clean water
PROGRAM

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Protecting Alameda County Creeks, Wetlands & the Bay

March 16, 2015

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

SUBJECT: **SUBMITTAL OF THE ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM URBAN CREEKS MONITORING REPORT**

Dear Bruce:

As you know, various submission and reporting provisions of the Municipal Regional Stormwater Permit (MRP) authorize Permittee implementation and compliance though coordination of the countywide stormwater programs. The member agency Permittees of the Alameda Countywide Clean Water Program (ACCWP) through their Management Committee, and in conformance with the Memorandum of Agreement signed by their governing bodies, have authorized and directed me to prepare and submit certain reports as part of their compliance with submission of MRP-required reports.

Therefore, with this letter, I am submitting this ACCWP Urban Creeks Monitoring Report on behalf of and for the benefit of the ACCWP member agency Permittees. By signing this letter on behalf of ACCWP, I certify under penalty of law that these documents and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who managed the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations. [40CFR 122.22(d)]

Sincerely,

James Scanlin
Program Manager

Attachments: Certification Statement (1 page)
ACCWP Urban Creeks Monitoring Report

Certification Statement

Report components

This submittal by the Alameda Countywide Clean Water Program includes the main body of the Urban Creeks Monitoring Report for October 2013 through September 2014 and the following appendices:

- A.1 Creek Status Monitoring Report - Regional Parameters
- A.2 Creek Status Monitoring Report -Targeted Parameters
- A.3 Pollutants of Concern (POC) Loads Monitoring Progress Report, Water Years (WYs) 2012, 2013, and 2014

Third party monitoring

Please note that consistent with provision C.8.a.iv of the MRP, two water quality monitoring requirements were fulfilled or partially fulfilled by third party monitoring in Water Year 2014:

- As described in Section 5.1 of the attached Urban Creeks Monitoring Report, the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) conducted a portion of the data collection in Water Year 2013 on behalf of Permittees, pursuant to provision C.8.e – pollutants of concern loads monitoring (i.e., Table 8.4, Categories 1 and 2). The results of that monitoring are reported in Appendix A.3 of the attached Urban Creeks Monitoring Report. The Electronic Data submittal to the Water Board (and the California Environmental Data Exchange Network) of all data collected from all stations monitored by both permit fees and the RMP in Water Year 2014 pursuant to this provision is planned for spring 2015 following completion of final quality assurance review.

- Additionally, as noted in Section 5.2 of the Urban Creeks Monitoring Report, data collected pursuant to provision C.8.e.iii (Long-term Monitoring – Table 8.4 – Category 3) was initiated by the State of California's Surface Water Ambient Monitoring Program (SWAMP) through its Stream Pollutant Trend Monitoring Program at two locations identified in Table 8.3 of the MRP. As stated in provision C.8.e.iii Permittees may use these data to comply with the monitoring requirements included in this provision. The schedule for SWAMP's review and reporting of data collected pursuant to this provision, however, differs from the schedule described in the MRP.

Per MRP provision C.8.a.iv the Permittees requested in March 2013 that the Executive Officer adjust the MRP due dates for these reporting deliverables to synchronize with the third party reporting schedules of SWAMP and the RMP, beginning with Water Year 2012 and continuing into all future years covered under the MRP.

ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM

URBAN CREEKS MONITORING REPORT

OCTOBER 2013 THROUGH SEPTEMBER 2014

MEMBER AGENCIES:
Alameda
Albany
Berkeley
Dublin
Emeryville
Fremont
Hayward
Livermore
Newark
Oakland
Piedmont
Pleasanton
San Leandro
Union City
County of Alameda
Alameda County Flood Control and Water Conservation District
Zone 7 Water Agency

Report prepared by
Alameda Countywide Clean Water Program
399 Elmhurst Street,
Hayward, California 94544

Submitted to:
California Regional Water Quality Control Board, San Francisco Bay Region

FINAL
March 16, 2015

ACKNOWLEDGEMENTS

ACCWP acknowledges the contributions of EOA, Inc. in assisting the preparation of the POC Loads Monitoring Section, and Gretel Silyn Roberts for assistance with the Quality Assurance review for Creek Status Monitoring. Additional acknowledgements for specific Appendices are included in those documents.

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LIST OF ATTACHMENTS

Attachment A. Electronic Data Submittal Transmittal Letter dated January 15, 2015 with attached file list and preliminary evaluation relative to applicable Water Quality Standards.

LIST OF APPENDICES

A.1 Creek Status Monitoring Report - Regional Parameters

A.2 Creek Status Monitoring Report -Targeted Parameters

A3 Pollutants of Concern (POC) Loads Monitoring Progress Report, Water Years (WYs) 2012, 2013, and 2014

LIST OF ACRONYMS

Acronym	Definition
AMS	Applied Marine Sciences
ACCWP	Alameda Countywide Clean Water Program
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	Benthic Index of Biological Integrity
BMI	Benthic Macroinvertebrate
CEDEN	California Environmental Data Exchange Network
CSCI	California Stream Condition Index
DO	Dissolved oxygen
MRP	Municipal Regional Stormwater Permit
NPDES	National Pollutant Discharge Elimination System
QAPP	Quality Assurance Project Plan
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program for Water Quality in San Francisco Bay
RWQCB	Regional Water Quality Control Board
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SSID	Stressor/Source Identification
SOP	Standard Operating Procedure
SWAMP	Surface Water Ambient Monitoring Program
USA	Unified Stream Assessment
WY	Water Year
ABL	Aquatic Bioassessment Laboratory
CL	Control Limit
DOC	Dissolved Organic Carbon
E. coli	Escherichia coli
EDD	Electronic Data Deliverable
LDM	Local Data Manager
LQAO	Local Quality Assurance Officer
MS	Matrix Spike
MSD	Matrix Spike Duplicate
PSD	Particle Size Distribution
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QAO	Quality Assurance Officer
RL	Reporting Limit
RPD	Relative Percent Difference
RWQCB	Regional Water Quality Control Board
SCL	Soil Control Lab
SSC	Suspended Sediment Concentration
TOC	Total Organic Carbon

SECTION 1 - INTRODUCTION

This Urban Creeks Monitoring Report (UCMR) is submitted by the Alameda Countywide Clean Water Program (Program, ACCWP), on behalf of all towns, cities, counties and flood control agencies represented by the Program[1] (i.e., Permittees) subject to the Municipal Regional Stormwater NPDES Permit (MRP, Order R2009-0074) issued by the San Francisco Regional Water Quality Control Board (Water Board) on October 14, 2009. This report (including all appendices and attachments) fulfills the requirements of MRP Provision C.8.g for interpreting and reporting monitoring data collected during Water Year 2014 (October 1, 2013 - September 30, 2014). Monitoring data presented in this report were submitted electronically to the Water Board by the Program on behalf of the represented Permittees and may be obtained via the San Francisco Bay Area Regional Data Center of the California Environmental Data Exchange Network (CEDEN) at http://www.ceden.org/.

This report is organized into two main parts – the main body and appendices. The main body provides brief summaries of accomplishments made in Water Year 2014 in compliance with MRP provision C.8. Summaries are organized by sub-provisions of the MRP and grouped into the following sections:

1 Introduction
2 San Francisco Estuary Receiving Water Monitoring
3 Creek Status Monitoring
4 Monitoring Projects
5 Pollutants of Concern and Long-Term Trends Monitoring
6 Citizen Monitoring and Participation
7 Reporting, Monitoring Protocols, and Data Quality

Appendices include data analyses for interpretive reporting focused on specific types of water quality monitoring required by the MRP. Appendices are also grouped together by sub-provision and referenced within the applicable sections of the report's main body.

The main body of this report and associated appendices address the following reporting requirements for the annual Urban Creeks Monitoring Report (Provision C.8.g.iii) including as appropriate for each type of monitoring in Provision C.8:

- Descriptions of monitoring purpose and study design rationale
- QA/QC summaries for sample collection and analytical methods, including a discussion of any limitations of the data;
- Descriptions of sampling protocols and analytical methods;
- Tables and Figures describing: Sample location descriptions (including waterbody names, and lat/longs); sample ID, collection date (and time where

[1] The Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and Zone 7 Water Agency.

relevant), media (e.g., water, filtered water, bed sediment, tissue); concentrations detected, measurement units, and detection limits;
- Data assessment, analysis, and interpretation for Provision C.8.c.;
- Pollutant load and concentration at each mass emissions station;
- A listing of volunteer and other non-Permittee entities whose data are included in the report;
- Assessment of compliance with applicable water quality standards; and,
- A signed certification statement.

Regional collaborative monitoring (BASMAA RMC)

Provision C.8.a (Compliance Options) of the MRP allows Permittees to address monitoring requirements through a "regional collaborative effort," their Stormwater Program, and/or individually. In June 2010, Permittees notified the Water Board in writing of their agreement to participate in a regional monitoring collaborative to address requirements in Provision C.8[2]. The regional monitoring collaborative is referred to as the Bay Area Stormwater Management Agencies (BASMAA) Regional Monitoring Coalition (RMC). With notification of participation in the RMC, Permittees were required to commence water quality data collection by October 2011. In a November 2, 2010 letter to the Permittees, the Water Board's Assistant Executive Officer (Thomas Mumley) acknowledged that all MRP Permittees have opted to conduct monitoring required by the MRP through a regional monitoring collaborative, i.e. the BASMAA RMC.

In February 2011, the RMC developed a Multi-Year Work Plan (RMC Work Plan) to provide a framework for implementing regional monitoring and assessment activities required under MRP provision C.8. The RMC Work Plan summarizes RMC projects planned for implementation between Fiscal Years 2009-10 and 2014-15. Projects were collectively developed by RMC representatives to the BASMAA Monitoring and Pollutants of Concern Committee (MPC), and were conceptually agreed to by the BASMAA Board of Directors (BOD). A total of 27 regional projects are identified in the RMC Work Plan, based on the requirements described in provision C.8 of the MRP.

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

[2] See Appendix A.1 for a list of all participants in the RMC.

SECTION 2 - SAN FRANCISCO ESTUARY RECEIVING WATER MONITORING (C.8.b)

As described in MRP provision C.8.b, Permittees are required to provide financial contributions towards implementing an Estuary receiving water monitoring program on an annual basis that at a minimum is equivalent to the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Since the adoption of the MRP, Permittees have complied with this provision by making financial contributions to the RMP directly or through stormwater programs (Table A - 1). Additionally, Permittees actively participated in RMP committees and work groups through Permittee and/or stormwater program staff as described in the following sections, which also provide a brief description of the RMP and associated monitoring activities conducted during this reporting period.

Table A - 1. Stormwater Program annual contributions to the Regional Monitoring Program for Water Quality in the San Francisco Bay Estuary in 2013 by MRP-related Programs

RMC Participant	2013 Contribution
Santa Clara Valley Urban Runoff Pollution Prevention Program	$177,950
Alameda Countywide Clean Water Program	$170,491[3]
Contra Costa Clean Water Program	$139,457
San Mateo Countywide Water Pollution Prevention Program	$84,303
Vallejo Sanitation and Flood Control District	$12,826
Fairfield-Suisun Urban Runoff Management Program	$15,041
Total	**$600,068**

The RMP is a long-term monitoring program that is discharger funded and shares direction and participation by regulatory agencies and the regulated community with the goal of assessing water quality in the San Francisco Bay.[4] The regulated community includes Permittees, publicly owned treatment works (POTWs), dredgers and industrial dischargers. The RMP is intended to answer the following core management questions:

- Are chemical concentrations in the Estuary potentially at levels of concern and are associated impacts likely?
- What are the concentrations and masses of contaminants in the Estuary and its segments?
- What are the sources, pathways, loadings, and processes leading to contaminant related impacts in the Estuary?

[3] ACCWP's 2014 contribution was $173,876.

[4] RMP Annual Work Plans can be found at www.sfei.org/rmp/what.

- Have the concentrations, masses, and associated impacts of contaminants in the Estuary increased or decreased?
- What are the projected concentrations, masses, and associated impacts of contaminants in the Estuary?

The RMP budget is generally broken into two major program elements: Status and Trends, and Pilot/Special Studies. The following paragraphs provide a brief overview of these programs.

RMP Status and Trends Monitoring Program

The Status and Trends Monitoring Program (S&T Program) is the long-term contaminant-monitoring component of the RMP. The S&T Program was initiated as a pilot study in 1989 and redesigned in 2007 based on a more rigorous statistical design that enables the detection of trends. In Water Year 2014 the S&T Program was comprised of the following program elements that collect data to address RMP management questions described above:

- Water/Sediment/Biota Chemistry and Toxicity Monitoring
- Sediment Benthos Monitoring
- Small and Large Tributary Loading Studies and Small Fish and Sport Fish Contamination Studies
- Studies to Determine the Causes of Sediment Toxicity
- Suspended Sediment, Hydrography and Phytoplankton Monitoring
- Bird Egg Monitoring

In fall 2011 the RMP Steering Committee, as part of a 5-year Master Planning process reviewed the S&T Program and agreed to reduce the frequency of some of data collection activities or elements in future years so that more funding will be available for pilot and special studies. Additional information on the S&T Program and associated monitoring data are available for downloading via the RMP website using the Status and Trends Monitoring Data Access Tool at www.sfei.org/rmp/data.htm.

RMP Pilot and Special Studies

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

In Water Year 2014, a considerable amount of RMP and Stormwater Program staff time was spent in overseeing and implementing special studies associated with the RMP's Small Tributary Loading Strategy (STLS) and the STLS Multi-Year Monitoring Plan (MYP). Pilot and special studies associated with the STLS are intended to fill data gaps associated with loadings of Pollutants of Concern (POC) from relatively small tributaries to the San Francisco Bay. Additional information is provided on STLS-related studies under section C.8.e (POC and Long-Term Trends Monitoring) of this Report.

Participation in Committees, Workgroups and Strategy Teams

In Water Year 2014, RMC Permittees actively participated in the following RMP Committees and work groups:

- Steering Committee (SC)
- Technical Review Committee (TRC)
- Sources, Pathways and Loadings Workgroup (SPLWG)
- Contaminant Fate Workgroup (CFWG)
- Exposure and Effects Workgroup (EEWG)
- Emerging Contaminant Workgroup (ECWG)
- Sport Fish Monitoring Workgroup
- Toxicity Workgroup
- Strategy Teams (e.g., PCBs, Mercury, Dioxins, Small Tributaries, Nutrients)

Committee and workgroup representation was provided by Permittee or stormwater program staff and/or individuals designated by RMC participants and the BASMAA BOD. During Water Year 2014ACCWP Program staff actively participated in the SPLWG, EEWG and the Small Tributaries Loading Strategy Work Group (see Section 5 below). Representation included participating in meetings, reviewing technical reports and work products, reviewing articles included in the RMP's Pulse of the Estuary, and providing general program direction to RMP staff. RMC representatives to the RMP also provided timely summaries and updates to other stormwater program representatives (on behalf of Permittees) during MPC and/or BOD meetings and solicited timely input as needed to ensure Permittees' interests were adequately represented.

SECTION 3 - CREEK STATUS MONITORING (C.8.c)

Provision C.8.c requires Permittees to conduct creek status monitoring that is intended to answer the following management questions:

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

Creek status monitoring parameters, methods, occurrences, durations and minimum number of sampling sites for each stormwater program are described in Table 8.1 of the MRP. Based on the implementation schedule described in MRP Provision C.8.a.ii, creek status monitoring coordinated through the RMC began in October 2011.

Regional and Local Monitoring Designs

The RMC's regional monitoring strategy for complying with MRP provision C.8.c - Creek Status Monitoring is described in its *Creek Status and Long-Term Trends Monitoring Plan* (BASMAA 2011). The strategy includes a regional ambient/probabilistic monitoring component and a component based on local "targeted" monitoring. The combination of these monitoring designs allows each individual RMC participating program to assess the status of beneficial uses in local creeks within its Program (jurisdictional)area, while also contributing data to answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks)[5].

The Program submitted its Creek status monitoring data for Water Year 2014to the Water Board by January 15, 2013 and January 15, 2014, respectively. The analyses of results from Creek Status Monitoring conducted by the Program in Water Year 2014are presented in Appendices A.1, and A.2 to this report, Table A - 2provides a list of which Creek Status monitoring parameters are included in the respective program-specific and jointly produced appendices.

Table A - 2.Location of monitoring result analyses for each parameter in MRP Table 8.1.

Biological Response and Stressor Indicators	Monitoring Design		Reporting
	Regional Ambient (Probabilistic)	Local (Targeted)	
Bioassessment & Physical Habitat Assessment	X		Appendix A.1
Chlorine	X		Appendix A.1
Nutrients	X		Appendix A.1
Water Toxicity	X		Appendix A.1
Sediment Toxicity	X		Appendix A.1
Sediment Chemistry	X		Appendix A.1
General Water Quality		X	Appendix A.2
Temperature		X	Appendix A.2
Bacteria		X	Appendix A.2
Stream Survey		X	Appendix A.2

[5]MRP provision C.8.a.i states in reference to all subsections of C.8 that "provided these datatypes, quantities, and quality are obtained, a regional monitoring collaborative may develop its own sampling design".

SECTION 4 - MONITORING PROJECTS (C.8.d)

Three types of monitoring projects are required by provision C.8.d of the MRP:

- Stressor/Source Identification Projects (C.8.d.i);
- BMP Effectiveness Investigations (C.8.d.ii); and,
- Geomorphic Projects (C.8.d.iii).

The overall scopes of these projects are generally described in the MRP and the RMC Work Plan. Based on MRP compliance schedules and program-specific requirements for these provisions, the following sections provide brief summaries of RMC participant progress made in Water Year 2014towards on monitoring projects required by the MRP.

Stressor/Source Identification Projects

As described in the MRP, Permittees who conduct Creek Status monitoring through a regional collaborative shall be required to initiate no more than ten Stressor/Source Identification projects when monitoring results trigger a follow-up action as indicated in MRP Table 8.1. To ensure consistency in interpretation of the Stressor/Source ID requirements (C.8.d.i) and a coordinated approach to compliance with that provision, RMC Permittee efforts in Water Year 2013includededa collaborative evaluation of Water Year 2012 Creek Status monitoring results and joint decision-making process for selecting sites for Stressor/Source Identification (SSID) follow-up by individual programs. RMC Program representatives reviewed the list of candidate SSID projects with Water Board staff in the April 2013 meeting of the RMC Work Group.

In consultation with Permittees, the Program developed plans to initiate the first follow-up action for each SSID projects in FY2013-14, but no later than the second fiscal year after the sampling event that triggered the project. As required by MRP Provision C.8.d.i, this first step was to conduct a site specific study (or non-site specific if the problem is widespread) in a stepwise process to identify and isolate the cause(s) of the trigger stressor/source. Initial study design, data collection and results for the following stressor/source identification projects were provided in progress reports attached to the IMR:

- Dublin Creek: trigger results for biological community condition and sediment quality at probabilistic site 204R00084
- Castro Valley Creek: trigger results for sediment quality at probabilistic site 204R00047
- Crow Creek - trigger results for Low Dissolved Oxygen from General Water Quality measurements at targeted site 204CRW030

Subsequent follow-up steps involving identification, implementation, and evaluation of controls have been discussed with relevant stakeholders, and further monitoring is planned for the Crow Creek system to evaluate the contributions of upstream (non-urban) factors to the low DO.

BMP Effectiveness Investigation

The MRP requires Permittees to investigate the effectiveness of one Best Management Practice (BMP) for stormwater treatment or hydrograph modification control. ACCWP Permittees are addressing this project through monitoring of a BMP that is also being used to fulfill provisions C.11.e and C.12.e, as allowed by provision C.8.d.ii. A pair of media filters for stormwater treatment are to be retrofitted at the Ettie Street Pump Station (ESPS) in Oakland with funding from a grant to BASMAA for the Clean Watersheds for a Clean Bay (CW4CB) project. As part of CW4CB Task 5, a consultant team prepared an effectiveness monitoring design for 8-10 pilot retrofit projects located throughout the jurisdictions of all MRP Permittees, which is limited to evaluating removal of mercury and PCBs. ACCWP has committed to implement the CW4CB monitoring design in WY2015 and also designed supplemental monitoring which will include additional analyses to address the full range of pollutants generally found in urban runoff.

Geomorphic Project

MRP provision C.8.d.iii requires Permittees to conduct one of three types of projects within Alameda County to answer the question: How and where can our creeks be restored or protected to cost-effectively reduce the impacts of pollutants, increased flow rates, and increased flow durations of urban runoff?

As discussed in the IMR, the Permittees collaborated with Community Conservation Solutions on the Green Solution Project to address the MRP project option in provision C.8.d.iii(2) to inventory locations for potential retrofit projects in which decentralized landscape-based stormwater retention units can be installed.

SECTION 5 - POC AND LONG-TERM TRENDS MONITORING (C.8.e)

5.1 POC LOADS MONITORING

Pollutants of Concern (POC) loads monitoring is required by provision C.8.e.i of the MRP. Loads monitoring is intended to assess inputs of POCs to the Bay from local tributaries and urban runoff, assess progress toward achieving wasteload allocations (WLAs) for TMDLs, and help resolve uncertainties associated with loading estimates for these pollutants. In particular, there are four priority management questions that need to be addressed though POC loads monitoring:

1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs?
2. What are the annual loads or concentrations of POCs from tributaries to the Bay?

3. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay? and,
4. 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?

To assist participants in effectively and efficiently conducting POC loads monitoring required by the MRP and answer POC loads management questions listed above, an RMP Small Tributaries Loading Strategy (STLS) was developed in 2009 by the STLS Team, which included representatives from BASMAA, Water Board staff, RMP/SFEI and technical advisors. The objective of the STLS is to develop a comprehensive planning framework to coordinate POC loads monitoring/modeling between the RMP and RMC participants. This framework and a summary of activities and products to date are provided in the STLS Multi-Year Plan (STLS-MYP). With concurrence of participating Water Board Staff, the STLS-MYP presents an alternative approach to the POC loads monitoring requirements described in MRP Provision C.8.e.i, as allowed by Provision C.8.e. The most recent version of the STLS Multi-Year Plan was appended to the BASMAA RMC's Urban Creeks Monitoring Report in 2013, with various appendices provided along with previous semi-annual Monitoring Status Reports. The main body of Version 2013 describes the major STLS elements, including recent activities summarized below.

RMC participant activities associated with POC loads monitoring during Water Year 2014focused on bottom-of-watershed monitoring and the continued development of a watershed pollutant load estimation model, both of which were coordinated through the STLS Team and the associated RMP Sources Pathways Loadings Work Group (SPLWG).

STLS Multi-Year Plan Activities

Based on the consensus of the STLS Team, RMC representatives in coordination with SFEI staff created the STLS Multi-Year Plan to assist Permittees in complying with provision C.8.e (POC Monitoring). The Multi-Year Plan is an alternative POC monitoring program to the one described in the MRP that equally addresses the management information needs described in the MRP. The alternative approach addresses the four core POC loads monitoring management questions, while integrating activities funded by BASMAA via the RMC with those funded by the RMP. The Multi-Year Plan provides a more comprehensive description and work plan for STLS activities on a 5 to10 year timeframe, including a detailed rationale for the methods and locations of proposed activities (e.g., POC loads monitoring in small tributaries).

The MYP includes four main elements that collectively address the four priority management questions for POC monitoring:

- Watershed modeling (Regional Watershed Spreadsheet Model);

- Bay Margins Modeling;
- Source Area Runoff Monitoring; and,
- Small Tributaries Monitoring

Previous MYP updates regarding STLS activities were provided in the Monitoring Status Report submitted to the Water Board in September 2012, and additional activities after July 2013 were summarized in the Urban Creeks Monitoring Report. The following paragraphs provide brief summaries of each of these elements and activities conducted during the period from October 2013 through September 2014:

Watershed Modeling – In Water Year 2014 the Permittees continued oversight of the Regional Watershed Spreadsheet Model development via the STLS Team and RMP Sources, Pathways and Loading Work Group (SPLWG). Program staff participated in review of -initial modeling results for PCBs and mercury and discussions of possible incremental enhancements to address multiple sources of uncertainty and limited availability of data for calibration.

Bay Margins Modeling –In WY2014 Program staff contributed to BASMAA review and comment of a PCB Strategy document for the RMP. The Strategy proposed a pilot study to develop Bay Margin conceptual models and sediment mass balances for one or two high Priority Margin Units where PCB impacts on the local foodweb may be significant. The RMP approved 2015 funding for this project, which also will outline a multi-year workplan in support of an anticipated future update of the PCB TMDL.

Source Area Runoff Monitoring – This element of the STLS is intended as a placeholder for studies to develop Event Mean Concentrations (EMCs) of POCs to parameterize the Regional Watershed Model.

Small Tributaries Watershed Monitoring – For this STLS element, the approach outlined in the Multi-Year Plan consists of intensively monitoring a total of six "bottom-of-watershed" stations, over several years to accumulate samples needed to calibrate the watershed model and assist in developing loading estimates from small tributaries for priority POCs. Monitoring is also intended to provide a more limited characterization of additional lower priority analytes. Monitoring was initiated in Water Years 2012 or 2013 at the following watershed stations:

- Lower Marsh Creek(Contra Costa County) in WY2012
- Guadalupe River (Santa Clara County) in WY2012
- Lower San Leandro Creek (Alameda County) in WY2012
- Sunnyvale East Channel (Santa Clara County) in WY2012
- North Richmond Pump Station (Contra Costa County) in WY2013
- Pulgas Pump Station (San Mateo County) in WY2013

SFEI operation of the Lower San Leandro Creek Station was begun in WY2012 by SFEI and continued by ACCWP starting in WY2013.

Monitoring methods and laboratory analyses according to the descriptions in the STLS Multi-Year Plan are documented in a Field Manual and Quality Assurance

Project Plan, currently under development as a BASMAA regional project. These documents are expected to be completed in Water Year 2014. Table A - 3 summarizes the analytes and analytical laboratories used for all samples. For Water Year 2014, BASMAA continued contracting with SFEI to coordinate laboratory analyses, data management and data quality assurance, to ensure data consistency among all watershed monitoring stations.

Water Year 2014 Results

Progress results of Water Year 2014 POC Monitoring conducted by the STLS team are included in Appendix A.3. A summary of ACCWP's POC monitoring activities conducted during this period are described below.

Table A - 3. Laboratory analysis methods used by the STLS team for POC (loads) monitoring in Water Year 2014.

Analyte	Analytical Method[1]	Analytical Laboratory
Carbaryl	EPA 632M	CA Dept. Fish & Wildlife WPCL
Fipronil	EPA 619M	CA Dept. Fish & Wildlife WPCL
Suspended Sediment Concentration	ASTM D3977	Caltest Analytical Laboratory
Total Phosphorus	(EBMUD 488 Phosphorus) SM20 4500-P E	Caltest Analytical Laboratory
Nitrate	(EPA 300.1) EPA 353.2	Caltest Analytical Laboratory
Dissolved Orthophosphate	(EPA 300.1) SM20 4500-P E	Caltest Analytical Laboratory
PAHs	AXYS MLA-021 Rev 10	AXYS Analytical Services Ltd.
PBDEs	AXYS MLA-033 Rev 06	AXYS Analytical Services Ltd.
PCBs	AXYS MLA-010 Rev 11	AXYS Analytical Services Ltd.
Pyrethroids	AXYS MLA-046 Rev 04	Caltest Analytical Laboratory
Total Methylmercury	EPA 1630M	Caltest Analytical Laboratory
Total Mercury	EPA 1631EM	Caltest Analytical Laboratory
Copper	EPA 1638M	Caltest Analytical Laboratory
Selenium	EPA 1638M	Caltest Analytical Laboratory
Total Hardness	EPA 1638M	Caltest Analytical Laboratory
Total Organic Carbon	{SM 5310 C) SM20 5310B	Caltest Analytical Laboratory

<u>Comparisons to Numeric Water Quality Objectives/Criteria for Specific Analytes</u>

Provision C.8.g.iii requires RMC participants to assess all data collected pursuant to provision C.8 for compliance with applicable water quality standards. In compliance with this requirement, an assessment of data collected at ACCWP's POC monitoring station at San Leandro Creek in Water Year 2014 is provided in the following section.[6]

When conducting a comparison to applicable water quality objectives/criteria, certain considerations should be taken into account to avoid the mischaracterization of water quality data:

Freshwater vs. Saltwater- POC monitoring data were collected in freshwater receiving water bodies above tidal influence and therefore comparisons were made to freshwater water quality objectives/criteria.

Aquatic Life vs. Human Health - Comparisons were primarily made to objectives/criteria for the protection of aquatic life, not objectives/criteria for the protection of human health to support the consumption of water or organisms. This decision was based on the assumption that water and organisms are not likely being consumed from the creeks monitored.

Acute vs. Chronic Objectives/Criteria - For POC monitoring required by provision C.8.e, data were collected in an attempt to develop more robust loading estimates from small tributaries. Therefore, detecting the concentration of a constituent in any single sample was not the primary driver of POC monitoring. Monitoring was conducted during episodic storm events and results do not likely represent long-term (chronic) concentrations of monitored constituents. POC monitoring data were therefore compared to "acute" water quality objectives/criteria for aquatic life that represent the highest concentrations of an analyte to which an aquatic community can be exposed briefly (e.g., 1-hour) without resulting in an unacceptable effect. For analytes for which no water quality objectives/criteria have been adopted, comparisons were not made.

It is important to note that acute water quality objectives or criteria have only been promulgated for a small set of analytes collected at the POC monitoring station. These include objectives for trace metals (i.e., copper, selenium and total mercury). Table A - 4 provides a comparison of data collected in WY2014 to applicable numeric water quality objectives/criteria adopted by the San Francisco Bay Water Board or the State of California for these analytes.

All samples collected in WY2014 were below applicable numeric water quality objectives (i.e., freshwater acute objective for aquatic life) for copper, mercury and selenium. Stormwater management activities are currently underway for copper (via MRP provision C.13), mercury (via MRP provision C.11), and selenium (via MRP provision C.14).

For all other analytes measured via POC monitoring (e.g., pyrethroid pesticides and polycyclic aromatic hydrocarbons), the State of California has yet to adopt numeric water quality objectives applicable to beneficial uses of interest. For these analytes,

[6] An assessment of data collected in compliance with provision C.8.c (Creek Status Monitoring) is provided in Appendices A.1 and A.2.

an assessment of compliance of applicable water quality standards cannot be conducted at this time.

Table A - 4. Comparison of WY2014 POC (loads) monitoring data collected by ACCWP in San Leandro Creek to applicable numeric water quality objectives and criteria.

Analyte	Fraction	Freshwater Acute Water Quality Objective for Aquatic Life[a]	Unit	# Samples > Objective
Copper	Dissolved	13[b]	µg/L	0/4
Selenium	Total	20	µg/L	0/4
Mercury	Total	2.1	µg/L	0/16

[a] San Francisco Bay Water Quality Control Plan (SFRWQCB 2011)
[b] The copper water quality objective is dependent on hardness; therefore, comparisons were made based on hardness values of samples collected synoptically with samples analyzed for copper. The objective presented in the table is based on a hardness of 100 mg/L.

Summary of Toxicity Testing Results

In addition to comparisons of data for specific analytes, the results of toxicity testing conducted on water samples collected during storm events in Water Year 2014were evaluated in the context of adopted water quality objectives. Toxicity testing was conducted at each POC monitoring station using four different types of test organisms:

- *Pimephales promelas* (freshwater fish)
- *Hyalella azte*ca (amphipod)
- *Ceriodaphnia dubia* (crustacean)
- *Selenastrum capricornutum* (alga)

Both acute and chronic endpoints were recorded. A summary of toxicity results is presented in

Table A - 5.

Table A - 5. Summary of WY2014 toxicity testing results for samples collected at the San Leandro Creek monitoring station.

	Pimephales promelas		***Hyalella azteca***	***Ceriodaphnia dubia***		***Selenastrum capricornutum***
	Significant Reduction in Survival	**Significant Reduction in Growth**	**Significant Reduction in Survival**	**Significant Reduction in Survival**	**Significant Reduction in Reproduction**	**Significant Reduction in Growth**
Samples with Significant Toxicity	0/4	0/4	**4/4**	0/4	0/4	0/4
% of Samples with Significant Toxicity	0%	0%	**100%**	0%	0%	0%

Of the organisms exposed to water collected from the San Leandro POC monitoring stations in WY2014, consistent toxicity was only observed for the amphipod Hyalella azteca (100% of samples). For all other organisms, no toxic endpoints were observed in WY2014.

Observations of toxicity to H. azteca are similar to those from recent wet weather monitoring conducted in Southern California (Riverside County 2007, Weston Solutions 2006), the Imperial Valley (Phillips et al. 2007), the Central Valley (Weston and Lydy 2010), and the Sacramento-San Joaquin Delta (Werner et al., 2010), where follow up toxicity identification evaluations indicated that pyrethroid pesticides were almost certainly the cause of the toxicity observed. Based on recent studies conducted in California receiving waters, pyrethroid pesticides have also been identified as the likely current causes of sediment toxicity in urban creeks (Ruby 2013, Amweg et al. 2005, Weston and Holmes 2005, Anderson et al. 2010). These results are not unexpected given that H. azteca is considerably more sensitive to pyrethroids than other species tested as part of the POC monitoring studies (Palmquist 2008).

To further explore the potential causes of toxicity to *H. azteca* in the four samples, pyrethroid concentrations in samples collected at the same time as toxicity samples were compiled and compared to thresholds (i.e., LC50s) known to be lethal to H. azteca. LC50s were identified through a review of the scientific literature and are only available for a limited number of types of pyrethroids[7]. The results of these comparisons are provided in Table A - 6.

