



**RMP**  
REGIONAL MONITORING  
PROGRAM FOR WATER QUALITY  
IN SAN FRANCISCO BAY

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# Pollutants of Concern Reconnaissance Monitoring Progress Report, Water Years 2015 - 2019

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## Preface

Reconnaissance monitoring for water years 2015, 2016, 2017, 2018 and 2019 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 (2020) is underway. An earlier draft of this report was prepared for the Bay Area Stormwater Management Agencies Association (BASMAA) in support of materials submitted on or before March 31<sup>st</sup> 2020 in compliance with the Municipal Regional Stormwater Permit (MRP) Order No. R2-2015-0049.

## Acknowledgements

We appreciate the support and guidance from members of the Sources, Pathways, and Loadings Workgroup of the RMP. The detailed work plan for 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, 2018 and 2019. Local members on the STLS Team at that time were Jim Scanlin (and Arleen Feng in earlier years [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 (San Francisco Bay Regional Water Board). RMP field and logistical support provided by San Francisco Estuary Institute (SFEI) in water year (WY) 2015 included Patrick Kim, Carolyn Doebling, and Phil Trowbridge; WY 2016 included Patrick Kim, Amy Richey, and Jennifer Sun; WY 2017 included Ila Shimabuku, Amy Richey, Steven Hagerty, Diana Lin, Margaret Sedlak, Jennifer Sun, Katie McKnight, Emily Clark, Don Yee, and Jennifer Hunt; WY 2018 included Nina Buzby, Amy Richey, Ila Shimabuku, Margaret Sedlak, and Don Yee; and WY 2019 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, 2018 and 2019. 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; Lisa Austin, Geosyntec, Khalil Abusaba, Wood Consultants, and Christian Kocher, ADH Environmental on behalf of the Contra Costa Clean Water Program; Jim Scanlin, Alameda Countywide Clean Water Program); and Richard Looker (SFBRWQCB). External independent review was provided by the SPLWG science advisors: Barbara Mahler, Tom Jobes, and Jon Butcher.

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## 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 a provision 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.). To address C8, a previously developed fixed station loads monitoring technique was refined that incorporated turbidity and stage sensors recording at 5-15 minute intervals with the collection of velocity and water samples using both manual and auto sampling techniques to compute loads. 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.

To support this increased focus, a stormwater reconnaissance monitoring field protocol was developed and implemented in water years (WYs) 2015 through 2019. Most of the sites monitored were in Alameda, Santa Clara, and San Mateo Counties, with fewer sites in Contra Costa and one in Solano County. At 67 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 2020 by the RMP. The San Mateo Countywide Water Pollution Prevention Program and the Santa Clara Valley Urban Runoff Pollution Prevention Program have also implemented the sampling protocol with their own funding.

As part of 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.

In summary, we now have three distinct stormwater sampling methods.

Method 1. Fixed location multi-year turbidity-based sampling protocol for accurate loads estimation.

Method 2. Water-based composite sampling protocol for single storm reconnaissance characterization and site comparisons to support management prioritization.

Method 3. Remotely deployable sedimentation sampling for preliminary screening to support further field sampling using the water-based composite sampling protocol.

This report presents all available stormwater data<sup>1</sup> collected by SFEI since WY 2003 when stormwater studies first began through SFEI contracts or RMP projects, not just the data collected for this WY 2015-2019 reconnaissance monitoring study (total of 88 sites). Prior to WY 2015, studies mostly employed Method 1, whereas beginning in WY 2015, sampling employed Methods 2 and 3.

### *Key Findings*

Based on this dataset 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, 25 sites (28%) with estimated particle concentrations of PCBs greater than 200 ng/g and 31 sites (35%) with estimated particle concentrations of Hg greater than 0.5 µg/g have been identified. Total PCB concentrations measured ranged 840-fold, from 533 to 448,000 pg/L. The three highest ranking sites for PCB 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, total PCB concentrations ranged 4111-fold, from 2 to 8,222 ng/g. The three sites with the highest estimated particle concentrations were Pulgas Pump Station South (8,220 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. HgT is thought to be more uniformly distributed than PCBs because it has more widespread sources in the urban environment, and Hg has a larger atmospheric component to its cycle. The highest 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). Estimated particle concentration ranged between 45 and 4,090 ng/g (91-fold), similar to the variation in water concentrations. The highest 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). The two Guadalupe River stations are downstream of the historic New Almaden Mining District whereas the Gilman St. sites in Berkeley drains an industrial area. Although there was a general but weak correlation between PCB and Hg concentrations in both water and on particles, the sites with the highest particle concentrations for Hg were typically not the sites with the highest concentrations for PCBs.

### *Remote Suspended Sediment Samplers*

Pilot results from the two remote suspended sediment sampler types showed generally good consistency with 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

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<sup>1</sup> Similar data collected by BASMAA in Santa Clara and San Mateo Counties is not included in this report. Also, BASMAA partners analyze sediment collected in upland areas (e.g., catch basins, roadside ditches, private property, etc.). These data are also not presented in this report.

composite samples. Therefore, the remote suspended sediment sampler method was accepted in spring 2018 and used in WY 2019 as a stand-alone method (side-by-side sampling with the composite method ceased and just the remote samplers were deployed at three sites) to support decisions about further sampling.

#### *Further Data Interpretation*

Relationships between PCB and HgT estimated particle concentrations, watershed characteristics, and other water quality measurements were evaluated. Based on data collected since WY 2003, PCB particle concentrations were correlated with impervious cover ( $r_s = 0.57$ ), old industrial land use ( $r_s = 0.61$ ), and HgT particle concentrations ( $r_s = 0.19$ ). PCB particle concentrations were inversely correlated with watershed area and particle concentrations for arsenic, cadmium, copper, lead, and zinc. HgT particle concentrations were not correlated with those of other trace metals ( $p > 0.1$ ) and had similar but weaker relationships as PCBs to impervious cover ( $r_s = 0.28$ ,  $p < 0.05$ ), old industrial land use ( $r_s = 0.26$ ,  $p < 0.05$ ), and watershed area ( $r_s = -0.28$ ,  $p < 0.05$ ). 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.

Most evidence suggests that, as a general category, old industrial land use exhibits the greatest loads and yields of PCBs relative to other land uses in the region. The watersheds/catchments for the 88 sites<sup>2</sup> that have been sampled for PCBs and Hg with RMP and grant funding since WY 2003 cover about 33% of the old industrial area in the region. Of the remaining areas in the region with old industrial land use yet to be sampled (77 km<sup>2</sup>), 48% of it lies within 1 km of the Bay and 74% is within 2 km of the Bay. These areas nearer the Bay 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. 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 the mass of pollution that is associated with these areas.

This Pollutants of Concern Reconnaissance Monitoring study will continue at least into WY 2020 with the goal of identifying 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 previous sampling results.

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<sup>2</sup> One site that was sampled for Hg (San Pedro stormdrain in San Jose), was not sampled for PCBs but since it is nested within Guadalupe River watershed, it does not influence this analysis.

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## 1. 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)<sup>3</sup>. With that additional effort, sufficient pollutant data have now been collected over a period from water years (WYs) 2003 – 2014 at 11 sites to estimate watershed scale pollutant loads 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 combined area of all 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). In this second iteration (MRP 2.0), the Water Board has asked that permittees place an increased

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<sup>3</sup> BASMAA is made up of a number of programs that represent Permittees and other local agencies

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. Specifically, the Water Board, through this permit, added a stipulation to identify 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 other 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 2015-2019 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 - 2019 by the San Mateo Countywide Water Pollution Prevention Program and the Santa Clara Valley Urban Runoff Pollution Prevention Program (EOA, 2020a and 2020b).

This report summarizes and provides a preliminary interpretation of data collected during WYs 2015-2019, as well as from previous studies overseen by this workgroup and others dating back to WY 2003. The data collected and presented here contribute to a broad effort of identifying potential management areas for pollutant reduction. The report is designed to be updated annually and will be updated again in approximately 12 months to include WY 2020 sampling data.

During Calendar Year (CY) 2018, the RMP also funded a data analysis project that aimed to mine and reinterpret all existing stormwater PCB data to add further supporting information to help guide management decisions. The primary goals of that analysis were to develop additional and improved methods for identifying and ranking watersheds/catchments of management interest for further investigation, and to guide future sampling design. Two methods were developed; a congener profile method (Davis and Gilbreath, 2019) and a loads and yields based ranking method (McKee et al., 2019). 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 modeling and trends strategy that outlines key elements for modeling regional scale loads and trends using dynamic simulation as well as a framework sampling design to support the model development (Wu, et. al., 2018). Reconnaissance data collected in WYs 2011 and 2015-2019 may provide “baseline” data for identifying concentration or particle concentration trends over time, could be statistically analyzed to independently generate land use based EMCs, or could be used for model verification purposes, all this with the understanding that management actions to control PCB and Hg loads were increasingly being implemented during this period. These ideas and uses could be the subjects of future RMP projects.

## **2. Methods**

### **2.1 Sampling locations**

Four objectives were used as a basis for site selection.

1. Identify potential high-leverage watersheds and catchments, including
  - a. Watersheds/catchments 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. Sample strategic large watersheds with USGS gauges to provide first-order loading estimates and to support calibration of the regional models (RWSM; County Program RAAs<sup>4</sup>; BAHM),
3. Validate unexpected low (potential false negative) concentrations to address the possibility of a single storm composite poorly characterizing a sampling location,
4. Fill data 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, subwatersheds, and storm drain catchments (Objective 1). The remaining resources were allocated to addressing the other three objectives. In WYs 2018 and 2019, approximately 50% of the resources were allocated to identifying potential high-leverage watersheds/catchments, while the other 50% was allocated to resampling stations previously measured in reconnaissance sampling in order to validate previously measured concentrations. RMP staff worked with the respective Countywide Programs to identify priority drainages for monitoring including storm drains, ditches/culverts, tidally influenced channels and culverts, and natural channels. During the summers of 2014-2018, 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 10-20 sites was selected each year to form the sampling location pool from which field staff would select from for each storm, depending on logistics, storm characteristics and tidal phase relative to storm timing.

Watershed sites with a wide variety of characteristics were sampled in WYs 2015-2019 (Figure 1 and Table 1). Of these sites, 21 were in Santa Clara County, 19 in San Mateo County, 16 in Alameda County, 10 in Contra Costa County<sup>5</sup> and 1 in Solano County. The drainage area for each sampling location ranged from 0.02 to 233 km<sup>2</sup> and imperviousness based on the National Land Cover Database (Homer et al., 2015) ranged from 2%-88%. Typically, however, the reconnaissance watersheds/catchments were characterized as small (75% had areas < 5.2 km<sup>2</sup>) with a high degree of imperviousness (75% of watersheds/catchments had >60% impervious cover). The percentage of old industrial<sup>6</sup> area in watersheds/catchments ranged from 0 to 87% (mean 22%) (dataset used included the land use dataset input to the Regional Watershed Spreadsheet Model) (SFEI, 2018). Although most of the sampling sites were selected primarily to identify potential high-leverage watersheds/catchments, some sites were resampled to verify whether the first sample collected at these locations 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

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<sup>4</sup> Reasonable Assurance Analysis (RAA) is being carried out by the county clean water programs following a guidance document produced for the Bay Area (BASMAA, 2017).

<sup>5</sup> 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.

<sup>6</sup> 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).

(McKee et al., 2018). 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, 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. The sampling carried out at the reconnaissance monitoring sites completed so far complements the more in-depth sampling campaigns (2-8 years of sampling at each site) that have been carried out at sites designated as a “Loadings Study” (Figure 1).

## 2.2 Field methods

### Mobilization and preparing to sample

Mobilization for sampling was typically triggered by a storm forecast. When a minimum rainfall of at least one-half inch<sup>7</sup> over 6 hours was forecast, sampling teams were deployed, ideally reaching the sampling site about one hour before the onset of rainfall<sup>8</sup>. When possible, one team sampled two sites close to one another to increase efficiency and reduce staffing costs per site per sample. Upon arrival, the team assembled equipment and carried out final site 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 81 (Teflon) sampler was used without a pump (Figure 2b).

