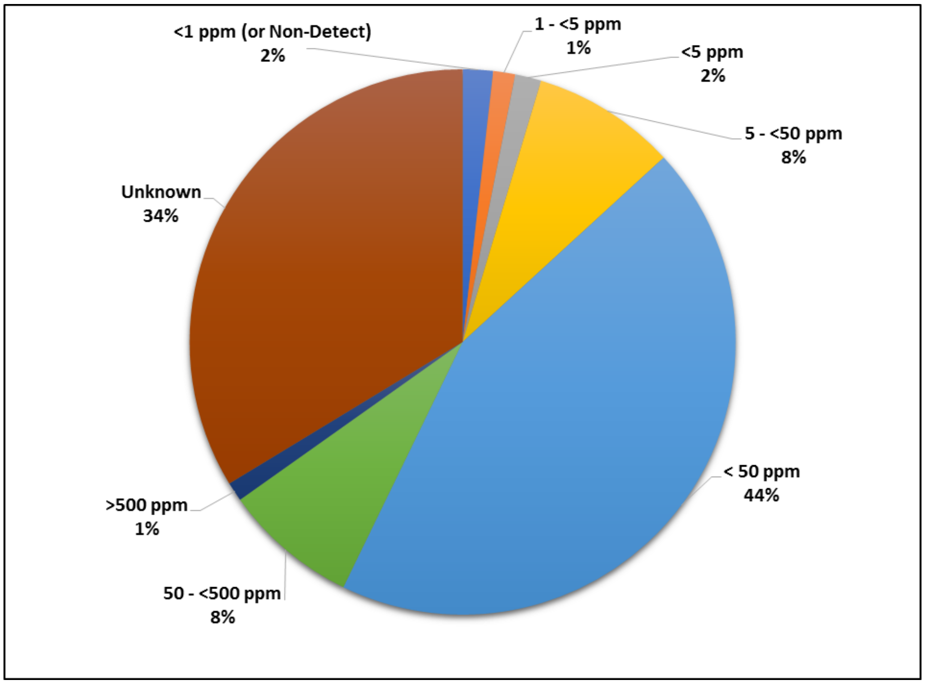

Figure 3. PCB Concentration data reported for releases from PG&E electrical equipment between 1993 and 2016.

Only 1% of the reported releases identified the PCBs concentrations as either below 1 ppm, or below detection limits. Although the quality of the PCBs concentration data in the release reports varies widely, these results clearly demonstrate that PG&E's electrical equipment in the Bay Area can still contain PCBs at concentrations of concern for water quality protection programs.

3.2.5 Cleanup Methods and Actions Taken in Response to OFEE Releases

Limited information is available on the spill response protocols used by electrical utility companies during cleanups. Based on information publicly available, electrical utility companies typically address spills or leaks from their equipment with Standard Operating Procedures (SOPs) that should conform to both State and Federal requirements. According to information provided to the SF Bay Water Board (PG&E 2000), PG&E spill response is guided by internal documents, including:

- ***Utility Operations Standard D-2320*** - for PCBs spills in the distribution system;
- ***PCB Management at Substations -*** for PCBs spills in the transmission system.

However, these documents are not publicly available for review.

The Cal OES reports provide almost no information on actions taken to stop active spills, or the methods used to cleanup spilled materials from surrounding surfaces, storm drain infrastructure, or creeks. Municipalities need this type of information to better understand any potential risks that remain following initial cleanup. Because of the challenges with achieving the stormwater runoff wasteload allocation in the PCBs TMDL, additional remedial actions may be warranted in some cases.

3.3 Potential Causes of Water Quality Problem

Given the history of PCBs use in electrical utility equipment, the current estimates of electrical equipment still in use that contain PCBs, and existing documentation that spills of PCBs from electrical utility equipment continue to occur, electrical utility equipment is likely a significant source of PCBs to stormwater runoff, and ultimately to the Bay. PG&E, the largest electric utility company in the Bay Area, was likely the largest single user of PCBs in the Bay Area, and as such, likely remains the largest current source of PCBs releases to MS4s from electrical utility equipment.