Results suggest that the concentration of cyfluthrin was above levels known to cause significant reduction in the survival to H. azteca. Specifically, observed

[7] Adverse effects concentrations for pyrethroids presented in Table 5.4 are not adopted water quality objectives and should not be used to draw conclusions about compliance with water quality standards. The comparison contained in this table is only intended to facilitate an evaluation of the potential need for further evaluation of the stressors causing the toxicity.

concentrations of cyfluthrin were greater than LC50s in three of the four water quality samples collected at the same time that significant toxicity was observed.

Given the results of previous toxicity studies conducted in receiving waters throughout California, it appears likely that pyrethroids could have caused toxicity to *H. azteca* observed at the San Leandro Creek POC station. Management actions designed to reduce the impacts of pesticide-related toxicity are outlined in the TMDL and Water Quality Attainment Strategy for Diazinon and Pesticide-related Toxicity in Urban Creeks, and are currently underway via provision C.9 of the MRP.

Table A - 6. Water quality samples from San Leandro Creek with observed toxicity to Hyalella azteca and concentrations of pesticides detected.

Sample Date	Mean % Survival *H. azteca*	Bifenthrin (ng/L)	Cyfluthrin (ng/L)	Cypermethrin (ng/L)	Delta/ Tralomethrin (ng/L)	Esfenvalerate (ng/L)	Permethrin (ng/L)	Carbaryl (ng/L)
	LC50 (ng/L)	**7.7[a]**	**2.3[a]**	**2.3[a]**	**10[b]**	**8[c]**	**48.9[d]**	**2100[e]**
2/6/14	2%	2.9	1.3[f]	0.4[f]	--	--	--	18[f]
2/9/14	24%	3.7	**2.4**	0.4[f]	--	--	--	11[f]
2/27/14	74%	3.9	**3.7**	0.8[f]	--	--	--	11[f]
2/28/14	84%	6.5	**4.7**	0.9[f]	--	0.2[f]	4.2[f]	---

[a] As reported by D. Weston, University of California, Berkeley.
[b] LC50 values for *Hyalella Azteca* unavailable. LC50 values listed are for Daphnia magna as reported by Xiu et al. (1989)
[c] Werner et al., unpublished
[d] Brander et al. (2009)
[e] USEPA (2012)
[f] Measurement less than reporting limit
Dashes represent concentrations less than method detection limits.
Bold values exceed the LC50

5.2 Long-Term Trends Monitoring (C.8.e)

In addition to POC loads monitoring, Provision C.8.e requires Permittees to conduct long-term trends monitoring to evaluate if stormwater discharges are causing or contributing to toxic impacts on aquatic life. Required long-term monitoring parameters, methods, intervals and occurrences are included as Category 3 parameters in Table 8.4 of the MRP, and prescribed long-term monitoring locations are included in Table 8.3. Similar to creek status and POC loads monitoring, long-term trends monitoring was scheduled to begin in October 2011 for RMC participants.

As described in the *RMC Creek Status and Trends Monitoring Plan* (BASMAA 2011), the State of California's Surface Water Ambient Monitoring Program (SWAMP) through its Statewide Stream Pollutant Trend Monitoring (SPoT) Program currently monitors the seven long-term monitoring sites required by Provision C.8.e.ii. Sampling via the SPoT program is currently conducted at the sampling interval and for parameters as described in Provision C.8.e.iii in the MRP. The SPoT program is generally conducted to answer the management question:

- **What are the long-term trends in water quality in creeks?**

Based on discussions with Region 2 SWAMP staff, RMC participants intend to comply with MRP provision C.8.e that are associated with long-term trends via monitoring conducted by the SPoT program. This manner of compliance is consistent with the MRP language in provision C.8.e.ii. The most recent SPoT program technical report covers data collected from 2008-2012 (Phillips et al., 2014). RMC representatives will continue to coordinate with the SPoT program on long-term monitoring to ensure MRP monitoring and reporting requirements are addressed[8]. Additional information on the SPoT program can be found at
http://www.waterboards.ca.gov/water_issues/programs/swamp/spot/

5.3 Sediment Delivery Estimate / Budget (C.8.e.vi) and Emerging Pollutants Work Plan (C.8.e.vii)

Provision C.8.e.vi of the MRP requires Permittees to develop a design for a robust sediment delivery estimate/sediment budget in local tributaries and urban drainages, and implement the study by July 1, 2012. The purpose of the sediment delivery estimate is to improve the Permittees' ability to estimate urban runoff contributions to loads of POCs, most of which are closely associated with sediment. To determine a strategy for a robust sediment estimate/budget, BASMAA representatives reviewed recent sediment delivery estimates developed by the RMP, and determined that these objectives would be met effectively through sediment-specific submodeling with the Regional Watershed Spreadsheet Model (RWSM), under the ongoing oversight of the RMP Sources Pathways Loadings Work Group and the Small Tributaries Loading Strategy (STLS) Work Group.

The implementation of the sediment delivery/budget study was designed to occur in coordination with the STLS Multi-Year Plan, with funding from both the RMP and BASMAA regional projects. Sediment-specific model developments included:

- Literature-based refinement of land-use based Event Mean Concentrations;
- Development of a sub-model incorporating bedrock type, hillslope and convergence processes, and level /age of urbanization;
- Incorporation and calibration of specific watershed sediment loads calculated from available USGS gauge data or previous monitoring stations; and

[8]MRP Provision C.8.a.iv "Third Party Monitoring" states that where an existing third-party organization has initiated plans to conduct monitoring that would fulfill one or more requirements of Provision C.8 but the monitoring would not meet MRP due date(s) by a year or less, the Permittees may request that the Executive Officer adjust the due date(s) to synchronize with such efforts.

- Coordination of sediment submodeling with RWSM model development for PCBs and mercury
- Mapping of areas upstream of reservoirs and application of estimated delivery ratios to adjust modeled loads for storage of sediment within watersheds

BASMAA-funded activities included:

- Sensitivity analyses and evaluation of weaknesses in the initial set of sediment runoff coefficients for the RWSM;
- Implementation of high-priority improvements and convening a panel of local experts to provide input on the geological bases for model coefficients;
- Analysis of results of calibration on modeled sediment estimates and model loads; and
- Development of a RWSM geoprocessing tool to incorporate the sediment model structure and its parameterization from locally derived land use/geological sediment erosion coefficients and equations.

SFEI produced annual progress reports on overall RWSM development (e.g. Lent et al. 2012) and provided a June 2013 internal update to BASMAA on the sediment model. In December 2013 SFEI distributed for STLS review a draft report section with preliminary results of the RWSM models for PCBs and mercury, which apply coefficients based on particle concentrations to the estimates of suspended sediment loadings from the modeled watersheds. SFEI noted that the sediment model remains unverified and the parameterization calibration runs would potentially be improved by the addition of a climatic parameter as recommended by the expert panel.

Provision C.8.e.vii of the MRP requires Permittees to develop a work plan and schedule for initial loading estimates and source analyses for contaminants of emerging concern (CECs). Contaminants that are mentioned in the MRP include: endocrine-disrupting compounds, PFOS/PFAS (PerfluorooctaneSulfonates (PFOS), Perfluoroalkylsulfonates (PFAS), and NP/NPEs (nonylphenols/nonylphenol esters - estrogen-like compounds). The work plan developed by Permittees is to be implemented in the next Permit term.

Consistent with these requirements, Permittees (via Countywide Stormwater Programs) have and will continue to coordinate the investigation and significance of CECs with the San Francisco Bay Regional Monitoring Program for Water Quality (RMP). As such, Permittees have participated in the development and funding of a CEC strategy entitled "Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations" (Sutton et.al. 2013). In addition, Permittees have and continue to participate in the broader Statewide CEC investigation and monitoring efforts through RMP coordination with the State Water Board's contractor, the Southern California Coastal Water Research Project (SCCWRP). The Permittees submitted details of these statewide and the RMP planning efforts in the March 2014 Integrated Monitoring Report as required by provision C.8.e.vii, During the next Permit term, Permittees intend to continue to work with the RMP staff and update the current CEC strategy as needed based on the significance of the results of the various ongoing investigations.

SECTION 6 - CITIZEN MONITORING AND PARTICIPATION (C.8.f)

In compliance with Provision C.8.f, Permittees are required to make reasonable efforts to seek out citizen and stakeholder input regarding waterbody function and quality, and to demonstrate within annual reports of their outreach efforts to these groups. During the reporting period in WY2014, ACCWP staff communications with local residents, creek groups and other residents, included:

- ACCWP re-deployed several continuous temperature loggers at sites previously recommended in the Sausal Creek watershed by Robert Leidy, then a member of the Friends of Sausal Creek Board of Directors.
- ACCWP notified creek groups and municipal staff of the increased observations of New Zealand Mud Snails in bioassessment samples.
- ACCWP staff shared Pollutants of Concern Loads Monitoring station data summaries and reports for the San Leandro Creek monitoring with staff of the Friends group and officials at the City of San Leandro.

SECTION 7 - REPORTING, DATA QUALITY AND DATA MANAGEMENT (C.8.g&h)

Provision C.8.g requires Permittees to report annually on water quality data collected in compliance with the MRP. Annual reporting requirements include: 1) water quality standard exceedances; 2) creek status monitoring electronic reporting; and 3) urban creeks monitoring reporting. The Program's, WY 2014 creek status monitoring electronic data were submitted to the Water Board January 15, 2014, including preliminary evaluations of data compared to water quality objectives.

This section evaluates data quality for ACCWP's Creek Status Monitoring in WY 2014. Additional evaluations of data quality for data collected pursuant to provision C.8.e are provided in Appendix A.3.

Provision C.8.h requires that water quality data collected by Permittees in compliance with the MRP should be of a quality that is consistent with the State of California's Surface Water Ambient Monitoring Program (SWAMP) standards, set forth in the SWAMP Quality Assurance Project Plan (QAPP). To assist Permittees in meeting SWAMP data quality standards and developing data management systems that allow for easy access of water quality monitoring data by Permittees, the RMC coordinated guidance for SWAMP comparable data collection through several regional projects:

Standard Operating and Quality Assurance Procedures

For Creek Status Monitoring the RMC adapted existing creek status monitoring SOPs and QAPP developed by SWAMP to document the field procedures necessary to maintain comparable, high quality data among RMC participants. Version 1of these documents (BASMAA 2012a, 2012b) were completed in Water Year 2012 prior to field work. All interpretative issues or concerns raised during the initial two years of monitoring were resolved through the RMC Work Group and were documented in Version 2 (BASMAA 2014a, 2014b) along with minor revisions addressing lessons learned.

For POC Loads Monitoring, a draft Field Manual and QAPP were developed through the STLS Team and described in the Multi-Year Plan. BASMAA implemented a master contract with SFEI to contract for laboratory analyses for all sites operated by RMC programs as well as those operated by SFEI for the RMP.

Information Management

For Creek Status Monitoring, the RMC participants developed an Information Management Systems (IMS) to provide SWAMP-compatible storage and import/export of data for all RMC programs. A data management subgroup of the RMC Work Group met periodically for training and review of data management issues, and to suggest enhancements for data checking and to increase efficiency,

For POC Loads Monitoring BASMAA contracted with SFEI to design and maintain an IMS for management of data from stations operated by the RMC programs. SFEI also provided ongoing updates to the IMS and performed QA review of the data collected by RMC programs, consistent with the QA for data collected through the RMP.

The IMSs provide standardized data storage formats, thus providing a mechanism for sharing data among RMC participants and efficient submittal of data electronically to the Water Board per provision C.8.g.

7.1 CREEK STATUS MONITORING DATA QUALITY REVIEW

All findings and data reported during Water Year (WY) 2014 were reviewed against RMC measurement quality objectives (BASMAA, 2014a). As in previous WYs, a subset of data collected in WY 2104 required qualification and additional discussion, which are summarized below along with identification of corrective actions. Refer to Appendices A.1 and A.2 for details regarding data quality issues for Creek Status Monitoring data.

Data Quality Issues

Bioassessment - Field Activities

Per the MRP, bioassessment is required at 20 probabilistic sites each year for ACCWP. A field audit of the sampling team was conducted by Kevin Lunde on 5/27/2014 at Site 204R01479. No major deficiencies were cited in the field.
The following QA issues were noted during bioassessment field operations in WY2014 (and are further detailed in the ACCWP Creek Status Monitoring Bioassessment and Physical Habitat Monitoring Field Report November 11, 2014):

- One sample was collected outside of prescribed index period. Per SWAMP Quality Assurance Team (QAT) recommendation, a descriptive comment is included in the submitted SWAMP template to reflect this.
- Three samples were collected within thirty-day window following a 0.5" precipitation event. Per SWAMP QAT recommendation, a descriptive comment was incorporated into the SWAMP template to reflect this.

Bioassessment - Water Chemistry

Several issues were reported by the analytical laboratory (Caltest), and the water chemistry data were qualified accordingly. These issues included:

- The method blank performed by the laboratory for SSC indicated minor blank contamination in two of 18 samples reported, and one of 18 samples reported for DOC; results were qualified by the laboratory appropriately.
- RPD in field duplicate samples exceeded control limits in one of two FDs collected for WY2014 for Ortho-P, and P; RPD exceeded CLs for both FD samples for Chl-a; results were qualified by the laboratory appropriately in each case. These results are consistent with prior years.
- Laboratory results for one of two MS samples analyzed for both Nitrate and Phosphorus were reported outside of recovery control limits; results were qualified by the laboratory appropriately.
- Laboratory results for both MS samples analyzed for silica were reported outside of recovery control limits; results were not qualified by the laboratory, but were qualified appropriately by local data manager.
- Laboratory results for MS / MSD pair analyzed for silica was reported outside of control limits for RPD; results were not qualified by the laboratory, but were qualified as appropriate by LDM.
- The Preparation Preservation and Fraction codes reported by the laboratory for analysis of Chloride and Nitrate were incorrect and were revised by the LDM.

Sediment Chemistry

Sediment chemistry field duplicate samples are reported collaboratively for the RMC, with one Program collecting samples and reporting results for the entire RMC each year. In 2014, San Mateo reported results for the 10% field duplicate rate required for regional compliance. For these duplicate analyses, three results fell outside of QAPP

CLs; two of the three were associated with grain size fractions, which is typical of the media and analyses.

For the ACCWP dataset, several issues were identified during data review by either the analytical laboratory or the LDM, as detailed below:

- For multiple analytes, MS recoveries were outside of CLs. These were appropriately flagged by the laboratory.
- For multiple analytes, LCS recoveries were outside of CLs. These were appropriately flagged by the laboratory.
- For one analysis, the MS recovery was outside of CLs, but not flagged by the laboratory. In this case, the LDM qualified the data as appropriate.
- For those analytes subcontracted by Caltest to SCL, a laboratory duplicate was not reported for analysis of PSD or grain size.

Fecal Indicator Bacteria

- One laboratory duplicate was recorded as slightly outside of CLs. This was flagged by the LDM.

General Water Quality Monitoring

General water quality measurements were in compliance with the QAPP MQOs with the exception of the following:

- DO measurements recorded at Stations 204AVJ080 and 204CRW042 either failed data quality checks or did not reflect typical values associated with urban streams:
  - DO and conductivity data recorded at 204CRW042 did not pass post-deployment field checks and were censored in electronic data deliverables.
  - At Station 204AVJ080, the DO measurements passed all field checks and were not censored for this reason.

Corrective Actions for Water Year 2014

General Water Quality Monitoring

- Both YSIs were returned to the manufacturer for annual maintenance and calibration.

Bioassessment Water Chemistry

- A list of QA and reporting issues compiled from all RMC Programs was sent to the laboratory Project Manager as part of the contracting process for WY2015. Laboratory management acknowledged the issues and confirmed they would address in WY2015 implementation.

Sediment Chemistry

- AMS communicated the issues regarding the analysis of PSD and TOC to the LPM, who confirmed they would discuss with the subcontract laboratory to rectify the situation for WY2015.

Review of WY 2012 and 2013 Corrective Actions:

A number of key recommendations and corrective actions from the WY2012 QA/QC review were collated in the IMR Appendix 6 report submission. A comprehensive review of these corrective actions was subsequently completed and all were addressed in WY2014 with the exception of the following issues which will be corrected in WY2015 monitoring:

- Investigate alternative approaches for field measurement of chlorine to mitigate the possibility of attaining measurements of free chlorine greater than total chlorine. Corrective Action –This continued to be an issue in WY2014 monitoring and the RMC Work group agreed to use colorimeters instead of test kits.

SECTION 8 - REFERENCES

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SECTION 9 - ATTACHMENTS

Attachment A. Electronic Data Submittal Transmittal Letter dated January 15, 2015 with attached file list and preliminary evaluation relative to applicable Water Quality Standards.

Protecting Alameda County Creeks, Wetlands & the Bay

clean water PROGRAM

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Zone 7 Water Agency

January 15, 2015

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

SUBJECT: Electronic Data Submittal - ACCWP Creek Status Monitoring from October 2013 through September 2014 Pursuant to Provision C.8.g

Dear Mr. Wolfe:

The member agency Permittees of the Alameda Countywide Clean Water Program (Program) through their Management Committee, and in conformance with the Memorandum of Agreement signed by their governing bodies, have authorized and directed me to prepare and submit certain reports as part of their compliance with Monitoring requirements of the Municipal Regional Stormwater NPDES Permit (MRP, Order No. R2-2009-0074, CAS612008).

With this letter I am submitting a CD-ROM containing the Program's Creek Status Monitoring data collected between October 1, 2013 and September 30, 2014 pursuant to Provision C.8.c of the MRP. These data are provided in Microsoft Excel files listed in Attachment A, which are formatted according to templates compatible with data management requirements of the Surface Water Ambient Monitoring Program (SWAMP). The Program is submitting these data to the Regional Water Board by January 15, 2014 as specified in Provision C.8.g.ii of the MRP. Other data addressing the requirements of MRP Provision C.8.e, which are fulfilled in part or in whole through the efforts of third parties other than the Program, will be submitted through the entities responsible for Quality Assurance in a time schedule consistent with the Provisions of the MRP[1].

By signing this letter on behalf of the program, I certify under penalty of law that this document and all attachments are prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who managed the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are

[1] Data management and Quality Assurance of the alternative approach to Pollutants of Concern Loads Monitoring for all sites, including the San Leandro Creek site operated by ACCWP, were performed by the San Francisco Estuary Institute through a collaboration between BASMAA and the RMP. Data collection and reporting for Long Term Trends Monitoring are the responsibility of the SWAMP Sediment Pollution Trends (SPoT) program.

significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations. [40CFR 122.22(d)].

The quality of all Creek Status Monitoring data was evaluated through data collection and evaluation methods consistent with the Standard Operating Procedures and Quality Assurance Project Plan developed through the BASMAA Regional Monitoring Coalition (RMC), a regional collaborative that includes all ACCWP member Permittees. These documents have been reviewed by Region 2 SWAMP staff for SWAMP-comparability where applicable, as provided in MRP C.8.h.

In conformance with MRP Provision C.8.g.ii, the Program has participated in the RMC's development of a regional information management system that supports electronic transfer of data to the Regional Data Center of the California Environmental Data Exchange Network (CEDEN). As requested by Water Board staff on August 5, 2011, concurrent with this submission the Program is transferring the subject monitoring data directly to CEDEN. As required in MRP Provision C.8.g.vii, the Program will notify stakeholders and members of the public of the availability of electronically submitted data and monitoring reports through its website and via other communications as appropriate.

We are in the process of identifying potential persistent water quality issues that would warrant a programmatic response as required by the MRP. Attachment A presents preliminary highlights of some of these issues. It should be emphasized that this water quality data review is preliminary and does not constitute a determination of whether water quality objectives were exceeded and/or if stormwater runoff or dry weather discharges are or may be causing or contributing to exceedances, if any. The Program is in the process of determining whether these data represent persistent exceedances in receiving waters; if it is determined that discharges under this permit are causing or contributing to persistent exceedances of the applicable water quality objectives, the Permittees will follow up as required by MRP Provision C.1.

Please contact me if you have any questions or comments.

Sincerely,

James Scanlin
Program Manager

Attachment: CD ROM
Attachment A: list of datafiles on CD-ROM

Copy via email: Alameda Countywide Clean Water Program Management Committee Representatives

Attachment A

Data files for ACCWP Creek Status Monitoring
October 1, 2013-September 30, 2014

Sources of templates for data files (see file ACCWP-EDS_ToC_WY2014.xlsx for details):

SWAMP v2.5 Database references at http://swamp.mpsl.mlml.calstate.edu/
Kevin Lunde, SFRWQCB SWAMP Program (Continuous Monitoring)
EOA, Inc. (Stream Survey using Urban Streams Assessment)

Based on preliminary review of water quality standards; these notes do not constitute a determination of whether water quality objectives were exceeded and/or if stormwater runoff or dry weather discharges are or may be causing or contributing to exceedances, Numeric water quality objectives for most data parameters have not been adopted to-date.

Sample Purpose	**Filename, including site ID**	**Evaluation of Water Quality[a]**
BMI, Algae, FieldMeasure, Habitat[2]	AC_BA_Phab_BMI_18Sites_2014.xls	No exceedance
WaterChem	AC_BA_WQ_18sites_2014.xls	Chloride concentrations greater than 250 mg/L single reading maximum for Alameda Creek Watershed/Municipal Supply at 204R01023, 204R01108, and 204R01433 Chlorine above 0.08mg/L at 205R01479 and 204R01620
WaterTox[3]	AC_SpringAqTox_Triad_2014.xls	Potential water toxicity effect for *Ceriodaphnia* reproduction at 203R00295
SedChem, SedTox[3], WaterTox[3], Chlorine	AC_DrySeason_AqTox_SedTox_SedChem_WQ_Triad_2014.xls	Potential water toxicity effect for *Selenastrum* growth at 204R00292, potential sediment toxicity effect for *Hyalella* growth at 203R00295
WaterChem (Pathogens)	AC_WQ_FIB_5sites_2014.xls	*E. coli* exceeded Basin Plan Table 3.2 criterion for REC-1 Beneficial Use at 204CVY020, 204CVY080 and 204CVY125 (moderately used) or 204CVY150 (infrequently used)
ContinuousMonitoring (GenWQ)	CM_ACCWP_YSI_204AVJ080_2014_spring.xls	No exceedance
ContinuousMonitoring (GenWQ)	CM_ACCWP_YSI_204CRW040_2014_spring.xls	Dissolved Oxygen concentrations were below the WQO for COLD Beneficial Use for 10% of readings

[2] Due to unusually dry seasonal streamflows, fewer than 20 bioassessment sites could be sampled during the 2014 index period. As agreed with RWQCB staff in meetings of the Regional Monitoring Coalition, additional sites will be sampled in 2015 to maintain an average of at least 20 bioassessment sites per year.

[3] Due to current formatting differences between CEDEN and the SWAMP templates accepted by the SWAMP datachecker, toxicity data are also being provided to SFEI in CEDEN-formatted files.

Sample Purpose	Filename, including site ID	Evaluation of Water Quality[a]
ContinuousMonitoring (GenWQ)	CM_ACCWP_YSI_204CRW042_2014_spring.xls	Dissolved Oxygen concentrations were below the WQO for COLD Beneficial Use for 6% of readings
ContinuousMonitoring (GenWQ)	CM_ACCWP_YSI_204AVJ080_2014_summer.xls	Dissolved Oxygen concentrations were below the WQO for COLD Beneficial Use for 98% of readings
ContinuousMonitoring (GenWQ)	CM_ACCWP_YSI_204CRW040_2014_summer.xls	Dissolved Oxygen concentrations were below the WQO for COLD Beneficial Use for 99% of readings
ContinuousMonitoring (GenWQ)	CM_ACCWP_YSI_204CRW042_2014_summer.xls	N/A-Equipment failure
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204AVJ070_2014	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204AVJ110_2014[4]	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204CRW030_2014	21% of rolling 7-day average above 19°C
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204CRW040_2014	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204CVY005_2014	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204LIO050_2014	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204LIO080_2014[4]	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204SAU035_2014	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204SAU070_2014	No exceedance
ContinuousMonitoring (Temp)	CM_ACCWP_HOBO_204SAU200_2014[4]	No exceedance
StreamSurvey	USA_ACCWP_AguaCaliente_2014.xlsx	N/A
StreamSurvey	USA_ACCWP_LagunaCreek_2014.xlsx	N/A
StreamSurvey	USA_ACCWP_LagunaCreekBypass_2014.xlsx	N/A
StreamSurvey	USA_ACCWP_WashingtonCreek_2014.xlsx	N/A

[4] Site 204AVJ110 dried out before the end of the deployment period and due to lack of wetted monitoring sites in the same stream a new mid-season deployment was made at 204SAU200. Site 204LIO080 also dried out in mid-season but was relocated to a deeper pool slightly upstream.

[a] Based on preliminary review of water quality standards; these notes do not constitute a determination of whether water quality objectives were exceeded and/or if stormwater runoff or dry weather discharges are or may be causing or contributing to exceedances, Numeric water quality objectives for most data parameters have not been adopted to-date.

ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM

CREEK STATUS MONITORING REPORT – REGIONAL PARAMETERS

APPENDIX A.1
URBAN CREEKS MONITORING REPORT
OCTOBER 2013 THROUGH SEPTEMBER 2014

Report prepared by

Alameda Countywide Clean Water Program
399 Elmhurst Street,
Hayward, California 94544

Submitted to:

California Regional Water Quality Control Board, San Francisco Bay Region

FINAL

March 15, 2015

MEMBER AGENCIES:

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Acknowledgements

EOA, Inc. contributed substantially to this report in preparation of the data analysis and discussion for bioassessment data. .

Preface

The Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) collaboratively developed an outline for preparation of the first Urban Creeks Monitoring Report (UCMR) that was submitted in March 2013 compliance with the Municipal Regional Stormwater Permit (MRP) Reporting Provision C.8.g.v for all monitoring conducted during the MRP permit term. The organization and formatting of this report, as well as analyses for water and sediment toxicity and chemistry, derive in large part from Regional Appendix A to the Urban Creeks Monitoring Report for WY2012 (BASMAA 2013).

The following participants make up the RMC and are responsible for preparing IMR documents on behalf of their respective member agencies:

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

This report was prepared by ACCWP to fulfill reporting requirements for a portion of the Creek Status monitoring data collected in Water Year 2014 (October 1, 2013 through September 30, 2014) as part of the RMC's Monitoring Plan (BASMAA 2011)for certain "regionally designed" parameters monitored according to Provision C.8.c of the MRP using a probabilistic monitoring design. This report is an Appendix to the full UCMR submitted by ACCWP on behalf of the following Permittees:

- The cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County;
- Alameda County Flood Control and Water Conservation District and
- Zone 7 Water Agency

Other data collected in Alameda County during this period pursuant to MRP Provision C.8 are reported in the main body and other appendices of ACCWP's UCMR.

As described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2011), RMC participants collected data by implementing Standard Operating Procedures (SOPs) in accordance with the Quality Assurance Program Plan (QAPP). Analytical laboratory analyses were also conducted under the direction of RMC participants.

In addition to the RMC participants, San Francisco Bay Regional Water Quality Control Board staff, Kevin Lunde and Jan O'Hara, also participated in RMC workgroup meetings that contributed to design and implementation of the RMC Monitoring Plan. Additionally, these staff also provided input to the outline of the initial Urban Creeks Monitoring Report (BASMAA 2013) and threshold trigger analyses conducted herein.

List of Acronyms

Acronym	Definition
ABL	Aquatic Bioassessment Laboratory
AFDM	Ash Free Dry Mass
AMS	Applied Marine Sciences, Inc.
ACCWP	Alameda Countywide Clean Water Program
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	Benthic Index of Biological Integrity
BMI	Benthic Macroinvertebrate
CDFG	California Department of Fish and Game (now CDFW)
CDFW	California Department of Fish and Wildlife
CEDEN	California Environmental Data Exchange Network
CRAM	California Rapid Assessment Method
CSCI	California Stream Condition Index
DO	Dissolved oxygen
GIS	Geographic Information System
GRTS	Generalized Random Tessellated Stratified
IBI	Index of Biological Integrity
MRP	Municipal Regional Stormwater Permit
MQO	Measurement Quality Objective
MWAT	Maximum Weekly Average Temperature
NorCal B-IBI	Northern California Benthic Index of Biological Integrity
NPDES	National Pollutant Discharge Elimination System
NT	Non-Target
PHab	(Bioassessment) Physical Habitat Assessment
PSA	Perennial Streams Assessment
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QAO	Quality Assurance Officer
RMC	Regional Monitoring Coalition
RWQCB	Regional Water Quality Control Board
SCCWRP	Southern California Coastal Water Research Project
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SMC	Southern California Stormwater Monitoring Coalition
SoCal B-IBI	Southern California Benthic Index of Biological Integrity
SOP	Standard Operating Procedure
SWAMP	Surface Water Ambient Monitoring Program
TNS	Target Not Sampled
WY	Water Year

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Executive Summary

In 2010, the seventeen member agencies of the Alameda Countywide Clean Water Program (ACCWP) joined other members of the Bay Area Stormwater Agencies Association (BASMAA) to form the BASMAA Regional Monitoring Coalition (RMC), as a collaborative effort to coordinate and oversee water quality monitoring required by Provision C.8 of the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit. This report presents the results of Creek Status Monitoring data collected by ACCWP during the Water Year (WY) 2014 extending from October 1, 2013 through September 30, 2014[1].

Other parameters were addressed using a targeted design, with regional coordination and common methodologies. These parameters, are reported in a separate Targeted Appendix A.2.

During WY 2014, ACCWP monitored 18 sites under the regional probabilistic design for bioassessment, physical habitat, and related water chemistry parameters. Three of the 18 sites were also monitored for water and sediment toxicity and sediment chemistry, as described in this report.

The bioassessment data were used to evaluate potential stressors that may affect aquatic habitat quality and beneficial uses through a preliminary condition assessment for the monitored sites. The probabilistic design requires at least three years to produce sufficient data to develop a statistically-robust characterization of regional creek conditions, so the analysis and interpretation that can be completed with the first three years of data are necessarily limited.

The following MRP reporting requirements (per Provision C.8.g.iv) are addressed within this report or other portions of the UCMR, as applicable:

- Descriptions of monitoring purpose and study design rationale
- QA/QC summaries for sample collection and analytical methods, including a discussion of any limitations of the data;
- Descriptions of sampling protocols and analytical methods;
- Tables and Figures describing: Sample location descriptions (including waterbody names, and lat/longs); sample ID, collection date (and time where relevant), media (e.g., water,

[1] Similar methods and QA/QC procedures are being implemented for Stressor-Source Identification (SSID) studies to investigate certain sites where WY2012 monitoring results indicated potential need for follow-up monitoring projects according to trigger criteria described in the MRP.

filtered water, bed sediment, tissue); concentrations detected, measurement units, and detection limits;

- Data assessment, analysis, and interpretation for Provision C.8.c.;
- Pollutant load and concentration at each mass emissions station;
- A listing of volunteer and other non-Permittee entities whose data are included in the report;
- Assessment of compliance with applicable water quality standards; and
- A signed certification statement.

Stressor analyses were evaluated using two indicator approaches: Benthic Macroinvertebrate Index of Biotic Integrity (B-IBI) scores developed for streams in Southern California, and the California Stream Condition Index (CSCI) which considers watershed attributes to identify comparable reference sites. The stressor analysis revealed that most sites show alteration of biological communities, and channel modification and other habitat changes associated with urbanization is a likely stressor for benthic macroinvertebrate communities.

In this report, the results of the above analyses are used in conjunction with related stressor assessments based on sediment chemistry and toxicity data[2] to determine potential follow-up actions. data and condition assessments to address the management questions underlying the RMC design (BASMAA 2011).

The stressor analysis revealed the following potential stressors for WY2014 ACCWP data.

- **Nutrients (and Conventional Constituents):** The MRP Table 8.1 trigger criterion for "Nutrients" (20% of results in one waterbody exceed one or more water quality standards or applicable thresholds) was considered to be met at only three of the 18 monitoring sites.
- **Water Toxicity:** For the wet season sampling, site 203R00295 exhibited statistically significant toxicity to *Ceriodaphnia dubia* reproduction, but not of a sufficient magnitude to indicate re-sampling. For the dry season sampling, site 204R00292 exhibited statistically significant toxicity to *Selanastrum capricornutum* growth; again, the toxicity was not of sufficient magnitude to indicate re-sampling.
- **Sediment Toxicity:** The sediment from site 203R00295 exhibited statistically significant toxicity to *Hyalella azteca* growth but not survival, which is the metric used to indicate toxic response within the MRP. There was therefore no requirement for follow-on testing.

[2] in Appendix A.2 of IMR Part A

- **Sediment Chemistry:** Sediment chemistry results produced evidence of potential stressors in several ways, based on the criteria from MRP Table H-1. For site 203R00295, a highly urbanized location between railroad tracks and the Eastshore Freeway, the main contributors to the relatively high number of TEC quotients >1 and the largest PEC quotient were PAHs and trace metals. At site 204R00927, a suburban location on Crow Creek upstream of I-580, approximately 70% of the reported pyrethroid TUs is associated with bifenthrin.

The results of the above analyses are used in conjunction with related bioassessment data and condition assessments to address the management questions underlying the RMC design (BASMAA 2011). The trigger analysis identified a number of sites that may deserve further investigation to provide better understanding of the sources/stressors likely contributing to reduce ecological condition in Bay Area creeks.

1. Introduction

This report fulfills a portion of the reporting requirements of Provision C.8.g.v of the Bay Area Municipal Regional Stormwater National Pollutant Discharge Elimination System Permit (MRP; SFBRWQCB 2009) for creek status monitoring data produced pursuant to MRP Provision C.8.c during Water Year (WY) 2014 (October 1, 2013 - September 30, 2014) under a regional probabilistic design. The regional probabilistic design was developed and implemented by the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC). Additional ProvisionC.8.c data are reported in other appendices and portions of ACCWP's Urban Creeks Monitoring Report, of which this is Appendix A.1.