### Manual time-paced composite stormwater sampling procedures

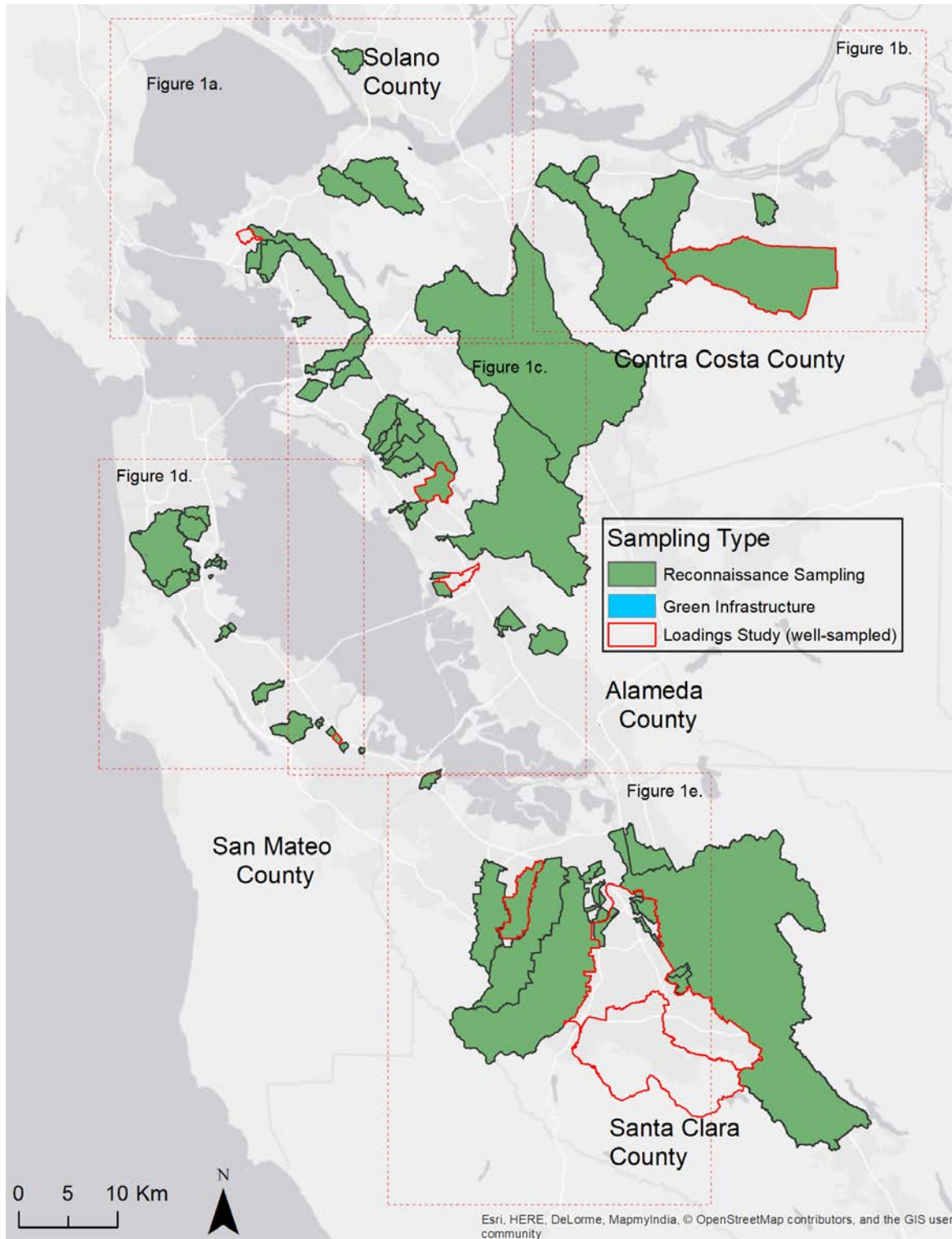
At each site, a time-paced composite sample was collected with a variable number of sub-samples, or aliquots. Based on the weather forecast, prevailing on-site conditions, and radar imagery, field staff estimated the duration of the storm and selected an aliquot size for each analyte (0.1-0.5 L) and number of aliquots (minimum=2; mode=5) to ensure the minimum volume requirements for each analyte (Hg, 0.25 L; SSC, 0.3 L; PCBs, 1 L; Grain Size, 1 L; TOC, 0.25 L) were reached before the end of the storm. Because the minimum volume requirements were less than the size of the sample bottles, there was flexibility to add aliquots in the event 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. Similarly, the time period between aliquots was decided just before the second aliquot was taken and then remained the same for the rest of the event. All aliquots for a storm were collected into the

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<sup>7</sup> This was relaxed in some years due to a lack of larger storms.

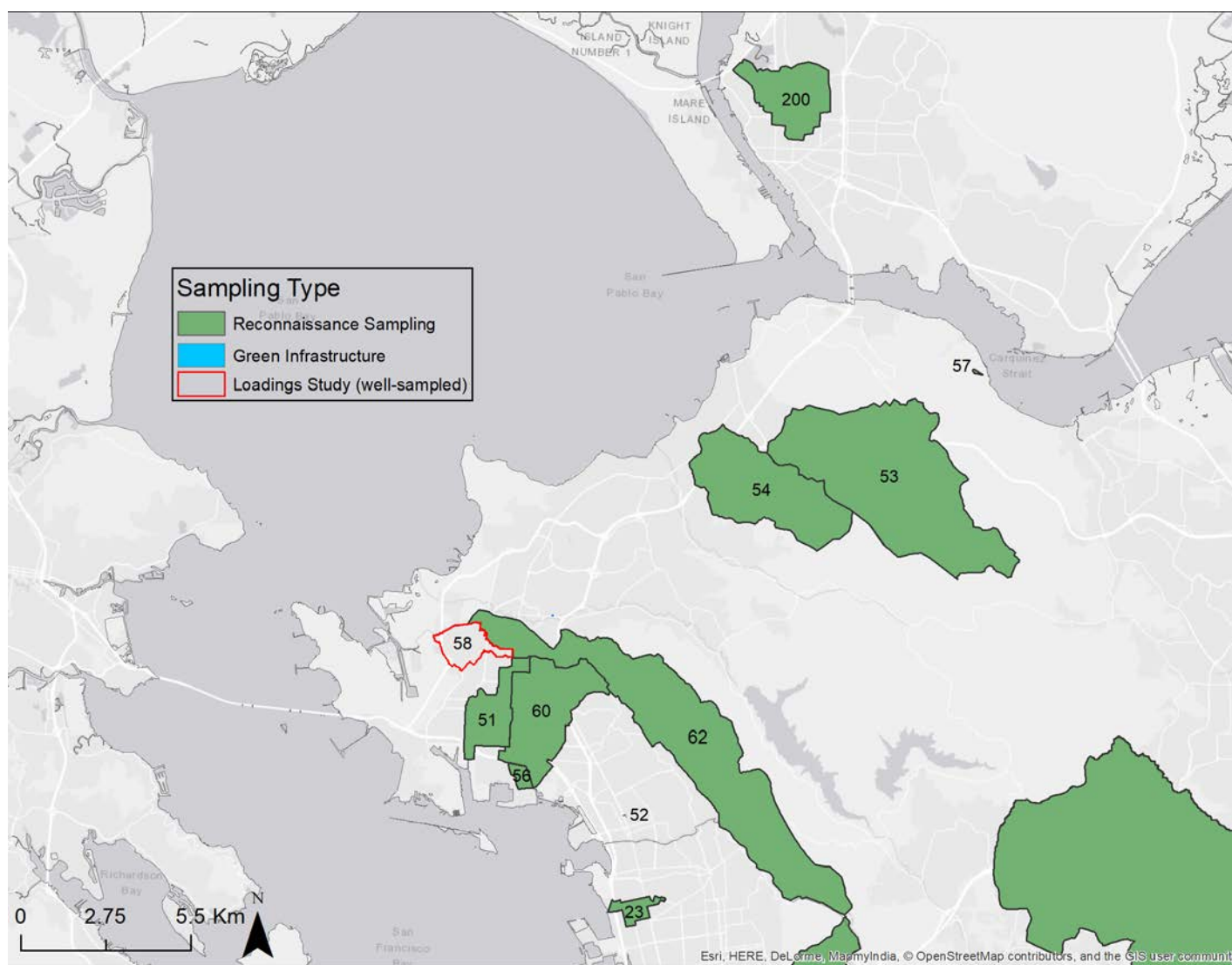
<sup>8</sup> Antecedent dry-weather was not considered prior to deployment. Antecedent conditions can have impacts on the concentration of certain build-up/wash-off pollutants like metals. For PCBs, however, antecedent dry-weather may be less important for the mobilization of in-situ legacy sources.

same bottle, kept in a cooler on ice during sampling, and then refrigerated at 4 °C before transport to a laboratory (see Yee et al. 2017 for information about bottles, preservatives and hold times).

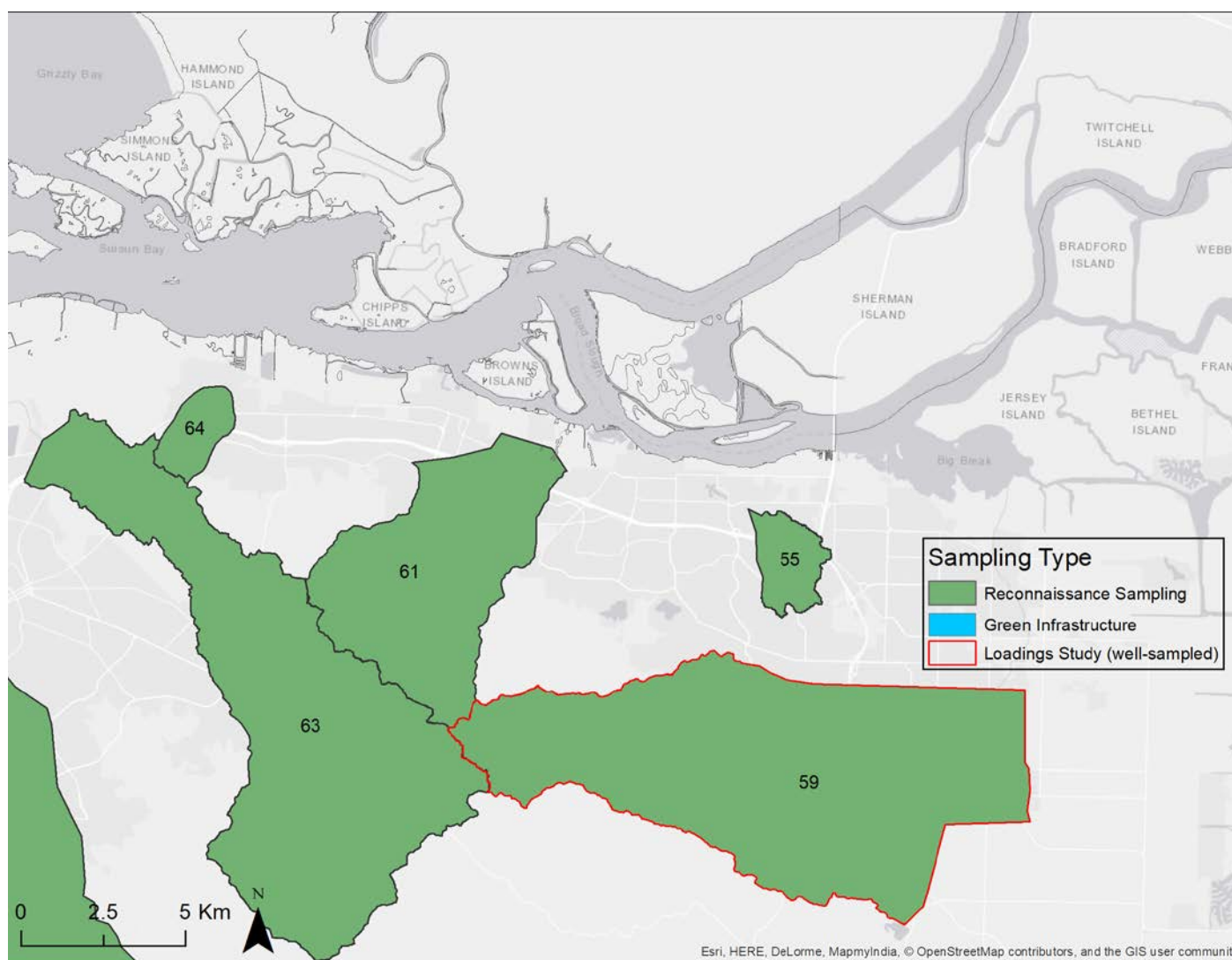


**Figure 1.** Watersheds/catchments sampled to date. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier.



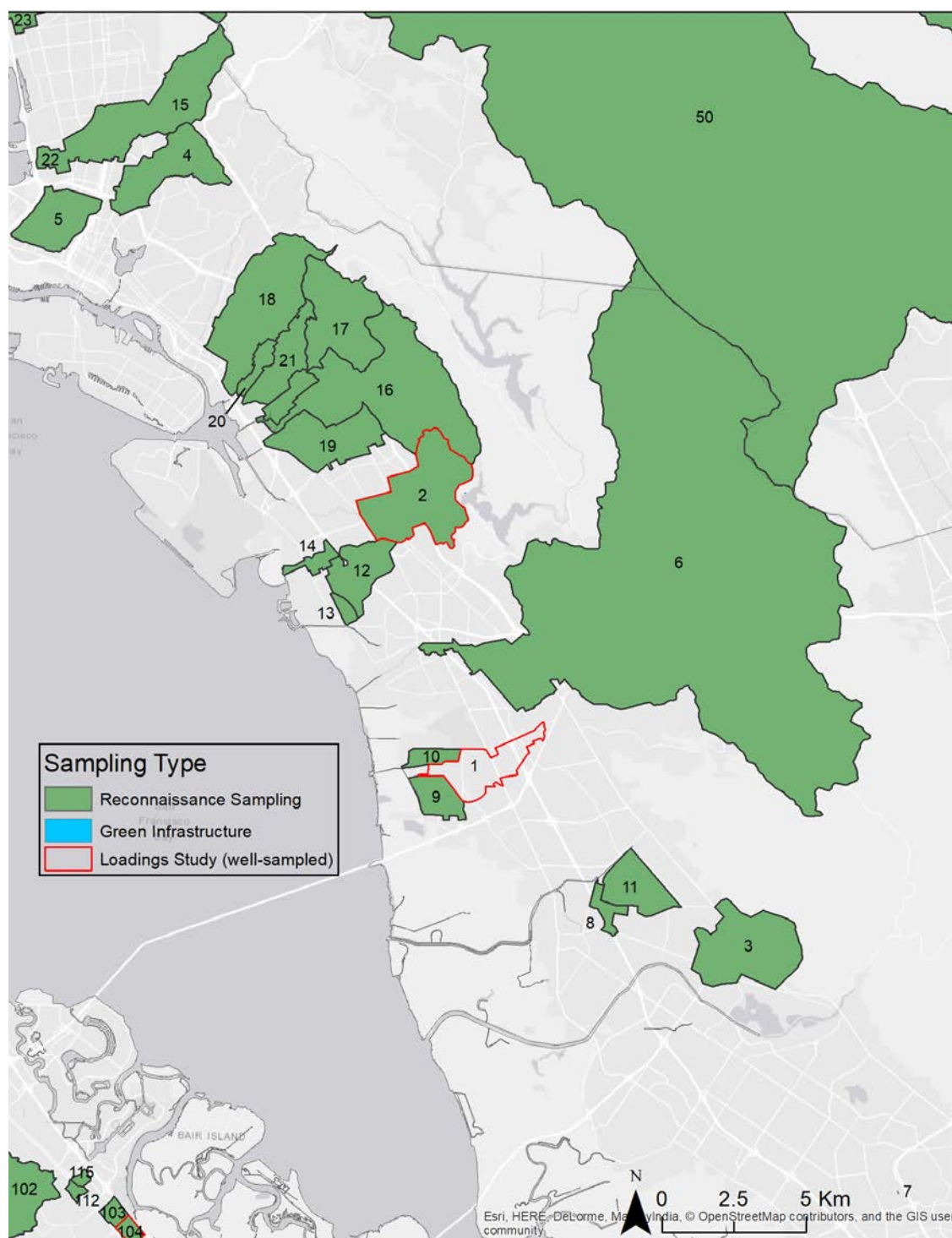


**Figure 1a.** Watershed boundaries of sites sampled in western Contra Costa County and Solano County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.