4.0 SSID Investigation Approach and Schedule

The overall approach for this SSID Investigation is to (1) conduct a desktop analysis and (2) propose a source control framework for electrical utility equipment to reduce ongoing PCBs loads to the Bay in stormwater runoff. The purpose of the desktop analysis is to better understand the extent and magnitude of electrical utility equipment as a source of PCBs to urban stormwater runoff, document past and current efforts to reduce PCBs releases from electrical utility equipment during spills or other accidental releases, and document measures already taken or underway to remove PCBs-containing oils and electrical equipment from active service across the Bay Area. The results of the desktop analysis will inform identifying new or improved control measures to avoid/reduce the release of PCBs from this source. This information may also be used to update the estimated PCBs loads to stormwater from this source, and inform development of a load reduction accounting methodology. This project will request the assistance and support of the SF Bay Water Board to gather the information needed from electrical utility companies to conduct the desktop analysis. Based on the outcomes of the desktop analysis, this project will then propose a framework for addressing PCBs from electrical utility equipment. The framework may include a recommendation to designate electrical utilities as a *Categorical Source* of PCBs to stormwater in order to facilitate the development of a comprehensive, regional control measure program to address this source.

This SSID Project is a BASMAA Regional Project. The BASMAA Monitoring and Pollutants of Concern Committee (BASMAA MPC) will oversee implementation of the project. Implementation of this work plan will contribute to fulfillment of MRP Provision C.8.e requirements for all BASMAA co-permittees.

4.1 Task 1: Desktop Analysis

The desktop analysis is designed to gather and evaluate information on electrical utility equipment in the Bay Area to determine if a *Categorical Source* referral is warranted, and to provide the foundation for development of a comprehensive regional control measure program to reduce PCBs loads from this source. The desktop analysis will include the following five sub-tasks:

- **Subtask 1.1 Request information from electrical utility companies.**
  This task will seek the assistance and support of the SF Bay Water Board to: obtain information from private utility companies that is not publicly available but is needed to better understand the extent and magnitude of PCBs releases from OFEE; identify the most appropriate actions to prevent or reduce releases from this source; and develop and implement effective reporting and control measures. For this task, the SF Bay Water Board will be asked to assist BASMAA in compelling electrical utility companies (e.g., PG&E) to provide the necessary information. A preliminary list of information that will be requested includes the following:
    - Spill reporting and notification procedures (both company-wide and location-specific);
    - Spill records NOT reported in Cal OES;
    - SOPs and other documentation used by electrical utilities and their contractors to guide spill response and cleanup actions when releases from OFEE occur;
    - SOPs and documentation, including analytical methods for PCBs used by electrical utilities and their contractors to identify and clean up regular leaks from OFEE during regular maintenance activities

  - Measurement data on concentrations of PCBs in OFEE;
  - Maintenance records that document when and where PCBs-containing OFEE are removed from the system and how often PCBs containing equipment is inspected for leaks or spills;
  - Documentation of past programs to voluntarily remove PCBs-containing oils or OFEE – including what equipment was removed, and the locations from which it was removed; and
  - Documentation of where PCBs-containing OFEE were located in the past, and where they are currently located across the Bay Area.

  This list will be reviewed prior to making any data requests. Additional data gaps may also be identified and added to the data request based on discussions with SF Bay Water Board staff and/or preliminary information provided by utility companies.

- **Subtask 1.2 Assess current electrical utility data.**
  This task will review, tabulate and analyze the information provided by electrical utility companies as a result of the SF Bay Water Board's request for information, in order to document the following:
  - Measurement data on PCBs concentrations and/or mass in OFEE;
  - Locations of PCBs-containing OFEE;
  - Quantity of PCBs-containing OFEE removed from service annually;
  - Occurrences of spills or releases from OFEE;
  - Current PCBs spill and cleanup reporting requirements; and
  - Current PCBs cleanup protocols.
- **Subtask 1.3 Improve estimates of PCBs loadings.**
  This task will combine the information provided in Subtask 1.2 with all existing data in order to develop improved estimates of current PCBs loadings from electrical utility equipment to MS4s in the study area. The quality of these estimates will partly depend on the quality of the data received from the utility companies.
- **Subtask 1.4 Refine PCBs reporting requirements**
  This task will review all current reporting and notification requirements to identify any improvements or clarifications that the SF Bay Water Board could require of electrical utilities to provide the type of data needed to better quantify the amount of PCBs released from OFEE spills, and to help ensure that adequate cleanup actions are being implemented.
- **Subtask 1.5 Evaluate PCBs cleanup protocols**
  This task will review all documented cleanup protocols that are currently used by electrical utility companies in order to identify any changes or improvements that could be recommended to further reduce the discharge of PCBs to the MS4 when releases occur.