The RMC was formed in early 2010 as a collaboration among several BASMAA members and all MRP Permittees (Table 1-1) to focus on development and implementation of a regionally-coordinated water quality monitoring program. The intent of the regional monitoring effort is to improve stormwater management in the region and address water quality monitoring required by the MRP[3]. Through its implementation, the RMC allows Permittees and the San Francisco Regional Water Quality Control Board (SF Bay RWQCB) to effectively modify their previous creek monitoring programs and improve their collective ability to answer core management questions in a cost-effective and scientifically rigorous way. Participation in the RMC is coordinated by countywide stormwater programs and/or Permittee representatives (or equivalent), and facilitated through the BASMAA Monitoring and Pollutants of Concern Committee (MPC). The RMC Work Group is a subgroup of the MPC that meets and communicates regularly to coordinate planning and implementation of monitoring-related activities. This workgroup includes staff from the SF Bay RWQCB at two levels – those generally engaged with the MRP as well as those working regionally with the State of California's Surface Water Ambient Monitoring Program (SWAMP).

[3]The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the five-year MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (SFRWQCB 2009). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley, which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities. Note that the RMC regional monitoring design was expanded to include the portion of eastern Contra Costa County that drains to the San Francisco Bay in order to assist the CCCWP in fulfilling parallel provisions in their NPDES permit from the Region 5 SF Bay RWQCB.

Table 1-1. Regional Monitoring Coalition Participants.

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

The goals of the RMC are to:

1. Assist Permittees[4] in complying with requirements in MRP Provision C.8 (Water Quality Monitoring);
2. Develop and implement regionally consistent creek monitoring approaches and designs in the San Francisco Bay Area, through the improved coordination among RMC participants, SF Bay RWQCB[5] and other agencies with common goals; and
3. Stabilize the costs of creek monitoring by reducing duplication of effort and streamlining monitoring-related activities.

This report presents the results of the portions of Creek Status Monitoring that were conducted using a regional ambient (probabilistic) monitoring design to comply with Provision C.8.c (Table 1-2). The list of parameters in Table 1-2 derive from the MRP Table 8-1 (SFBRWQCB 2009; BASMAA 2012A, 2012B).

[4]For the CCCWP this includes addressing the eastern portion of Contra Costa County that drains to the San Francisco Bay that is within the jurisdiction of the Region 5 Regional Water Quality Control Board.

[5]The intent is to coordinate with SF Bay RWQCB staff working regionally with the State of California's Surface Water Ambient Monitoring Program (SWAMP).

Table 1-2. Creek Status Monitoring Parameters sampled in compliance with MRP Provision C.8.c. and the associated reporting format and Appendix to the ACCWP UCMR.

Biological Response and Stressor Indicators	Monitoring Design		Reporting
	Regional Ambient (Probabilistic)	Local (Targeted)	
Bioassessment & Physical Habitat Assessment	X		Appendix A.1
Chlorine	X		Appendix A.1
Nutrients	X		Appendix A.1
Water Toxicity	X		Appendix A.1
Sediment Toxicity	X		Appendix A.1
Sediment Chemistry	X		Appendix A.1
General Water Quality		X	Appendix A.2
Temperature		X	Appendix A.2
Bacteria		X	Appendix A.2
Stream Survey		X	Appendix A.2

Prior to formation of the RMC, San Francisco Bay Area stormwater programs implemented monitoring designs that targeted creek reaches of interest to address site-specific management questions. Because the representativeness of such targeted data was unknown, the overall condition of all creek reaches in the Bay Area was also unknown. The RMC addressed this issue by augmenting targeted monitoring designs with an ambient (probabilistic) creek status design that integrates many elements of the individualized monitoring programs that currently exist in the region.

The probabilistic monitoring design described in subsequent sections of this report complies with MRP Provision C.8.c[6] by addressing the core monitoring questions listed below, which are further elaborated upon later in this report and in the main IMR. This monitoring design allow each individual RMC participating program to assess stream ecosystem conditions within its program area (e.g., county boundary) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks.

1. What is the condition of aquatic life in creeks in the San Francisco Bay Area; are water quality objectives met and are beneficial uses supported?

[6] The MRP states that Provision C.8.c status monitoring is intended to answer the following questions: "Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers and tributaries?"; "Are conditions in local receiving waters supportive of or likely to be supportive of beneficial uses?". The management questions described in this plan are intended to answer the questions posed in the MRP.

2. What are the major stressors[7] to aquatic life?
3. What are the long-term trends in water quality in creeks over time?

The remainder of this report addresses Study Area and Monitoring Design (Section 2), data collection and analysis methods (Section 3), results and discussion (Section 4), and Conclusions and Next Steps (Section 5). More specifically, this report includes the standard report content as required by MRP Provision C.8.g.v in the respective sections referenced in Table 1-3. Additional details or discussion may also be found in other Appendices or in the main IMR.

Table 1-3.Index to Standard Report Content per MRP Provision C.8.g.vi.

Report Section	Standard Report Content
2.0	Monitoring purpose and study design rationale
3.0	Sampling protocols and analytical methods
4.1, also see Main UCMR body, Section 7	QA/QC summaries for sample collection and analytical methods
2.1	Sample location descriptions, sample dates, IDs
4.0	Sample concentrations detected, measurement units, detection limits
4.0	Data assessment, analysis and interpretation
See Main UCMR body, Section 6	List of volunteer and other non-Permittee entities whose data are included in the report.
5.0	Assessment of compliance with applicable water quality standards

2. Study Area & Monitoring Design

2.1 RMC Area

Status and trends monitoring was conducted in non-tidally influenced, flowing water bodies (i.e., creeks, streams and rivers) interspersed among 3,407 square miles of land in the RMC area. The water bodies monitored were drawn from a master list that included all perennial and non-perennial creeks and rivers that run through urban and non-urban areas within the portions of the five participating counties that fall within the SF Bay RWQCB boundary, and the eastern portion of Contra Costa County that drains to the Central Valley Regional Board (Figure 2-1).A total of 60 sites were sampled in 2012by RMC participants, with another 70sites sampled in 2013. Of these, data from 30 sites monitored in 2012 (Table 2-1) and 40 sites in 2013 (Table 2-2) by the four contributing Programs are included within the analysis for this report.

[7] Stressors are interpreted per MRP Table 8-1 (SFBRWQCB 2009) as results that "trigger" action based upon comparison with an identified threshold.

2.2 Regional Monitoring Design

In 2011, the RMC developed a regional probabilistic monitoring design to identify ambient conditions of creeks in the five main counties subject to the requirements of the MRP (SFBRWQCB 2009). The regional design was developed using the Generalized Random Tessellation Stratified (GRTS) approach developed by the United States Environmental Protection Agency (USEPA) and Oregon State University (Stevens and Olson 2004). GRTS offers multiple benefits for coordinating amongst monitoring entities including the ability to develop a spatially balanced design that produces statistically representative data with known confidence intervals. The GRTS approach has been implemented recently in California by several agencies including the statewide Perennial Streams Assessment (PSA) conducted by SWAMP (Ode et al. 2011) and the Southern California Stormwater Monitoring Coalition's(SMC) regional monitoring program conducted by municipal stormwater programs in Southern California (SMC 2007). For the purpose of developing the RMC's probabilistic design, the RMC area is considered to represent the "sample universe".

2.2.1 Site Selection

Sample sites were selected and attributed using the GRTS approach from a sample frame consisting of a creek network geographic information system (GIS) data set within the RMC boundary[8] (BASMAA 2011). This approach was agreed to by SF Bay RWQCB staff during RMC workgroup meetings although it differs from that specified in MRP Provision C.8.c.iv., e.g., sampling on the basis of individual watersheds in rotation and selecting sites to characterize segments of a waterbody(s).The sample frame includes non-tidally influenced perennial and non-perennial creeks within five management units representing areas managed by the storm water programs associated with the RMC. The sample frame was stratified by management unit to ensure that MRP Provision C.8.c sample size requirements (SFBRWQCB 2009) would be achieved.

The National Hydrography Plus Dataset (1:100,000) was selected as the creek network data layer to provide consistency with both the Statewide PSA and the SMC, and the opportunity for future data coordination with these programs. The RMC sample frame was classified by county and land use (i.e., urban and non-urban) to allow for comparisons between these strata. Urban areas were delineated by combining urban area boundaries and city boundaries defined by the U.S. Census (2000). Non-urban areas were defined as the remainder of the areas within the sample universe (i.e., RMC area).Based on discussion during RMC Workgroup meetings, with SF Bay

[8]Based on discussion during RMC Workgroup meetings, with SF Bay RWQCB staff present, the sample frame was extended to include the portion of Eastern Contra Costa County that drains to the San Francisco Bay in order to address parallel provisions in CCCWP's Region 5 Permit for Eastern Contra Costa County. The rest of the sample frame is within the boundaries of SFBRWQCB jurisdiction.

RWQCB staff present, RMC participants weighted their sampling efforts so that annual sampling efforts are approximately 80% in urban areas and 20% in non-urban areas for the purpose of comparison. RMC participants coordinated with the SF Bay RWQCB by identifying additional non-urban sites from their respective counties for SWAMP sampling.

Bioassessment sites sampled by ACCWP during the reporting period are shown in Figure 2-1 and Table 2-1.

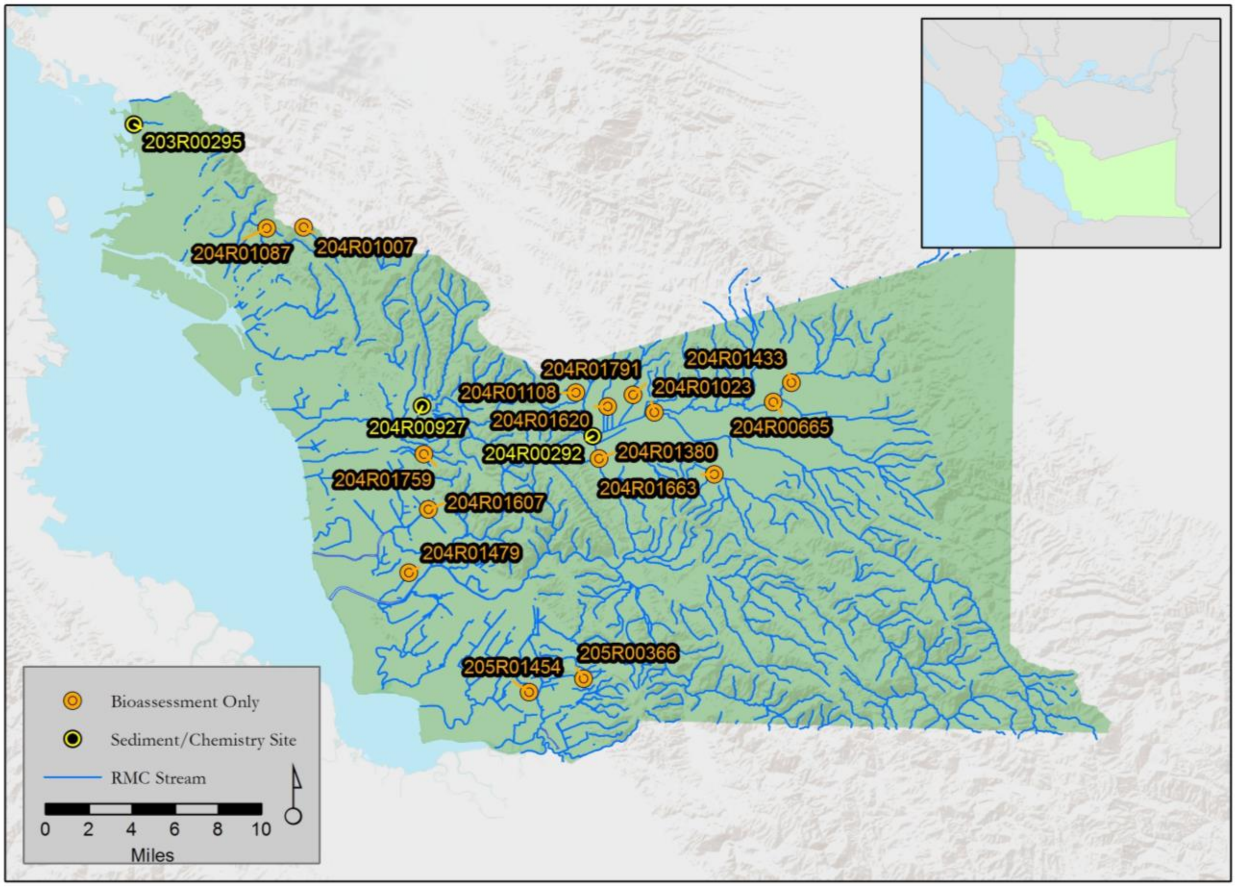

Figure 2-1. Alameda County sites sampled from the RMC probabilistic monitoring design in Water Year 2014.

Table 2-1. Alameda County Bioassessment Sites Sampled in Water Year 2014 by ACCWP. Triad sites also were sampled for water toxicity on 3/17/12 and 3/30/2014, and for sediment toxicity and chemistry on 7/23/14.

Site ID	Creek Name	Land Use	Latitude	Longitude	Sampling Date	Triad samples
203R00295	Codornices	Urban	37.88181	-122.30687	7/1/14*	Yes
204R00292	Arroyo Mocho	Urban	37.67869	-121.90884	5/7/14	Yes
204R00665	Arroyo Las Positas	Urban	37.70141	-121.76169	4/16/14	No
204R00927	Crow Creek	Urban	37.69521	-122.05672	5/13/14	Yes
204R01007	Redwood Creek	Urban	37.81271	-122.15799	4/16/14	No
204R01023	Arroyo Mocho	Urban	37.69403	-121.85899	4/16/14	No
204R01087	Palo Seco Creek	Urban	37.81374	-122.19398	6/3/14	No
204R01108	Zone 7 Line J-1	Urban	37.70703	-121.92703	5/12/14	No
204R01380	Arroyo de la Laguna	Urban	37.66264	-121.90626	5/12/14	No
204R01433	Zone 7 Line H	Urban	37.71612	-121.74254	5/8/14	No
204R01479	Zone 5 Line J-2	Urban	37.58229	-122.06515	4/15/14	No
204R01607	Zone 3A Line N	Urban	37.62605	-122.05022	5/7/14	No
204R01620	Chabot Canal	Urban	37.69773	-121.89989	4/28/14	No
204R01663	Arroyo Valle	Urban	37.65411	-121.81013	5/14/14	No
204R01759	Ward Creek	Urban	37.66409	-122.05561	5/27/14	No
204R01791	Tassajara Creek	Urban	37.70659	-121.87872	4/28/14	No
205R00366	Canada del Aliso	Urban	37.51409	-121.91744	4/29/14	No
205R01454	Zone 6 Line G	Urban	37.50359	-121.96218	4/17/14	No

* See discussion in Section 3.2.1.

2.2.2 Management Questions

The RMC regional monitoring design was developed to address the management questions listed below. Those appearing in bolded font are addressed in this report in a preliminary manner. Those in normal font could not be addressed at this time due to the limited sample size available from the initial two years of monitoring, but can be answered in future years once sample sizes increase.

Table 2-2 illustrates the length of time that would be required to establish statistically representative sample sizes for each of the classified strata in the regional monitoring design, estimated for continuation of the present rate of annual bioassessment sampling.

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

2.23 Monitoring Design Implementation

Sampling was conducted in accordance with the RMC Multi-year Monitoring Plan (BASMAA 2011). The sampling plan (Table 2-2) illustrates the total number of sites that each RMC program plans to sample within the MRP term (SFBRWQCB 2009). It also illustrates the number of sampling years required to establish statistically representative samples for each strata (e.g., management unit and urban or non-urban land use) included in the regional monitoring design. Approximately 80% of the sites sampled annually by RMC participants are in urban areas and 20% are in non-urban areas. Due to unforeseen field circumstances, however, this percentage may vary by year. For example, some sites may not be sampleable due to seasonal drying and/or access issues, thereby altering the relative proportion of urban-to-non-urban sites sampled in a given year. Such outcomes can be addressed in subsequent sampling years by adjusting the relative proportion of urban and non-urban sites. In the 2012 field season 18 sites could not be sampled for these reasons (see Attachment A), resulting in a total annual sample of 54 urban and 12 non-urban sites (Table 2-3).

Table 2-2. Cumulative numbers of bioassessment samples per monitoring year according to RMC design; shaded cells indicate when a minimum sample size may be available to develop a statistically representative data set to address management questions related to condition of aquatic life.

Monitoring Year	RMC Area (Region-wide)		Santa Clara County		Alameda County		Contra Costa County		San Mateo County		Fairfield, Suisun City and Vallejo[b]	
Land Use	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*
Year 1 (WY 012)	**48**	22	16	6	16	6	8	4	8	4	0	2
Year 2 (WY2013)	**100**	**44**	**32**	12	**32**	12	16	8	16	8	8	0
Year 3[c] (WY2014)	**156**	**66**	**48**	18	**48**	18	24	12	24	12	12	6
Year 4 (WY2015)	**204**	**88**	**64**	24	**64**	24	**32**	16	**32**	16	12	8
Year 5 (WY2016)	**256**	**110**	**80**	**30**	**80**	**30**	**40**	20	**40**	20	16	10

[a] Assumes San Francisco Bay RWQCB will continue WY2012-13 sample effort of two non-urban sites annually in each RMC County

[b] Assumes: FSURMP and Vallejo only monitor urban sites; FSURMP monitors 4 sites in Year 2, 3 and 5; and Vallejo monitors 4 sites in Year 3.

[c]Final year of monitoring under the MRP 5-Year Permit.

3. Monitoring Methods

This section describes the methods used to evaluate monitoring sites identified in the regional sample draw, consistent with the Southern California Coastal Water Research Project (SCCWRP) Bioassessment Program (SCCWRP 2012), and to sample field data, consistent with the RMC workplan (BASMAA 2011), Field parameters sampled at all sites included benthic macroinvertebrate community, algal community and biomass, and physical habitat, Physico-chemical measurements (dissolved oxygen, temperature, conductivity, and pH), chlorine, and nutrients were sampled concurrently as required by the SWAMP protocol or MRP. At three of the sites, separate field visits were made to collect water samples for testing water toxicity, and sediment samples for testing sediment toxicity and chemistry.

3.1 Site Evaluation

Sites identified in the regional sample draw were evaluated by each RMC participant in chronological order using a two-step process, consistent with that described by SCCWRP[9]

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

(2012). Each site was evaluated to determine if it met the following RMC sampling location criteria:

1. The location (latitude/longitude) provided for a site is located on or is within 300meters of a non-impounded receiving water body;
2. Site is not tidally influenced;
3. Site is wadeable during the sampling index period;
4. Site has sufficient flow during the sampling index period to support standard operating procedures for biological and nutrient sampling.
5. Site is physically accessible and can be entered safely at the time of sampling;
6. Site may be physically accessed and sampled within a single day;
7. Landowner(s) grant permission to access the site[10].

In the first step, these criteria were evaluated to the extent possible using a "desktop analysis." Site evaluations were completed during the second step via field reconnaissance visits. Based on the outcome of site evaluations, sites were classified into one of three categories:

- **Target** - Sites that met all seven criteria were classified as **target sampleable** status**(TS),** and sites that met criteria 1 through 4, but did not meet at least one of criteria 5 through 7 were classified as **target non-sampleable (TNS)**.
- **Non-Target (NT)** - Sites that did not meet at least one of criteria 1 through 4 were classified as non-target status.
- **Unknown (U)** -Sites were classified with unknown status when it could be reasonably inferred either via desktop analysis or a field visit that the site was a valid receiving water body and information for any of the seven criteria was unconfirmed.

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

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

Observations of flow status occurring during fall site reconnaissance events prior to occurrence of significant precipitation, and spring sampling occurring post- wet weather season were combined to classify sites as perennial or non-perennial as follows:

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

- **Perennial:** fall flow status either Wet Flowing or Wet Trickle and spring flow sufficient to sample.
- **Non-Perennial:** fall flow status either Majority Wet, Minority Wet, or No Water, and spring flow sufficient to sample.

Many sites classified as Unknown in WY 2012 were reclassified in WY 2013 as Target or Non-Target. Due to low seasonal rainfall in the first part of WY2013, many Target sites were unsampleable due to low or no streamflow present during the index period.

3.2 Field Data Collection Methods

Field data were collected in accordance with existing SWAMP-comparable methods and procedures, as described in the RMC Quality Assurance Project Plan (QAPP) and the associated Standard Operating Procedures which were updated to maintain their currency and optimal applicability (BASMAA 2014a, 2014b) The SOPs were developed using a standard format that describes health and safety cautions and considerations, relevant training, site selection, and sampling methods/procedures, including pre-fieldwork mobilization activities to prepare equipment, sample collection, and de-mobilization activities to preserve and transport samples. The SOPs relevant to the monitoring discussed in this report are listed in Table 3-1.

Table 3-1. RMC Standard Operating Procedures (SOPs) pertaining to regional creek status monitoring.

SOP #	SOP
FS-1	Benthic Macroinvertebrate and Algae Bioassessments, and Physical Habitat Measurements
FS-2	Water Quality Sampling for Chemical Analysis, Pathogen Indicators, and Toxicity Testing
FS-3	Field Measurements, Manual
FS-4	Field Measurements, Continuous General Water Quality
FS-6	Collection of Bedded Sediment Samples
FS-7	Field Equipment Cleaning Procedures
FS-8	Field Equipment Decontamination Procedures
FS-9	Sample Container, Handling, and Chain of Custody Procedures
FS-10	Completion and Processing of Field Datasheets
FS-11	Site and Sample Naming Convention
FS-12	Ambient Creek Status Monitoring Site Evaluation
FS-13	QA/QC Data Review

3.2.1 Bioassessments

In accordance with the RMC QAPP (BASMAA 2012a, 2014a), bioassessments are intended to be conducted during the spring index period (approximately April 15 – July 15) and at a minimum of 30 days after any significant storm (roughly defined as at least 0.5-inch of rainfall within a 24-hour period). There were two main deviations from this protocol for WY2014, as discussed below.

Unlike prior years, Alameda County did not experience a late season, significant precipitation event that required delay of initial sampling beyond the index period start date. However, an April 25th precipitation event of over 0.5" in portions of Alameda County delayed sampling scheduled shortly thereafter. A search of precipitation records compiled at Weather Underground weather stations across the County (http://www.wunderground.com/) indicated that rainfall during this event exceeded the 0.5" threshold at all west County locations including Castro Valley, and at Dublin locations within the east County.

Due to the overall low rainfall associated with WY2014 and the expected early drying of targeted monitoring sites, field sampling was restarted in some areas that exceeded the 0.5" threshold after an approximate two-week delay, but still within the thirty-day waiting period; these sites included:

- • 204R01791 (sampled 5/12/14);
- • 204R01108 (sampled 5/12/14); and
- • 204R00927 (sampled 5/13/14).

In follow-on discussions coordinated through the RMC, Marine Pollution Studies Laboratory Quality Assurance Team personnel indicated that bioassessment QA protocols are still under development, and that there are no result qualifiers appropriate for this situation.[11] To account for this situation, completed SWAMP templates associated with these three sites, at the recommendation of MLML personnel, incorporated a detailed sample comment to reflect this situation.

Despite the April 25th storm event, creeks targeted for bioassessments generally experienced a relatively early drop in streamflow, which precluded sampling at an unexpectedly high proportion of target sites. This resulted in the total number of sampleable bioassessment sites dropping below 20 to 18. As agreed by RMC participants, at least two additional sites will be sampled in Water Year 2015 to maintain the annual average at 20.

One of the 18 sites successfully sampled, 203R00295, served as one of three triad sites for 2014. Due to delay in obtaining permissions, field personnel were unable to conduct bioassessment sampling at this site until after the index period had closed on June 15th; sampling was conducted on July 1, 2014. As discussed above for waiting time after significant rainfall, there is no relevant SWAMP qualifier and data management personnel entered a sample comment to reflect this situation.

[11] Personal communication with Will Hagan, MLML Quality Assurance Team, November 10, 2014.

Benthic Macroinvertebrates

The BMI samples were collected using the Reachwide Benthos (RWB) method described in SOP FS-1 (BASMAA 2012b, 2014b). .

Each bioassessment sampling site consisted of an approximately 150-meter stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. The sampling position within each transect alternated between 25%, 50% and 75% distance of the wetted width of the stream. Benthic macroinvertebrates (BMIs) were collected from a 1 ft2 area approximately 1 m downstream of each transect. The benthos were disturbed by manually rubbing coarse substrate followed by disturbing the upper layers of substrate to a depth of 4-6 inches to dislodge any remaining invertebrates into the net. Slack water habitat procedures were used at transects with deep and/or slow moving water (Ode 2007). Material collected from the eleven subsamples was composited in the field by transferring entire sample into one to two 1000 ml wide-mouth jar(s) and preserved with 95% ethanol.

Algae

Filamentous algae and diatoms were collected using the Reach-wide Benthos (RWB) method described in SOP FS-1 (BASMAA 2012b, 2014b). Algae samples were collected synoptically with BMI samples. The sampling position within each transect was the same as used for BMI sampling, however, samples were collected six inches upstream of the BMI sampling position and prior to BMI collection from that location. The algae were collected using a range of methods and equipment, depending on the particular substrate occurring at the site (i.e., erosional, depositional, large and/or immobile, etc.) per SOP FS-1. Erosional substrates included any material (substrate or organics) that was small enough to be removed from the stream bed, but large enough in size to isolate an area equal in size to a rubber delimiter (12.6 cm2 in area). When a sample location along a transect was too deep to sample, a more suitable location was selected, either on the same transect or from one further upstream. Algae samples were collected at each transect prior to moving on to the next transect. Sample material (substrate and water) from all eleven transects was combined in a sample bucket, agitated, and a suspended algae sample was then poured into a 500 mL cylinder, creating a composite sample for the site. A 45 mL subsample was taken from the algae composite sample and combined with 5 mL glutaraldehyde into a 50 mL sample tube for taxonomic identification of soft algae. Similarly, a 40 mL subsample was extracted from the algae composite sample and combined with 10 mL of 10% formalin into a 50 mL sample tube for taxonomic identification of diatoms. Laboratory processing included identification and enumeration of 300 natural units of soft algae and 600 diatom valves to the lowest practical taxonomic level.

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

3.2.2 Physical Habitat

Physical habitat assessments (PHab) were conducted at each BMI bioassessment sampling event using the PHab protocols described in Ode (2007) and augmented by Fetscher et al. (2009) (see SOP FS-1, BASMAA 2012b, 2014b). Physical habitat data were collected at each of the 11 transects and at 10 additional inter-transects (located between each main transect) by implementing the "Basic" level of effort, with the following additional measurements/assessments as defined in the "Full" level of effort (as prescribed in the MRP): water depth and pebble counts, cobble embeddedness, flow habitat delineation, and instream habitat complexity. At algae sampling locations, additional assessment of presence of micro- and macroalgae was conducted during the pebble counts. In addition, water velocities were measured at a single location in the sample reach (when possible) using protocols described in Ode (2007).

3.2.3 Physico-chemical Measurements

Field personnel measured dissolved oxygen, temperature, conductivity, and pH during bioassessment sampling using a multi-parameter probe (see SOP FS-3, BASMAA 2014b). Dissolved oxygen, specific conductivity, water temperature and pH measurements were made either by direct submersion of the instrument probe into the sample stream, or by collection and immediate analysis of grab sample in the field. Water quality measurements were taken approximately 0.1 m below the water surface at locations of the stream that appears to be completely mixed, ideally at the centroid of the stream. Measurements should occur upstream of sampling personnel and equipment and upstream of areas where bed sediments have been disturbed, or prior to such bed disturbance.

3.2.4 Other Water Quality Analytes

Chlorine

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

Nutrients and Conventional Analytes

Concurrent with bioassessments, field personnel collected water samples for nutrient analyses using the Standard Grab Sample Collection Method as described in SOP FS-2 (BASMAA 2014b). Sample containers were rinsed, as appropriate, using ambient water and completely filled and recapped below water surface whenever possible. An intermediate container was used to collect water for all sample containers pre-preserved by the laboratory. Syringe filtration method was used to collect samples for analyses of Dissolved Ortho-P, with Dissolved Organic Carbon now filtered in the lab within the requisite 48-hr hold time. Sample container size and type, preservative type and associated holding times for each analyte are described in Table 1 of FS-9 (BASMAA 2014b). All sample containers were labeled and stored on ice for transportation to laboratory, with exception of analysis of Ash Free Dry Mass and Chlorophyll-a samples, which were field-frozen on dry ice by sampling teams upon collection.

3.2.5 Water Toxicity

Field personnel collected water samples using the Standard Grab Sample Collection Method described above, filling the required number of 4-L amber glass bottles with ambient water, putting them on ice to cool to 4 ±2 °C, and delivering to the laboratory within the required hold time. Bottle labels and COCs included station ID, sample code, matrix type, analysis type, project ID, and date and time of collection. The laboratory was notified of the impending sample delivery to meet the 36-hour sample delivery time requirement. Procedures used for sampling and transporting samples are described in SOP FS-2 (BASMAA 2014b).

3.2.6 Sediment Chemistry & Sediment Toxicity

In the case where sediment samples and water samples / measurements were collected at the same event, sediment samples were collected after any water samples were collected. Before conducting sampling, field personnel surveyed the proposed sampling area to identify appropriate fine-sediment depositional areas, to avoid disturbing possible sediment collection sub-sites. Personnel carefully entered the stream and started sampling at the closest appropriate reach, continuing upstream. Sediment samples were collected from the top 2 cm of sediment in a compositing container, thoroughly homogenized, and then aliquotted into separate jars for chemical and toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA 2014b). Sample jars were submitted to respective laboratories per SOP FS-9 (BASMAA 2014b).

3.3 Laboratory Analysis Methods

ACCWP and other RMC participants agreed to use the same laboratories for individual parameters, developed standards for contracting with the labs, and coordinated quality assurance issues. All samples collected by RMC participants that were sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods as described in the RMC QAPP (BASMAA 2012a, 2014a). Analytical laboratory methods, are also reported in BASMAA (2012a). Analytical laboratory contractors used for benthic macroinvertebrate and algae analyses included:

- BioAssessment Services, Inc. – BMI identification
- EcoAnalysts, Inc. – Algae identification
- CalTest, Inc. – Sediment Chemistry, Nutrients, Chlorophyll a, Ash Free Dry Mass
- Pacific EcoRisk, Inc. - Water and Sediment Toxicity

The laboratory analytical methods identified BMIs at a Level 1 Standard Taxonomic Level of Effort, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family (Chironomidae). Soft algae and diatom samples were analyzed following Surface Water Ambient Monitoring Program (SWAMP) protocols (SWRCB 2011a, SWRCB 2011b). The taxonomic resolution for all data was compared and revised when necessary to match the SWAMP master taxonomic list.

3.4 Data Analysis

This section describes methods used to analyze Bioassessment data collected during Water Year 2014. As the cumulative RMC sample sizes increase through monitoring conducted in future years (Table 2-3), it will be possible to develop a statistically representative data set to address management questions related to condition of aquatic life and report on these per MRP Provision C.8.g.iv.

3.4.1 Biological Condition

Indices of biological integrity (IBIs) are analytical tools that calculate a site condition score based on a series of biological metrics representing taxonomic richness, composition, tolerance, and functional feeding groups. IBI development in California is better established for BMIs (i.e., B-IBIs) than for algae. Regional benthic macroinvertebrate IBIs have been developed and tested extensively for four regions of California, including Southern California (Ode et al. 2005), Northern California (Rehn et al. 2005), Eastern Sierra Nevada (Herbst et al. 2009) and the Central Valley (Rehn et al. 2008). Due to similarity in ecoregions with Alameda County, the Southern California (SoCal) B-IBI was used to evaluate biological condition for this report.

A new assessment tool for BMI data has been developed by the State Water Resources Control Board (State Water Board) to support the development of the State's Biological Integrity Assessment Implementation Plan. The California Stream Condition Index (CSCI) is an assessment tool based on benthic macroinvertebrates that is designed to provide both site-specificity and statewide consistency (i.e., can be applied to all perennial wadeable streams within all ecoregions of California). The performance of the CSCI is supported by the use of a large reference data set that represents the full range of natural conditions in California; and by the development of site-specific models for predicting biological communities (Mazor et al. in review). The site-specific model is based on two components: 1) taxonomic completeness, as measured by the ratio of observed-to-expected taxa (O/E); and 2) ecological structure, measured as a predictive multi-metric index (pMMI) that is based on reference conditions. The CSCI is computed as the average of the sum of O/E and pMMI. The State Board is continuing to evaluate the performance of CSCI in a regulatory context and RWQCB staff has indicated that it will be referenced as a trigger in the re-issuance of the MRP (anticipated effective date July 1, 2015). To further test the performance of the assessment tool, the CSCI was used to evaluate BMI data for this report.

The State Water Board is developing and testing assessment tools for benthic algae data as a measure of biological condition and identification of potential stressors. A comprehensive set of stream algal IBIs that include metrics for both diatoms and soft-algae have recently been developed and tested in Southern California (Fetscher et al. 2013a). Fetscher et al. (2013a) evaluated a total of 25 IBIs comprising of either single-assemblage metrics (i.e., either diatoms or soft algae) or combinations of metrics presenting both assemblages (i.e., "hybrid" IBI). The study identified four high performing IBIs including three hybrid IBIs and one single-assemblage IBI for diatoms. The performance was assessed by the IBIs responsiveness to stress. The "H20" hybrid IBI (Algal IBI) was also tested in other ecoregions of the state and showed relatively good performance in Chapparal region, which includes the San Francisco Bay Area (Fetscher et al. 2013b). As a result, the Algal IBI was used to evaluate the algae data for this report. The algae IBI results should be considered preliminary until additional research shows that these tools perform well for data collected in Alameda County.