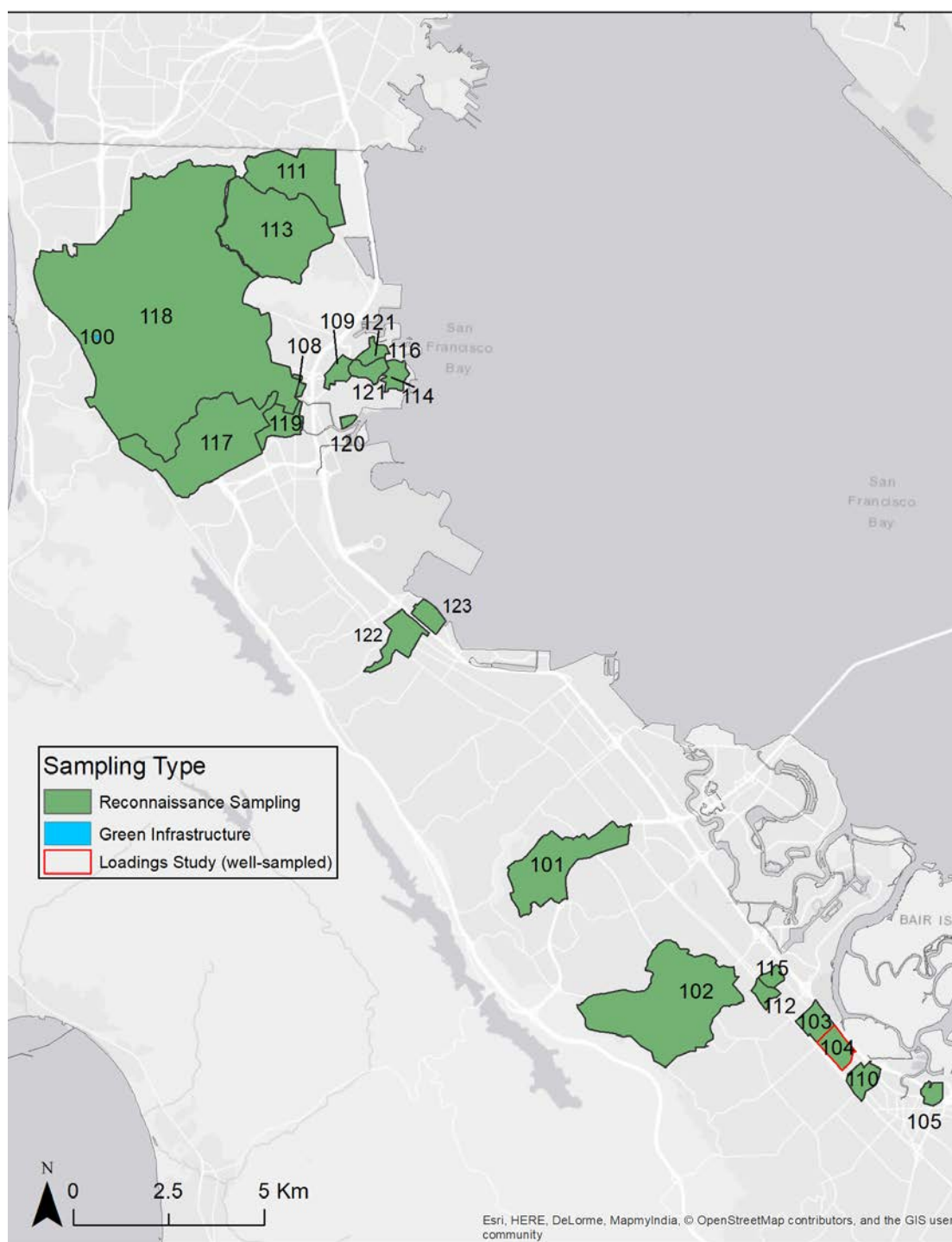


**Figure 1b.** Watershed boundaries of sites sampled in eastern Contra Costa County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.

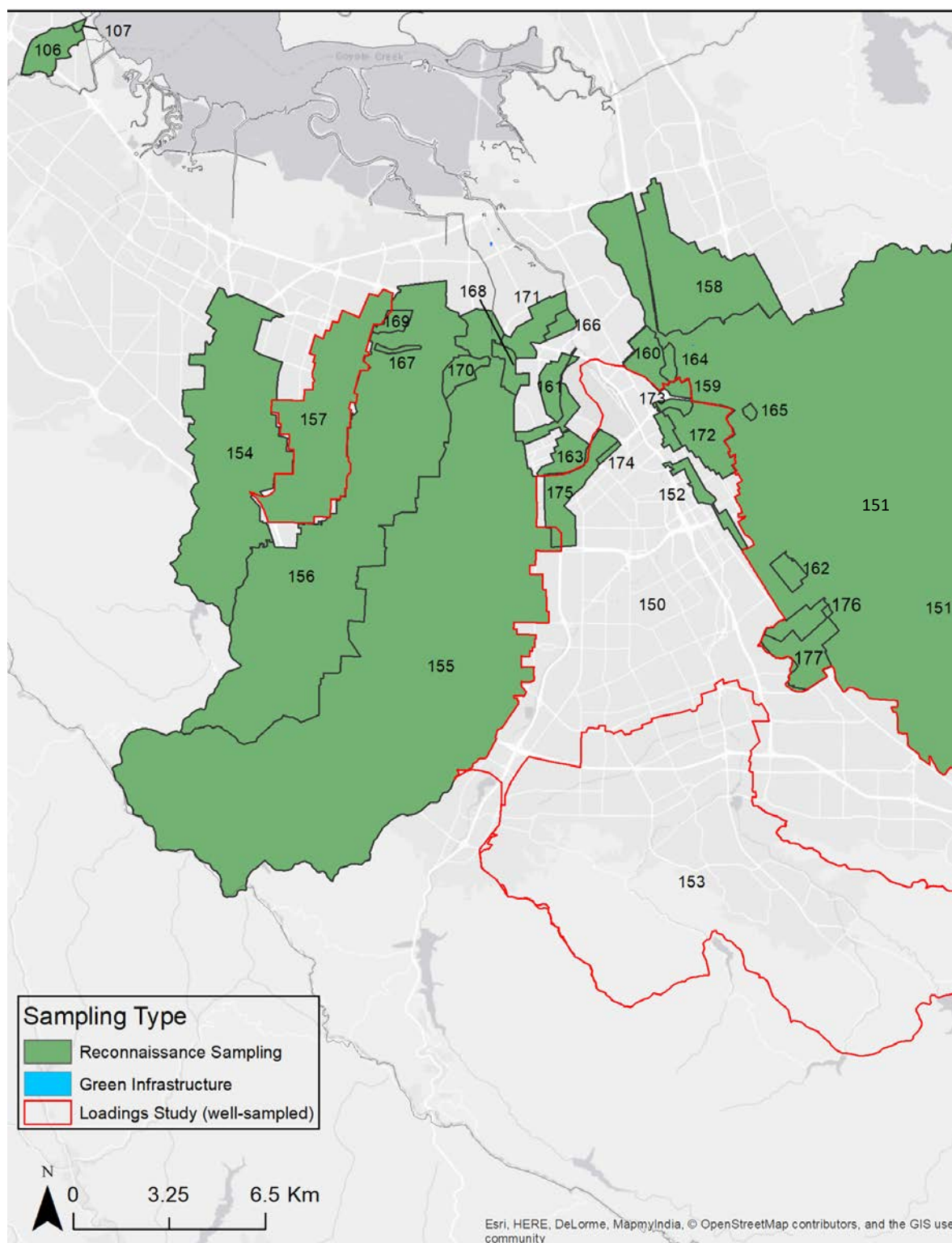




**Figure 1c.** Watershed boundaries of sites sampled in Alameda County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.



**Figure 1d.** Watershed boundaries of sites sampled in northern San Mateo County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.



**Figure 1e.** Watershed boundaries of sites sampled in Santa Clara County. Note: The drainage management areas (DMAs) of the Green Infrastructure sampling sites are so small they are not visible, though they are given a numeric map key identifier. See Table 1 for information on each numbered watershed or drainage management area.

# WYs 2015 through 2019 POC Reconnaissance Monitoring

**Table 1.** Key characteristics of the 91<sup>9</sup> sampling locations. Gaps in continuous numbering allow for the future addition of locations so that the unique identifying numbers for each county remain in the same count of 50.

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%

<sup>9</sup> There are 91 total sampling locations. Of these, 67 were sampled during WYs 2015-2019, 87 had water concentrations for PCBs, and 88 had water concentrations for HgT.

# WYs 2015 through 2019 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 (%)
19	Alameda	Oakland	Line 12M at Coliseum Way	Line12MColWay	MS4	37.74689	-122.20069	2/9/17 & 11/28/2018	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%
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 Seaclyff Ct. Pedestrian Br.	RodeoCk	Receiving Water	38.01604	-122.25381	1/18/17	23.41	2%	3%
53 <sup>10</sup>	Contra Costa	Rodeo	Rodeo Creek at Viewpoint Blvd.	RodeoCk	Receiving Water	38.018472	-122.256647	1/6/2019	23.5	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%
62	Contra Costa	Richmond	Wildcat Creek	Wildcat Creek	Receiving Water	37.960329°	-122.366840°	1/30/19	23.44	53%	1%
63	Contra Costa	Concord	Mount Diablo Creek	Mount Diablo Creek	Receiving Water	38.018756°	-122.026878°	1/15/19	75.56	9%	0%
64	Contra Costa	BayPoint	BayPoint	BayPoint	Receiving Water	38.034075°	-121.962504°	1/15/19	4.35	21%	0%
100	San Mateo	Daly City	Gellert Park Daly City Library	Gellert Park	Bioretention	37.663037	-122.470585	WY 2009	0.02	40%	0%

<sup>10</sup> At the scale of the map, the two Rodeo Creek sampling points are close enough that the watershed polygon on the map is the same.



## WYs 2015 through 2019 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 (%)
			Bioretention Influent		Influent						
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%
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%
122	San Mateo	Burlingame	SMBUR164A	SMBUR164A	MS4	37.5995966	-122.3752573	11/28/18	0.98	71%	37%

## WYs 2015 through 2019 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 (%)
123	San Mateo	Burlingame	SMBUR85A	SMBUR85A	MS4	37.60194467	-122.3749872	11/28/18	0.42	81%	44%
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%
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	Seaboard 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	Seaboard 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%

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Map Key	County	City	Watershed Name	Catchment Code	MS4 or Receiving Water	Latitude	Longitude	Sample Date	Area (sq km)	Impervious Cover (%)	Old Industrial (%)
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%
176	Santa Clara	San Jose	SC100CTC400A	SC100CTC400A	MS4	37.30299651	-121.8399512	1/16/19	1.38	63%	8%
177	Santa Clara	San Jose	SC100CTC500A	SC100CTC500A	MS4	37.30148661	-121.8381464	1/16/19	3.01	54%	7%
200	Solano	Vallejo	Austin Ck at Hwy 37	AustinCk	Receiving Water	38.12670	-122.26791	3/24/17	4.88	61%	2%



### Remote suspended sediment sampling procedures

After pilot testing in 2015-2018 (Table 2), In spring 2018, the SPLWG oversight committee recommended the use of remote samplers as an acceptable screening tool based on data collected between WYs 2015-2018 (see Gilbreath et al. 2019 for in depth review of the pilot data for the remote sampler trial).

During WY 2019 sampling, a Walling Tube (Phillips et al., 2000) suspended sediment sampler was deployed at three sites prior to three storms and retrieved within two days of the end of each storm. Only the remote sampler was used at these sites to characterize water quality; no manual sampling was performed simultaneously. The Walling Tube was used in open channels, deployed at approximately mid-channel, and secured to the natural bed with hose clamps attached to temporarily installed rebar (Figure 2c).

Water and sediment collected in the samplers were decanted into one or two large 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. Samples were analyzed as whole-water samples (because of insufficient solid mass to analyze as a sediment sample). Between sampling sites, the remote samplers were thoroughly cleaned using a brush and Alconox detergent, followed by a deionized water (DI) rinse.

## 2.3 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., 2019). Laboratory methods were chosen based on a combination of factors, including method detection limits, accuracy and precision, and cost (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.

## 2.4 Interpretive methods

### Estimated particle concentrations

The reconnaissance monitoring field protocol is designed to collect one composite whole water sample for each analyte during a single storm at each site to characterize concentrations during storm flow. Measured PCB and Hg concentrations at a site could have large inter-storm variability related to storm size, 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; ratio of mass of a given pollutant of concern to mass of suspended sediment) has been demonstrated to have less inter-storm variability than whole water concentrations, and therefore

(a)



(b)



(c)



(d)



**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 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; and (d) a Hamlin Sampler.

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**Table 2.** Locations where remote sediment samplers were pilot tested in previous sampling years and the three locations where the samplers were deployed in WY 2019.