4.2 Task 2: Develop Source Control Framework

Based on the results of the desktop analysis, this task will propose an appropriate framework for managing and implementing control measures to reduce PCBs from electrical utility equipment. The framework should include prescribed methods and procedures for unplanned spills and releases from OFEE, as well as a plan for continued reduction of PCBs from in-use OFEE, and potentially further identification and cleanup of historic release sites. The framework will likely include the following elements:

- Summary of the outcomes of the desktop analysis results, including:
    a. Summary of information provided by electrical utility companies as a result of the SF Bay Water Board's request for information from electrical utilities;
    b. Improved estimates of current PCBs loadings from electrical utility equipment based on information received;
    c. Documentation of current spill clean-up and reporting actions, and existing programs for proactive removal of PCBs-containing oils and equipment conducted by electrical utility companies;
    d. Recommended PCBs spill and cleanup reporting requirements that the SF Bay Water Board could require of electrical utilities;
    e. Recommended improvements to PCBs spill cleanup protocol(s) that would reduce the discharge of PCBs to MS4s that the SF Bay Water Board could require of electrical utilities.
- A recommendation (based on the results of the Task 1 desktop analysis) about designation of electrical utility equipment as a *Categorical Source*.
- Recommended approach to manage and control releases of PCBs from electrical utility companies. For example, if a *Categorical Source* referral is submitted, the recommended approach will focus on development of a comprehensive regional control measure program. The program would include requirements the SF Bay Water Board could impose on electrical utility companies in the Bay Area, such as new spill reporting and cleanup protocols.

4.3 Task 3: Develop methodologies to account for PCB load reductions from new source control measures

BASMAA will further apply the results of the desktop analysis to develop methodologies to account for the PCBs load reductions that can be achieved via the new clean-up and reporting protocols identified above in Task 2.

4.4 Task 3: Develop SSID Project Report

BASMAA will prepare a report describing the desktop analysis and outcomes. The report will summarize the information provided by electrical utility companies and identify recommendations to modify or improve current control measures or management actions that will reduce PCBs released to MS4s. The Management Questions described in Section 2.3 will be addressed:

1. What is the current magnitude and extent of PCBs stormwater loadings from electrical utility equipment and operations in the San Francisco Bay Area region?
2. Are there aspects of equipment or operational procedures that electrical utilities should be required to report to the SF Bay Water Board?
3. Are there additional spill and clean-up controls needed to reduce water quality impacts from the release of PCBs in electrical utility equipment?

4. Are there additional proactive activities needed to avoid releases of PCBs from electrical utility equipment?
5. What are the PCBs load reductions that can be achieved through implementation of a regional reporting and control measure program?

4.5 Project Schedule

Table 2 summarizes the tasks and anticipated outcomes described in this work plan, and the proposed schedule for each task. This is an approximately one-year effort to be conducted primarily in Fiscal Year 2019-2020. However, Task 1 (information request) will likely be made before the end of Fiscal Year 2018-2019. It is anticipated that the SSID project report will be completed in June 2020. The schedule in Table 2 is dependent upon the timing, extent, and format of the data that are received from electrical utility companies based on the SF Bay Water Board's request for information.

Table 2. Tasks, Anticipated Outcomes, and Schedule.

Task Description		Anticipated Outcome(s)	Anticipated Completion Date
Task 1: Desktop Analysis			
1.1	***Request information from electrical utility companies***	Language for information request provided to SF Bay Water Board.	Apr-2019
1.2	***Assess current electrical utility data***	Summary tables of information and analyses of the data received from electrical utility companies.	Oct-2019
1.3	***Improve estimates of PCBs loadings***	Tables with estimated annual PCBs loads to MS4s from electrical utility equipment.	Nov-2019
1.4	***Refine PCBs reporting requirements***	Recommended improved PCBs spill and cleanup reporting requirements for electrical utility companies.	Dec-2019
1.5	***Evaluate PCBs clean-up protocols***	Recommended improved PCBs cleanup protocols for electrical utilities companies.	Dec-2019
Task 2: Develop Source Control Framework		Recommended source control framework for electrical utility equipment.	Jan-2020
Task 3: Develop PCBs Load Reduction Accounting Methodology		Recommended methodology to account for PCBs load reductions achieved through implementation of new source controls.	Jan-2020
Task 4: Reporting		Regional SSID Project Report	Jun-2020

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