Bioassessment Data

Southern California Index of Biological Integrity

The BMI data were compiled, formatted and forwarded to the Moss Landing Marine Laboratory[12] where Southern California (SoCal) Benthic Macroinvertebrate Index of Biotic

[12]Moss Landing Marine Laboratory supports SWAMP in the management of bioassessment data.

Integrity (B-IBI) scores were calculated using the SWAMP reporting module. The reporting module includes a routine that subsamples to a standardized number of 500 BMIs prior to the calculation of metrics used in B-IBIs. The metrics used to calculate the SoCal B-IBI include the following:

- EPT Taxa
- Number Coleoptera Taxa
- Number Predator Taxa
- Percent Intolerant
- Percent Non-Insecta Taxa
- Percent Collector-Filter + Collector-Gather Individuals

Percent Tolerant Taxa (8-10)

California Stream Condition Index Score

The California Stream Condition Index (CSCI) scores were calculated using the same BMI data used to calculate the B-IBI described above. Delineations for the drainage area upstream of each BMI sampling location were compiled or created in ArcGIS, using 30 meter Digital Elevation Model (DEM) data and the Arc Hydro tool in ArcGIS. In most cases, the watershed/catchments polygons created in ArcGIS required editing to adjust the downstream edge of the drainage area to the sampling locations. When necessary, existing data sources, including watershed/catchment data developed by SFEI and Oakland Museum and storm drain network data, where used to modify the DEM derived watershed boundaries. These modification were typical in the low gradient urban areas along the San Francisco Bay and Livermore Valley. All delineations were independently reviewed for accuracy using Google Earth.

To develop the CSCI scores, eight additional GIS datasets were compiled from the California Department of Fish and Wildlife and analyzed in ArcGIS to calculate a range of environmental predictors for each sampling location. Site elevation, temperature, and precipitation values were obtained directly at the sampling location. Elevation range was calculated from the difference in elevation in the watershed of the lowest and highest values. Summer precipitation, soil bulk density, soil erodibility, and soil phosphorus content are predictors that are averaged across each watershed, and are calculated in ArcGIS using a zonal statistics tool (http://www.arcgis.com/).

The environmental predictors and BMI data were formatted into comma delimited files and used as input for the RStudio statistical package and the necessary CSCI program scripts provided by SCCWRP staff. The CSCI program includes a subsampling routine that produces a standardized number of 500 BMIs. The program output includes a summary table that averages CSCI scores over 20 iterations and calculates O/E and pMMI metrics. The output table also flags sites with inadequate numbers of unambiguous taxa (i.e., CSCI requires at least 360 unambiguous taxa).

The CSCI scores were evaluated using condition categories developed by Mazor et al. (in review). Four classes were defined using a distribution of scores at reference calibration sites throughout the State of California (Table 3-1). The categories are described as "likely intact" (greater than 30th percentile of reference site scores); "possibly intact" (between the 10th and the 30th percentiles); "likely altered" (between the 1st and 10th percentiles; and "very likely altered" (less than the 1st percentile).

Table 3-1. Condition categories used to evaluate CSCI scores.

CSCI Score	Category
$\geq$ 0.92	Likely Intact
0.79 – 0.92	Possibly Intact
0.63 – 0.79	Likely Altered
$\leq$ 0.63	Very Likely Altered

Hybrid "H20" Algae Index of Biological Integrity Score

The algae data were compiled, formatted and sent to the Moss Landing Marine Laboratory, where the "H20" hybrid algae IBI (Algal IBI) was calculated use the SWAMP Reporting Module. The Algal IBI is comprised of the following eight metrics ("d" indicates that a given metric is based on diatoms and "s" indicates soft algae; of the latter, "sp" indicates that the metric is based on relative species numbers):

- Proportion nitrogen heterotrophs (d)
- Proportion requiring >50% dissolved oxygen saturation (d)
- Proportion sediment tolerant (highly motile) (d)
- Proportion halobiontic (d)
- Proportion low N indicators (d)
- Proportion high Cu indicators (s, sp)
- Proportion high DOC indicators (s, sp)
- Proportion low TP indicators (s, sp)

3.4.3 Physical habitat condition

BASMAA (2013) prepared a data analysis of physical habitat scores from all RMC bioassessment sites monitored in WY2012, based on the combination of scores for three physical habitat sub-categories. While these scores can be useful in interpreting results from individual sites, their interpretation did not add substantially to the information from the IBI scores. The CSCI uses characteristics of the watershed draining to each site to develop the score for that site and thus integrates larger-scale physical habitat structure into the condition assessment.

3.4.4 Water and Sediment Chemistry and Toxicity

As part of the Stressor Assessment for this report, water and sediment chemistry and toxicity data generated during Water Year 2014 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or diminished biological conditions. Per Table 8.1 of the MRP (SFBRWQCB 2009), creek status monitoring data must be evaluated with respect to specified “Results that Trigger a Monitoring Project in Provision C.8.d.i.” The trigger criteria listed in Table 8.1 were used as the principal means of evaluating the creek status monitoring data to identify sites where water quality impacts may have occurred. For water and sediment chemistry and toxicity data, the relevant trigger criteria are as follows:

- **Nutrients**: 20% of results in one waterbody exceed one or more water quality standard or established threshold. (Note: per MRP Table 8.1, this group of constituents includes variants of nitrogen and phosphorous, as well as conventional constituents.)
- **Water Toxicity**: if toxicity results are less than 50% of Laboratory Control results, re-sample and re-test; if second sample yields less than 50% of Laboratory Control results, proceed to C.8.d.i. (Stressor/Source Identification).
- **Sediment Toxicity**: toxicity results are statistically different than and more than 20% less than results for Laboratory Control.
- **Sediment Chemistry**: three or more chemicals exceed Threshold Effect Concentrations (TECs), mean Probable Effect Concentrations (PEC) Quotient greater than 0.5, or pyrethroids Toxicity Unit (TU) sum is greater than 1.0.

For sediment chemistry trigger criteria, threshold effect concentrations (TECs) and probable effect concentrations (PECs) are as defined in MacDonald et al., 2000. For all non-pyrethroid contaminants specified in MacDonald et al. (2000), the ratio of the measured concentration to the respective TEC value was computed as the TEC quotient. All results where a TEC quotient was equal to or greater than 1.0 were identified. PEC quotients were also computed for those same non-pyrethroid sediment chemistry constituents using PEC values from MacDonald et al. (2000).

For each site the mean PEC quotient was then computed, and sites where mean PEC quotient was equal to or greater than 0.5 were identified. Pyrethroids toxic unit equivalents (TUs) were computed for individual pyrethroid results, based on available literature values for pyrethroids in sediment LC50 values.[13] Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC50 values were derived on the basis of TOC-normalized pyrethroid concentrations. Therefore, the pyrethroid concentrations as reported by the lab were divided by the measured total organic carbon (TOC) concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid. Then for each site, the TU equivalents for the various individual pyrethroids were summed, and sites where the summed TU was equal to or greater than 1.0 were identified.

3.5 Quality Assurance and Control

Data quality assessment and quality control procedures are described in detail in the BASMAA RMC QAPP (BASMAA 2014a). They generally involved the following:

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

Data were collected according to the procedures described in the relevant SOPs (BASMAA 2014b), including appropriate documentation of data sheets and samples, and sample handling and custody. Laboratories providing analytical support to the RMC were selected based on demonstrated capability to adhere to specified protocols.

All data were thoroughly reviewed for conformance with QAPP requirements and field procedures were reviewed for compliance with the methods specified in the relevant SOPs. Data quality was assessed and qualifiers were assigned as necessary in accordance with SWAMP requirements. See Section 7 for evaluations of Program-specific data quality associated with monitoring conducted in WY2014.

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

4. Results & Discussion

The MRP places an emphasis on minimizing sources of pollutants that could impair water quality as a central purpose of urban runoff management programs. The MRP requires monitoring to address the management question,

- ***"What are the sources to urban runoff that contribute to receiving water problems?"***

The RMC accomplishes this through a multi-step process that involves conducting monitoring to provide data to inform an assessment of conditions and identification of stressors that may be impacting water quality and/or biological conditions. The information generated through the condition assessment and stressor assessment will then be used to help direct efforts to identify sources of problematic pollutants or other stressors in urban runoff discharges.

In this section, following a brief statement of data quality, the bioassessment data are evaluated against the trigger criteria shown in Table 8.1 and Table H-1 (for sediment triad data) of the MRP (SFBRWQCB 2009) to provide a preliminary identification of potential stressors. The results of the initial stressor assessment evaluation (BASMAA 2013) were used to initiate a stressor-source identification projects as described in the 2014 IMR...

4.1 Statement of Data Quality

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

A comprehensive QA/QC program was implemented by each of the RMC Programs, which is solely responsible for the quality of the data submitted on its behalf, covering all aspects of the regional/probabilistic monitoring. In general, QA/QC procedures were implemented as specified in the RMC QAPP (BASMAA, 2014a), and monitoring was performed according to protocols specified in the RMC SOPs (BASMAA, 2014b), and in conformity with SWAMP protocols. The results of general evaluations of laboratory-generated QA/QC results are included in Section 7 of the main UCMR body. Issues noted by the laboratories and/or field crews for regional parameters are noted below where relevant.

4.1.1 Sediment Chemistry

Several issues were reported by the analytical laboratory (Caltest), and the sediment chemistry data were qualified accordingly. These issues included:

- Matrix Spike recoveries outside of control limits for acenapthene.

Other issues in conflict with RMC QAPP MQOs were not identified by the laboratory, but were identified during QA review and were qualified as appropriate. These issues included:

- Matrix Spike recoveries outside of control limits noted due to possible matrix interferences for PAHs methylnaphthalene-1 and methylnaphthalene-2
- Laboratory reporting limits (RLs) for multiple trace metals exceeded RMC QAPP RLs due to the dry weight conversion, as well as target and non-target matrix interferences, which required the laboratories to concentrate less than normal. These data were not flagged, however, as the data points in question were all reported at concentrations above the reporting limits.
- The relative percent difference (RPD) reported for Zn MS/MSD was outside CLs.
- The subcontractor performing analysis of total organic carbon (TOC) and particle size distribution (SCL) did not report a laboratory duplicate as required by the RMC QAPP due to a miscommunication between the contract lab and subcontract lab. We have requested that Caltest inform SCL of the need for duplicates to be conducted in the future, which will be incorporated within WY2015 pricing and reporting.

4.1.2 Water Chemistry

Several issues were noted with respect to water chemistry analyses, including:

- In both 2012 and 2013, RMC field crews noted multiple instances where free chlorine was measured with the Hach field kits at concentrations higher than total chlorine.
- A limited number of Lab QA/QC sample results for nutrients and conventional parameters were reported by the laboratory as qualified data due to minor issues not thought to affect the accuracy of sample results.
- Results of required field duplicates for several analytes exceeded QAPP MQOs. As the control limits for field duplicates are identical to those of lab duplicate analyses, this is not a surprising occurrence. WY2014 data were qualified as dictated by comparison with RMC MQOs (BASMAA 2014a).

4.2 Condition Assessment

Condition assessment addresses the RMC core management question

- ***"What is the condition of aquatic life in creeks in the RMC area; are aquatic life beneficial uses supported?"***

Table 4-1 lists the beneficial uses of creeks sampled during WY 2014. By default creeks and other fresh water bodies are assigned the WARM and WILD presumptive uses in the Basin Plan (SFBRWQCB 2013).

Table 4-1. ACCWP creeks sampled in WY2014 and associated designated beneficial uses listed in the San Francisco Bay Region Basin Plan (SFBRWQCB 2013). Creeks not listed in Chapter 2 of the Basin Plan do not appear in this table.

		Human Consumptive Uses								Aquatic Life Uses							Wildlife Use	Recreational Uses		
Site ID	**Waterbody**	**AGR**	**MUN**	**FRSH**	**GWR**	**IND**	**PROC**	**COMM**	**SHELL**	**COLD**	**EST**	**MAR**	**MIGR**	**RARE**	**SPWN**	**WARM**	**WILD**	**REC-1**	**REC-2**	**NAV**
ALAMEDA COUNTY																				
203R00295	Codornices Creek									E			E	E	E	E	E	E	E	
204R00292	Arroyo Mocho				E					E			E		E	E	E	E	E	
204R00665	Arroyo Las Positas				E					E			E	E	E	E	E	E	E	
204R00927	Crow Creek									E			E	E	E	E	E	E	E	
204R01007	Redwood Creek			E						E					E	E	E	E	E	
204R01023	Arroyo Mocho				E					E			E		E	E	E	E	E	
204R01380	Arroyo de la Laguna				E					E			E		E	E	E	E	E	
204R01663	Arroyo del Valle		E		E					E			P	E	E	E	E	E	E	
204R01759	Ward Creek															E	E	E	E	
204R01791	Tassajara Creek				E					P			E	E	E	E	E	E	E	
205R00366	Canada del Aliso															E	E	E	E	

Notes:

COLD = Cold Fresh Water Habitat

FRSH = Freshwater Replenishment

GWR - Groundwater Recharge

MIGR = Fish Migration

MUN = Municipal and Domestic Water

NAV = Navigation

RARE= Preservation of Rare and Endangered Species

REC-1 = Water Contact Recreation

REC-2 = Non-contact Recreation

WARM = Warm Freshwater Habitat

WILD = Wildlife Habitat

P = Potential Use

E = Existing Use

L = Limited Use.

* = "Water quality objectives apply; water contact recreation is prohibited or limited to protect public health" (SFBRWQCB 2013).

4.2.1 Assessing Biological Condition

Biological condition scores, presented as SoCal B-IBI, CSCI, and Algal IBI scores, for the 18 sites sampled in Alameda County during WY2014 are listed in Table 4-2. Condition categories for CSCI score are also shown. Site characteristics related to land use classification, flow status, and channel modification status are presented in the table for reference.

Using the condition categories for CSCI, 14 sites (78%) were rated as “very likely altered” condition, two sites (11%) were rated as “likely altered” condition, one site (5.6%) rated as “possibly intact” condition, and one site (5.6%) rated as “likely intact” condition. The two highest scoring sites were classified as non-perennial, urban sites. Condition categories for CSCI scores are shown for the 18 bioassessment sites in Figure 4-1.

Table 4-2. CSCI, SoCal IBI, and Algae (H20) IBI scores for 18 probabilistic sites sampled in Alameda County during WWY2014, along with Site characteristics related to land use classification, flow status, and channel modification status.

Station Code	Creek	Impervious Percent	Land Use	Flow Status	Highly Modified Channel	CSCI Score	CSCI Condition Category	SoCal B-IBI Score	Algae IBI
204R01087	Palo Seco Creek	3.4%	Urban	Non-perennial	No	1	Likely Intact	88	64
204R01759		25.8%	Urban	Non-perennial	No	0.8	Possibly Intact	56	18
204R01007	Redwood Creek	1.5%	Nonurban	Unknown	No	0.7	Likely Altered	47	36
204R00665	Arroyo Las Positas	13.2%	Nonurban	Unknown	No	0.63	Likely Altered	14	22
204R00927	Crow Creek	6.2%	Urban	Perennial	No	0.57	Very Likely Altered	6	39
204R01663	Arroyo del Valle	2.4%	Urban	Unknown	No	0.57	Very Likely Altered	23	50
204R01791	Tassajara Creek	5.5%	Urban	Non-perennial	No	0.42	Very Likely Altered	15	22
205R00366	Canada del Aliso	12.3%	Urban	Perennial	No	0.42	Very Likely Altered	19	46
204R01023	Arroyo Las Positas	11.1%	Urban	Unknown	Yes	0.41	Very Likely Altered	5	18
204R01433		35.6%	Urban	Non-perennial	No	0.41	Very Likely Altered	3	21
204R01380	Arroyo de la Laguna	16.4%	Urban	Perennial	Yes	0.4	Very Likely Altered	6	9
204R01108		21.1%	Urban	Perennial	Yes	0.37	Very Likely Altered	1	22
203R00295	Codornices Creek	57.9%	Urban	Perennial	No	0.31	Very Likely Altered	12	50
204R00292	Arroyo Mocho	12.8%	Urban	Perennial	Yes	0.3	Very Likely Altered	1	11
204R01620		51.6%	Urban	Perennial	Yes	0.23	Very Likely Altered	1	12
205R01454		23.1%	Urban	Perennial	Yes	0.21	Very Likely Altered	2	15
204R01607		38.5%	Urban	Perennial	Yes	0.16	Very Likely Altered	9	22
204R01479		59.4%	Urban	Non-perennial	Yes	0.14	Very Likely Altered	9	15

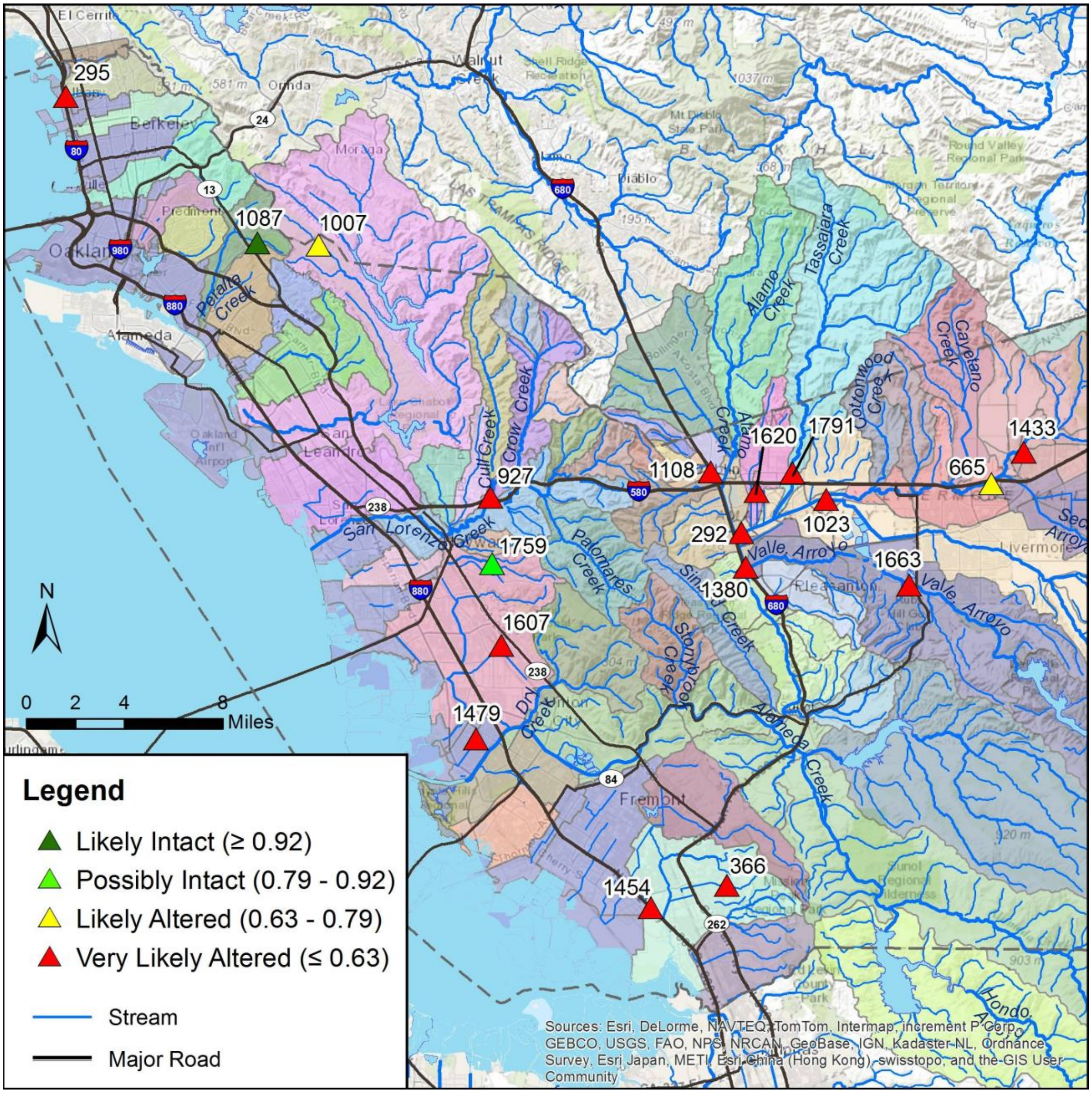

Figure 4-1. Condition categories for CSCI scores for 18 bioassessment locations sampled by ACCWP during WY2014.

4.2.2 Stressor Indicators: Biological Assessment

Benthic Macroinvertebrates

Descriptive statistics for both SoCal B-IBI and CSCI scores are shown in Table 4-3. Descriptive statistics for CSCI and B-IBI scores for the 18 sampling events conducted in Alameda County during Water Year 2014... A comparison between SoCal B-IBI and CSCI scores showed a good correlation (R2 =0.72) suggesting that the CSCI may be a comparable tool to assess the condition of aquatic life in Alameda County creeks (Figure 4-2). The distribution of CSCI scores, however show much greater variability among the sites, especially at the middle and low end of scoring range (Figure 4-3).

Table 4-3. Descriptive statistics for CSCI and B-IBI scores for the 18 sampling events conducted in Alameda County during Water Year 2014..

Statistic	CSCI (>0)	SoCal B-IBI (0-100)	Hybrid "H20" Algae IBI (0-100)
Min	0.14	1	9
Median	0.41	9	22
Mean	0.45	18	27
Max	1.00	88	64

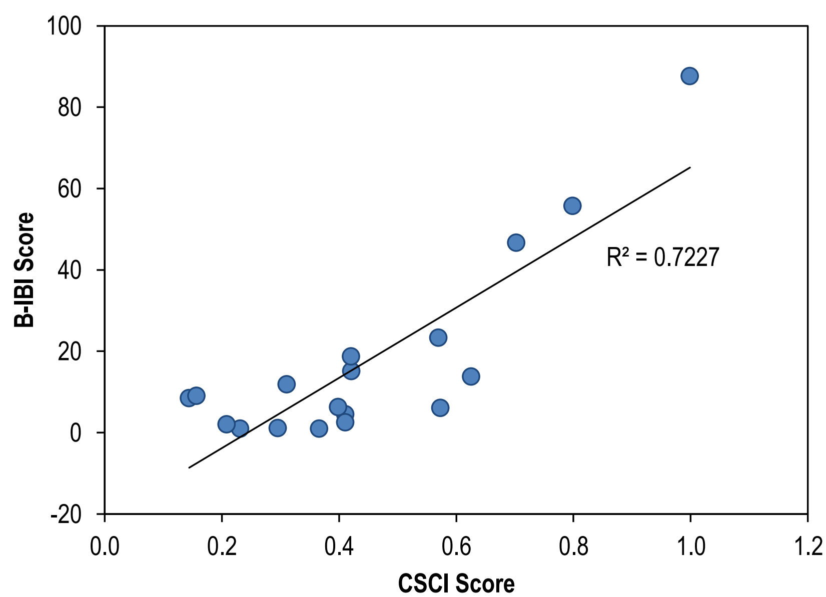

Figure 4-2. Linear regression between SoCal B-IBI and CSCI scores for the 18 sampling events conducted in Alameda County during Water Year 2014.

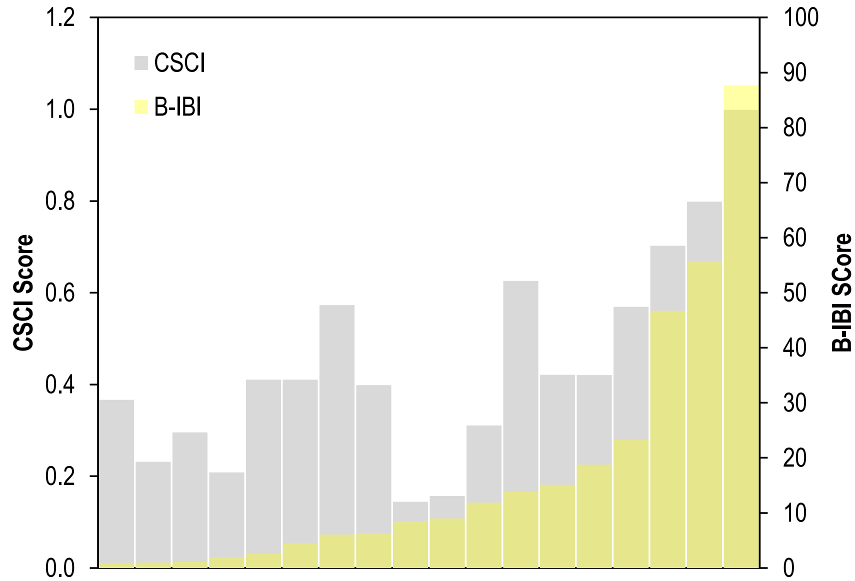

Figure 4-3. SoCal B-IBI and CSCI scores plotted for the 18 sampling events conducted in Alameda County during Water Year 2014. Data is sorted with SoCal B-IBI scores increasing from left to right.

These results suggest that the CSCI may be more responsive to the site specificity of BMI taxa due to the inclusion of a taxonomic completeness component (O/E) and/or the predictive ability of the pMMI as compared to the exclusive MMI approach of the SoCal IBI. Alternatively, the CSCI scores may not be accurately predicting the expected number of taxa resulting in an over- or under-estimated measure of taxonomic completeness. The O/E component was consistently higher than its corresponding pMMI component, which may be driving the variability in the overall CSCI score (Figure 4-4).

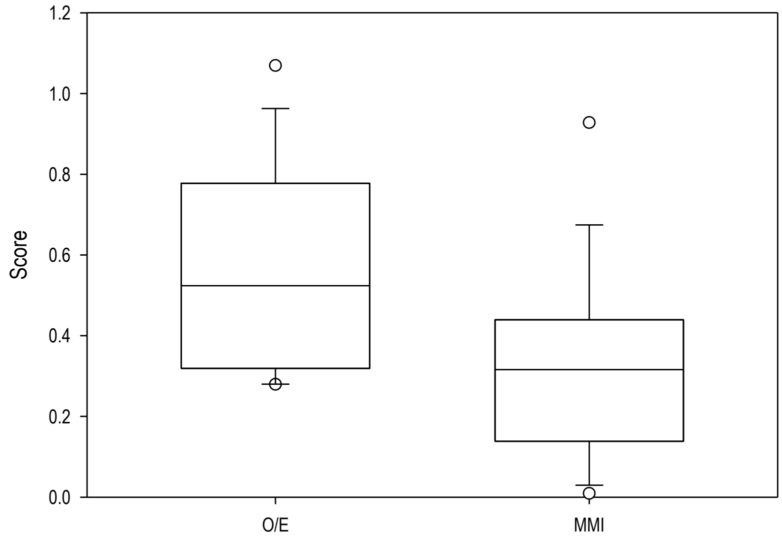

Figure 4-4. Box plots showing distribution of CSCI O/E and pMMI scores for 18 samples collected in Alameda County during Water Year 2014.

Comparisons of biological condition scores were made using flow and land use characteristics for each site. The SoCal B-IBI scores and CSCI scores were compared for non-perennial (n=5) and perennial (n=9) sites sampled in Alameda County during WY2014 (Figure 4-5). Flow status was evaluated by ACCWP during site observations conducted during the dry season. Sites on streams subject to inter-annual variations in water imports, or otherwise lacking reliable flow information, were indicated as "unknown" (n=4). Non-perennial sites had much larger CSCI and SoCal B-IBI ranges than perennial sites, but the median CSCI and IBI scores were only slightly higher than those for non-perennial sites. This indicates that the majority of sites, regardless of flow, had similar poor conditions for BMI, but a few non-perennial sites were much better condition than the other Alameda County sites sampled in WY2014.

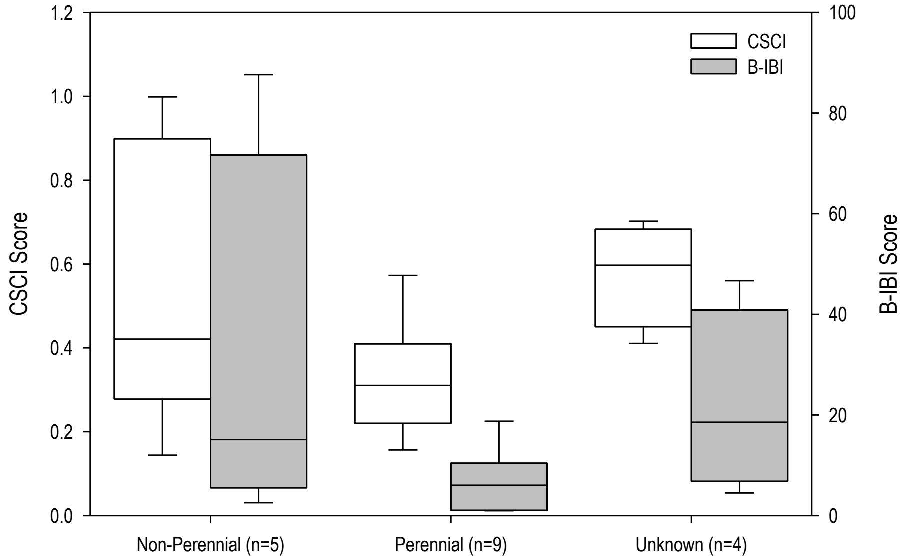

Figure 4-5. Box plots showing distribution of SoCal B-IBI and CSCI scores for non-perennial (n=5) and perennial (n=9) sites sampled in Alameda County during Water Year 2014. The flow status of four sites is unknown, and they are grouped separately.

Biological condition scores were also compared using land use (i.e., urban versus non-urban) classifications (Figure 4-6). The land use classification for sample sites is based on the RMC sample frame, which was developed using a combination of urban areas (as defined by Association of Bay Area Governments) and city boundaries. For some areas, city boundaries include parks and undeveloped areas. Thus sampling locations that are classified as urban may have a wide range of impacts associated with urban development. While there were only two non-urban sites, their CSCI scores were both higher than the CSCI scores for the urban sites. However, there is some overlap for SoCal B-IBI scores, though the median non-urban scores were much higher than the urban scores for both metrics.

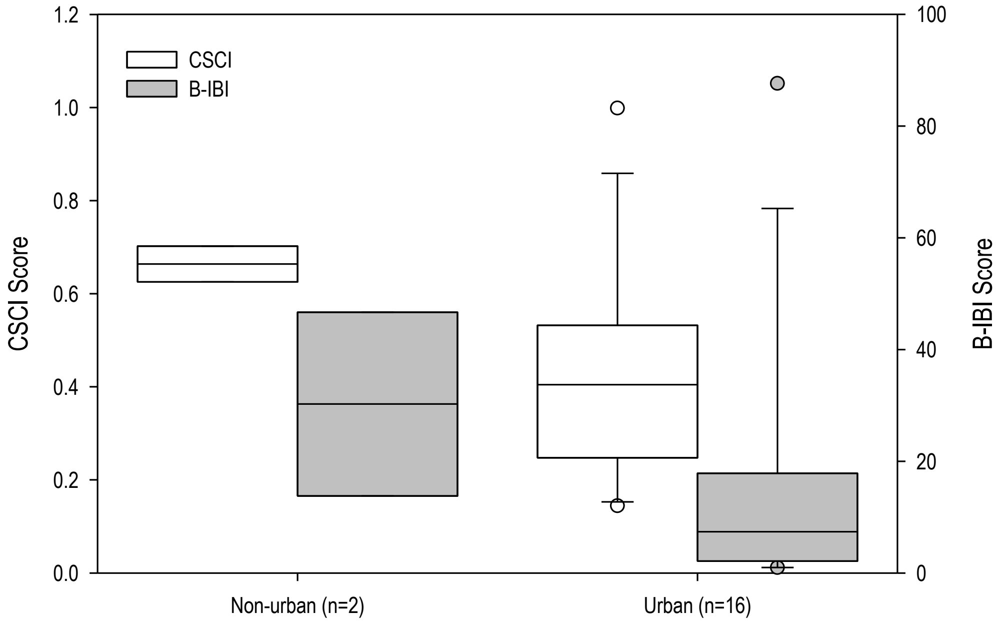

Figure 4-6. Box plots showing distribution of SoCal B-IBI and CSCI scores for non-urban (n=2) and urban (n=16) sites sampled in Alameda County during Water Year 2014

Another measure of urbanization was derived using the upstream watershed areas for each sampling location and overlaying with land use data in GIS database. The percent of impervious area in the upstream watershed was calculated for all sites and used to compare biological condition scores at three different levels of urbanization: >3%, 3-10% and >10% impervious (Figure 4-7).

The linear regression between CSCI scores and percent watershed impervious for all 18 sites sampled in Alameda County in WY2014 is shown in Figure 4-8. As expected, both CSCI and SoCal B-IBI scores decrease with increasing imperviousness. With the exception of two outliers (with CSCI scores at 1.0 and 0.80), there is a moderately strong negative association between CSCI score and watershed imperviousness. Including all 18 sites, the correlation coefficient is 0.38, but without the two outliers, the correlation coefficient increases to 0.54.