Site	County	Date	Sampler(s) deployed	Comments	Pilot test or solo deployment?
Meeker Slough	Contra Costa	11/2015	Hamlin and Walling Tube	Sampling effort was unsuccessful because of very high velocities. Both samplers washed downstream because they were not sufficiently weighted down and debris caught on the securing lines.	Pilot test
Outfall to Lower Silver Creek	Santa Clara	2/06/15	Hamlin and Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Charcot Ave Storm Drain	Santa Clara	4/07/15	Hamlin	Sampling effort was successful. This sample was analyzed as a sediment sample.	Pilot test
Cooley Landing Storm Drain	San Mateo	2/06/15	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Duane Ct and Ave Triangle SD	Santa Clara	1/6/2016	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Victor Nelo PS Outfall	Santa Clara	1/19/2016	Hamlin and Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Forbes Blvd Outfall	San Mateo	3/5/2016	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Tunnel Ave Ditch	San Mateo	3/5/2016	Hamlin and Walling Tuber	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Taylor Way SD	San Mateo	3/11/2016	Hamlin	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Colma Creek Outfall	San Mateo	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 added cleaner sediment into the sampler and therefore the result may be biased low. This sample was analyzed as a water sample.	Pilot test
Austin Creek	Solano	3/24/2017	Hamlin and Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Refugio Creek	Contra Costa	1/18/2017	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Rodeo Creek	Contra Costa	1/18/2017	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Outfall at Gilman St.	Contra Costa	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 lie horizontally along the bed. This	Pilot test

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				sample was analyzed as a water sample.	
Meeker West	Contra Costa	1/9/2018	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Pilot test
Bay Point	Contra Costa	1/15/2019	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Solo deployment
Mount Diablo Creek	Contra Costa	1/15/2019	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Solo deployment
Wildcat Creek	Contra Costa	1/30/2019	Walling Tube	Sampling effort was successful. This sample was analyzed as a water sample.	Solo deployment

**Table 3.** Laboratory analysis methods.

Analysis	Matrix	Analytical Method	Lab <sup>11</sup>	Filtered	Field Preservation	Contract Lab / Preservation Hold Time
PCBs (40) <sup>12</sup> -Total	Water	EPA 1668	SGS AXYS	No	NA	NA
PCBs (40) <sup>8</sup> -Dissolved	Water	EPA 1668	SGS AXYS	Yes	NA	NA
PCBs (40) <sup>8</sup>	Sediment	EPA 1668	SGS AXYS	NA	NA	NA
Mercury-Total	Water	EPA 1631E	BAL	No	NA	BRL preservation with BrCl within 28 days
Mercury-Dissolved	Water	EPA 1631E	BAL	Yes	Na	BRL preservation with BrCl within 28 days
Mercury	Sediment	EPA 1631E, Appendix	BAL	NA	NA	7 days
Metals-Total (As, Cd, Pb, Cu, Zn)	Water	EPA 1638 mod	BAL	No	HNO <sub>3</sub>	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

the EPC is likely a better characterization of water quality at a site than water concentration alone, and is also 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 EPC was computed for each composite water sample (Equation 1):

<sup>11</sup> Labs and locations: SGS AXYS, British Columbia, Canada; Brooks Applied Labs (formerly Brooks Rand Laboratories), Bothell, WA; USGS, Santa Cruz, CA; East Bay Municipal Utilities District, Oakland, CA, ALS Environmental, Kelso, WA.

<sup>12</sup> 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).

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

Although normalizing PCB and Hg concentrations to SSC provides an improved metric for comparing sites, climatic conditions can nonetheless influence relative ranking based on EPCs. The nature of that influence may differ between watershed locations depending on source characteristics. For example, a higher proportion of polluted sediment may be triggered during dry years when there is little dilution by sediment erosion from rural parts of the watershed. This scenario is most likely to occur in mixed land-use watersheds with large amounts of pervious area. In contrast, a small patch of polluted soil in a highly impervious watershed may be eroded and transported any time rainfall intensity reaches some threshold. In this instance, a false negative could occur if sampling only occurs during rain events that do not meet that intensity threshold. Such processes can only be identified when data are collected for a single site during many types of storms.

Because of concerns regarding inter-storm variability, relative ranking of sites based on EPC 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/catchments 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, more advanced interpretive methods could be used that take 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 CYs 2018 and 2019 to develop advanced data analysis methods (McKee et al., 2019; Davis and Gilbreath, 2019) and these methods are now being applied to the entire data set (McKee et al., in preparation).

#### Derivations of central tendency for comparisons with past data

A mean, median, geometric mean, time-weighted mean, or flow-weighted mean have all been used to summarize the central tendency of data from RMP studies with discrete stormwater samples, and depending on the circumstance, any can be considered the right way. However, to compare the composite sample concentrations (comprised of multiple individual grab samples composited into a single bottle) collected in WYs 2015-19 with discrete grab samples collected at several time points in a storm in previous studies, the average of the discrete grab sample concentrations for the pollutant of interest for an event at a site was divided by the average of the SSC discrete grab sample concentrations. In this case, this is the only right way of computing the average that provides directly comparable data between sites. 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).

### 3. Results and Discussion

This report presents all available stormwater data<sup>13</sup> collected since WY 2003 when stormwater studies first began through SFEI contracts or RMP projects, including data collected in intensive loading studies from WYs 2003-2010 and 2012-2014, a similar reconnaissance study done in WY 2011, and studies of green infrastructure have been done intermittently since WY 2009. 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? (related to MQs 1 and 2; see page 1)
- 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? (influences collection of data to address MQs 1 & 2. The analysis related to this question is presented in Gilbreath et al., 2019)
- c) How do concentrations and EPCs for PCBs and Hg relate to other trace contaminant concentrations and land use? (related to MQs 1 & 2)

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 high.

#### 3.1 Stormwater SSC concentrations

Suspended sediment concentrations from the 88<sup>14</sup> sampling locations ranged from 16 to 1,354 mg/L, with a median of 93 mg/L. About 30% of the watersheds included in these statistics have greater than 5% agricultural and uncompacted open spaces. If those watersheds/catchments are removed, the 63 remaining are nearly wholly urban (maximum agricultural plus uncompacted open space of 2.1%). The urban, impervious watersheds/catchments have low SSC (relative to the watersheds with greater than 5% open and uncompacted area). Summary statistics for SSC for these 63 urban watersheds/catchments are given in Table 4.

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<sup>13</sup> Similar data collected by BASMAA in Santa Clara and San Mateo Counties are not included in this report.

<sup>14</sup> This count excludes the sites in which only a remote suspended sediment sampler was deployed. Because those samplers are intended to concentrate suspended sediment, the measurement of SSC is not comparable to the composite sampling. There are 91 total sampling locations. Of these, 67 were sampled during WYs 2015-2019, 87 had water concentrations for PCBs, and 88 had water concentrations for HgT.



**Table 4.** Summary statistics (count, minimum, maximum and percentiles) of SSC (in mg/L) for urban watersheds/catchments with agricultural and uncompacted open space <2.2%.

	All Counties	Alameda	Contra Costa	San Mateo	Santa Clara
Number of sampled (n)	63	18	5	18	21
Minimum	16	60	57	16	27
10 <sup>th</sup> Percentile	26	68	NA	21	34
25 <sup>th</sup> Percentile	45	81	57	26	46
50 <sup>th</sup> Percentile	77	133	61	44	73
75 <sup>th</sup> Percentile	143	203	123	83	118
90 <sup>th</sup> Percentile	223	388	NA	160	148
Maximum	671	671	151	265	250

### 3.2 PCBs stormwater concentrations and estimated particle concentrations

Total PCB concentrations from 87 sampling sites<sup>15</sup> ranged from 533 to 448,000 pg/L (840-fold variation), excluding one sample that had a large number of individual congeners below the method detection limit (<MDL; Table 5). Based on water composite concentrations for all available data, the 10 highest ranking sites for PCBs were (from high to low): Pulgas Pump Station-South, Santa Fe Channel, Industrial Rd Ditch, Line 12H at Coliseum Way, Sunnyvale East Channel, Line 12M at Coliseum Way, Pulgas Pump Station-North, Ettie Street Pump Station, Ridder Park Dr Storm Drain and Gull Dr. Outfall (Table 5, Figure 3). Old industrial land use and PCB concentration were moderately correlated ( $r = 0.61$ ); old industrial land use for these 10 sites ranges from 3-79% (mean 35%, median 32%), illustrating that land use alone is insufficient to identify high leverage areas. Rather, localized sources (e.g., former transformer manufacturing locations, locations of transformer spills, properties that used PCBs where the soils have been contaminated but not remediated to TMDL levels) are likely the most important factor controlling PCB concentrations, although these sources frequently are located in old industrial areas.

For PCBs, EPCs ranged between 2 and 8,222 (4,111-fold variation). Based on EPCs, the 10 highest-ranking sites for PCBs were: 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 Linden Ave. SD. Sites ranked highest based on stormwater concentrations and those ranked highest based on EPCs corresponded well. Six sampling sites were among the 10 highest-ranking sites for both metrics (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 (10<sup>th</sup>) in EPCs but low on water concentration (35<sup>th</sup>) because of very low SSC.

<sup>15</sup> There are 91 sites in Table 5 but one site, San Pedro Storm drain, was only analyzed samples for Hg, not PCBs, and three samples were measured using suspended sediment samplers for which only the particle ratio is comparable to the other manually collected data.



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**Table 5.** PCB and total mercury (HgT) water concentrations and estimated particle concentrations (EPCs) measured in Bay Area tributaries based on all RMP data collected in stormwater since water year 2003. 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) indicate two watersheds/catchments with the same rank. NR = not ranked because concentration was below the MDL or because the study was part of a bioretention study and data is based on a relatively very small watershed.

Watershed/ Catchment	County	Water Year sampled	Area (km <sup>2</sup> )	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, 2013- 2014	0.58	87%	54%	8222	1	448	1	350	46.5	19	62	54	66
Industrial Rd Ditch	San Mateo	2016	0.23	85%	79%	6139	2	160	3	535	27	14	72	26	83
Line 12H at Coliseum Way	Alameda	2017	0.97	71%	10%	2601	3	156	4	602	19	36	45	60	59.5
Santa Fe Channel	Contra Costa	2011	3.3	69%	3%	1295	4	198	2	570	22.5	86	12.5	151	23
Gull Dr SD	San Mateo	2016	0.30	78%	54%	903	5	39.8	12	320	53	5.4	85	43	74
Pulgas Pump Station- North	San Mateo	2011	0.55	84%	52%	893	6	60.3	7	400	40	24	56.5	60	59.5
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	San Mateo	2017	0.09	88%	87%	788	7	33.9	17	210	69	9	82	43	72.5
Outfall to Lower Silver Creek	Santa Clara	2015	0.17	79%	78%	783	8	44.6	11	420	37	24	56.5	57	64
Ettie Street Pump Station	Alameda	2011	4.0	75%	22%	759	9	59.0	8	690	14	55	25.5	80	51
S Linden Ave SD (291)	San Mateo	2017	0.78	88%	57%	736	10	11.8	35	775	10	12	78	16	88
Gull Dr Outfall	San Mateo	2016 & 2018	0.43	75%	42%	599	11	49.5	10	180	74.5	7.6	83	62	57
Austin Ck at Hwy 37	Solano	2017	4.9	61%	2%	573	12	11.5	37	640	17	13	76.5	20	87
Ridder Park Dr Storm Drain	Santa Clara	2015	0.50	72%	57%	488	13	55.5	9	330	51	37	44	114	34
MeekerWest	Contra Costa	2018	0.41	70%	69%	458	14	28.0	22	530	29	32	48	61	58

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Watershed/ Catchment	County	Water Year sampled	Area (km <sup>2</sup> )	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	14	2820	3	233	5	81	49
Line 12I at Coliseum Way	Alameda	2017	3.4	63%	9%	398	16	37.0	15	129	82	12	80	93	44.5
Sunnyvale East Channel	Santa Clara	2011	15	59%	4%	343	17	96.6	5	200	71	50	29	250	14
Line 3A-M at 3A-D	Alameda	2015	0.88	73%	12%	337	18	24.8	23	1170	4	86	12.5	74	53
SMBUR85A	San Mateo	2019	0.42	81%	44%	334	19	31.1	19	440	34	41	40	93	44.5
Line 12M at Coliseum Way	Alameda	2017, 2019	5.3	69%	22%	280	20	82.7	6	348	48	89	11	263	13
North Richmond Pump Station	Contra Costa	2011- 2014	2.0	62%	18%	241	21	13.2	33	810	9	47	30.5	58	62
Seaboard Ave Storm Drain SC-050GAC580	Santa Clara	2015	1.4	81%	68%	236	22	19.9	27	550	25	47	30.5	85	46
Line 4-E	Alameda	2015	2.0	81%	27%	219	23	37.4	13	350	46.5	59	22	170	20
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	Contra Costa	2017 & 2018	36.67	18%	5%	219	24	5.64	57	540	26	16	66	27	81.5
Glen Echo Creek	Alameda	2011	5.5	39%	0%	191	25	31.1	20	210	70	73	17	348	11
Seaboard Ave Storm Drain SC-050GAC600	Santa Clara	2015	2.8	62%	18%	186	26	13.5	32	530	28	38	42.5	73	54
Line 12F below PG&E station	Alameda	2017	10	56%	3%	184	27	21.0	26	373	42	43	37	114	34
South Linden Pump Station	San Mateo	2015	0.14	83%	22%	182	28	7.81	50	680	15	29	52	43	72.5
Taylor Way SD	San Mateo	2016	0.27	67%	11%	169	29	4.23	62	1156	5	29	53	25	84
Line 9-D	Alameda	2015	3.6	78%	46%	153	30	10.5	41	240	63.5	17	64.5	69	56
Meeker Slough	Contra Costa	2015 & 2018	7.3	64%	6%	140	31	7.91	49	770	11	45	33	57	65
Rock Springs Dr Storm Drain	Santa Clara	2015	0.83	80%	10%	128	32	5.25	58	930	7	38	42.5	41	75.5

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Watershed/ Catchment	County	Water Year sampled	Area (km <sup>2</sup> )	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
GR outfall 066GAC900	Santa Clara	2018	0.17	66%	1%	125	33	3.36	68	644	16	17	63	27	81.5
Charcot Ave Storm Drain	Santa Clara	2015	1.8	79%	24%	123	34	14.9	30	560	24	67	19	121	32
Veterans Pump Station	San Mateo	2015	0.52	67%	7%	121	35	3.52	67	470	32	14	71	29	80
Gateway Ave Storm Drain	San Mateo	2015	0.36	69%	52%	117	36	5.24	59	440	33	20	61	45	70.5
Guadalupe River at Hwy 101	Santa Clara	2003- 2006, 2010, 2012- 2014	233	39%	3%	115	37	23.7	24	3600	2	603	1	560	5
Line 9D1 PS at outfall to Line 9D	Alameda	2016	0.48	88%	62%	110	38	18.1	29	720	13	118	7.5	164	21
Tunnel Ave Ditch	San Mateo	2016	3.0	47%	8%	109	39	10.5	39	760	12	73	18	96	40.5
Valley Dr SD	San Mateo	2016	5.2	21%	7%	109	40	10.4	42	276	61	27	55	96	40.5
Runnymede Ditch	San Mateo	2015	2.1	53%	2%	108	41	28.5	21	190	73	52	28	265	12
E Gish Rd Storm Drain	Santa Clara	2015	0.45	84%	70%	99	42	14.4	31	590	21	85	14	145	26
Line 3A-M-1 at Industrial Pump Station	Alameda	2015	3.4	78%	26%	96	43	8.92	44	340	49	31	49	93	43
Line 13A at end of slough	Alameda	2016	0.83	84%	68%	96	44	34.3	16	331	50	118	7.5	357	9
Line 12A at Shellmound	Alameda	2018	10.48	41%	6%	95	45	10.8	38	406	38	46	32	114	34
SC100CTC500A	Santa Clara	2019	3.01	54%	7%	94	46	10.5	40	386	41	43	36	111	36.5
Rosemary St SD 066GAC550C	Santa Clara	2017	3.7	64%	11%	89	47	4.11	64	591	20	27	54	46	69

## WYs 2015 through 2019 POC Reconnaissance Monitoring

Watershed/ Catchment	County	Water Year sampled	Area (km <sup>2</sup> )	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
North Fourth St SD 066GAC550B	Santa Clara	2017	1.0	68%	27%	87	48	4.17	63	477	31	23	59	48	67.5
Zone 4 Line A	Alameda	2007- 2010	4.2	68%	12%	82	49	18.4	28	170	76	30	51	176	19
Forbes Blvd Outfall	San Mateo	2016	0.40	79%	0%	80	50	1.84	77	637	18	15	70	23	85
Storm Drain near Cooley Landing	San Mateo	2015	0.11	73%	39%	79	51	6.47	55	430	35	35	46	82	48
Lawrence & Central Expwys SD	Santa Clara	2016	1.2	66%	1%	78	52	4.51	61	226	65	13	73.5	58	63
Condensa St SD	Santa Clara	2016	0.24	70%	32%	74	53	2.60	75	329	52	12	81	35	78
San Leandro Creek	Alameda	2011- 2014	8.9	38%	0%	66	54	8.61	47	860	8	117	9	136	30
Oddstad Pump Station	San Mateo	2015	0.28	74%	11%	62	55	9.20	43	370	43	55	25.5	148	25
Line 4-B-1	Alameda	2015	1.0	85%	28%	57	56	8.67	46	280	58.5	43	35	152	22
Line 12A under Temescal Ck Park	Alameda	2016	9.4		1%	54	57	7.80	51	290	57	42	38	143	27
Victor Nelo PS Outfall	Santa Clara	2016	0.58	87%	4%	51	58	2.29	76	351	44	16	68	45	70.5
SMBUR164A	San Mateo	2019	0.98	71%	37%	48	59	3.87	65	276	60	22	60	80	50
Line 12K at Coliseum Entrance	Alameda	2017	16	31%	1%	48	60	32.0	18	429	36	288	4	671	4
GR outfall 066GAC850	Santa Clara	2018	3.35	61%	6%	45	61	6.63	53	107	85	16	67	149	24
Haig St SD	Santa Clara	2016	2.1	72%	10%	43	62	1.45	79	194	72	7	84	34	79
SC100CTC400A	Santa Clara	2019	1.38	63%	8%	38	63	2.92	71	303	56	23	58	77	52
Colma Ck at S. Linden Blvd	San Mateo	2017	35	41%	3%	37	64	2.65	74	215	68	15	69	71	55
Line 12J at mouth to 12K	Alameda	2017	8.8	30%	2%	35	65	6.48	54	401	39	73	16	183	18

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Watershed/ Catchment	County	Water Year sampled	Area (km <sup>2</sup> )	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
Wildcat Creek	Contra Costa	2019	23.44	53%	1%	32	66	NA	NA	No data	No data	No data	No data	**	NR
S Spruce Ave SD at Mayfair Ave (296)	San Mateo	2017	5.1	39%	1%	30	67	3.36	69	350	45	39	41	111	36.5
Lower Coyote Creek	Santa Clara	2005	327	22%	1%	30	68	4.58	60	240	63.5	34	47	142	29
Calabazas Creek	Santa Clara	2011	50	44%	3%	29	69	11.5	36	150	80	59	22	393	7
E Outfall to San Tomas at Scott Blvd	Santa Clara	2016	0.67	66%	31%	27	70	2.80	73	127	83	13	73.5	103	39
San Lorenzo Creek	Alameda	2011	125	13%	0%	25	71	12.9	34	180	74.5	41	39	228	16
Stevens Creek	Santa Clara	2011	26	38%	1%	23	72	8.16	48	220	66.5	77	15	350	10
Guadalupe River at Foxworthy Road/ Almaden Expressway	Santa Clara	2010	107	22%	0%	19	73	3.12	70	4090	1	529	2	129	31
Duane Ct and Ave Triangle SD	Santa Clara	2016	1.0	79%	23%	17	74	0.832	81	268	62	13	75	48	67.5
Lower Penitencia Creek	Santa Clara	2011, 2015	12	65%	2%	16	75	1.59	78	160	77.5	17	64.5	106	38
Borel Creek	San Mateo	2011	3.2	31%	0%	15	76	6.13	56	160	77.5	58	24	363	8
San Tomas Creek	Santa Clara	2011	108	33%	0%	14	77	2.83	72	280	58.5	59	22	211	17
Little Bull Valley	Contra Costa	2018	0.02	67%	2%	13	78	0.543	82	312	55	13	76.5	41	75.5
Zone 5 Line M	Alameda	2011	8.1	34%	5%	13	79.5	21.1	25	570	22.5	505	3	886	3
Belmont Creek	San Mateo	2011	7.2	27%	0%	13	79.5	3.60	66	220	66.5	53	27	241	15
BayPoint	Contra Costa	2019	4.35	21%	0%	12	81	NA	NA	140	81	NA	NA	**	NR

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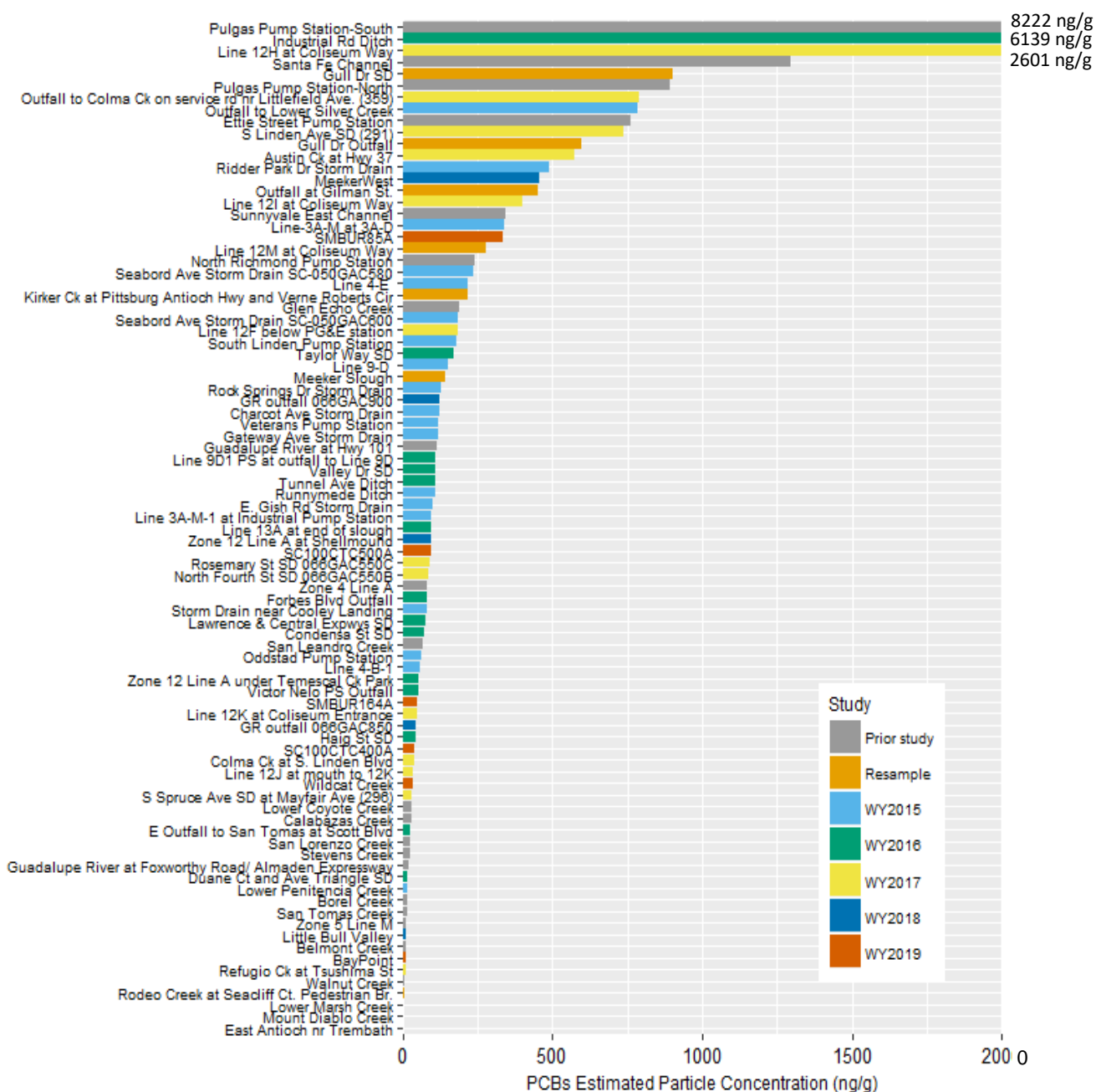
Watershed/ Catchment	County	Water Year sampled	Area (km <sup>2</sup> )	Impervious cover (%)	Old Industrial land use (%)	Polychlorinated biphenyls (PCBs)				Total Mercury (HgT)				Suspended Sediment Concentration (SSC)	
						Estimated Particle Concentration		Composite /mean water concentration		Estimated 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
Refugio Ck at Tsushima St	Contra Costa	2017	11	23%	0%	9	82	0.533	83	509	30	30	50	59	61
Walnut Creek	Contra Costa	2011	232	15%	0%	7	83	8.83	45	70	87	94	10	1343	2
Rodeo Creek at Seacliff Ct. Pedestrian Br. <sup>16</sup>	Contra Costa	2017, 2019	23.41	2%	1%	6	84	7.21	52	93	86	65	20	1354	1
Lower Marsh Creek	Contra Costa	2011- 2014	84	10%	0%	3	85	1.45	80	110	84	44	34	400	6
Mount Diablo Creek	Contra Costa	2019	75.56	9%	0%	2	86	NA	NA	157	79	NA	NA	**	NR
San Pedro Storm Drain	Santa Clara	2006	1.3	72%	16%	No data	No data	No data	No data	1120	6	160	6	143	28
Gellert Park Daly City Library Bioretention Influent	San Mateo	2009	0.02	40%	0%	36	NR <sup>a</sup>	0.725	NR <sup>a</sup>	1010	NR <sup>a</sup>	22	NR <sup>a</sup>	22	86
Fremont Osgood Road Bioretention Influent	Alameda	2012, 2013	0.00	76%	0%	45	NR <sup>a</sup>	2.91	NR <sup>a</sup>	120	NR <sup>a</sup>	10	NR <sup>a</sup>	83	47
El Cerrito Bioretention Influent	Contra Costa	2012, 2014-15, 2017	0.00	74%	0%	310	NR <sup>a</sup>	29.7	NR <sup>a</sup>	196	NR <sup>a</sup>	19	NR <sup>a</sup>	96	42
East Antioch nr Trembath	Contra Costa	2017	5.3	26%	3%	NR <sup>a</sup>	NR <sup>a</sup>	<MDL	NR <sup>a</sup>	313	54	12	79	39	77

NR<sup>a</sup> = site not included in ranking. These are very small catchments with unique sampling designs for evaluation of green infrastructure.