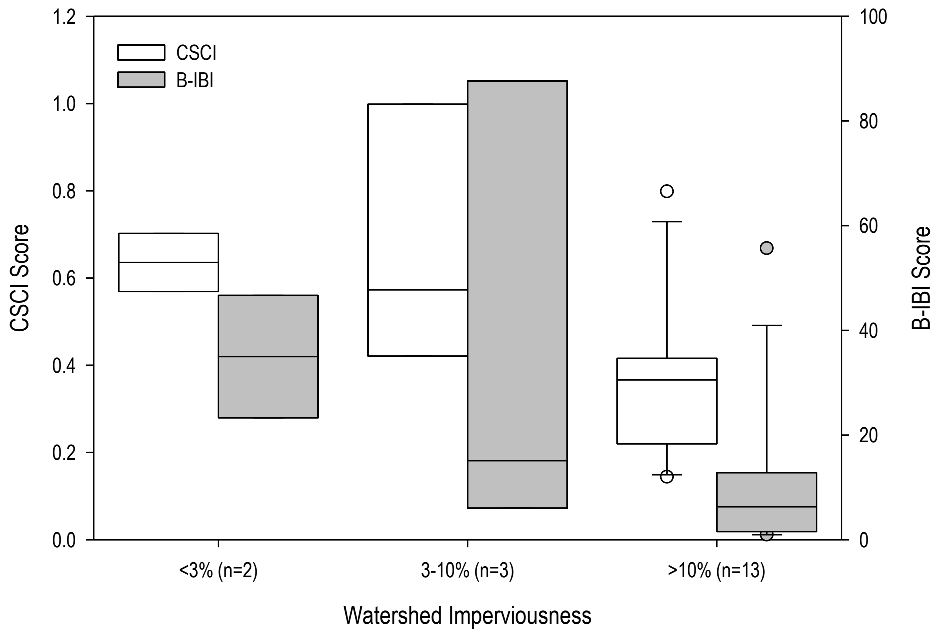

Figure 4-7. Box plots showing distribution of SoCal B-IBI and CSCI scores at sites sampled in Alameda County during Water Year 2014 for three classifications of urbanization, defined as percent watershed imperviousness.

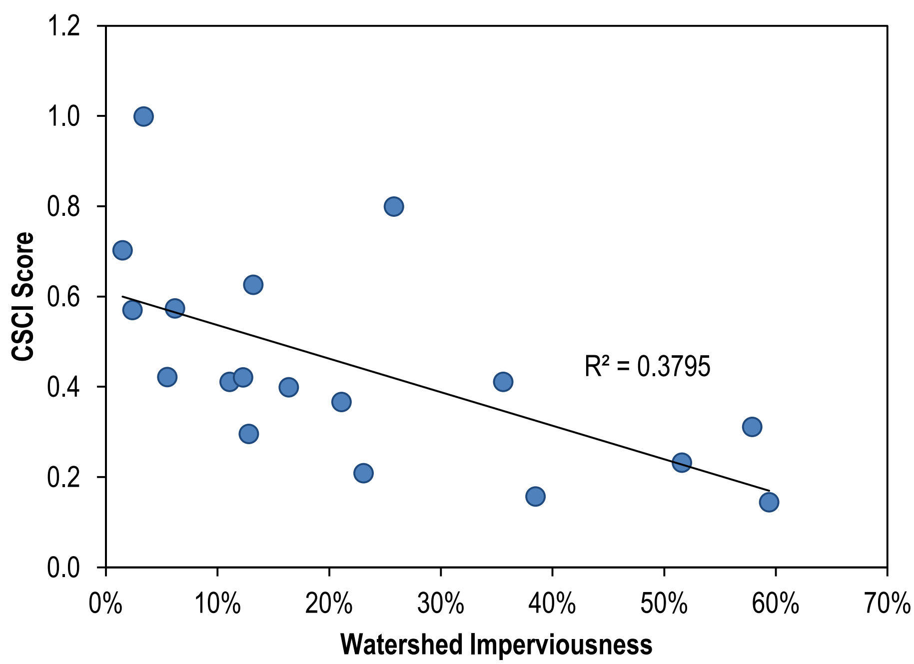

Figure 4-8. Linear regression between CSCI scores and percent watershed imperviousness for the 18 sites sampled in Alameda County during Water Year 2014.

Benthic Algae

The Algae IBI scores for the 18 sites were compared to CSCI scores (Figure 4-9). The Algae IBI showed moderately low correlation to CSCI scores (R^2=0.31), suggesting that algal assemblage has different response to stressors as compared to the BMI assemblage.

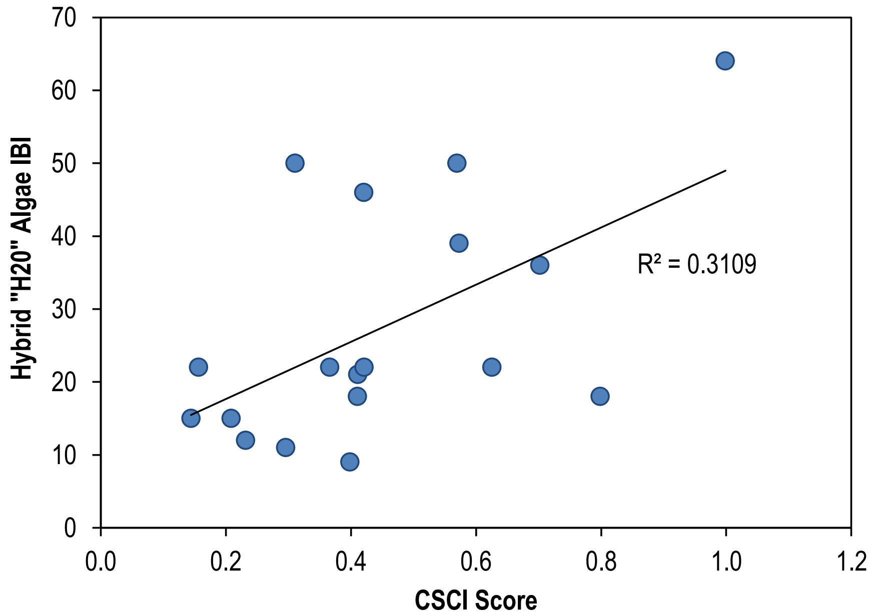

Figure 4-9. Linear regression of Algae IBI score and CSCI score for 18 sites in Alameda County sampled during Water Year 2014.

4.2.3 Stressor Indicators: Chemical and Toxicity

Water Chemistry Parameters

Table 4-4 provides a summary of descriptive statistics for the nutrients and related conventional constituents collected in association with the bioassessments in receiving waters. For the purposes of data analysis, Total Nitrogen was calculated as the sum of nitrate + nitrite + Total Kjeldahl Nitrogen (TKN).

Table 4-4. Descriptive statistics for water chemistry results collected at RMC sites during WY2014.

"Nutrients"	N	N ≥ RL	Min	Max	Max Detected	Mean
Chloride	18	1	<1.2	420	420	143.4
Chlorophyll a	18	1	<2.8	236	236	76.8
Dissolved Organic Carbon	18	0	1.6	7.2	7.2	3.5
Ammonia as N	18	18	<0.04	<0.1	NA	0.03
Nitrate as N	18	9	<0.01	3.6	3.6	0.03
Nitrite as N	18	15	<0.005	0.06	0.06	0.01
Nitrogen, Total Kjeldahl	18	0	0.13	1.1	1.1	0.5
OrthoPhosphate as P	18	1	<0.06	0.32	0.32	0.07
Phosphorus as P	18	0	0.019	0.45	0.45	0.09
Suspended Sediment Concentration	18	6	<2	45	45	12.5
Silica as SiO2	18	0	12	35	35	20.6

Water and Sediment Toxicity Testing

The laboratory determines whether a sample is "toxic" by statistical comparison of the results from multiple test replicates of selected aquatic species in the environmental sample to multiple test replicates of those species in laboratory control water. The threshold for determining statistical significance between environmental samples and control samples is fairly small, with statistically significant toxicity often occurring for environmental test results that are as high as 90% of the Control. Therefore, there is a wide range of possible toxic effects that can be observed – from 0% to approximately 90% of the Control values.

For water sample toxicity tests, MRP Table 8.1 identifies toxicity results of less than 50% of the Control (e.g., increased mortality, decreased reproduction, etc.) as requiring follow-up action. For sediment sample tests, MRP Table H-1 identifies toxicity results more than 20% less than the control as requiring follow-up action.[14] Therefore, in the tables that follow, samples that are identified by the lab as toxic (based on statistical comparison of samples vs. Control at $p < 0.05$) are further evaluated to determine whether the result was less than 50% of the associated Control (for water samples) or statistically different and more than 20% less than the Control (for sediment samples).

Samples for triad sites were targeted to be collected within creeks at sites where bioassessments were conducted in the same water year, where flow regime was assessed as perennial, and where

[14] Footnote #162 to Table H-1 of the MRP reads, "Toxicity is exhibited when Hyallela (sic) survival statistically different than and < 20 percent of control". Consistent with the UCMR (BASMAA 2013), for the purposes of this report, this is assumed to be intended to read "…statistically different than and more than 20 percent less than control".

sufficient fine-grained surficial sediments were likely to be present during dry season. The toxicity testing results are presented in context of the following three groups: 1) wet season water samples, 2) dry season water samples, and 3) dry season sediment samples. For each of these groups, the results are first presented in a table indicating which samples were found to be toxic by virtue of a statistically significant difference from the Control as determined by the laboratory. Detailed results are then presented in a subsequent table for the toxic samples, along with an assessment as to whether the toxic effect was less than 50% of the Control for water samples, or more than 20% less than the Control for sediment samples.

Wet Season Aquatic Toxicity

Per the MRP, field personnel collected ambient water samples at three locations during storm events in March 2014, and tested for toxic effects using four species: an aquatic plant (*Selenastrum capricornutum*), two aquatic invertebrates (*Ceriodaphnia dubia* and *Hyalella azteca*), and one fish species (*Pimephales promelas* or fathead minnow). The following sections discuss the results of WY2014 monitoring in the context of MRP triggers.

In 2014, no wet season samples were found to be toxic to *H. azteca, P. promelas,* or *S. capricornutum*. One sample was identified as exhibiting statistically significant toxic to *C. dubia* reproduction (Table 4-5). Unlike prior years, no pathogen-related mortality (PRM) was identified in ACCWP samples.

Table 4-5. Summary of WY2014 wet season water toxicity results for four-species tests.

Wet Season Water Samples			Toxicity relative to the Lab Control treatment?					
County/ Program	**Sample Station**	**Collection Date**	***S. capricornutum***	***C. dubia***		***H. azteca***	***P. Promelas***	
			Growth	Survival	Reproduction	Survival	Survival	Growth
ACCWP	203R00295	3/29/14	No	No	**Yes**	No	No	No
ACCWP	204R00292	3/29/14	No	No	No	No	No	No
ACCWP	204R00927	3/29/14	No	No	No	No	No	No

Table 4-6 provides detailed results for the single ACCWP WY2014 wet weather receiving water sample tested against the four target species and found to be toxic relative to the laboratory control. None of the samples collected met the MRP trigger requiring re-testing.

Table 4-6. Comparison between laboratory control and receiving water sample toxicity results (*C. dubia*) for ACCWP samples collected in wet season WY2014 identified with statistically-significant toxicity.

County/ Program	Test Initiation Date	Species Tested	Treatment/ Sample ID	10-Day Mean % Survival	Mean Reproduction (# neonates/ female)	Comparison to MRP Table 8.1 Trigger Criteria
ACCWP	3/30/14	*C. dubia*	Lab Control	100	32.4	NA
	3/30/14		203R00295	80	**26.9***	Not < 50% of control

* The response at this test treatment was significantly less than the Lab Control at p < 0.05.

Dry Season Aquatic Toxicity

Field personnel collected water samples during the summer 2014 from the same three sites where wet season sampling occurred, and were again tested for aquatic toxicity using the same four test species. The results are summarized in Table 4-7. In comparisons to the control samples, only the sample collected at site 204R00292 exhibited statistically-significant toxicity, in this case to the test species *S. capriconutum*.

Table 4-7. Summary of WY2014 and WY2013 dry season aquatic toxicity results.

Dry Season Water Samples			Toxicity relative to the Lab Control treatment?					
County/ Program	**Sample Station**	**Collection Date**	***S. capricornutum***	***C. dubia***		***H. azteca***	***P. Promelas***	
			Growth	Survival	Reproduction	Survival	Survival	Growth
ACCWP	203R00295	7/23/14	No	No	No	No	No	No
ACCWP	204R00292	7/23/14	**Yes**	No	No	No	No	No
ACCWP	204R00927	7/23/14	No	No	No	No	No	No

The single sample identified as toxic to *S. capriconutum* did not meet the MRP trigger for follow-on testing (Table 4-8).

Table 4-8. Comparison between laboratory control and receiving water sample toxicity results (*S. capriconutum)* for ACCWP samples collected in dry season WY2014 identified with statistically-significant toxicity.

County/ Program	Test Initiation Date	Species Tested	Treatment/ Sample ID	Mean Algal Cell Density (cells/mL x 10^6)	Comparison to MRP Table 8.1 Trigger Criteria
ACCWP	7/24/14	*H. azteca*	Lab Control	2.75	NA
	7/24/14		204R00292	**1.85***	Not < 50% of control

* The response at this test treatment was significantly less than the Lab Control at $p < 0.05$.

Dry Season Sediment Toxicity

During the dry season, field personnel collected sediment samples concurrently with water toxicity samples, and tested sample material for both sediment toxicity and an extensive list of sediment chemistry constituents. For sediment toxicity, testing was performed with just one species, *H. azteca*, a common benthic invertebrate. Both acute (survival) and chronic (growth) endpoints were reported.

The results of the ACCWP WY2014 sediment toxicity testing are summarized in Table 4-9. Three of the five samples collected in WY2012 by the collaborating Programs were determined to be toxic to *H. azteca* for the acute endpoint (survival). There were no determinations of significant toxicity based upon the chronic endpoint (growth) in 2012. In 2013, three of seven samples collected were determined to be toxic to *H. azteca* for survival, and two of seven samples were identified as toxic for growth.

Table 4-9. Summary of WY2014 dry season sediment toxicity results.

Dry Season Sediment Samples			Toxicity relative to the Lab Control treatment?	
County/ Program	Sample Station	Collection Date	*H. azteca*	
			Survival	Growth
ACCWP	203R00295	7/23/14	No	**Yes**
ACCWP	204R00292	7/23/14	No	No
ACCWP	204R00927	7/23/14	No	No

Detailed results of sediment samples identified as having toxic effects from the WY2014 dry season samples are shown in Table 4-10, along with comparisons to the relevant trigger criteria from MRP Tables 8.1 and H-1. For WY2014, there was a single instance of a sample exhibiting significant toxicity that did not meet the MRP trigger of *H. azteca* survival reported as more than 20% less than the control (203R00295).

Table 4-10. Detailed sediment toxicity results for dry season samples exhibiting significant toxicity to *H. azteca*.

County/ Program	Test Initiation Date	Treatment/ Sample ID	Mean % Survival	Mean Dry Weight (mg)	Comparison to MRP Tables 8.1 and H-1 Trigger Criteria
ACCWP	7/14/13	Lab Control	98.8	0.13	NA
	7/14/13	204R00447	93.8	**0.11***	No MRP comparison for growth endpoint

* The response at this test treatment was significantly less than the Lab Control treatment response at $p < 0.05$.

Sediment Chemistry Parameters

Descriptive statistics for sediment chemistry data for samples collected in WY2014 are provided in Table 4-11. Analytes are presented in alphabetical order.

It should be noted that a number of the sediment chemistry constituents assessed per the list in MacDonald et al. (2000) required some grouping of analytes. For example, the MacDonald "chlordane" constituent required the combination of "chlordane, cis" and "chlordane, trans" from the laboratory data, and the MacDonald "total DDTs" parameter required the aggregation of 6 isomers of DDD, DDE and DDT. The MacDonald list also includes 10 individual PAH compounds, as well as "Total PAHs". For this report, "Total PAHs" was computed as the sum of all 24 PAH compounds reported by the laboratory.

Table 4-11. Descriptive statistics for ACCWP WY2014 sediment chemistry results

Analyte	N	N ≥ MDL	Min	Max	Max Detected	Mean[1]
Acenaphthene	3	2	<3.1	52	52	18.4
Acenaphthylene	3	2	<3.1	14	14	5.7
Anthracene	3	2	<3.1	110	110	37.7
Arsenic	3	0	2.5	14	14	7.6
Benz(a)anthracene	3	2	<3.1	45	45	16.1
Benzo(a)pyrene	3	2	<3.1	330	330	111.1
Benzo(b)fluoranthene	3	2	<3.1	490	490	164.4
Benzo(e)pyrene	3	2	<3.1	360	360	121.1
Benzo(g,h,i)perylene	3	2	<3.2	170	170	59.7
Benzo(k)fluoranthene	3	2	<3.1	150	150	51.1
Bifenthrin	3	1	<0.11	1.4	1.4	0.9
Biphenyl	3	2	<3.4	7.4	7.4	3.6
Cadmium	3	0	0.11	0.37	0.37	0.2
Chlordane, cis-	3	3	<0.65	<0.68	<0.68	0.3
Chlordane, trans-	3	3	<0.66	<0.69	<0.69	0.3
Chromium	3	0	24	66	66	47.7
Chrysene	3	1	<3.2	620	620	214.2
Copper	3	0	8.8	51	51	34.3
Cyfluthrin, total	3	1	<0.096	1.1	1.1	0.6
Cyhalothrin, Total lambda-	3	3	<0.11	<0.12	<0.12	0.1
Cypermethrin, total	3	3	<0.092	<0.097	<0.097	0.0
DDD(o,p')	3	3	<0.29	<0.3	<0.3	0.1
DDD(p,p')	3	3	<0.77	<0.81	<0.81	0.4
DDE(o,p')	3	3	<0.26	<0.27	<0.27	0.1
DDE(p,p')	3	3	<0.63	<0.66	<0.66	0.3
DDT(o,p')	3	3	<0.3	<0.31	<0.31	0.2
DDT(p,p')	3	3	<0.4	<0.42	<0.42	0.2
Deltamethrin/Tralomethrin	3	3	<0.14	<0.15	<0.15	0.1
Dibenz(a,h)anthracene	3	2	<3.1	56	56	19.7
Dibenzothiophene	3	2	<3.4	33	33	12.2
Dieldrin	3	3	<0.71	<0.74	<0.74	0.4
Dimethylnaphthalene, 2,6-	3	2	<3.1	18	18	7.1
Endrin	3	3	<0.75	<0.78	<0.78	0.4
Esfenvalerate/Fenvalerate, total	3	3	<0.082	<0.086	<0.086	0.0
Fluoranthene	3	1	<3.2	430	430	147.5
Fluorene	3	1	<3.2	72	72	25.9
Heptachlor epoxide	3	3	<0.63	<0.66	<0.66	0.3
Indeno(1,2,3-c,d)pyrene	3	2	<3.1	160	160	54.4
Lead	3	0	6	68	68	27.6
Lindane (gamma-HCH)	3	3	<0.66	<0.69	<0.69	0.3

Analyte	N	N ≥ MDL	Min	Max	Max Detected	Mean[1]
Mercury	3	0	0.04	2.3	2.3	0.8
Methylnaphthalene, 1-	3	2	<3.1	12	12	5.1
Methylnaphthalene, 2-	3	2	<3.1	16	16	6.4
Methylphenanthrene, 1-	3	3	<3.1	<3.2	<3.2	1.6
Naphthalene	3	2	<3.1	28	28	10.4
Nickel	3	0	29	85	85	62.3
Permethrin, cis-	3	1	<0.37	2.8	2.8	1.3
Permethrin, trans-	3	2	<0.36	1.2	1.2	0.5
Perylene	3	1	<3.2	93	93	60.9
Phenanthrene	3	1	<3.2	370	370	126.4
Pyrene	3	1	<3.2	320	320	111.2
Total Organic Carbon	3	0	0.52	3.7	3.7	1.7
Zinc	3	0	36	150	150	88.7

Notes:

[1]As described previously, means calculated using a substitution of ½ MDL for non-detects.

4.3 Stressor Assessment

This section addresses the question:

- "What are major stressors to aquatic life in the RMC area?"

Each monitoring category required by MRP Provision C.8.c is associated in Table 8-1 with a specification for "Results that Trigger a Monitoring Project in Provision C.8.d.i" (Stressor/Source Identification). These definitions in Table 8.1 are considered to represent "trigger criteria", meaning that the relevant monitoring results should be forwarded for consideration as potential Stressor/Source Identification Projects per Provision C.8.d.i.

The biological, physical, chemical and toxicity testing data produced by ACCWP during WY2014 were compiled and evaluated against these trigger criteria. When the data analysis indicated that the associated trigger criteria were reached, those sites and results were identified as potentially warranting further investigation.

When interpreting analytical chemistry results, laboratory data often contain a relatively high proportion that is reported as either below method detection limits (MDLs) or between detection and reporting limits (RLs). Dealing with data in this range of the analytical spectrum introduces some level of uncertainty, especially when attempting to generate summary statistics for a dataset. In the compilation of statistics for analytical chemistry that follow, non-detect data (ND) were substituted with a concentration equal to one-half of the respective MDL as reported by the laboratory. This follows procedures followed in reporting the WY2012 and 2013 Integrated Monitoring Report Appendix A.2 prepared for the four collaborating RMC Programs (AMS 2014). The use of one-half of the MDL is the most common substitution in environmental science (e.g., Helsel 2010), and is thought to be more representative of laboratory results. Some of the results may therefore be slightly biased high or low with this associated analytical uncertainty, but this is not expected to affect the conclusions to any great extent.

4.3.1 Stressor Analysis: Bioassessment

Biological assessment condition categories (e.g., good, fair, poor) can assist in the presentation of bioassessment data and may or may not be tied to regulatory outcomes. For the purpose of this report, condition categories for Alameda County sites are presented using SoCal B-IBI and CSCI scores.

The SoCal B-IBI condition categories are listed in Table 4-12 and provisional CSCI categories are presented in

Table 4-13. To date, the State of California has not developed condition categories or thresholds to evaluate either B-IBI or CSCI scores and therefore scores at this point are not associated with regulatory outcomes. Condition categories for the algae IBI were not developed at this time.

Table 4-12. Condition categories used to evaluate SoCal B-IBI scores

Condition Category	Southern California B-IBI
Very Good	80-100
Good	60-79
Fair	40-59
Poor	20-39
Very Poor	0-19

Table 4-13. Condition categories used to evaluate CSCI scores.

Category	CSCI Score
Good	> 0.83
Fair	0.55 – 0.83
Poor	< 0.55

Using the CSCI condition categories for the 18 sites sampled during WY2014, 1 site (%) scored as "good", 5 sites (28%) as "fair", and 12 sites (67%) as "poor" (**Error! Reference source not found.**). The four highest scoring sites exhibited predominantly non-urban land uses in their upstream watersheds, with the two highest scoring sites in protected open space areas. These four sites may also have scored somewhat higher than expected due to their flow status classification as Non-Perennial or Unknown, since in wetter rain years these have been generally considered to be Perennial. All poor sites using the CSCI were ranked very poor using the SoCal B-IBI. Highly modified channels represented 88% of the sites in the CSCI poor category. These results are generally similar to the analysis of a larger dataset of Alameda County sites sampled in prior Water Years for which biological conditions scores were calculated and presented in the March 2014 IMR.

The stressor analysis revealed that most sites show alteration of biological communities, and channel modification and other habitat changes associated with urbanization is a likely stressor for benthic macroinvertebrate communities. The low scores and condition categories for most sites sampled in WYs 2012 and 2013 are consistent with results from of previous years of monitoring in Alameda County and also supported by studies elsewhere.

Geomorphic changes to stream systems are commonly considered to begin as the effective impervious area of their catchment reaches approximately 10% (e.g. Schuler, 2004, SFBRWQCB 2012). However Coleman et al. (2005) found that much lower thresholds of imperviousness initiated channel enlargement in the Southern California streams they studied, suggesting that arid-climate ephemeral to intermittent streams are very sensitive to slight changes in impervious area within their watersheds.

4.3.2 Stressor Analysis: Chemistry and Toxicity

Stressor analysis provides an analysis of the water and sediment chemistry and toxicity testing results in comparison to various thresholds included in the MRP. This analysis is intended to provide a means of identifying potential stressors that may impact beneficial uses at the creek status monitoring locations.

Water Chemistry Parameters

According to MRP Table 8.1, the trigger criterion ("Results that Trigger a Monitoring Project in Provision C.8.d.i) for the "Nutrients" constituents analyzed in conjunction with the bioassessment monitoring is *"20% of results in one waterbody exceed one or more water quality standard or established threshold*." A search for relevant water quality standards or accepted thresholds was conducted using available sources, including the SF Basin Water Quality Control Plan (Basin Plan) (SFBRWQCB 2013), the California Toxics Rule (CTR) (USEPA 2000a), and various USEPA sources. Of the eleven water quality constituents monitored in association with the bioassessment monitoring (referred to collectively as "Nutrients" in MRP Table 8.1), water quality standards or established thresholds are available only for ammonia (unionized form), chloride, and nitrate plus nitrite, the latter two for waters with MUN beneficial use only, as indicated in Table 4-14.

For ammonia, the standard provided in the SF Bay Basin Plan (p. 3-7) applies to the un-ionized fraction, as the underlying criterion is based on un-ionized ammonia, which is the more toxic form. Conversion of RMC monitoring data from the measured total ammonia to un-ionized ammonia was therefore necessary. The conversion was based on a formula provided by the American Fisheries Society[15], and calculates un-ionized ammonia in freshwater systems from analytical results for total ammonia and field-measured pH, temperature, and electrical conductivity.

For chloride, a Secondary Maximum Contaminant Level (MCL) of 250 mg/L applies to those waters with MUN beneficial use, per the Basin Plan (Table 3-5), Title 22 of the California Code of Regulations (CDPH, internet source), and the USEPA Drinking Water Quality Standards (USEPA, internet source). This same threshold is additionally established in the Basin Plan (Table 3-7) for waters in the Alameda Creek watershed above Niles. For all other waters, the Criteria Maximum Concentration (CMC) water quality criterion of 860 mg/L (acute) and the

[15]http://fisheries.org/hatchery

Criterion Continuous Concentration (CCC) of 230 mg/L (USEPA Water Quality Criteria[16]) for the protection of aquatic life were used for comparison purposes.[17]

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

[16]National Recommended Water Quality Criteria**.** EPA's compilation of national recommended water quality criteria is presented as a summary table containing recommended water quality criteria for the protection of aquatic life and human health in surface water for approximately 150 pollutants. These criteria are published pursuant to Section 304(a) of the Clean Water Act (CWA) and provide guidance for states and tribes to use in adopting water quality standards.

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

[17]Per UCMR (BASMAA 2012) the RMC participants used the 230 mg/L threshold as a conservative benchmark for comparison purposes for all locations not specifically identified within the Basin Plan, i.e. sites not within the Alameda Creek watershed above Niles nor identified as MUN; rather than the maximum concentration criterion of 830mg/L .

Table 4-14. Water quality thresholds available for comparison to ACCWP WY2014 water chemistry constituents

Sample Parameter	Threshold	Units	Frequency/ Period	Application	Source
Ammonia	0.025	mg/L	Annual median	Unionized ammonia, as N. [Maxima also apply to Central Bay and u/s (0.16) and Lower Bay (0.4)]	SF Bay Basin Plan Ch. 3, p. 3-7
Chloride	230	mg/L	Criterion Continuous Concentration	Freshwater aquatic life	USEPA Nat'l. Rec. WQ Criteria, Aquatic Life Criteria
Chloride	860	mg/L	Criteria Maximum Concentration	Freshwater aquatic life	USEPA Nat'l. Rec. WQ Criteria, Aquatic Life Criteria Table
Chloride	250	mg/L	Secondary Maximum Contaminant Level	Alameda Creek Watershed above Niles and MUN waters, Title 22 Drinking Waters	SF Bay Basin Plan Ch. 3, Tables 3-5 and 3-7; CA Code Title 22; USEPA Drinking Water Stds. Secondary MCL
Nitrate + Nitrite (as N)	10	mg/L	Maximum Contaminant Level	Areas designated as Municipal Supply	SF Bay Basin Plan Ch. 3, Table 3-5

The comparisons of the measured nutrients data to the thresholds listed in Table 4-14 are shown in Table 4-15. The results for these three constituents are plotted against the prevailing thresholds in Figure 4-1 through Figure 4-3. Of the 18 sites monitored, the water quality standard was exceeded at one site for chloride (204R00068 in 2012).[18] Two results (sites 205R00686 and 207R03504, both sampled in 2013) exceeded the un-ionized ammonia standard.[19] No samples exceeded the nitrate + nitrite standard. The MRP Table 8.1 trigger criterion for “Nutrients” (20% of results in one waterbody exceed one or more water quality standards or applicable thresholds) was therefore considered to be exceeded at 3 of the 18 sites (17%).

[18] This assessment is unaffected by usage of the CCC of 230 mg/L or CMC of 860 mg/L, as the single instance occurred at a site within Alameda Creek above Niles, and is therefore measured against the criterion of 250 mg/L.

[19] It should be noted that this standard is an annual median concentration, and comparison to an acute threshold may change this determination.

Table 4-15. Comparison of water quality (nutrient) data to associated water quality thresholds for WY2014 water chemistry results. (NDs estimated as ½ MDL).

County/ Program	Site Code	Alameda Creek Above Niles	MUN	Parameter and Threshold			# of Parameters >Threshold/ Waterbody	% of Parameters >Threshold/ Waterbody
				Un-ionized Ammonia (as N)	Chloride	Nitrate + Nitrite (as N)		
				25 µg/L	230/250 mg/L [1]	10 mg/L [2]		
ACCWP	203R00295			0.29	25	NA	0	0%
ACCWP	204R00292	X		1.81	220	NA	0	0%
ACCWP	204R00665	X		0.28	210	NA	0	0%
ACCWP	204R00927			1.48	78	NA	0	0%
ACCWP	204R01007			0.17	23	NA	0	0%
ACCWP	204R01023	X		2.44	**260**	NA	0	**50%**
ACCWP	204R01087			0.44	29	NA	0	0%
ACCWP	204R01108			0.62	**360**	NA	0	**50%**
ACCWP	204R01380	X		1.03	150	NA	0	0%
ACCWP	204R01433			0.26	**420**	NA	0	**50%**
ACCWP	204R01479			0.38	94	NA	0	0%
ACCWP	204R01607			0.29	56	NA	0	0%
ACCWP	204R01620			0.17	220	NA	0	0%
ACCWP	204R01663		X	1.53	130	0.012	0	0%
ACCWP	204R01759			0.49	54	NA	0	0%
ACCWP	204R01791	X		0.52	55	NA	0	0%
ACCWP	205R00366			0.42	150	NA	0	0%
ACCWP	205R01454			0.27	47	NA	0	0%
# Values >Threshold:				0	3	0		
% Values >Threshold:				0%	17%	0%		
Overall Number and % of Sites Meeting Trigger Criterion [3]:							**3**	**17%**

[1] 250 mg/L threshold applies for sites with MUN beneficial use and Alameda Creek above Niles per Basin Plan

[2] Nitrate + nitrite threshold applies only to sites with MUN beneficial use

[3] Sites where >20% of results exceed one or more water quality standard or established threshold

NA = threshold does not apply

Bolded value exceeds threshold

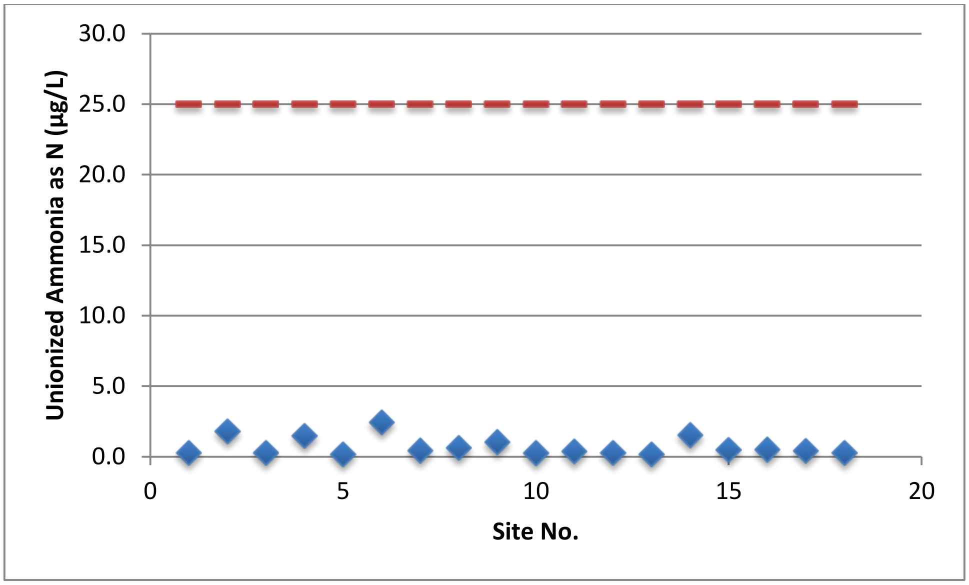

Figure 4-10. Plot of ACCWP WY2014 unionized ammonia data (calculated from total ammonia, pH, temperature, and electrical conductivity) with threshold of 25 µg/L indicated.