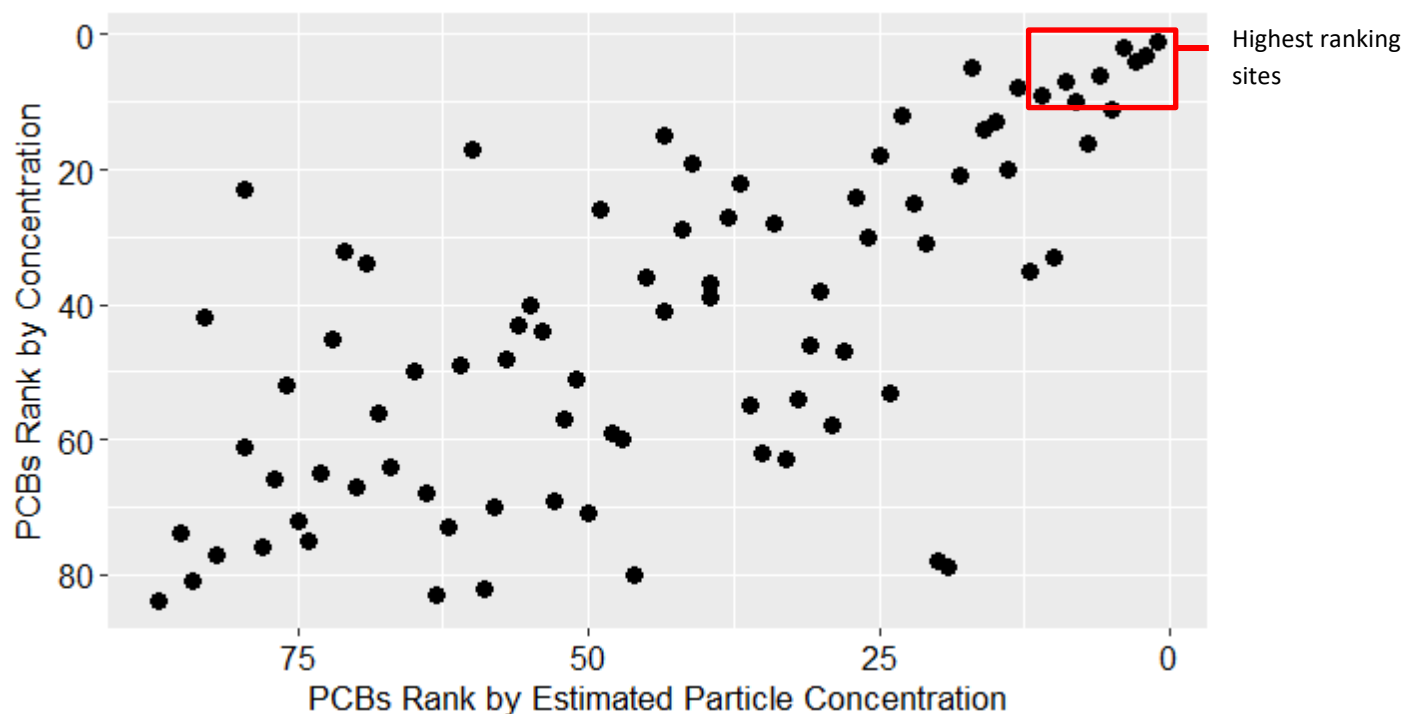
\*\* Collection was done using a suspended sediment sampler, which concentrates suspended sediment and therefore is not comparable to the samples collected using manual compositing techniques of whole water.

<sup>16</sup> Rodeo Creek was sampled in WY 2017 at Seacliff Ct, Pedestrian Bridge. In WY 2019, the bridge was closed and instead sampling occurred 370 m downstream at Viewpoint Blvd. The results from the two nearby locations are combined in this row.

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**Figure 3.** PCB estimated particle concentrations (EPCs) for watershed and catchment sampling sites measured in water years 2003-2019 (where more than one storm was sampled at a site, the reported concentration 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) extend beyond upper bound of the 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) and on water concentrations. 1 = highest rank; 84 = lowest rank.

A high rank in water concentration and a low rank in EPC indicates the presence of PCB sources but dilution by relatively high loading of clean sediment (e.g., >75<sup>th</sup> percentile of SSC, Table 5). Examples include Line 13A at end of slough (357 mg SS/L) and Line 12K at Coliseum Entrance (671 mg SS/L). Conversely, a high rank in EPC and low rank in water concentration indicates that mobilization of PCB-contaminated sediment is high relative to mobilization of cleaner sediment; these samples often have a relatively low SSC. Examples include South Linden Ave. SD (16 mg SS/L), Austin Ck at Hwy 37 (20 mg SS/L) and Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Circle (27 mg SS/L). This latter scenario is more likely to occur in watersheds/catchments that are highly impervious with little erosion and transport of clean sediment from undeveloped areas.

Most of the sites investigated had PCB EPCs that were higher than those 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<sup>3</sup> (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) had a composite averaged PCB water concentration of <1,330 pg/L (Table 5) and none of the 87 sampling locations had composite averaged PCB EPCs of <1.4 ng/g (Table 5; Figure 3). The lowest PCB EPC measured to date was for Mount Diablo Creek (1.8 ng/g).



### 3.3 Mercury stormwater concentrations and estimated particle concentrations

Total mercury concentrations in composite water samples ranged 112-fold from 5.4 to 603 ng/L among the 88 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 the legacy New Almaden Mining District upstream), Guadalupe River at Foxworthy Road/ Almaden Expressway (0% old industrial and 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), Line 13-A at end of slough (68% old industrial), Line 9-D-1 PS at outfall to Line 9-D (62% old industrial), San Leandro Creek at San Leandro Blvd. (0% old industrial) and Walnut Creek (0% old industrial) (Table 5). There is a weak and positive relationship between mercury concentrations and old industrial land use, in contrast to the stronger relationship between PCB concentrations and industrial land use. None of the top 10 sites for Hg were among the top 10 for PCBs, also suggesting there is no direct relationship between mercury and PCBs in stormwater runoff in the Bay Area.

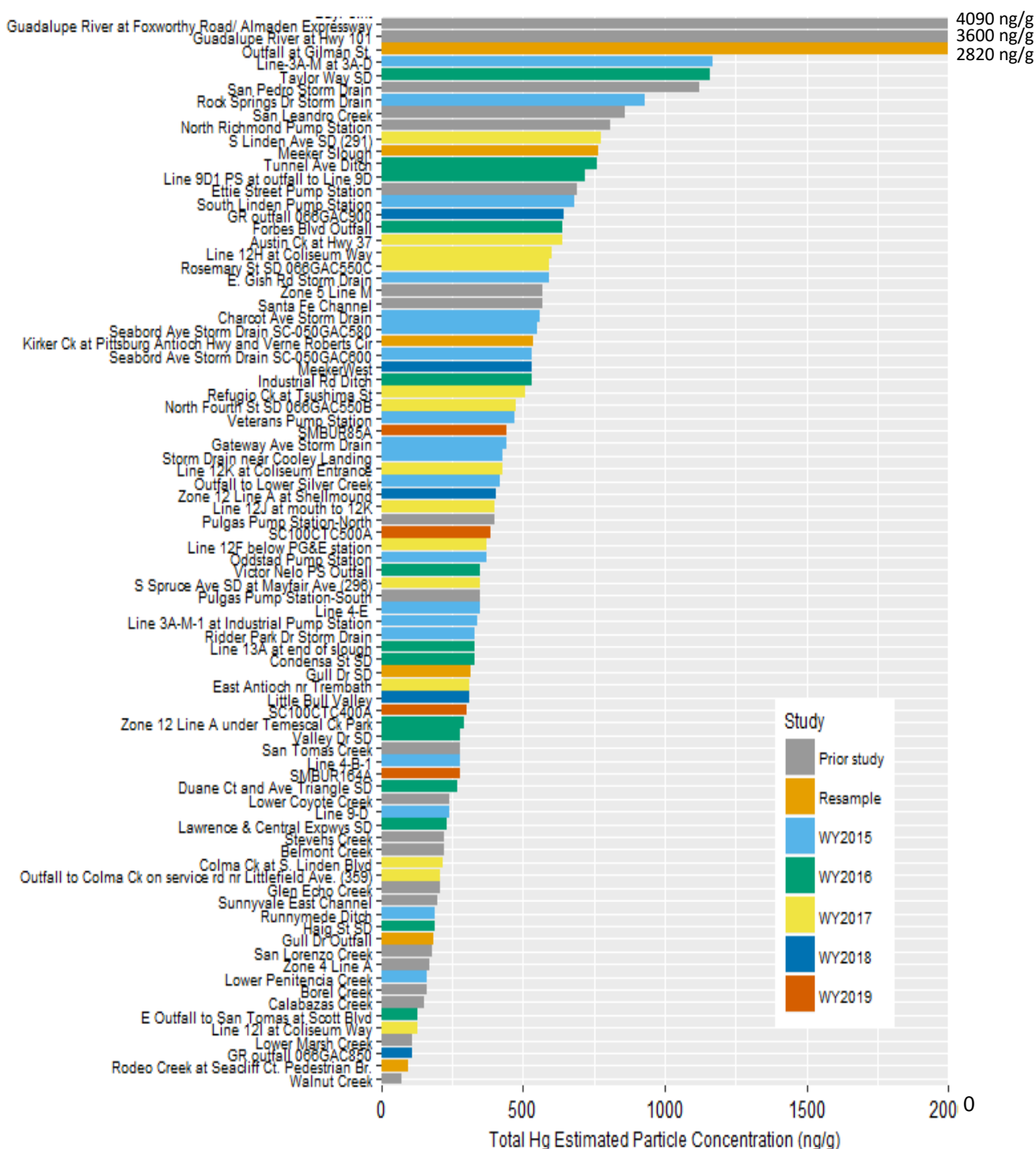
There are several watersheds/catchments with relatively low Hg concentrations. The HgT load allocation of 82 kg from the TMDL (SFBRWQCB, 2006) translates to a mean water concentration of 53 ng/L, based on an annual average flow from small tributaries of 1.5 km<sup>3</sup> (Wu et al., 2017). Sixty-one of 88 sampling locations have composite HgT water concentrations below this concentration (Table 4). There are likely few Hg sources in these watersheds/catchments besides atmospheric deposition<sup>17</sup>.

Estimated particle concentrations of HgT ranged between 45 and 4,090 ng/g (91-fold). The 10 most polluted sites for HgT based on EPCs were 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). Only one of these 10 sites was among the 10 most highly-ranked sites for PCBs (South Linden Ave. SD), but 6 additional watersheds/catchments rank in the 20 most highly-ranked sites for both pollutants (Figure 6), providing the opportunity to address both PCBs and HgT. Twenty-seven 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). Unlike PCBs, there is no relation between water concentration and EPC for HgT (Figure 7). Therefore, ranking of sites for HgT should be approached more cautiously than for PCBs.

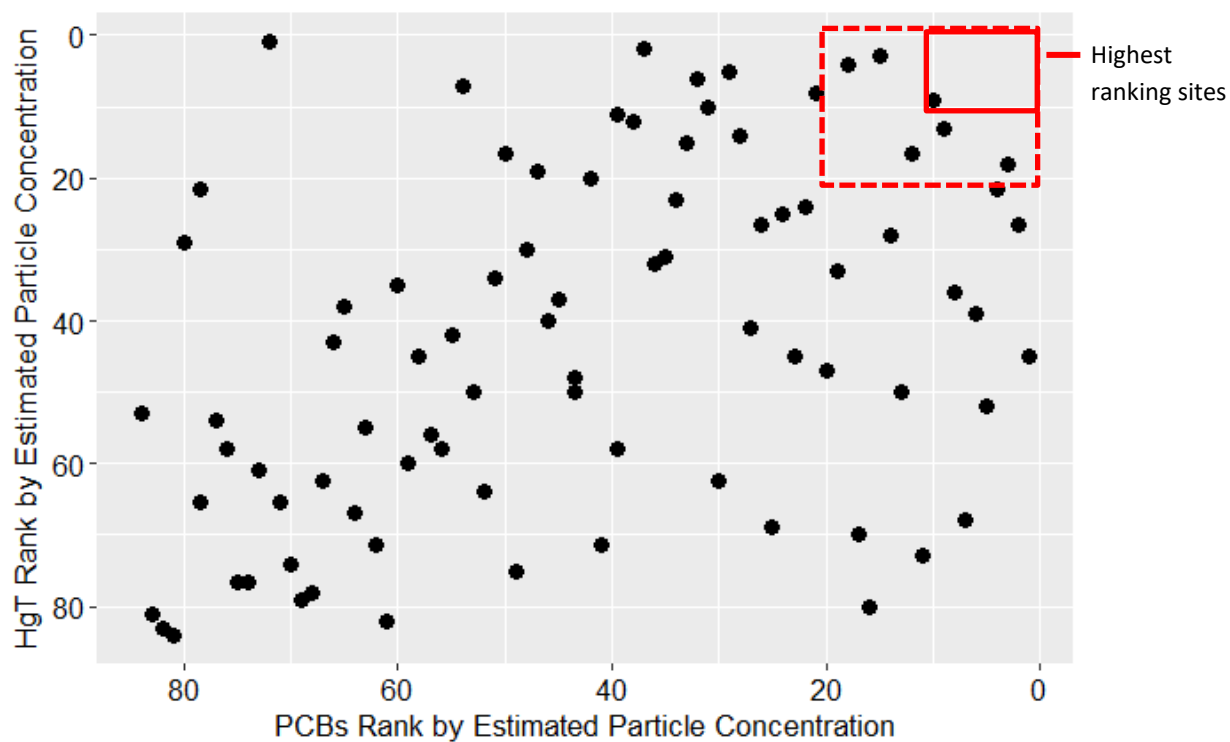
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<sup>17</sup> Multiple studies in the Bay Area on atmospheric deposition rates for HgT reported very similar wet deposition rates of 4.2 µg/m<sup>2</sup>/y (Tsai and Hoenicke, 2001) and 4.4 µg/m<sup>2</sup>/y (Steding and Flegal, 2002), and Tsai and Hoenicke reported a total (wet + dry) deposition rate of 18-21 µg/m<sup>2</sup>/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).

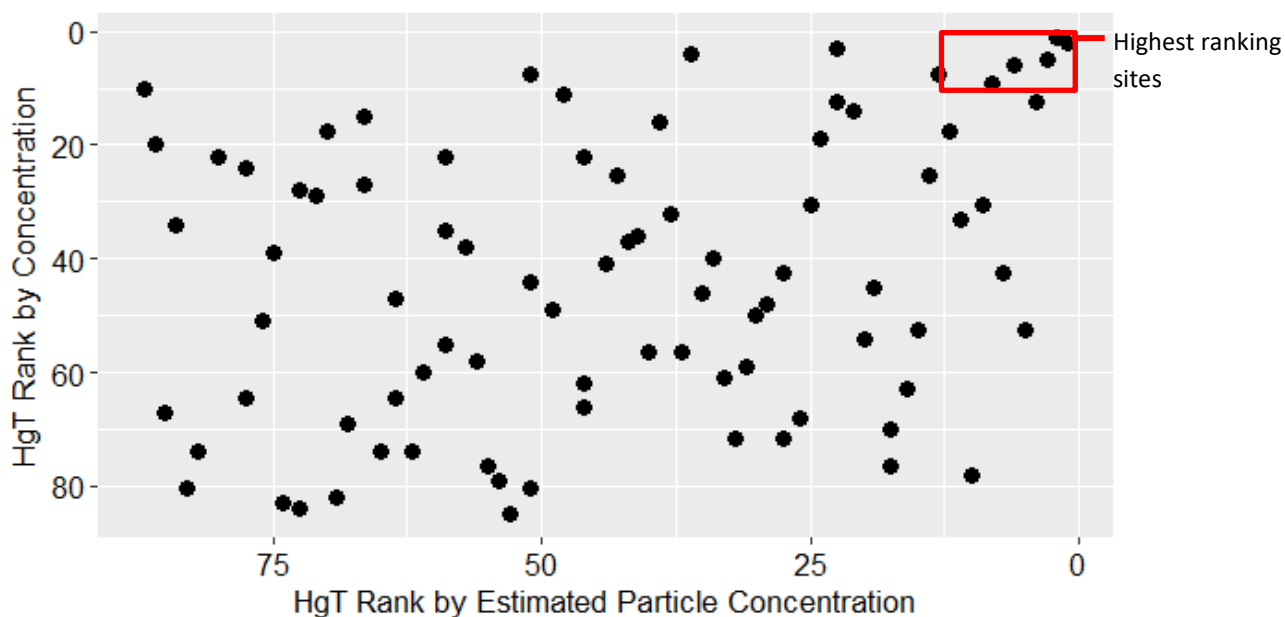
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**Figure 5.** All sampling locations measured to date (water years 2003-2019) ranked by total mercury (HgT) estimated particle concentrations (EPCs). The sample count represented by each bar in the graph is provided in Appendix D.



**Figure 6.** Comparison of site rankings for PCB and total mercury (HgT) estimated particle concentrations (EPCs). 1 = highest rank; 84 = 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; 85 = lowest rank.

### 3.4 Trace element (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<sup>18</sup> were similar in range to those previously measured in the Bay Area.

- Arsenic (As): Concentrations ranged from less than the MDL (0.34 µg/L for that sample) to 2.66 µg/L (Table 6). Similar total As concentrations have been measured previously (Guadalupe River at Hwy 101: mean=1.9 µg/L; Zone 4 Line A: mean=1.6 µg/L) and are lower than measured at North Richmond Pump Station (mean=11 µg/L) (Appendix A3 in McKee et al., 2015).
- Cadmium (Cd): Concentrations ranged from 0.023-0.55 µg/L (Table 6), 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): 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): 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): Concentrations ranged from 39.4-337 µg/L (Table 6). Zinc 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, magnesium (Mg; 528-7350 µg/L) and selenium (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 concentrations (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 correlation with flow (David et al., 2015; McKee and Gilbreath, 2015; McKee et al., 2017), Se concentrations measured with the current sampling protocol, with a focus on high flow, were likely biased low relative to those measured with sampling designs that included low flow 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/L). Care, therefore, should be taken if Se concentrations reported here were used to estimate regional loads.

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<sup>18</sup> Trace elements were not measured in WYs 2018 or 2019.

## WYs 2015 through 2019 POC Reconnaissance Monitoring

**Table 6.** Concentrations of selected trace elements measured during 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	<b>0.552</b>	23.3	19.4			152
East Antioch nr Trembath	1/8/2017	1.57	0.119	<b>3.53</b>	1.68	5,363	0.53	<b>36.3</b>
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	<b>0.023</b>	3.63	1.18	<b>528</b>	<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	<b>0.91</b>			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	<b>11,100</b>	<b>0.67</b>	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			<b>337</b>
Ridder Park Dr SD	12/15/2014	<b>2.66</b>	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	<b>52.7</b>	<b>21.3</b>			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

### 3.5 Relationships between PCBs and Hg and other trace elements and land-cover attributes

Spearman rank correlations were analyzed to identify potential relationships between PCBs, HgT, trace elements, and land use variables<sup>19</sup> (Table 7). Beginning in WY 2003, numerous sites have been evaluated for selected trace elements in addition to HgT. These sites include the fixed 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 multiple 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 6). 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 was collected at 28 locations in this study and at an additional 21 locations in previous studies.

PCBs correlate positively with impervious cover and old industrial land use, and inversely with watershed area (Table 7), on the basis of Spearman rank correlation analysis<sup>20</sup>. The highest PCB concentrations were measured in small watersheds with a high proportion of impervious cover and old industrial area (Figure 8). However, the lack of a stronger correlation between PCBs and these geospatial variables 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 sampling. PCBs did not correlate with any of the trace elements with the exception of an inverse relationship with arsenic.

These observations are consistent with previous analysis (McKee et al., 2012), and with the concept that larger watersheds tend to have mixed land use and thus a lower proportional amount of PCB source areas relative to smaller watersheds that are more urbanized and more industrialized. There was also a positive but relatively weak relationship between PCBs and HgT, consistent with the general relationships between impervious cover and both PCBs and HgT. This observation contrasts with conclusions drawn from the WY 2011 dataset, for which there was a stronger relationship between PCBs and HgT (McKee et al., 2012). This difference might reflect a stronger focus on PCBs during the WY 2015-2019 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. Additionally, or alternatively, the weakness of the

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<sup>19</sup> HgT data associated with the main channel of the Guadalupe River were removed from the analysis because of historic mining influence in the watershed. 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).

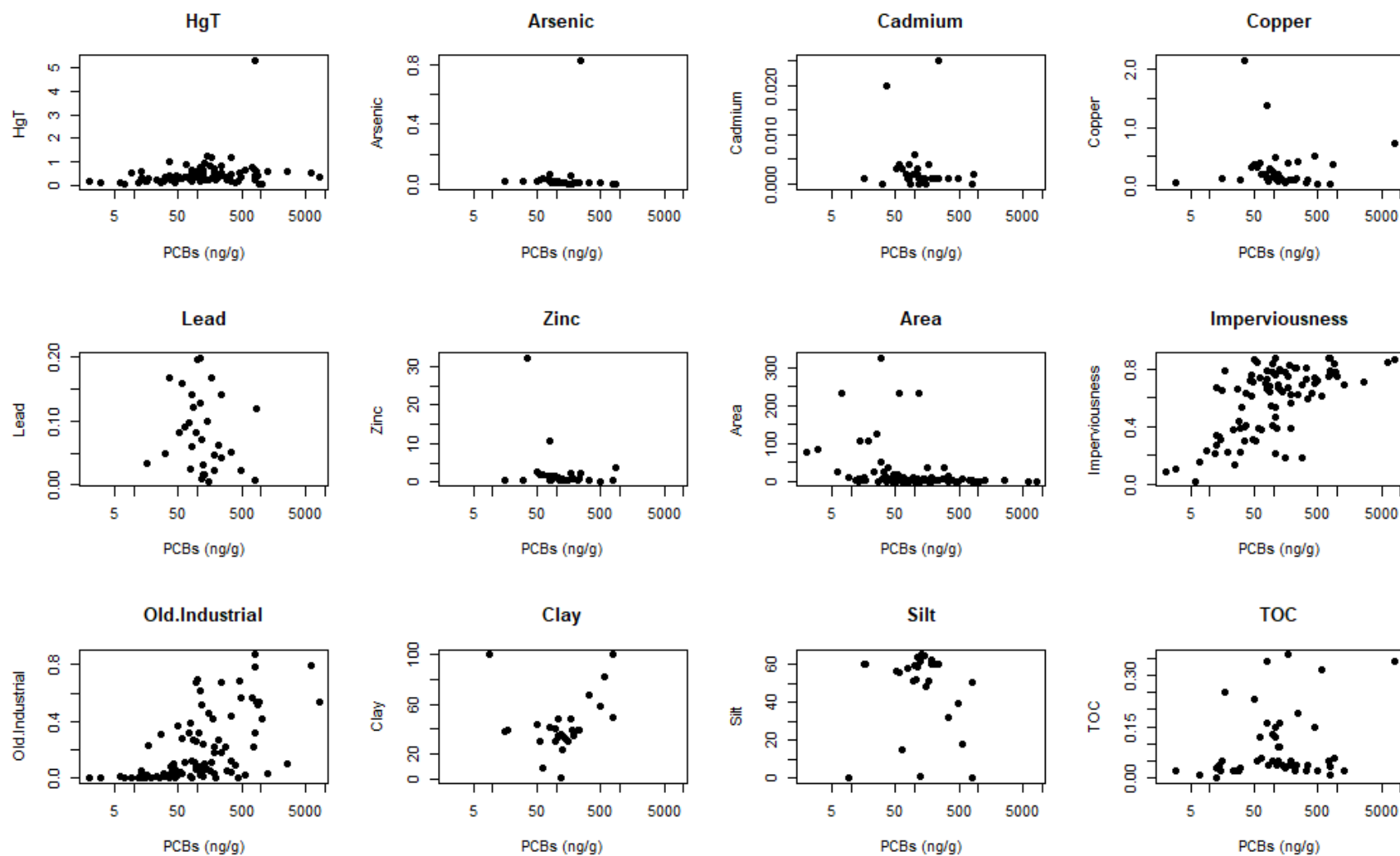
<sup>20</sup> The rank correlation was preferred because it makes no assumption of the type of relationship (linear or other) or the data distribution (normal data distribution is a requirement of a Pearson Product Moment correlation); in the Spearman correlation, every data pair has an equal influence on the coefficient.

**Table 7.** 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 95. Correlation coefficients (r) 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)	0.4												
Arsenic (ug/mg)	-0.61	-0.03											
Cadmium (ug/mg)	-0.28	0.25	0.67										
Copper (ug/mg)	-0.07	0.15	0.56	0.743									
Lead (ug/mg)	-0.25	0.16	0.583	0.863	0.711								
Zinc (ug/mg)	-0.24	-0.24	0.497	0.801	0.894	0.691							
Area (sq km)	-0.44	-0.28	0.00	-0.24	-0.43	-0.08	-0.41						
% Imperviousness	0.567	0.28	-0.35	0.00	0.181	-0.10	0.167	-0.76					
% Old Industrial	0.61	0.26	-0.48	-0.2	-0.21	-0.25	-0.15	-0.55	0.754				
% Clay (<0.0039 mm)	0.23	0.08	-0.12	0.046	-0.23	-0.03	-0.16	-0.19	-0.03	0.081			
% Silt (0.0039 to <0.0625 mm)	-0.07	0.15	-0.14	-0.17	0.274	0.00	0.174	0.147	0.051	-0	-0.37		
% Sands (0.0625 to <2.0 mm)	-0.13	-0.19	0.094	0.006	-0.02	0.094	-0.03	0.259	-0.09	-0.08	-0.83	-0.07	
TOC (mg/mg)	0.224	0.4	0.70	0.60	0.875	0.466	0.756	-0.46	0.406	0.157	-0.2	0.204	-0.02

$p$  value <0.05





**Figure 8.** Relationships between observed estimated particle concentrations (EPCs) of PCBs and total mercury (HgT), trace elements, and impervious land cover, old industrial land use, grainsize (clay and silt), and total organic carbon (TOC).

relationship between PCBs and HgT may partly be associated with the larger role of atmospheric recirculation in the mercury cycle than the PCB cycle and with large differences between the use history of each pollutant. Correlations between HgT and impervious cover, old industrial land use, and watershed area were similar to but weaker than those for PCBs and these geospatial variables. Neither PCBs nor Hg were strongly correlated with other trace metals. Based on 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.

### 3.7 Sampling progress in relation to data uses

It has been argued 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 33% of the old industrial land use in the region. The best coverage to date has occurred in Santa Clara County (78% of old industrial land use in the county is in watersheds that have been sampled), followed by San Mateo County (36%) and Alameda County (31%). In Contra Costa County, only 15%<sup>21</sup> 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 across all the counties, 48% of it lies within 1 km and 74% 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 and to better identify sources for potential management.

## 4. Summary and Recommendations

This report presents all available stormwater data<sup>22</sup> collected since WY 2003 when stormwater studies first began through SFEI contracts or RMP projects, not just the data collected for this WY 2015-2019 reconnaissance monitoring study (total of 91 sites). Prior to WY 2015, studies mostly employed Method 1, whereas beginning in WY 2015, with the exception of green stormwater infrastructure studies, sampling employed Methods 2 and 3.

Method 1. Fixed location multi-year turbidity-based sampling protocol for accurate loads estimation

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<sup>21</sup> This result is largely due to the fact that fewer samples have been collected in Contra Costa County than the Alameda, San Mateo and Santa Clara Counties.

<sup>22</sup> Similar data collected by Santa Clara and San Mateo County stormwater programs are not included in this report.

Method 2. Water based composite sampling protocol for single storm reconnaissance characterization and relative site comparisons to support management prioritization

Method 3. Remotely deployable sedimentation sampling protocol for preliminary screening to support further field sampling using our water based composite sampling protocol

During WYs 2015-2019, composite water samples were collected at 66 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<sup>23</sup>. Sampling efficiency was increased, when possible, by sampling two nearby sites during a single storm. At three of these sites, collection was done using a remote sampler only – a method that was pilot tested during WYs 2015-2018 and approved for use in spring 2018. Several 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 following recommendations are based on the WY 2015-2019 results.