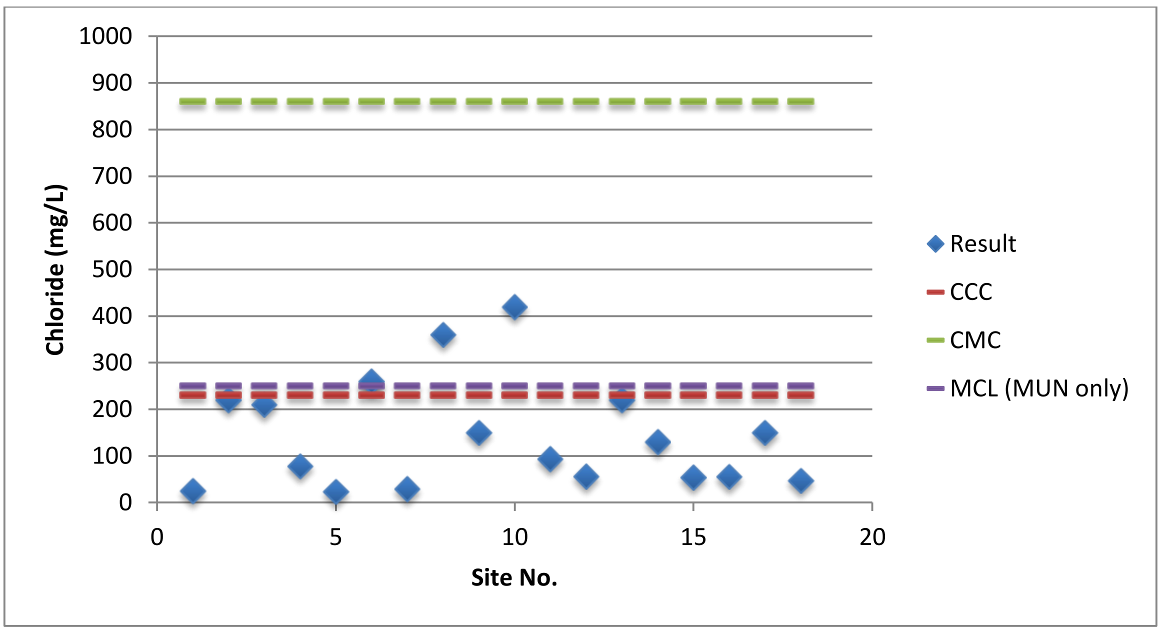

Figure 4-11. Plot of ACCWP WY2014 chloride data with relevant Aquatic Life and MUN thresholds indicated.

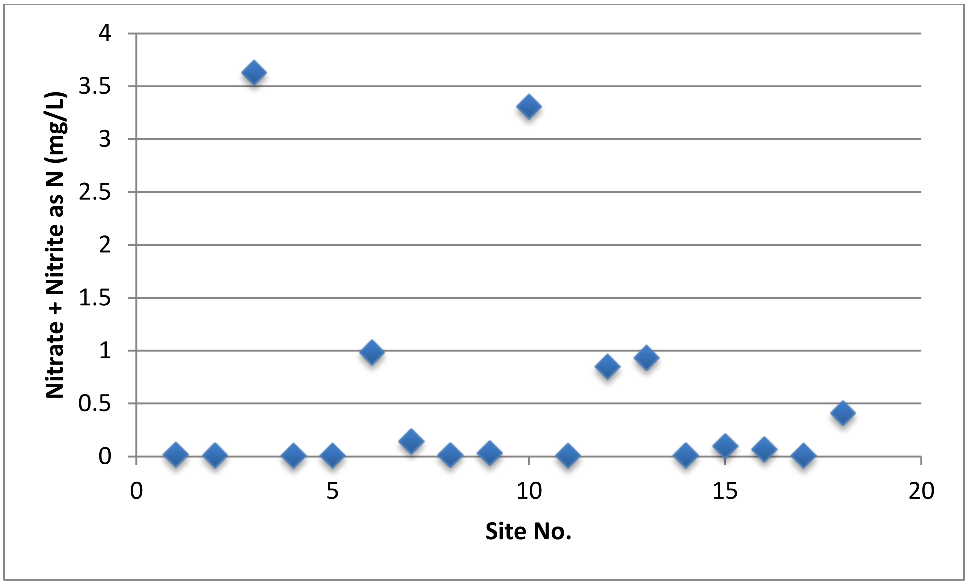

Figure 4-12. Plot of ACCWP WY2014 nitrate + nitrite as N data, WY2012 and WY2013 data (threshold not shown = 10 mg/L for MUN only).

Free and Total Chlorine Testing

The results of field testing for free and total chlorine and comparisons to the MRP Table 8.1 trigger threshold are summarized in

Table 4-16.

The MRP trigger criterion for chlorine states, "After immediate resampling, concentrations remain >0.08 mg/L".

There were 21 site measurements for free and total chlorine collected by ACCWP in WY2014, as the toxicity sites were each tested twice (spring and summer). In 2013, there were 45 measurements collected, with the added participation of FSURMP and Vallejo. Of the 74 measurements collected overall, 15% exceeded the threshold for free chlorine, and 12% exceeded the threshold for total chlorine; as noted previously, there appears to be an issue with the field kits and free chlorine measurements sometimes exceeded those for total chlorine. Overall, the percentage of samples meeting the trigger threshold for free and/or total chlorine was 19%.

Table 4-16. Summary of ACCWP WY2014 chlorine testing results in comparison to Municipal Regional Permit trigger criteria.

County/ Program	Site Code	Sample Date	Chlorine, Free	Chlorine, Total	Meets Trigger Threshold?
ACCWP	203R00295	7/1/14	<0.04	<0.04	No
ACCWP	204R00292	5/7/14	<0.04	<0.04	No
ACCWP	204R00665	4/16/14	<0.04	0.04	No
ACCWP	204R00927	5/13/14	<0.04	<0.04	No
ACCWP	204R01007	6/2/14	0.06	0.06	No
ACCWP	204R01023	4/16/14	<0.04	<0.04	No
ACCWP	204R01087	6/3/14	0.04	0.04	No
ACCWP	204R01108	5/12/14	0.12	0.12	**Yes**
ACCWP	204R01380	5/12/14	<0.04	<0.04	No
ACCWP	204R01433	5/8/14	0.12	0.06	**Yes**
ACCWP	204R01479	4/15/14	<0.04	<0.04	No
ACCWP	204R01607	5/7/14	<0.04	<0.04	No
ACCWP	204R01620	4/28/14	0.06	0.04	No
ACCWP	204R01663	5/14/14	0.04	0.04	No
ACCWP	204R01759	5/27/14	<0.04	<0.04	No
ACCWP	204R01791	4/28/14	<0.04	<0.04	No
ACCWP	205R00366	4/29/14	<0.04	<0.04	No
ACCWP	205R01454	4/17/14	<0.04	0.04	No
ACCWP	203R00295	7/23/14	<0.04	0.04	No
ACCWP	204R00292	7/23/14	0.06	0.06	No
ACCWP	204R00927	7/23/14	<0.04	<0.04	No
Number of samples exceeding 0.08 mg/L:			2	1	2
Percentage of samples exceeding 0.08 mg/L:			10%	5%	10%

Water and Sediment Toxicity Testing

The analysis of toxicity testing results and comparisons to MRP trigger thresholds, as presented in detail earlier in this section, are summarized in Table 4-17 for those WY2014 samples that exhibited statistically-significant toxicity.

The MRP Table 8.1 trigger criterion for water column toxicity stipulates "If toxicity results less than 50% of control results, repeat sample. If 2nd sample yields less than 50% of control results, proceed to C.8.d.i." For the wet season sampling, site 203R00295 exhibited statistically significant toxicity to *Ceriodaphnia dubia* reproduction, but not of a sufficient magnitude to indicate re-sampling. For the dry season sampling, site 204R00292 exhibited statistically significant toxicity to *Selanastrum capricornutum* growth; again, the toxicity was not of sufficient magnitude to indicate re-sampling.

Associated with the dry season aquatic toxicity monitoring, AMS collected samples at the three triad sites for analysis of sediment toxicity. The sediment from site 203R00295 exhibited statistically significant toxicity to *Hyalella azteca* growth but not survival, which is the metric used to indicate toxic response within the MRP. There was therefore no requirement for follow-on testing.

Table 4-17. Overall summary of WY2014 aquatic and sediment toxicity samples with toxic response in comparison to Municipal Regional Permit trigger criteria.

County/ Program	Test Initiation Date	Species Tested	Test Regimen	Treatment/ Sample ID	Comparison to Table 8.1 (Water) and Table H-1 (Sediment) Trigger Criteria
Water					
ACCWP	3/29/14	*C. dubia*	Chronic (reproduction)	203R00295	Not < 50% of Control
ACCWP	7/23/14	*S. capricornutum*	Chronic (growth)	204R00292	Not < 50% of Control
Sediment					
ACCWP	7/23/14	*H. azteca*	Chronic (growth)	203R00295	No MRP comparison for growth endpoint

Sediment Chemistry Parameters

Sediment chemistry results are evaluated as potential stressors in three ways, based upon the following criteria from MRP Table H-1:

- Calculation of threshold effect concentration (TEC) quotients by analyte; determine whether site has three or more TEC quotients greater than or equal to 1.0;[20]
- Calculation of probable effect concentration (PEC) quotients for all analytes at a given site; determine whether site has mean PEC quotient greater than or equal to 0.5; and,

[20] Consistent with 2012 Regional UCMR (BASMAA 2013) interpretation, this analysis assumes that there is a typographical error in Table H-1 and that the criterion is meant to read, “3 or more chemicals exceed TECs”.

- Calculation of pyrethroid toxic unit (TU) equivalents as sum of TU equivalents for all measured pyrethroids; determine whether site has sum of TU equivalents greater than or equal to 1.0.

More detail is provided below on each of these three factors.

For sediment chemistry results, Table 4-18 provides threshold effect concentration (TEC) quotients for all non-pyrethroid sediment chemistry constituents, calculated as the measured concentration divided by the TEC value, per MacDonald et al. (2000). This table also provides a count of the number of constituents that exceed TEC values for each site, as evidenced by a TEC quotient greater than or equal to 1.0.

The number of TEC quotients greater than or equal to 1.0 for each site ranges from a low of 1 to a high of 13, out of 27 constituents included in MacDonald et al. (2000). Two of three sites sampled met the relevant trigger criterion from MRP Table H-1, which is interpreted to stipulate three or more constituents with TEC quotients greater than or equal to 1.0. For site 203R00295, a highly urbanized location between railroad tracks and the Eastshore Freeway in north Berkeley, the main contributors to the relatively high number of TEC quotients >1 were PAHs and trace metals.

Table 4-19 provides PEC quotients for all non-pyrethroid sediment chemistry constituents, and calculated mean values of the PEC quotients for each site. None of the sites sampled in WY2014 met the MRP Table H-1 action criteria of a mean PEC greater than 0.5. The mean PEC quotients are shown graphically by site in Figure 4-4.

Table 4-20 provides a summary of the calculated toxic unit equivalents for the pyrethroids for which there are published LC50 values in the literature, as well as a sum of calculated toxic unit (TU) equivalents for each site. Because organic carbon mitigates the toxicity of pyrethroid pesticides in sediments, the LC50 values were derived on the basis of TOC-normalized pyrethroid concentrations. Therefore, the pyrethroid concentrations as reported by the lab were divided by the measured TOC concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid. The individual TU equivalents were then summed to produce a total pyrethroid TU equivalent value for each site. At one of three sites sampled in WY2014 (204R00927), individual pyrethroid TU equivalents met the MRP Table H-1 action criterion with at least one TU quotient greater than or equal to 1.0; the pyrethroids generating TUs above 1 were bifenthrin (TU=5.2) and cyfluthrin (TU=1.2). At two of the sites, (204R00927 and 203R00295) the sum of the seven individual TUs were above 1.0. These results are shown graphically in Figure 4-5. In most cases, the greatest contributor to the TU sum is bifenthrin (making up more than 50% of the sum TUs at both 203R00295 and 204R00927).

Some of the calculated numbers for TEC quotients, PEC quotients, and pyrethroid TU equivalents may be artificially elevated due to the method used to account for filling in non-detect data (as discussed previously, concentrations equal to one-half of the respective laboratory MDLs were substituted for non-detect data so these statistics could be computed). This, however, is not expected to greatly influence assessments.

Table 4-18. Threshold Effect Concentration (TEC) quotients for 2012 and 2013 sediment chemistry constituents. Bolded values indicate TEC quotient ≥ 1.0

Stormwater Program, Site ID	203R00295	204R00447	204R00927
Metals (mg/kg DW)			
Arsenic	0.65	**1.43**	0.26
Cadmium	0.37	0.18	0.11
Chromium	**1.22**	**1.52**	0.55
Copper	**1.36**	**1.61**	0.28
Lead	**1.90**	0.24	0.17
Mercury	**12.78**	0.42	0.22
Nickel	**3.74**	**3.22**	**1.28**
Zinc	**1.24**	0.00	0.00
PAHs (µg/kg DW)			
Anthracene	**1.92**	0.03	0.03
Fluorene	0.93	0.02	0.05
Naphthalene	0.16	0.01	0.01
Phenanthrene	**1.81**	0.01	0.04
Benz(a)anthracene	0.42	0.01	0.01
Benzo(a)pyrene	**2.20**	0.01	0.01
Chrysene	**3.73**	0.01	0.13
Fluoranthene	**1.02**	0.00	0.03
Pyrene	**1.64**	0.01	0.06
Total PAHs	**2.45**	0.02	0.11
Pesticides (µg/kg DW)			
Chlordane	0.21	0.21	0.20
Dieldrin	0.19	0.19	0.19
Endrin	0.18	0.18	0.17
Heptachlor Epoxide	0.13	0.13	0.13
Lindane (gamma-HCH)	0.15	0.14	0.14
Sum DDD	0.11	0.11	0.11
Sum DDE	0.15	0.15	0.14
Sum DDT	0.09	0.09	0.08
Total DDTs	0.26	0.26	0.25
Number of constituents with TEC quotient ≥ 1.0	**13**	**4**	**1**

Table 4-19. Probable Effect Concentration (PEC) quotients for WY2014 sediment chemistry constituents. Yellow highlighted cells indicate sites where mean PEC quotient ≥ 0.5 (trigger threshold per MRP Table H-1); bolded values indicate individual PEC quotients > 1.0.

Stormwater Program, Site ID	203R00295	204R00292	204R00927
Metals (mg/kg DW)			
Arsenic	0.19	0.42	0.08
Cadmium	0.07	0.04	0.02
Chromium	0.48	0.59	0.22
Copper	0.29	0.34	0.06
Lead	0.53	0.07	0.05
Mercury	**2.17**	0.07	0.04
Nickel	**1.75**	**1.50**	0.60
Zinc	0.33	0.00	0.00
PAHs (µg/kg DW)			
Anthracene	0.13	0.00	0.00
Fluorene	0.13	0.00	0.01
Naphthalene	0.05	0.00	0.00
Phenanthrene	0.32	0.00	0.01
Benz(a)anthracene	0.04	0.00	0.00
Benzo(a)pyrene	0.23	0.00	0.00
Chrysene	0.48	0.00	0.02
Fluoranthene	0.19	0.00	0.00
Pyrene	0.21	0.00	0.01
Total PAHs	0.17	0.00	0.01
Pesticides (µg/kg DW)			
Chlordane	0.04	0.04	0.04
Dieldrin	0.01	0.01	0.01
Endrin	0.00	0.00	0.00
Heptachlor Epoxide	0.02	0.02	0.02
Lindane (gamma-HCH)	0.07	0.07	0.07
Sum DDD	0.02	0.02	0.02
Sum DDE	0.01	0.01	0.01
Sum DDT	0.01	0.01	0.01
Total DDTs	0.00	0.00	0.00
Mean PEC Quotient	0.29	0.12	0.05

Table 4-20. Calculated pyrethroid toxic unit equivalents, WY2014 sediment chemistry data. Yellow highlighted cells indicate sites where the sum of the pyrethroid TU equivalents is ≥ 1.0; bolded values indicate individual pyrethroid TUs > 1.0.

Pyrethroid	LC50	203R00295	204R00292	204R00927
Bifenthrin, TOC-normalized	0.52	0.68	0.12	**5.18**
Cyfluthrin, TOC-normalized	1.08	0.28	0.05	**1.21**
Cypermethrin, TOC-normalized	0.38	0.03	0.15	0.23
Deltamethrin, TOC-normalized	0.79	0.03	0.11	0.17
Esfenvalerate, TOC-normalized	1.54	0.01	0.03	0.05
Lambda-Cyhalothrin, TOC-normalized	0.45	0.04	0.16	0.24
Permethrin, TOC-normalized	10.83	0.10	0.04	0.19
Sum of Toxic Unit Equivalents per Site		1.15	0.66	7.27

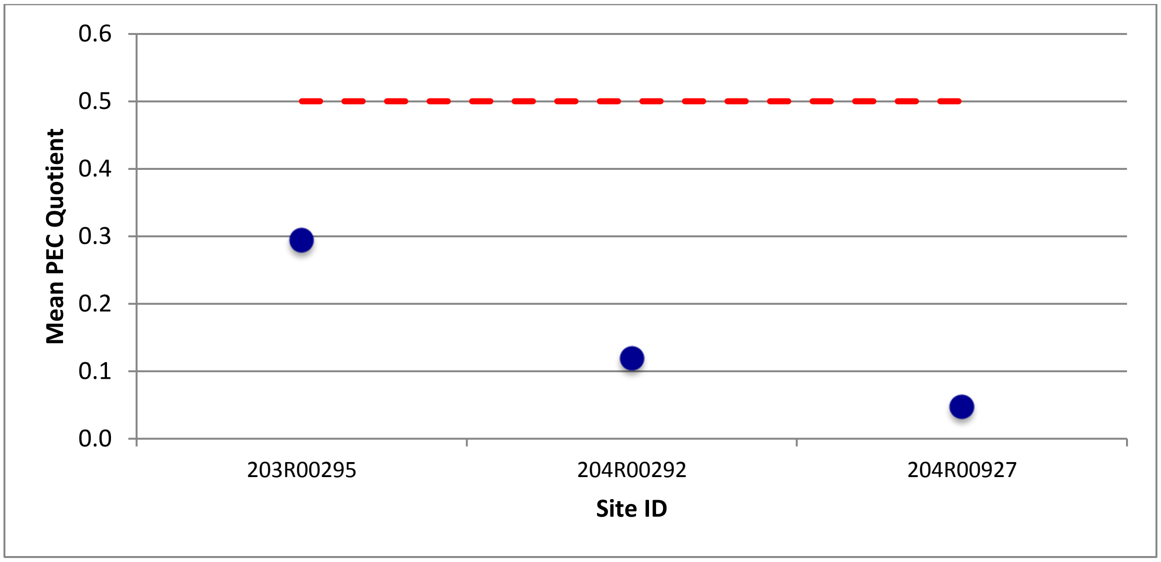

Figure 4-13. Plot of mean PEC quotient per site, WY2014 data. The dashed line indicates a threshold of 0.5 mean PEC quotient.

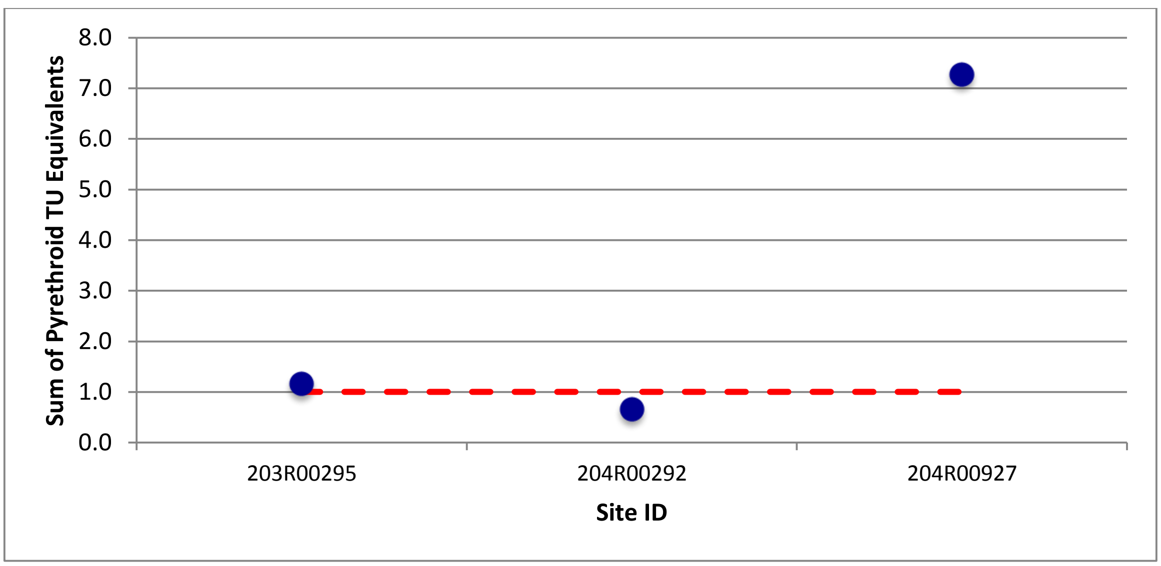

Figure 4-14. Plot of the sum of pyrethroid toxic unit equivalents per site, WY2014 data. The dashed line indicates a threshold of 1.0 TUs.

Sediment Triad Analysis

Table 4-21 summarizes stressor evaluation results for those sites with data collected for sediment chemistry, sediment toxicity and bioassessment parameters. Biological condition assessments are also shown for these sites based on the CSCI scores.

Table 4-21. Summary of sediment quality triad evaluation results, WY2014 data. Yellow highlighted cells indicate results above MRP trigger threshold.

Agency/ Program	Waterbody	Site ID	CSCI Condition Category	Sediment Toxicity	# TEC Quotients ≥ 1.0:	Mean PEC Quotient	Sum of TU Equiv.	Next Step per MRP Table H-1
ACCWP	Codornices Creek	203R00295	Poor	No	13	0.29	1.15	A
ACCWP	Arroyo Mocho	204R00292	Poor	No	4	0.12	0.66	A
ACCWP	Crow Creek	204R00927	Fair	No	1	0.05	7.27	A

Key to Next Steps:

Action Code	Exceeds Bioassessment/ Toxicity/ Chemistry Threshold	Next Step per MRP Table H-1 (selected)
A	Yes/No/Yes	(1) Identify cause of impacts. (2) Where impacts are under Permittee's control, take management actions to minimize the impacts caused by urban runoff; initiate no later than the second fiscal year following the sampling event.
B	No/No/Yes	If PEC exceedance is Hg or PCBs, address under TMDLs.
C	Yes/Yes/Yes	(1) Identify cause(s) of impacts and spatial extent. (2) Where impacts are under Permittee's control, take management actions to address impacts.
D	No/Yes/Yes	(1) Take confirmatory sample for toxicity. (2) If toxicity repeated, attempt to identify cause and spatial extent. (3) Where impacts are under Permittee's control, take management actions to minimize upstream sources.

While MacDonald et al. (2000) generated PECs for multiple trace element, PAH, OC pesticide, and pyrethroid pesticide parameters, there was insufficient data at time of its publication to evaluate the consensus PECs generated as to their predictive ability for associated sediment toxicity for each of the analytes reported. Analytes for which predictive ability is particularly uncertain include various PAH (anthracene, fluorine, and fluoranthene) and OC pesticide (dieldrin, DDDs, DDTs, endrin, heptachlor epoxide, and lindane) parameters (MacDonald et al. 2000).

Additionally, MacDonald et al. (2000) TECs and PECs were generated with the assumption that the predictive ability of the thresholds would be acceptable if the prediction was correct 75% of the time. For the three samples collected by ACCWP in WY2014, no samples exceeded the mean PEC criterion of 0.5. For the two samples that had more than three analytes exceed associated TECs, neither sample met the MRP threshold for toxicity.

When examining pyrethroids concentrations, a similar degree of uncertainty exists. Weston (2005) reported that predictions of sediment toxicity to *H. azteca* were supported by observed results for sites with TU ratios below one (little or no mortality) and above four (high or full mortality). For TUs between one and four, however, the predictive ability of the TU is less certain (Weston 2005). For the three samples analyzed by ACCWP in WY2014, each fell into a different category re: TU results (low mortality, high mortality, and uncertain). This uncertainty can potentially be seen in the RMC results where a sample with a pyrethroid TU of 1.2 was associated with results exhibiting statistically-significant toxicity to *H. Azteca* growth, and one with a TU of 7.3 did not exhibit any toxicity (Table 4-20 and Table 4-17).

5. Conclusions and Next Steps

During WY2014, ACCWP monitored 18 sites under the RMC regional probabilistic design for bioassessment, physical habitat, and related water chemistry parameters. Three sites were also monitored for water and sediment toxicity and sediment chemistry. The water and sediment chemistry and toxicity data were used to evaluate potential stressors that may affect aquatic habitat quality and beneficial uses. Each program also used bioassessment and related data to develop a preliminary condition assessment for the monitored sites, to be used in conjunction with the stressor assessment based on sediment chemistry and toxicity.

The following MRP reporting requirements (Provision C.8.g.iv) were addressed within this report as applicable:

- Descriptions of monitoring purpose and study design rationale
- QA/QC summaries for sample collection and analytical methods, including a discussion of any limitations of the data;
- Descriptions of sampling protocols and analytical methods;
- Tables and Figures describing: Sample location descriptions (including waterbody names, and lat/longs); sample ID, collection date (and time where relevant), media (e.g., water, filtered water, bed sediment, tissue); concentrations detected, measurement units, and detection limits;
- Data assessment, analysis, and interpretation for Provision C.8.c.;
- Pollutant load and concentration at each mass emissions station;
- A listing of volunteer and other non-Permittee entities whose data are included in the report;
- Assessment of compliance with applicable water quality standards;

Candidate sites classified with unknown sampling status as of WY2014 may continue to be evaluated by the individual stormwater programs for potential sampling in WY2015.

5.1 Summary of Stressor Analyses

The stressor analysis revealed the following potential stressors or stress conditions at WY 2014 sites:

- **Water Quality** – Of 11 parameters[21] sampled in association with bioassessment monitoring, applicable water quality standards were only identified for ammonia, chloride, and nitrate + nitrite (sites with MUN beneficial use only). Of the results generated at the 18 sites monitored by ACCWP reporting herein for those three parameters, only three chloride concentrations exceeded the applicable water quality standard or threshold. The MRP Table 8.1 trigger thresholds for "Nutrients" (i.e., 20% of results in one waterbody exceed one or more water quality standards or applicable thresholds) was therefore exceeded at 3 of the 18 sites.
- **Water Toxicity –** For WY2014, 24 toxicity endpoints were derived through testing of 4 species at 3 sites regionwide during one wet season and one dry season event. Of these endpoints, two sample / test combinations exhibited statistically-significant toxicity as reported by the analytical laboratory (*C. dubia* reproduction at site 203R00295 and *S. capricornutum* at site 204R00292). No samples exhibited toxicity with survival and/or growth "< 50% of Control," indicating re-testing per MRP Table 8.1. Therefore, no re-testing was required during WY2014.
- **Sediment Toxicity –** Of the bedded sediment collected from 3 sites, a toxic response in test species *H. azteca* was observed at 1 site. Results did not meet the MRP Table H-1 sediment toxicity criterion interpreted as being more than 20% less than the control.
- **Sediment Chemistry -** Results produced evidence of potential stressors in 2 ways, based on the criteria from MRP Table H-1: **(**1) at 2 of 3 sites, 3 or more constituents exhibited TEC quotients greater than 1.0[22] and (2) at 2 of 3 sites, the sum of TU equivalents for all measured pyrethroids was greater than or equal to 1.0. In relation to the third metric, at no sites was the mean PEC quotient > 0.5.
- **Sediment Triad Analyses including bioassessment** – sediment chemistry and toxicity results were evaluated as two of the three lines of evidence used in the triad approach for assessing overall stream condition, along with biological community data which indicated impacted communities at most sites.

[21] Algal mass (ash-free dry weight), Chlorophyll a, Dissolved Organic Carbon, Ammonia, Nitrate, Total Nitrogen, Dissolved OrthoPhosphate, Phosphorus, Suspended Sediment Concentration, Silica and Chloride

[22] For most sites, chromium and nickel concentrations in sediment exceeded TEC values. Considering that both metals are naturally occurring at relatively high levels in Bay Area soils, and concentrations generally exceed TEC values in reference or non-urban sites, TEC values presented in MacDonald et al. (2000) may not be applicable to the Bay Area. These observations should be considered in future evaluations of sediment chemistry data collected by RMC participants in Bay Area creeks.

5.2 Next Steps

MRP Table 8.1 requires bioassessment results to be evaluated for triggers as a triad along with results of sediment toxicity and chemistry according to the criteria in MRP Attachment H-1as shown above. During WY2013, the RMC collaboratively reviewed trigger results from WY2012 and selected a total of ten sites in four counties for implementation of stressor/source identification (SSID) projects based on prioritization of the type, extent and geographic spread of the triggers. Technical studies for SSID projects are to be initiated by the second Fiscal Year following the year in which the potential stressor was identified. ACCWP's progress reports on an SSID projects in Dublin Creek (Appendix A.4A to IMR Part A) reviews bioassessment scores for three sites along an urbanization gradient within that watershed.

ACCWP and other RMC participants will continue to implement the regional probabilistic monitoring design in WY2015. Site evaluation is underway for new bioassessment sites for Water Year 2015. Candidate sites classified with unknown sampling status as of WY2014 may continue to be evaluated for potential sampling in Water Year 2015.

6. References

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ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM

clean water PROGRAM

CREEK STATUS MONITORING REPORT - TARGETED PARAMETERS

APPENDIX A.2
URBAN CREEKS MONITORING REPORT
OCTOBER 2013 THROUGH SEPTEMBER 2014

MEMBER AGENCIES:

Alameda

Albany

Berkeley

Dublin

Emeryville

Fremont

Hayward

Livermore

Newark

Oakland

Piedmont

Pleasanton

San Leandro

Union City

County of Alameda

Alameda County Flood Control and Water Conservation District

Zone 7 Water Agency

Report prepared by

Alameda Countywide Clean Water Program
399 Elmhurst Street,
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Submitted to:

California Regional Water Quality Control Board, San Francisco Bay Region

FINAL

March 16, 2015

Protecting Alameda County Creeks, Wetlands & the Bay

Preface

The Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) collaboratively developed an outline for preparation of the Integrated Monitoring Report (IMR) to be submitted in compliance with the Municipal Regional Stormwater Permit (MRP) Reporting Provision C.8.g.v for all monitoring conducted during the MRP permit term.

The following participants make up the RMC and are responsible for preparing IMR documents on behalf of their respective member agencies:

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

This report was prepared by ACCWP to fulfill reporting requirements for a portion of the Creek Status monitoring data collected in Water Years 2012 (October 1, 2011 through September 30, 2012) and 2013 (October 1, 2012 through September 30, 2013) as part of the RMC's Monitoring Plan (BASMAA, 2011) for certain parameters monitored according to Provision C.8.c of the MRP. This report is an Appendix to the full IMR Part A submitted by ACCWP on behalf of the following Permittees:

- The cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City;
- Alameda County;
- Alameda County Flood Control and Water Conservation District and
- Zone 7 Water Agency

Data presented in this report were produced under the direction of the ACCWP using a targeted (non-probabilistic) monitoring design. Other data collected in Alameda County during this period pursuant to MRP Provision C.8 are reported in the main body and other appendices of ACCWP's Integrated Monitoring Report, Part A.

In accordance with the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA, 2011),targeted monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Program Plan (QAPP; BASMAA, 2012a and 2014a) and BASMAA RMC Standard Operating Procedures (SOPs, BASMAA, 2012band 2014b). Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP[1]. ACCWP also submitted the data included in this report to the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) in electronic SWAMP-comparable format.

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

List of Acronyms

Acronym	**Definition**
AMS	Applied Marine Sciences
ACCWP	Alameda Countywide Clean Water Program
ACFCWCD	Alameda County Flood Control Water Conservation District
BASMAA	Bay Area Stormwater Management Agency Association
CCCWP	Contra Costa Clean Water Program
CEDEN	California Environmental Data Exchange Network
CRAM	California Rapid Assessment Method
DO	Dissolved oxygen
DQO	Data Quality Objective
EBMUD	East Bay Municipal Utility District
E.coli	*Escherichia coli*
FOSC	Friends of Sausal Creek
FSURMP	Fairfield Suisun Urban Runoff Management Program
I-	Interstate Highway
IMR	Integrated Monitoring Report
MPC	Monitoring and Pollutants of Concern Committee
MPN	Most Probable Number
MRP	Municipal Regional Permit
MQO	Measurable Quality Objective
MWAT	Maximum Weekly Average Temperature
NPDES	National Pollution Discharge Elimination System
QAPP	Quality Assurance Project Plan
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program
RWQCB	Regional Water Quality Control Board
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Protocol
SSID	Stressor/Source Identification
SWAMP	Surface Water Ambient Monitoring Program
UCMP	Urban Creek Monitoring Report
USA	Unified Stream Assessment
USEPA	United States Environmental Protection Agency
WQO	Water Quality Objective
WY	Water Year

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Attachment D Washington Creek Surveyed Reaches

Executive Summary

In 2010, the seventeen members of the Alameda Countywide Clean Water Program (ACCWP) joined other members of the Bay Area Stormwater Agencies Association (BASMAA) to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by Provision C.8 of the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP). This report presents the details of the Creek Status Monitoring for parameters that use a targeted (non-probabilistic) monitoring design, and is one of several documents preparedto comply with the MRP Reporting Provision C.8.g.

The ACCWP Targeted Creek Status Monitoring in Water Year 2014 (WY2014) was conducted in the Castro Valley and Crow Creek tributaries to San Lorenzo Creek, as well as a number of Oakland creeks (Arroyo Viejo, Lion and Sausal), and included:

- Continuous temperature monitoring at eight locations at hourly intervals over five months;
- General water quality monitoring at three locations with assessment of temperature, dissolved oxygen (DO), pH and specific conductivity at 15-minute intervals during two one week periods in Spring and late Summer/Fall;
- Pathogen indicator (*E. coli* and fecal coliform) quantification once at five sites each year; and
- Nine miles of stream surveys using the Center for Watershed Protection's protocol for Unified Stream Assessment.

The results of the targeted Urban Creek Monitoring indicated:

Continuous Temperature

Continuous temperature monitoring results reached trigger criteria for Mean Weekly Average Temperatures at each of the three sites in the Castro Valley Creek watershed generated rolling averages above the 19º C threshed: 204CVY005 at 11%, 204CRW030 at 21%, and 204CRW040 at 3% of calculated rolling averages. Five sites in Oakland creeks resulted in zero calculated seven-day rolling averages above the threshold of 19º C.

General Water Quality

Results of the General Water Quality assessment are presented in Table E-1 for all parameters where at least some of the rolling 7-day averages reached the applicable water quality standard or threshold used for comparison. Dissolved oxygen was the only parameter for which at least some of the rolling 7-day averages reached or were below the threshold trigger criterion in the MRP Table 8.1.

Table E-1. Percentage of Weekly 7-Day Rolling Averages Meeting MRP Trigger Thresholds for General Water Quality Monitoring sites in WY2014

Site ID	Monitoring Season	Applicable threshold or water quality standard				
		Temperature > 19°C	pH < 6.5	pH > 8.5	DO < 5mg/L (WARM)	DO < 7mg/L (COLD)
204AVJ080	Summer/Fall	0.0%	0.0%	0.0%	**100%**	**100%**
204CRW040	Summer/Fall	0.0%	0.0%	0.0%	**89%**	**100%**
204CRW042	Summer/Fall	0.0%	0.0%	0.0%	NA*	NA*

BOLD: percentage of rolling averages reaching trigger criteria, if above zero.
*Equipment failure

Pathogen Indicator Bacteria

Seven of ten water samples collected for pathogen indicators recorded elevated fecal coliform and *E.coli* concentrations of between 700 and 2,200 most probable number (MPN) per 100mL. The results are presented in Table E-2. Actual creek contact at most of these sites is sporadic at best and does not correspond to the assumptions for human health risk assessment that were used to develop the water quality standard being used for comparison. Due to high sample variability the results of a single sample are insufficient to determine average levels of pathogen indicators, and in dry weather urban runoff is likely to make little or no contribution to the observed bacterial levels.

Table E-2: Comparison of WY2014 Pathogen Indicator Concentrations to Water Quality Objectives and Triggers.

Site ID	Site Description	Creek Name	Fecal Coliform (MPN*/100mL)	*E. coli* (MPN*/100 mL)
204CVY020	Chabot Creek at Carlos Bee Park	Chabot Creek	**2,200**	**2,200**
204CVY080	Castro Valley Creek above confluence with Chabot Creek	Castro Valley Creek	130	**2,200**
204CVY125	Castro Valley Creek below Castro Valley Blvd.	Castro Valley Creek	**1,700**	**700**
204CVY140	Castro Valley Creek North side of Berdina Rd	Castro Valley Creek	170	170
204CVY150	Castro Valley Creek North side of Heyer Ave	Castro Valley Creek	**900**	**900**

*Most Probable Number per 100mL
BOLD font indicates result meets trigger conditions.

Stream Survey

The overall reach assessment scores for surveyed portions of the Laguna Creek watershed ranged from 26 to 57. Washington Creek reaches had the highest average score of 44, with slightly more complex instream habitat and vegetated banks. Laguna Creek had the lowest average score of 38, with heavily modified channel reaches and significant floodplain encroachment..

Stressor Evaluation

Where applicable, targeted monitoring data were evaluated against numeric Water Quality Objectives or other applicable thresholds described for each parameter in Table 8.1 of the MRP, to determine whether results "trigger" a potential stressor/source identification monitoring project as described in MRP Provision C.8.d.i). The following trigger conditions were identified:

- Temperature triggers were observed at 3 sites in Crow Creek..
- Dissolved oxygen concentrations were lower than 7mg/L in at least 20% of results for at least one deployment at Sites 204AVJ080 and 204CRW040 based on analysis of the 7-day rolling averages for continuous monitoring observations.
- Seven of the ten water samples analyzed for pathogen indicators were above trigger levels for lightly and moderately used REC1 beneficial use, although limited public accessibility at many sites make human usage much less likely to produce the exposure risks assumed in developing the water quality criteria used for reference.

Where triggers or potential trigger conditions have been identified in WY2014 results, ACCWP will work with local stormwater managers to identify appropriate follow-up activities.

1 Introduction

This Creek Status Monitoring Report complies with Municipal Regional Permit (MRP) Reporting Provision C.8.gfor a portion of Creek Status Monitoring data collected on behalf of Alameda County Permittees during Water Years 2012 and 2013 (October 1, 2011 through September 30) in compliance with MRP Provision C.8.c. Data presented in this report were developed using a targeted (non-probabilistic) monitoring design. This report is Appendix A.3 to the overall to the Integrated Monitoring Report (IMR) prepared by the BASMAA Regional Monitoring Coalition (RMC).

The RMC was formed in early 2010 as a collaboration among a number of BASMAA members and MRP Permittees listed in Table 1-1. The RMC's focus is developing and implementing a regionally coordinated water quality monitoring program to address water quality monitoring required by theMRP. Implementation of the RMC's Creek Status and Long-Term Trends Monitoring Plan allows Permittees and the Water Board to effectively modify their existing creek monitoring programs, and improve their ability to collectively answer core management questions in a cost-effective and scientifically rigorous way. Participation in the RMC is facilitated through the BASMAA Monitoring and Pollutants of Concern Committee (MPC) and its associated RMC Work Group.

The goals of the RMC are to:

1. Assist Permittees in complying with requirements in MRP Provision C.8 (Water Quality Monitoring);
2. Develop and implement regionally consistent creek monitoring approaches and designs in theBay Area, through the improved coordination among RMC participants and other agencies such as the Regional Water Quality Control Board (RWQCB) that share common goals; and
3. Stabilize the costs of creek monitoring by reducing duplication of effort and streamlining reporting.

Table 1-1. Regional Monitoring Coalition Participants.

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

The RMC addresses the scope of sub-provisions specified in MRP Provision C.8.c (Table 1-2).This report includes the standard report content as required by MRP Provision C.8.g.v in the respective sections referenced in Table 1-2and presents the results of the portions of Creek Status Monitoring that were conducted to comply with Provision C.8.c using a targeted (non-probabilistic) monitoring design (Table 1-3)as described in the RMC's Status and Long-Term Trends Monitoring Plan (BASMAA, 2011).

Table 1-2. Municipal Regional Permit Provisions Addressed by the Regional Monitoring Coalition.

MRP C.8 Subprovision Number	MRP C.8 Sub-provision Title	Reporting Documents
C.8.a	Compliance Options	Regional Monitoring Coalition Creek Status & Long-Term Trends Monitoring Plan.
C.8.b	San Francisco Bay Estuary Monitoring	Regional Monitoring Plan Annual Monitoring Results.
C.8.c	Creek Status and Long-Term Trends Monitoring	Urban Creeks Monitoring Report.
C.8.d	Monitoring Projects: Stressor/Source Identification; BMP Effectiveness Investigation; Geomorphic Project.	Stressor/Source Identification Report; BMP Effectiveness Report; Urban Creeks Monitoring Report.
C.8.e	Pollutants of Concern (Loads) Monitoring	Urban Creeks Monitoring Report.
C.8.f	Citizen Monitoring and Participation	Urban Creeks Monitoring Report.
C.8.g	Data Analysis and Reporting	Urban Creeks Monitoring Report.

Table 1-3. Creek Status Monitoring Parameters Monitored in Compliance with MRP Provision C.8.c.and the Associated Reporting Format.

Monitoring Elements of MRP Provision C.8.c	Monitoring Design		Reporting	
	Regional Ambient (Probabilistic)	Local (Targeted)	Regional	Local
Bioassessment & Physical Habitat Assessment	X		X	
Chlorine	X		X	
Nutrients	X		X	
Water Toxicity	X		X	
Sediment Toxicity	X		X	
Sediment Chemistry	X		X	
General Water Quality		X		X
Temperature		X		X
Bacteria		X		X
Stream Survey		X		X

The remainder of this report describes the Study Area and Monitoring Design (Section 2), the Monitoring Methods (Section 3), the Results (Section4), the preliminary Stressor Assessment (Section 5), and the Conclusions & Next Steps (Section 6).

2 Study Area & Design

2.1 Regional Monitoring Coalition Area

The RMC area encompasses 3,407 square miles of land in the San Francisco Bay Area. This includes the portions of the five participating counties that fall within the San Francisco Bay RWQCB boundary, as well as the eastern portion of Contra Costa County that drains to the Central Valley region (Figure 2-1). Creek Status monitoring is being conducted in flowing water bodies (i.e., creeks, streams and rivers) interspersed among the RMC area, including perennial and non-perennial creeks and rivers that run through both urban and non-urban areas.

2.2 Alameda County Targeted Monitoring Areas

Alameda County occupies 739 square miles (1,914 sq. km) of land area in the East Bay region of the San Francisco Bay Area, and discharges to portions of the Central Bay, South Bay and Lower South Bay. Its population of 1,510,271 (as of April 2010) is densest in the Bay Plain western portion of the County, where the largest cities include Oakland, Fremont, Berkeley and Hayward. The eastern portion of the county includes the cities of Dublin, Livermore and Pleasanton occupying the Livermore-Amador Valley, a portion of the very large and mostly undeveloped Alameda Creek Watershed.

In WY2014, ACCWP's targeted monitoring focused on three areas:

- Crow and Castro Valley Creeks within the larger San Lorenzo Creek watershed were monitored for temperature, General Water Quality, and Pathogen Indicators.
- Several creeks in Oakland including Lion Creek, Arroyo Viejo and Sausal Creek were monitored for temperature, and in one case also for General Water Quality.
- Stream surveys were conducted on several creeks and channels in the Laguna Creek watershed in Fremont.

During each year of monitoring, watersheds were chosen each with distinct management issues and stakeholder concerns as described in the sections below.

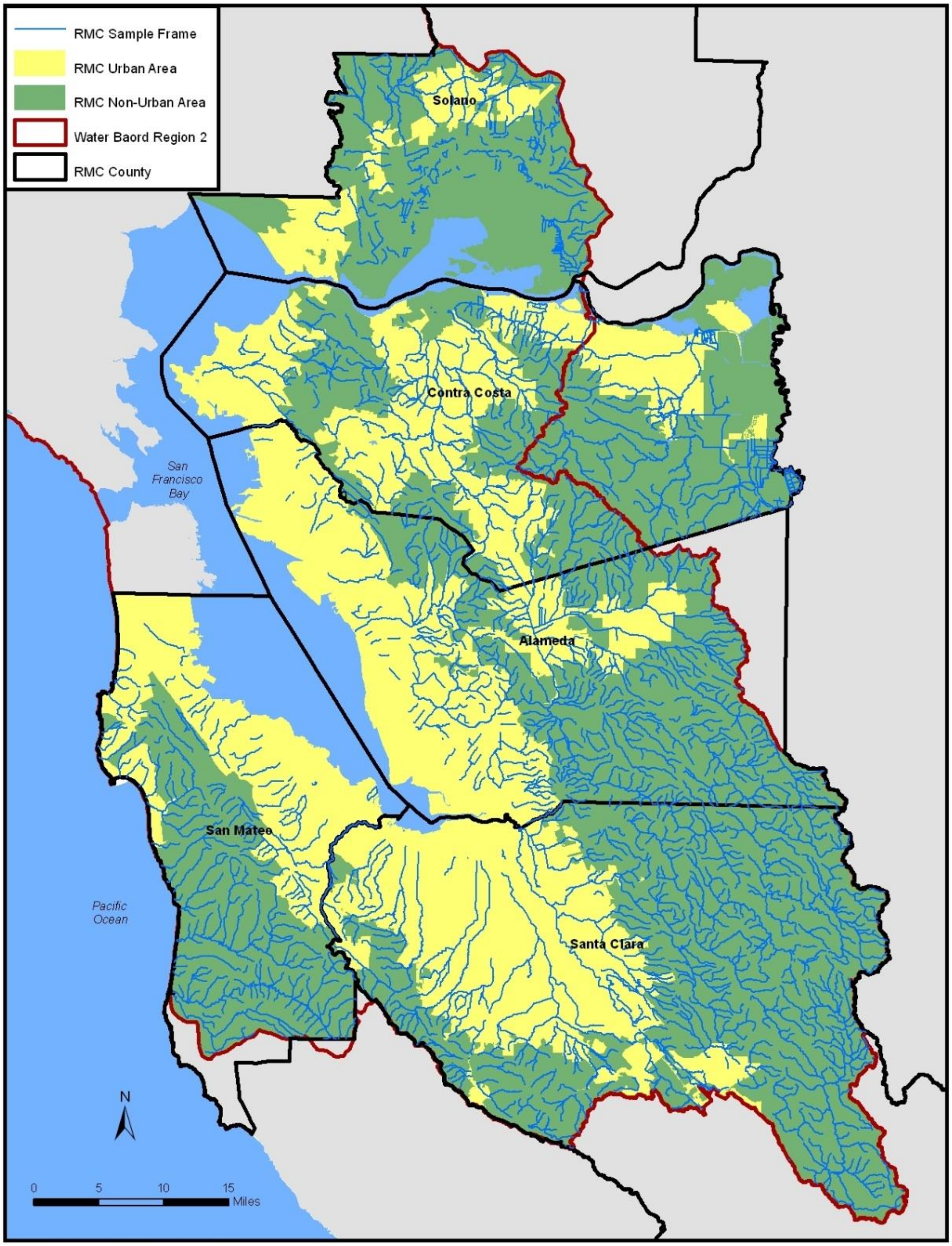


Figure 2-1. Map of BASMAA RMC Area, Major Creeks, Transportation Features.

San Lorenzo Creek Watershed

The overall San Lorenzo Creek Watershed drainsapproximately 48 square miles (30,000 acres) of land and extends from the San Francisco Bay to the ridge-tops of the East Bay hills (Figure 2-2). The watershed encompasses both urban and non-urban areas, mostly in unincorporated portions of Alameda County. Within the watershed are over 81 miles of natural creeks including some segments of Castro Valley and Chabot Creeks within the urbanized area, and Crow Creek spanning both rural and suburban development. Table 2-1 shows the Beneficial Uses assigned to these creeks (SFRWQCB 2011).

Table 2-1. Selected Beneficial Uses Assigned to Subwatersheds of San Lorenzo Creek Monitored in Water Year 2014.

Creek	COLD	MIGR	WARM, WILD	REC-1, REC2
Castro Valley Creek, including Chabot	X	--	X	X
Crow Creek	X	X	X	X

Crow Creek Subwatershed

The upper tributaries of Crow Creek lie in grasslands and oak woodlands. Much of this estimated 11.2 square mile (29.1 km^2) square mile watershed is heavily grazed, and also has the most equine facilities of any of the subwatersheds of San Lorenzo Creek. The Unincorporated Alameda County Clean Water Program and the District have worked with the Alameda Resource Conservation District on outreach and inspection for these facilities. Most ownership of creeks is private. In the lower, suburban reaches of Crow Creek it receives sporadic inputs from Cull Creek, a primarily non-urban watershed that is partially detained in Cull Reservoir just above the confluence (Figure 2-3). Based on General Water Quality monitoring results in WY2012, a Stressor-Source ID project was initiated for low Dissolved Oxygen (DO) in Crow Creek during the summer.

Castro Valley and Chabot Creek Subwatersheds

The total Castro Valley Creek watershed encompasses about 5.5 square miles of primarily residential land use with smaller amounts of open space and commercial and industrial areas. Figure 2-3 shows the creek's two main branches which have undergone different degrees of channel alteration:

- Castro Valley Creek is the longer, eastern branch that flows from undeveloped open space through urbanized Castro Valley to its confluence with the main stem of San Lorenzo Creek. While most of the reaches have been extensively channelized, and culverted sections are extensive in side tributaries and under major roads or freeways, the main channel remains open for much of its length;

- Chabot Creek, the western branch, is located almost entirely in storm drains and engineered channels. A relatively natural channel section occurs in Carlos Bee Park just above its confluence with the Castro Valley branch.

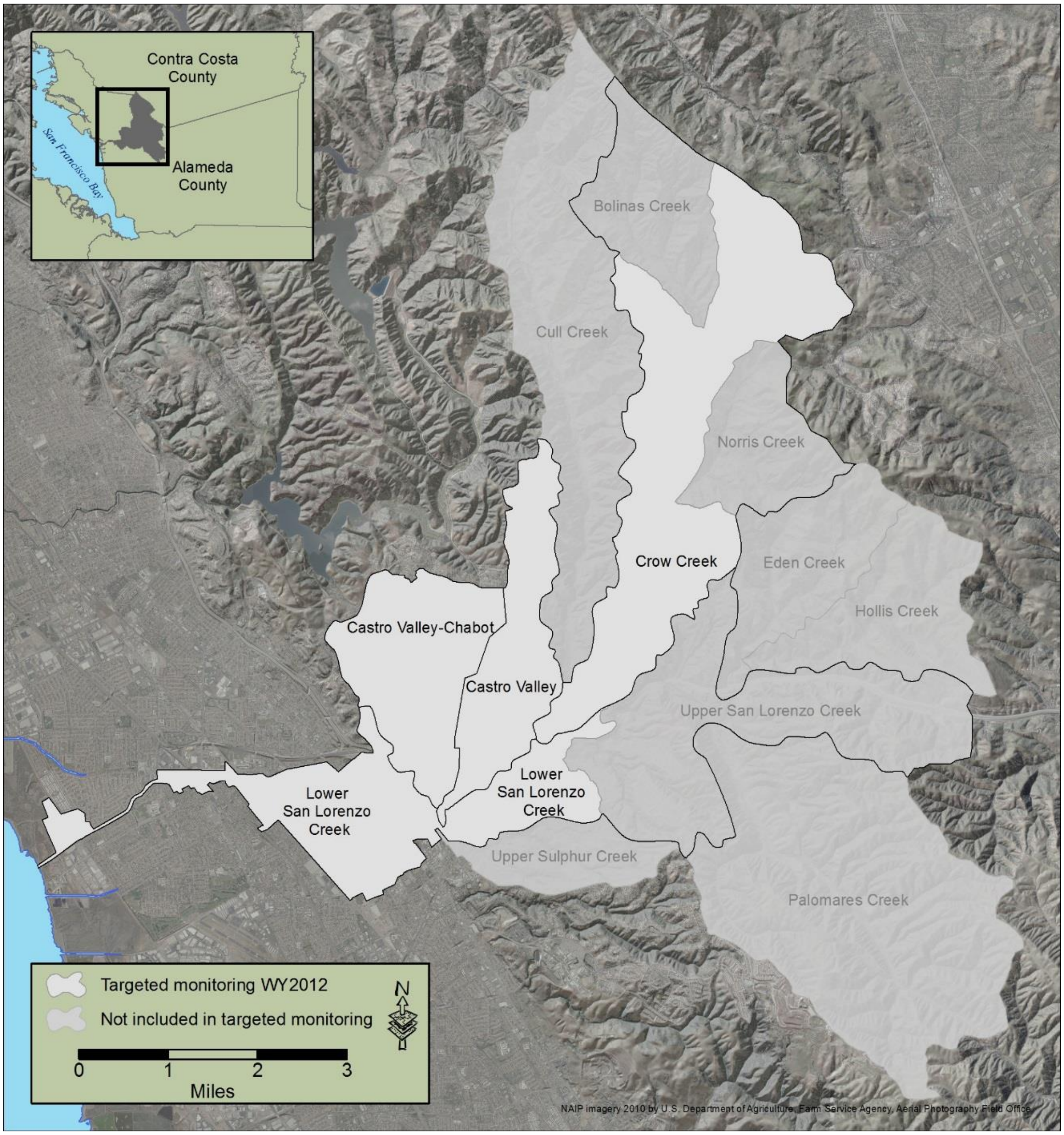


Figure 2-2. Map of the San Lorenzo Creek Watershed and Major Subwatersheds.

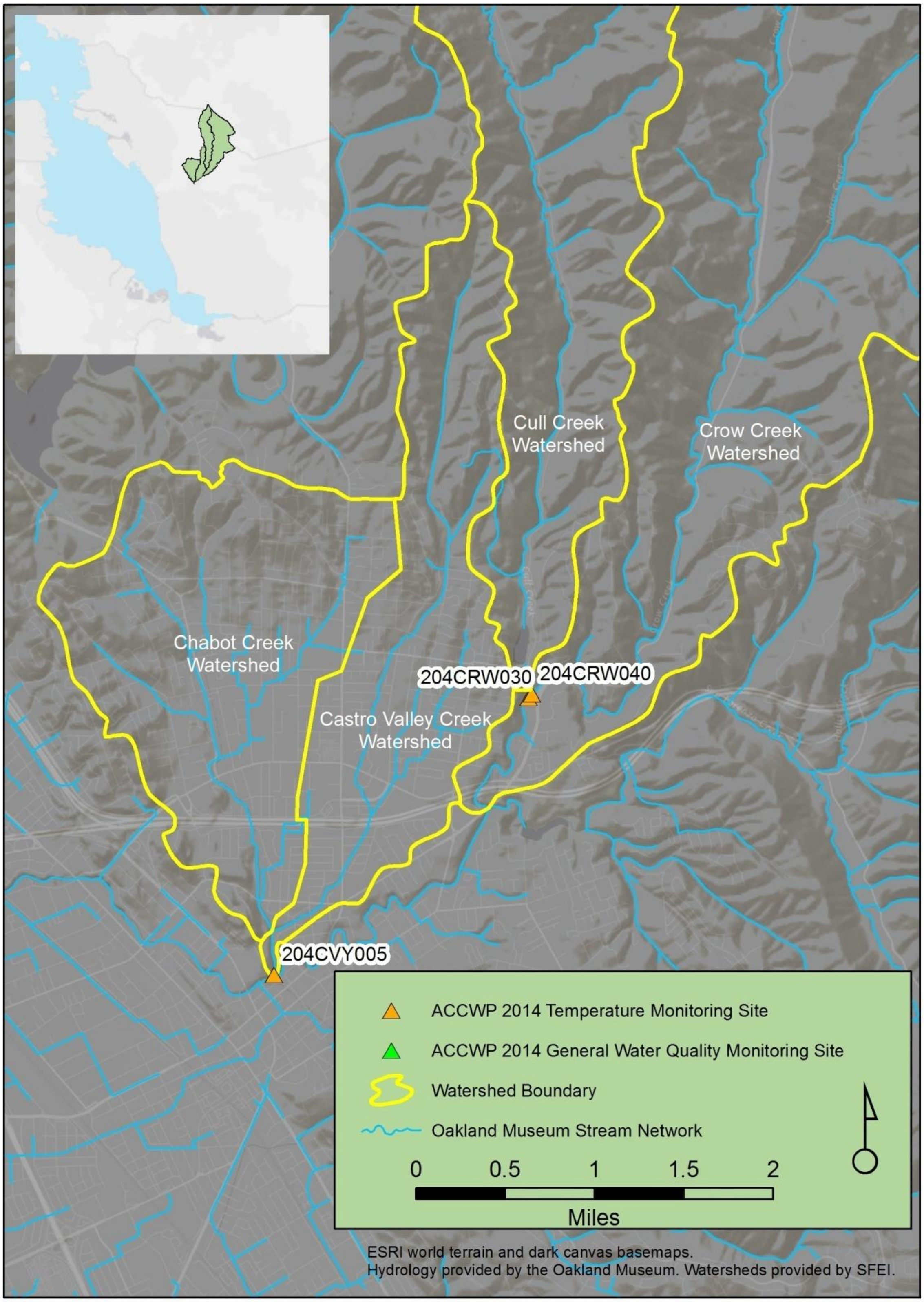


Figure 2-3. Temperature and General Water Quality Monitoring Locations in Castro Valley and Crow Creeks in Water Year 2014.

Oakland Creeks

Targeted monitoring was conducted in several creeks within the City of Oakland during WY2012 and/or WY2013. Table 2-2 shows the Beneficial Uses assigned to these creeks (SFRWQCB 2011).

Table 2-2. Selected Beneficial Uses Assigned to Oakland Creeks Monitored in Water Year 2014.

Creek	COLD	RARE, SPWN	WARM, WILD	REC-1, REC2
Sausal Creek.	X	X	X	X
Lion Creek	X	--	X	X
Arroyo Viejo	X	--	X	X

Lion Creek

The Lion Creek watershed encompasses 3.5 square miles (9.1 km^2) in East Oakland (

Figure 2-4). Tributary subwatersheds in the hills include Horseshoe Creek, with relatively extensive open space, and Chimes Creek with mostly residential land uses. Much of the former creek in the Oakland flatlands below Mills College has been culverted.

Arroyo Viejo

Arroyo Viejo flows to Damon Slough at San Leandro Bay from Knowland Park in the East Oakland Hills, with a total watershed area of about 4,000 acres or 6.3 square miles (16.3 $km^{2,\ see}$

Figure 2-4). Main tributaries above Interstate Highway (I)-580, include the Rifle Range Branch, Melrose Highlands Branch, and Country Club Branch, with the 73rd Avenue Branch drainage below I-580. Arroyo Viejo is a perennial stream flowing through a mix of underground culverts and engineered channels in the Oakland flatlands.

Sausal Creek Watershed

The Sausal Creek Watershed encompasses approximately 2,700 acres or 4.2 square miles (11 km^2) within the city of Oakland (

Figure 2-4. Temperature and General Water Quality Monitoring Locations in Lion Creek and Arroyo Viejo in Water Year 2014.

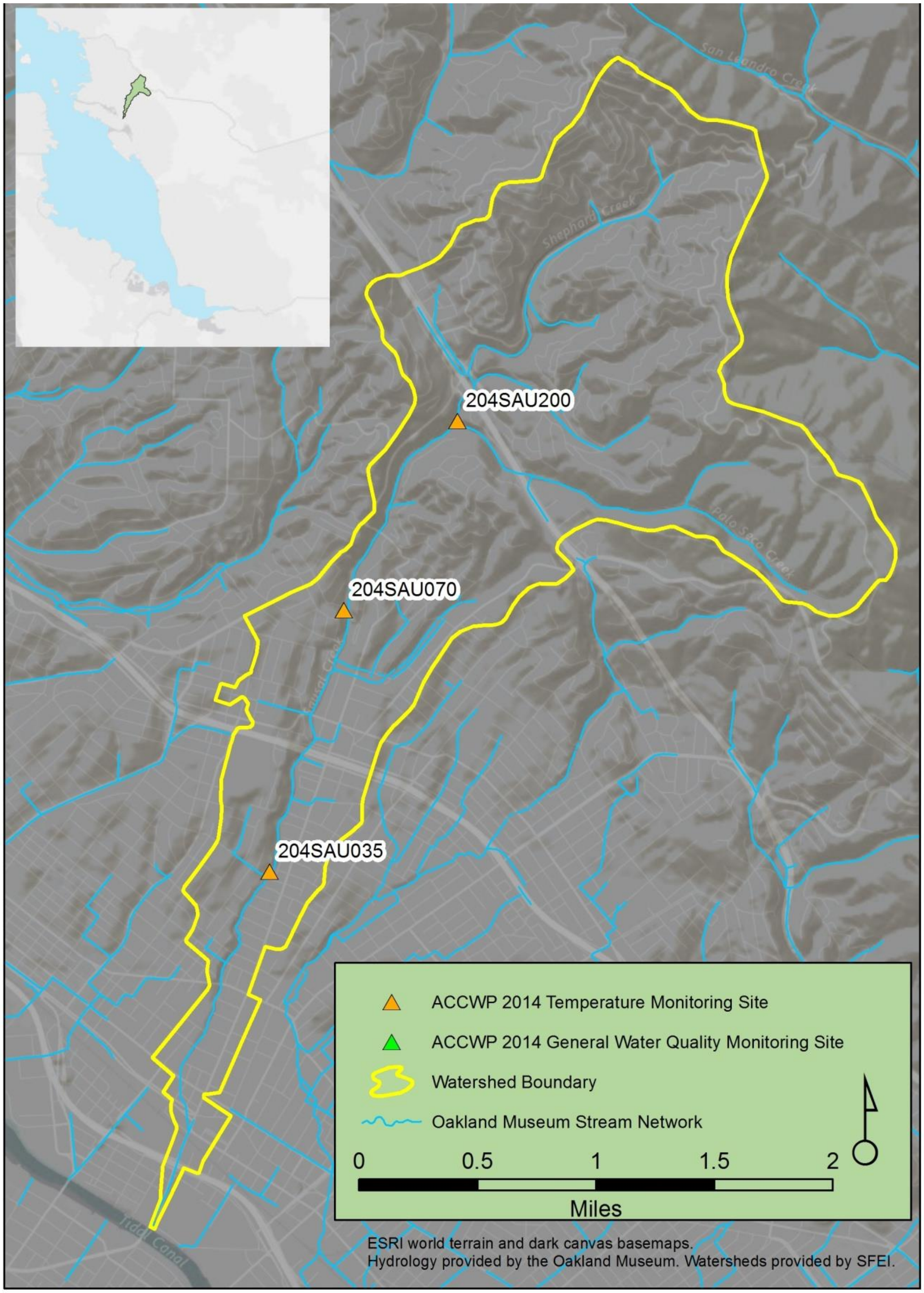


Figure 2-5). Although approximately twenty percent of the watershed remains as open space, most of the watershed is a mix of residential and commercial land uses. The headwaters and riparian

corridor are relatively intact and preserved public parks, while the sections below Dimond Park are mostly culverted or channelized. The watershed is home to an active watershed stewardship group, the Friends of Sausal Creek (FOSC), which developed a Watershed Action Plan (Stott Associates, 2000) focusing on six overall goals,

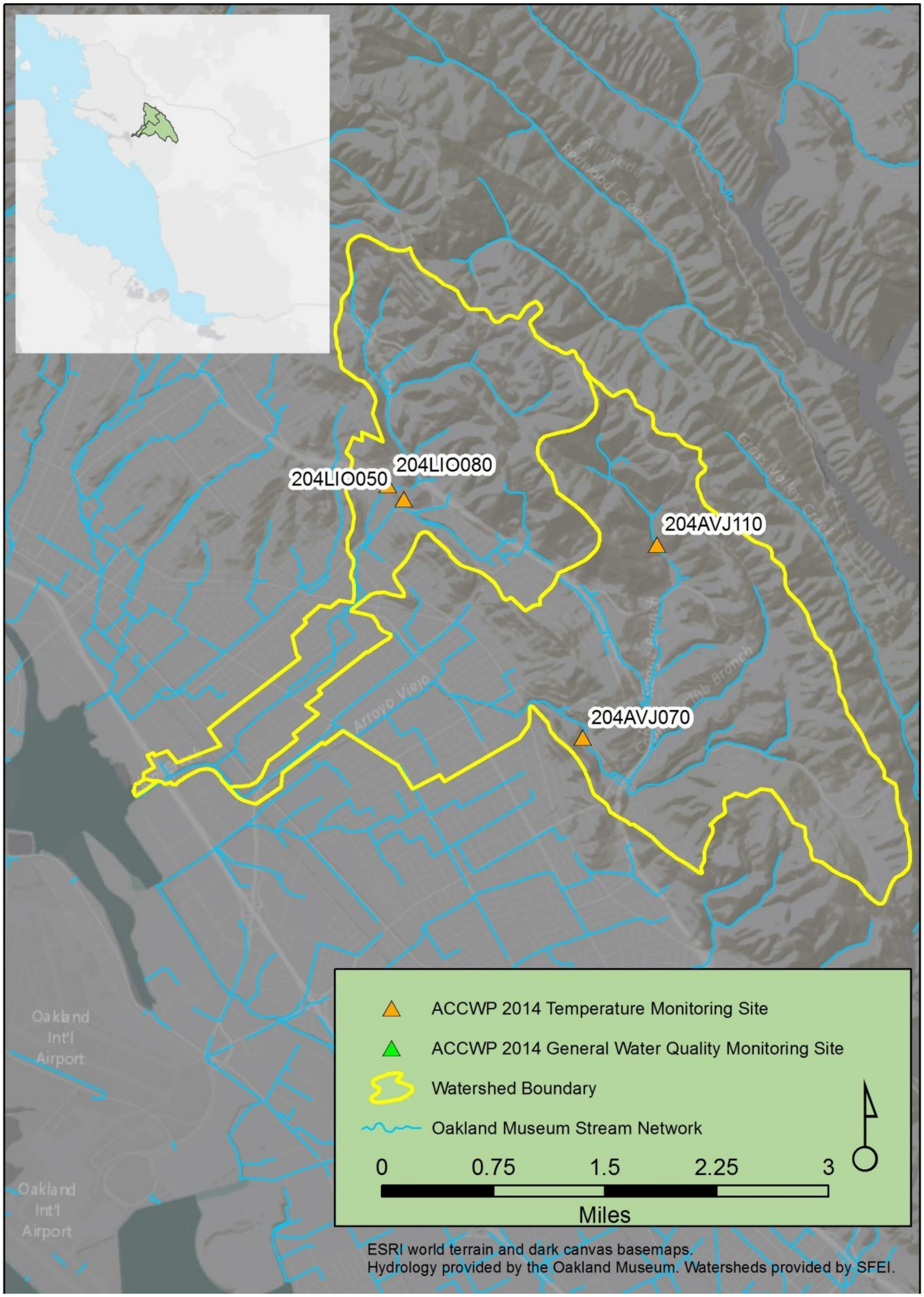


Figure 2-4. Temperature and General Water Quality Monitoring Locations in Lion Creek and Arroyo Viejo in Water Year 2014.