- Continue to select sites based on the four main selection objectives (Section 2.2). Most 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 for PCBs.
- Continue to use the composite sampling field protocol as developed and applied during WYs 2015-2019 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.
- Results from the remote sampler pilot study indicated reasonable comparability to manually collected sample concentrations. It is recommended that future sampling continue to include the use of remote samplers as a low-cost screening tool to identify sites for further sampling using the reconnaissance characterization monitoring protocol.
- Apply the advanced data analysis method for identifying and ranking watersheds of management interest most if not all watersheds ranked in this report. This recommendation will be fully implemented during the 2020 calendar year. The results once peer-reviewed could contribute to site selection in WY 2021.
- 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 as part of the advanced data analysis project.

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<sup>23</sup> Another 25 sites were sampled prior to WY 2015.

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## **6. Appendices**

## Appendix A: Characteristics of Larger Watersheds

Characteristics of larger watersheds to be monitored, proposed sampling location, and proposed sampling trigger criteria. In WY 2017, the sampling trigger criteria for flow and rainfall were met but large watershed sampling was focused on the Guadalupe River rather than the watersheds on this list due to a piggybacking opportunity associated with Hg.

Proposed sampling location							Relevant USGS gauge for 1st order loads computations	
Watershed system	Watershed Area (km <sup>2</sup> )	Impervious Surface (%)	Industrial (%)	Sampling Objective	Commentary	Proposed Sampling Triggers	Gauge number	Area at USGS Gauge (sq <sup>2</sup> )
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 2015-2019 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 pollutants of concern (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 where manual water composites would be collected in parallel to test the comparability between sampling methods.

## 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)<sup>24</sup> 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; the USGS hold time is 100 days); 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 sediment in runoff (and particle size distributions within that SSC) can be highly variable, even when collected by minutes, so results were flagged as estimated concentrations 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. 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 +

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<sup>24</sup> 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).

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 three method blanks in that batch was 0.33 mg/L, less 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 2018, the SSC and particle size distribution (PSD)<sup>25</sup> 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.

In WY 2019, the SSC data from USGS-PCMSC were acceptable, aside from failing hold-time targets. SSC samples were all analyzed outside of hold time (between 98 and 175 days after collection, exceeding the 7-day hold time specified in the RMP QAPP). Minimum detection limits (MDLs) were generally sufficient, with zero non-detects (NDs) reported. Two method blanks were analyzed and both were below the MDL. Spiked samples are not typically reported for SSC. 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 0%, below the 10% target.

No samples for PSD analysis were collected in WY 2019.

### *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

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<sup>25</sup> 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).

still below the MDL, so results were not flagged. Matrix spike samples were used to evaluate accuracy, although many samples were not spiked high enough for adequate evaluation (must be at least two times the parent sample concentration). Recovery errors in the remaining DOC matrix spikes were all below the 10% target MQO. TOC errors in WY 2015 averaged 14%, above the 10% MQO, and TOC was therefore qualified but not censored. Laboratory replicate samples evaluated for precision had an average RSD of <2% for DOC and TOC, and 5.5% for POC, within the 10% target MQO. RSDs for field replicates were also within the target MQO of 10% (3% for DOC and 9% for TOC), so no precision qualifiers were needed.

POC and DOC were also analyzed by ALS in 2016. One POC sample was flagged for a holding time of 104 days (past the specified 100 days). All OC analytes were detected in all field samples and were not detected in method blanks, but DOC was detected in filter blanks at 1.6% of the average field sample and 5% of the lowest field sample. The average recovery error was 4% for POC evaluated in LCS samples, and 2% for DOC and TOC in matrix spikes, within the target MQO of 10%. Precision on POC LCS replicates averaged 5.5% RSD, and 2% for DOC and TOC field sample lab replicates, well within the 10% target MQO. No recovery or precision qualifiers were needed. The average 2016 POC was about three times higher than 2014 results. DOC and TOC were 55% and 117% of 2016 results, respectively.

In 2017, method detection limits were sufficient with no non-detects (NDs) reported except for method blanks. DOC and TOC were found in one method blank in one lab batch for both analytes. Four DOC and eight TOC results were flagged with the non-censoring qualifier "VIP". TOC was found in the field blank and its 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.

No samples for TOC analysis were collected in WY 2019.

#### *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 SGS 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 sediment 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.

SGS 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.

SGS 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, SGS 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.

In WY 2019, SGS AXYS analyzed total water samples for PCBs (no samples for dissolved or particulate fractions were submitted for analysis). Method detection limits (MDLs) were satisfactory for the PCBs with only four non-detects reported (one for PCB008, PCB019, PCB049 and PCB15). PCB concentrations above the MDL were reported for the one method blank for PCB 028, PCB 031, PCB 033, PCB 044, PCB 049, PCB 052, PCB 066, PCB 070, PCB 105, PCB 110, PCB 149, PCB 153, and PCB 180. As a consequence, one PCB 049 result was flagged with the censoring QA code of "VRIP" (Data rejected - Analyte detected in field or lab generated blank, flagged by QAO) for blank contamination. The other blank contaminated results were flagged by the analyzing laboratory so no additional flags had to be added.

PCB concentrations above the MDL were reported in the field blanks for PCB 018, PCB 028, PCB 031, PCB 033, PCB 044, PCB 049, PCB 052, PCB 066, PCB 070, PCB 095, PCB 132, PCB 138, and PCB 149. But the average concentrations in the field blanks were less than 1% of the average field sample concentrations. No certified reference material samples, and no matrix spike samples were analyzed/reported. The percent error for the three PCBs included in the single laboratory control sample (PCB 105, PCB 118, and PCB 156) were 2%, 3%, and 3%, respectively (recoveries were 102%, 103%, and 97%) all well below the 35% target MQO. No qualifiers were added. Lab replicates were not analyzed/reported so blind field



replicates were used to decide whether precision flags were needed for the PCB results. The RPDs were all below the MQO target of 35%, ranging from 1.87% to 29.58%. No qualifiers were needed.

### *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  $\text{CaCO}_3$ ), 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  $\text{CaCO}_3$ ), 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 concentrations. No additional qualifiers were added.

In WY 2019, 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. Total mercury was measured/reported at concentrations above the MDL for two lab blanks in one of the lab batches, and as a consequence four sample concentrations were flagged with the QACode "VIP" (Analyte detected in field or lab generated blank, flagged by QAO) for blank contamination. The average percent error for total mercury in the certified reference materials was 1.21% (average recovery 101.21%) well below the target MQO of 35%. No qualifiers were added. The average percent error for total mercury in the matrix spike samples was 8.32% (average recovery 91.68%) below the target MQO listed in the 2018 RMP QAPP of 35%. The percent error for total mercury in the single laboratory control samples was 3.35% (recovery 96.65%) below the 35% target MQO. Lab replicates were used to decide whether precision flags were needed for the total mercury results. The average RPD of 0.76% was below the MQO target of 35%. No qualifiers were needed. The average certified reference material samples RPD was 1.39% below the 35% MQO target. The average RPD for the matrix spike replicates of 2.21% was likewise below the target MQO of 35%. No field replicates were analyzed/reported.

#### *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 two 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	Remote Sample
Belmont Creek	Prior to WY2015	4	0	NA	0
Borel Creek	Prior to WY2015	5	0	NA	0
Calabazas Creek	Prior to WY2015	5	0	NA	0
Ettie Street Pump Station	Prior to WY2015	4	0	NA	0
Glen Echo Creek	Prior to WY2015	4	0	NA	0
Guadalupe River at Foxworthy Road/ Almaden Expressway	Prior to WY2015	14 PCB; 46 Hg	0	NA	0
Guadalupe River at Hwy 101	Prior to WY2015	119 PCB; 261 Hg	0	NA	0
Lower Coyote Creek	Prior to WY2015	5 PCB; 6 Hg	0	NA	0
Lower Marsh Creek	Prior to WY2015	28 PCB; 31 Hg	0	NA	0
Lower Penitencia Creek	Prior to WY2015	4	0	NA	0
North Richmond Pump Station	Prior to WY2015	38	0	NA	0
Pulgas Pump Station-North	Prior to WY2015	4	0	NA	0
Pulgas Pump Station-South	Prior to WY2015	29 PCB; 26 Hg	0	NA	0
San Leandro Creek	Prior to WY2015	39 PCB; 38 Hg	0	NA	0
San Lorenzo Creek	Prior to WY2015	5 PCB; 6 Hg	0	NA	0
San Pedro Storm Drain	Prior to WY2015	0 PCB; 3 Hg	0	NA	0
San Tomas Creek	Prior to WY2015	5	0	NA	0
Santa Fe Channel	Prior to WY2015	5	0	NA	0
Stevens Creek	Prior to WY2015	6	0	NA	0
Sunnyvale East Channel	Prior to WY2015	42 PCB; 41 Hg	0	NA	0
Walnut Creek	Prior to WY2015	6 PCB; 5 Hg	0	NA	0
Zone 4 Line A	Prior to WY2015	69 PCB; 94 Hg	0	NA	0
Zone 5 Line M	Prior to WY2015	4	0	NA	0
Charcot Ave Storm Drain	WY2015	0	1	6	1
E. Gish Rd Storm Drain	WY2015	0	1	5	0
Gateway Ave Storm Drain	WY2015	0	1	6	0
Line 3A-M-1 at Industrial Pump Station	WY2015	0	1	6	0
Line 4-B-1	WY2015	0	1	5	0
Line 9-D	WY2015	0	1	8	0
Line-3A-M at 3A-D	WY2015	0	1	5	0
Line4-E	WY2015	0	1	6	0
Lower Penitencia Creek	WY2015	0	1	7	0
Meeker Slough	WY2015	0	1	6	0
Oddstad Pump Station	WY2015	0	1	6	0
Outfall to Lower Silver Creek	WY2015	0	1	5	1
Ridder Park Dr Storm Drain	WY2015	0	1	5	0
Rock Springs Dr Storm Drain	WY2015	0	1	5	0
Runnymede Ditch	WY2015	0	1	6	0
Seaboard Ave Storm Drain SC-050GAC580	WY2015	0	1	5	0
Seaboard Ave Storm Drain SC-050GAC600	WY2015	0	1	5	0
South Linden Pump Station	WY2015	0	1	5	0
Storm Drain near Cooley Landing	WY2015	0	1	6	1

## WYs 2015 through 2019 POC Reconnaissance Monitoring

Catchment	Year Sampled	Discrete Grabs	Composite Samples	Number of Aliquots per composite sample	Remote Sample
Veterans Pump Station	WY2015	0	1	5	0
Condensa St SD	WY2016	0	1	6	0
Duane Ct and Ave Triangle SD	WY2016	0	1	5	0
Duane Ct and Ave Triangle SD	WY2016	0	1	3	1
E Outfall to San Tomas at Scott Blvd	WY2016	0	1	6	0
Forbes Blvd Outfall	WY2016	0	1	5	1
Gull Dr Outfall	WY2016	0	1	5	0
Gull Dr SD	WY2016	0	1	5	0
Haig St SD	WY2016	0	1	6	0
Industrial Rd Ditch	WY2016	0	1	4	0
Lawrence & Central Expwys SD	WY2016	0	1	3	0
Line 13A at end of slough	WY2016	0	1	7	0
Line 9D1 PS at outfall to Line 9D	WY2016	0	1	8	0
Outfall at Gilman St.	WY2016	0	1	9	0
Taylor Way SD	WY2016	0	1	5	1
Tunnel Ave Ditch	WY2016	0	1	6	1
Valley Dr SD	WY2016	0	1	6	0
Victor Nelo PS Outfall	WY2016	0	1	9	1
Zone 12 Line A under Temescal Ck Park	WY2016	0	1	8	0
Line 12H at Coliseum Way	WY2017	0	1	3	0
Outfall to Colma Ck on service rd nr Littlefield Ave. (359)	WY2017	0	1	2	1
S Linden Ave SD (291)	WY2017	0	1	7	0
Austin Ck at Hwy 37	WY2017	0	1	6	1
Line 12I at Coliseum Way	WY2017	0	1	3	0
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	WY2017	0	1	4	0
Line 12M at Coliseum Way	WY2017	0	1	4	0
Line 12F below PG&E station	WY2017	0	1	3	0
Rosemary St SD 066GAC550C	WY2017	0	1	5	0
North Fourth St SD 066GAC550B	WY2017	0	1	5	0
Line 12K at Coliseum Entrance	WY2017	0	1	4	0
Colma Ck at S. Linden Blvd	WY2017	0	1	5	0
Line 12J at mouth to 12K	WY2017	0	1	3	0
S Spruce Ave SD at Mayfair Ave (296)	WY2017	0	1	8	0
Guadalupe River at Hwy 101	WY2017	0	0	7	0
Refugio Ck at Tsushima St	WY2017	0	1	6	1
Rodeo Creek at Seacliff Ct. Pedestrian Br.	WY2017	0	1	7	1
East Antioch nr Trembath	WY2017	0	1	6	0
Outfall at Gilman St.	WY2018	0	1	5	1
Zone 12 Line A at Shellmound	WY2018	0	1	6	0
Meeker Slough	WY2018	0	1	5	0
MeekerWest	WY2018	0	1	5	1
Little Bull Valley	WY2018	0	1	2	0
Kirker Ck at Pittsburg Antioch Hwy and Verne Roberts Cir	WY2018	0	1	5	0
Gull Dr Outfall	WY2018	0	1	6	0
Gull Dr SD	WY2018	0	1	5	0
GR outfall 066GAC850	WY2018	0	1	4	0
GR outfall 066GAC900	WY2018	0	1	4	0
SC100CTC400A	WY2019	0	1	5	0

# WYs 2015 through 2019 POC Reconnaissance Monitoring

Catchment	Year Sampled	Discrete Grabs	Composite Samples	Number of Aliquots per composite sample	Remote Sample
SC100CTC500A	WY2019	0	1	5	0
Line 12M at Coliseum Way	WY2019	0	1	4	0
Rodeo Creek	WY2019	0	1	5	0
SMBUR164A	WY2019	0	1	4	0
SMBUR85A	WY2019	0	1	4	0
Bay Point	WY2019	0	0	NA	1
Mount Diablo Creek	WY2019	0	0	NA	1
Wildcat Creek	WY2019	0	0	NA	1