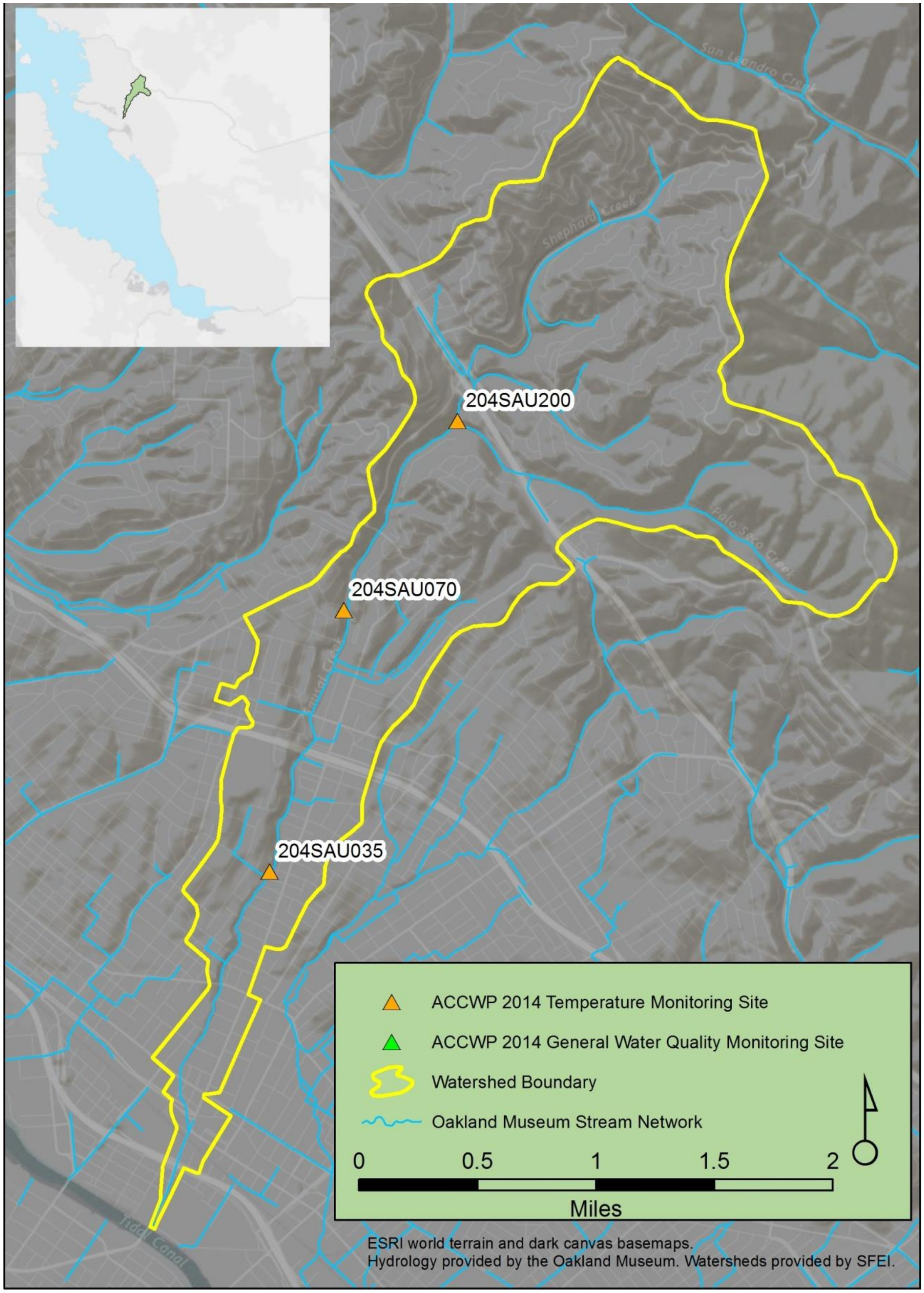


Figure 2-5. Temperature Monitoring Locations in Sausal Creek in Water Year 2014.

including improvement of water quality as well as protection and restoration of natural resources and enhancing community awareness and stewardship. FOSC has monitored and advocated for a resident population of rainbow trout in the upper watershed.

Laguna Creek System in Fremont

The Laguna Creek watershed covers approximately one-third of the land area of Fremont in western Alameda County. The watershed encompasses a wide diversity of land uses, including significant areas of ranchlands, parklands, industrial, commercial, and high- and low-density residential. The creeks in the watershed display a range of characteristics, from those associated with both fairly natural systems and highly altered ones. The main Laguna Creek channel drains into Mud Slough which flows into Coyote Creek before entering San Francisco Bay. The WY2014 Stream Survey assessed the main stem of Laguna Creek, an artificially engineered stormwater bypass channel in the lower watershed, and two main tributaries, Agua Caliente and Washington Creek (see Figures 2-6 to 2-9).

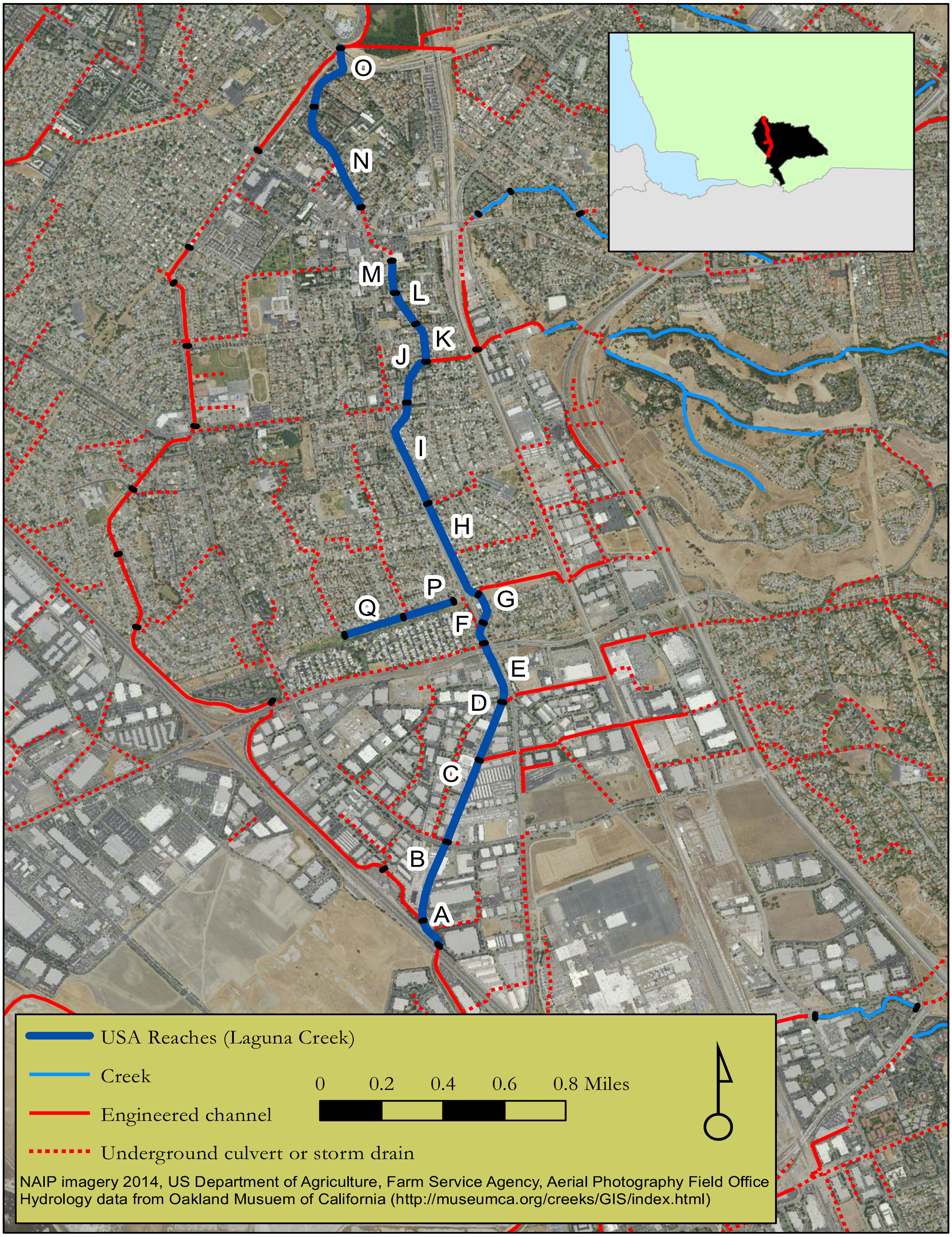


Figure 2-6. 2014 Surveyed Reaches in Laguna Creek

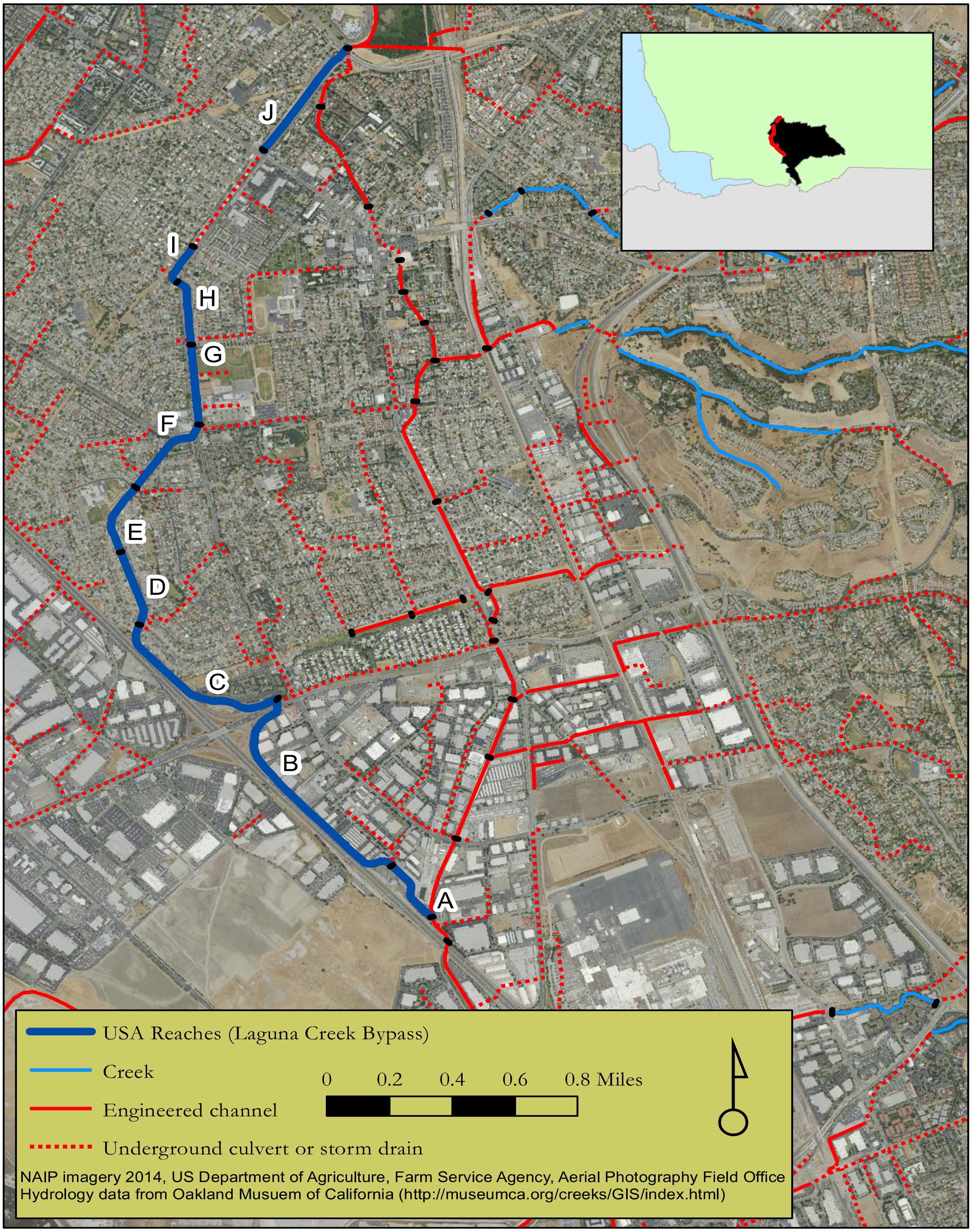


Figure 2-7. 2014 Surveyed Reaches in Laguna Creek Bypass

Figure 2-8. 2014 Surveyed Reaches in Agua Caliente

Figure 2-9. 2014 Surveyed Reaches in Washington Creek

2.3 Targeted Monitoring Design

In the targeted monitoring program design, site locations were identified based on the directed principle[2] to address the following management questions:

1) *What is the range of general water quality measurements at targeted sites of interest?*

2) *Do general water quality measurements indicate potential impacts to aquatic life?*

3) *What are the pathogen indicator concentrations at creek sites where water contact recreation may occur?*

4) *What are the overall physical and/or ecological conditions of creek reaches and specific point impacts within each reach?*

Table 2-3 summarizes ACCWP targeted monitoring conducted during WY2014 including:

- Eight Continuous Water Temperature monitoring locations;
- Three General Water Quality monitoring locations;
- Five Pathogen Indicator monitoring locations; and

Thirty-five Stream Survey Reaches were also monitored encompassing approximately 9.2 creek miles (See Section 4.5 for listing).

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

Table 2-3. Summary of Targeted Monitoring Locations and Parameters for Water Year 2014 in Alameda County

Site Characteristics					Parameters		
Creek/Sub-watershed	Site Code (RMC No)	Site Description	Latitude	Longitude	Pathogen Indicators	Water Temperature (continuous)	General Water Quality
Arroyo Viejo	204AVJ070	Arroyo Viejo at Holy Redeemer College	37.75822	-122.15622		X	
Arroyo Viejo	204AVJ080	Upstream/east of Golf Links Rd, just below I-580	37.75503	-122.15227			Spring
			37.75489	-122.15235			September
Arroyo Viejo	204AVJ110	Rifle Range branch in Leona Canyon Open Space	37.77719	-122.14769		Spring only	
Lion Creek	204LIO050	Chimes Creek at Mills College	37.78013	-122.17889		X	
Lion Creek	204LIO080	Mills College at Alumni House	37.78227	-122.18096		Spring only	
			37.78236	-122.18089		July-Sep only	
Cull Creek	204CUL010	Cull Creek below dam above "overpass" bridge in Bay Trees Park	37.7027	-122.05539		X	
Crow Creek	204CRW020	Crow Creek near Earl Warren Park	37.70012	-122.05506		X	
Crow Creek	204CRW030	Crow Creek below confluence with Cull Creek	37.70017	-122.05523		X	
Crow Creek	204CRW040	Crow Creek at confluence with Cull (concrete section)	37.70152	-122.05454		X	
			36.69865	-121.80985			Spring
			37.70115	-122.05512			Summer
Crow Creek	204CRW042	Approx 50 m upstream (south) of Crow Creek Rd. at first crossing	37.70004	-122.0492			Spring
			37.69997	-122.04932			Summer
Castro Valley Creek	204CVY005	Castro Valley Creek above confluence with San Lorenzo	37.67833	-122.08031		X	
Sausal Creek	204SAU035	Upstream of E. 27th Street	37.7913	-122.2212		X	
Sausal Creek	204SAU070	Downstream of El Centro Ave.	37.80738	-122.21597		X	
Sausal Creek	204SAU200	Above confluence with Palo Seco Creek	37.81911	-122.2075		July-Sep only	

Site Characteristics					Parameters		
Creek/Sub-watershed	**Site Code (RMC No)**	**Site Description**	**Latitude**	**Longitude**	**Pathogen Indicators**	**Water Temperature (continuous)**	**General Water Quality**
Castro Valley Creek	CVY020	Chabot Creek at Carlos Bee Park	37.68189	-122.08083	X		
Castro Valley Creek	CVY080	Castro Valley Creek above confluence with Chabot Creek	37.68237	-122.07858	X		
Castro Valley Creek	CVY125	Below Castro Valley Blvd.	37.69505	-122.07245	X		
Castro Valley Creek	CVY140	North side of Berdina Rd	37.70134	-122.07023	X		
Castro Valley Creek	CVY150	North side of Heyer Ave	37.70462	-122.06915	X		

Criteria for Site Selection

All target sampling sites were selected by the ACCWP Monitoring Program Coordinator, in coordination with others as described below. Specific considerations applied to selection of locations for the different parameters as described below:

Continuous Temperature

Each monitoring year, eight continuous water quality monitoring locations were chosen based on a combination of criteria. A predominant criterion was that the streams have COLD beneficial use designation for which these parameters are important indicators. Based on available historical data for the San Lorenzo Creek watershed, simple temperature monitoring was chosen for the less urbanized portions of Crow Creek to complement the shorter-duration water quality monitoring in more urbanized reaches in Castro Valley and Oakland. In the case of Sausal Creek, the temperature loggers were deployed at a subset of the six sites monitored in WY2014 at the recommendation of Robert Leidy, an active FOSC Board member interested in assessment of different tributaries' suitability for trout.

In choosing sampling sites for WY2014, ACCWP included some Crow Creek sites to assist with SSID follow-up, and otherwise focused on Oakland watersheds with as many as possible of the following attributes:

- Significant natural resource quality, combined with COLD beneficial use; and
- Known or likely areas of perennial flow.

Sampling sites were adjusted in the field in order to deploy continuous monitoring equipment at locations where (1) water level was expected to be of sufficient depth to cover loggers over the course of the entire dry season, and (2) avoid highly trafficked areas.

General Water Quality

The goal of site selection for the three general water quality monitoring locations was to provide more intra-annual characterization of sites previously monitored for either or temperature alone. A site above 204CRW040 was also selected to assist the SSID by characterizing summertime DO conditions upstream of the urban storm drain system. However DO monitoring at this site was unsuccessful in the summer-fall deployment due to equipment failure.

Other considerations in site selection included:

- Opportunities to compare different tributaries or portions of the main stem above and below tributary or storm drain inputs;
- Public access to portions of the creek;

- Stewardship interest by active creek groups or institutional managers (e.g. Mills College, Oakland Zoo); and
- Management questions of interest to the City of Oakland's Creek and Watershed program.

Pathogen Indicators

In WY2014, the five pathogen indicator sampling sites were all located within a2.8km segment of Castro Valley Creek. Castro Valley is an urban watershed and several of the Castro Valley Creek reaches have public access.

Stream Survey

Surveyed reaches in WY2014 targeted several watersheds in Fremont, as described below.

3 Monitoring Methods

This section provides a brief overview of methods employed to measure each parameter in the targeted monitoring design. Greater detail on each method is included in the referenced SOPs.

3.1 Data Collection Methods

Field data were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC Quality Assurance Project Plan (QAPP) (BASMAA 2014a) and Standard Operating Procedures (SOP) (BASMAA 2014b), updated in 2013 from the earlier 2012 versions to reflect lessons learned through 2012 implementation; these revisions also incorporated updated data Quality Assurance procedures consistent with added data checking functions of the RMC database to supplement the tools available from SWAMP[3].The SOPs relevant to the monitoring discussed in this report are listed in Table 3-1.

[3] Available at http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/qapp/qaprp082209.pdf

Table 3-1: Standard Operating Procedures for to BASMAA RMC Monitoring at Targeted Sites.

SOP #	SOP Title
FS-1	BMI and Algae Bioassessments, and Physical Habitat Measurements
FS-2	Water Quality Sampling for Chemical Analysis, Pathogen Indicators, and Toxicity
FS-3	Field Measurements, Manual
FS-4	Field Measurements, Continuous General Water Quality
FS-5	Temperature, Automated, Digital Logger
FS-7	Field Equipment Cleaning Procedures
FS-8	Field Equipment Decontamination Procedures
FS-9	Sample Container, Handling, and Chain of Custody Procedures
FS-10	Completion and Processing of Field Datasheets
FS-11	Site and Sample Naming Convention
FS-12	Ambient Creek Status Monitoring Site Evaluation
FS-13	QA/QC Data Review
N/A	Unified Stream Assessment: A User’s Manual, v2.0

Continuous Temperature Monitoring

All sampling conformed to protocols identified in the RMC QAPP and SOPs (Table 3-1). Field crews deployed digital temperature loggers in April at nine sites as shown in Table 3-2. Temperature loggers were programmed to record temperature data at sixty-minute intervals.

AMS personnel conducted a mid-term maintenance and data download of deployed temperature probes between July 16th and July 25th, 2014; field personnel did not maintain 204SAU35 due to safety concerns. Six of the nine maintained units were found submerged and in good condition. Two sites required additional activity:

- 204LIO080 – The pool where the unit was deployed had gone dry sometime between deployment and maintenance. Field staff relocated the unit upstream to a deeper pool still experiencing flow from the small reservoir above.
- 204AVJ110 – The entire stretch of creek in the vicinity of deployment went dry between time of deployment and maintenance. The unit was removed and not replaced.

To account for the loss of the Arroyo Viejo site due to lack of water, one additional unit was deployed at site 204SAU200.

Table 3-2. Water Year 2014 Continuous Water Temperature Monitoring at Alameda County Targeted Monitoring Locations (see text for discussion of 204AVJ110 and 204LIO080.

Site Code (RMC No)	Site Name / Location	Latitude	Longitude	Install Date	Mid-term Re-install	Removal Date
204AVJ110	Rifle Range Branch	37.77719	-122.14769	April 25	July 16	
204AVJ070	Arroyo Viejo at Holy Redeemer College	37.75822	-122.15622	April 25		October 6
204LIO050	Chimes Creek at Mills College	37.78013	-122.17889	April 25		October 6
204LIO080 (relocated in July)	Mills College at Alumni House	37.78227	-122.18096	April 25	July 16	
	Mills College at Alumni House	37.78236	-122.18089		July 16	October 6
204SAU035	Sausal Creek at E. 27th Street	37.79130	-122.22120	April 25		October 27
204SAU070	Sausal at El Centro	37.80738	-122.21597	April 25		October 6
204SAU200	Sausal above Palo Seco	37.81911	-122.20750		July 25	October 6
204CRW030	Crow Creek below Cull Creek (natural channel section)	37.70121	-122.05488	April 25		October 7
204CRW040	Crow Creekat confluence with Cull (concrete section)	37.70152	-122.05454	April 25		October 6
204CVY005	Castro Valley Creek above confluence with San Lorenzo	37.67833	-122.08031	April 25		October 6

General Water Quality Measurements

General water quality monitoring included continuous measurements for temperature, DO, pH and specific conductivity for deployment at three sites. Parameters were measured for a period of between one and two weeks twice per year, once during the spring index period for bioassessment sampling and again during the August – September timeframe (Table 3-3). All sampling conformed to protocols identified in the RMC QAPP and SOPs.

Automated monitoring equipment (YSI 6600 Sonde) was deployed with the data recorded automatically at fifteen-minute intervals.

For the summer deployment at site 204CRW042, the conductivity probe failed during deployment. This affects measurement and reporting of specific conductivity, salinity, and DO, which have all been qualified as “FIF” in the reporting template, indicating probe failure. The probe issue was identified during post-deployment calibration checks and was addressed prior to subsequent deployment of the unit at site 204AVJ080.

For the summer deployment at site 204AVJ080, field personnel noted construction activities occurring in the stream nearby to the deployment location during the planned installation on August 18th, which delayed the installation to allow construction activities to proceed. The installation was rescheduled for September 9th. The data collected during this deployment is, however, suggestive of a potential change in the flow regime during the course of the deployment, which may or may not be related to construction activities. Beginning with deployment on September 9th, oxygen levels steadily decline from 88% saturation and over 8 mg/L DO to approximately 1% saturation and 0.1 mg/L within 24 hours. Oxygen measurements remained at these approximate levels until spiking upward on September 25th at 5am, which coincides with noticeable decreases in conductivity / salinity and increase in pH. For the five-hour period starting with this observed change and continuing until the retrieval of the unit, the DO stabilized above 8.5 mg/L and oxygen saturation stayed mainly above 90%. As the unit passed all calibration and drift checks, the data are not qualified and is considered representative of site conditions occurring during deployment.

Table 3-3. General Water Quality Monitoring at Alameda County Targeted Monitoring Locations, WY2014.

Site Code (RMC No)	Description	Deployment	Lat	Long	Dates
204AVJ080	Lateral pool upstream of Golf Links Rd, just below I-580	Spring	37.75503	-122.15227	5/27/14 to 6/6/14
		Summer-Fall	37.75489	-122.15235	9/9/14 to 9/25/14
204CRW040	Crow Creek at confluence with Cull (concrete section)	Spring	36.69865	-121.80985	5/13/14 to 5/22/14
		Summer-Fall	37.70115	-122.05512	8/28/14 to 9/9/14
204CRW042	Approx 50 m upstream (south) of Crow Creek Rd. at first crossing	Spring	37.70004	-122.04920	5/13/14 to 5/22/14
		Summer-Fall	37.69997	-122.04932	8/28/14 to 9/9/14

Pathogen Indicators Sampling

Single samples were collected for pathogen indicator enumeration in accordance with the requirements of provision C.8.c of the permit. Field crews conducted pathogen indicator sampling using the RMC SOPs (Table 3-1). Sampling techniques included direct filling of containers, and immediate transfer of samples to analytical laboratories within specified holding time requirements.

Field crews collected water samples for analysis of *Escherichia coli* (*E. coli*) and fecal coliform at five sites on July 8, 2015. The sampling sites shown in Table 3-4 were at or near sites sampled in WY 12, except for 204CVY125 which was located upstream of the original 204CVY120, due to lack of flowing water at the target coordinates.

Error! Reference source not found.**Table 3-4. Pathogen Indicator Monitoring at Alameda County Targeted Monitoring Locations, WY2014.**

Site Code	Description	Lat	Long
204CVY020	Chabot Creek at Carlos Bee Park	37.68189	-122.08083
204CVY080	Castro Valley Creek above confluence with Chabot Creek	37.68237	-122.07858
204CVY125	Castro Valley Creek below Castro Valley Blvd.	37.69505	-122.07245
204CVY140	Castro Valley Creek at north side of Berdina Rd	37.70134	-122.07023
204CVY150	Castro Valley Creek at north h side of Heyer Ave.	37.70462	-122.06915

Stream Surveys

Field crews conducted stream surveys using the *Unified Stream Assessment: A User's Manual* (Center for Watershed Protection, 2005) with data forms modified by SCVURPPP to better reflect conditions in urbanized streams (SCVWD, 2005). The Unified Stream Assessment (USA) uses visual observations and limited measurements taken during a continuous walk of accessible portions of the targeted creek corridor to rapidly evaluate creek conditions, problems, and opportunities for improvement within the urban creek corridor.

In order to increase survey efficiency and be consistent with previous investigations performed for the ACCWP (e.g., EOA 2006), minor modifications were made to the standard USA protocol in the way in which assessed information was recorded. Modified versions of several impact forms were used when less detailed data were needed for the purposes of the assessment. For example, in place of using a separate sheet to record each occurrence of an outfall, stream crossing, and utility within a reach, field crews compiled information for multiple occurrences of these on a single form.

The USA protocol includes separating the creek corridor into survey reaches. Each reach represents a relatively uniform set of conditions within the creek corridor. Factors that contribute to delineating a reach include land use in the immediate vicinity, elevation, creek order, access, and total length. In this study, reaches were identified and delineated by the ACCWP Program Coordinator, began and ended at major creek crossings or grade changes. Creek sections that were inaccessible (due to factors such as culverts, vegetation, or access permission not granted) were not assessed.

A single overall reach assessment was conducted for each reach. The reach level assessment qualitatively evaluated characteristics such as base flow, dominant substrate, water clarity, biota, shading, and active channel dynamics. In addition, each reach was ranked for overall creek condition and overall buffer and floodplain condition based on eight subcategories:

- instream habitat;
- vegetative protection;
- bank erosion;
- floodplain connection;
- vegetated buffer width;
- floodplain vegetation, floodplain habitat; and
- floodplain encroachment.

Each subcategory was given a score on a 20-point scale. The subcategory scores were summed to give a total reach score ranging from zero (poor condition) to 160 (optimal condition).

Per the USA protocol, field datasheets were completed to identify within each reach the locations and general characteristics of seven potential creek impacts:

- erosion;
- channel modification;
- outfalls;
- creek crossings;
- trash/debris;
- utilities; and
- miscellaneous features.

All survey work was completed between September 17, 2013 and October 9, 2013. Approximately 10.96 miles were assessed during the effort. An additional 1.96 miles (above the MRP-required 9 per year) were added on to make up for the targeted miles that were not completed during the WY2012 ACCWP USA surveys, and to complete full assessments of the streams that were surveyed this 2013 field season.

Quality Assurance/Quality Control

Data quality assessment and quality control procedures are described in detail in the BASMAA RMC QAPP (BASMAA 2014a). Data Quality Objectives (DQOs) were established to ensure that data collected are of adequate quality and sufficient for the intended uses. DQOs address both quantitative and qualitative assessment of the acceptability of data. The qualitative goals include representativeness and comparability. The quantitative goals include specifications for completeness, sensitivity (detection and quantization limits), precision, accuracy, and contamination. To ensure consistent and comparable field techniques, pre-survey field training and *in-situ* field assessments were conducted. Data were collected according to the procedures described in the relevant SOPs, including appropriate documentation of data sheets and samples, and sample handling and custody. Laboratories providing analytical support to the RMC were selected based on demonstrated capability to adhere to specified protocols.

3.2 Data Quality Assessment Procedures

Following completion of the field and laboratory work, the field data sheets and laboratory reports were reviewed by the Local Monitoring Coordinator or Quality Assurance Officer, and compared both against the methods and protocols specified in the SOPs and QAPP. The findings and results then were evaluated against the relevant DQOs to provide the basis for an assessment of programmatic data quality. The data quality assessment included the following elements:

- Conformance with field and laboratory methods as specified in SOPs and QAPP, including sample collection and analytical methods, sample preservation, sample holding times, etc.;
- Numbers of measurements/samples/analyses completed vs. planned, and identification of reasons for any missed samples;
- Results of duplicate analyses based on calculation of relative percent differences (precision results);
- Results of field blanks associated with filtered samples (bias results);
- Results of spiked sample analyses based on spike percent recovery (accuracy results); and
- Identification of any contamination issues based on analyses of lab blanks and field blanks.

3.3 Data Analysis and Interpretation

Continuous temperature and general water quality data were plotted as box plots[4] for each site during each deployment.

The hourly water temperature measurements were calculated as daily arithmetic means over a 24-hour period from midnight to 11:00 PM. Seven-day “rolling” average stream temperatures were calculated for each day, beginning on deployment Day 7, by averaging temperatures collected at fifteen-minute intervals throughout the previous seven days. Seven-day rolling averages for general water quality parameters were calculated in a similar fashion, although the frequency of measurements was higher (15 minutes for general water quality vs. one hour for continuous temperature)

[4]A box plot splits the data set into quartiles. The body of the plot consists of a "box", which goes from the first quartile to the third quartile. Within the box, a vertical line is drawn at the median of the data set. Two horizontal lines, called whiskers, extend from the front and back of the box. The front whisker goes from the first quartile to the smallest non-outlier in the data set, and the back whisker goes from the third quartile to the largest non-outlier. If the data set includes one or more outliers, they are plotted separately as points.

Targeted monitoring data were evaluated against Water Quality Objectives (WQO) or other applicable thresholds, as described in Table 5-1, to determine whether results may “trigger” a potential stressor/source identification monitoring project (per MRP Provision C.8.d.i).

4 Results

This section presents monitoring results based on each program component. Each section addresses the study question:

> *What are the ranges of general water quality, continuous water temperature, pathogen indicators, and stream ecosystem conditions at locations sampled in the Program area?*

4.1 Statement of Data Quality

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

A comprehensive QA/QC program was implemented by each of the RMC Programs, which is solely responsible for the quality of the data submitted on its behalf, covering all aspects of the regional/probabilistic monitoring. In general, QA/QC procedures were implemented as specified in the RMC QAPP (BASMAA, 2014a), and monitoring was performed according to protocols specified in the RMC SOPs (BASMAA, 2014b), and in conformity with SWAMP protocols. The results of general evaluations of laboratory-generated QA/QC results are included in Section 7 of the main UCMR body. Issues noted by the laboratories and/or field crews are noted below where relevant.

Field data sheets and laboratory reports were reviewed by the local Monitoring Coordinator or Program Quality Assurance Officer, and the results evaluated against the relevant DQOs as described in the RMC QAPP (BASMAA, 2014a) and SOPs (BASMAA, 2014b). Results were compiled for the qualitative metrics (representativeness and comparability), as well as the quantitative metrics (completeness, sensitivity [detection and quantization limits], precision, accuracy, and contamination). The following sections (0 - 0) provide summaries of all pertinent data quality issues from the WY2014 targeted parameters and corrective actions to address data quality issues.

Method Deviations

There were no deviations from the methods provided in the QAPP with the exception of pathogen indicator analyses where Standard Methods 9221 was used instead of the IDEXX Quantitray method. Both use a most probable number (MPN) analysis and therefore have comparable results. Corrective action: QAPP DQOs associated with analysis of fecal indicator bacteria will be reviewed and revised prior to 2013 Creek Status Monitoring implementation to ensure consistency of methods with QAPP requirements.

There were no deviations from the methods provided in the QAPP. In WY2012, a method deviation occurred with regards to the analysis for fecal indicator bacteria. Through corrective action, this was resolved for in WY2013.

Number of Measurements Taken Compared to Planned

There were no deviations from the planned number of samples collected described in the QAPP with the exception of:

- General Water Quality.
- Continuous temperature monitors were deployed at a total of nine locations, one more than the MRP requirement of eight locations, to account for potential loss or failure. At the mid-season maintenance check in July, two sites had gone dry. The unit at 204LIO080 was relocated upstream to a deeper pool. No nearby location was available as as substitute for 204AVJ110; instead it was deployed at 204SAU200.

Non-detects – Reporting Limits Not Met

All QA/QC measures listed in the QAPP were met. There were no issues with non-detects reported.

Precision Results

The lab duplicate run associated with the pathogen indicator sample for 204CVY020 resulted in a RPD of 26%, which is slightly outside of the QAPP Control Limit of 25%. This sample will therefore be flagged in the reporting template with a “VIL” qualifier, which indicates the RPD is outside of laboratory control limits.

Accuracy Results

No matrix spike samples were found to be outside of acceptable percent recovery range collected.

Contamination Issues

There were no contamination issues observed in any of the samples, as determined by field and laboratory blanks collected during WY2014 sampling.

4.2 Continuous Water Temperature Monitoring

Data were collected over a five-month period with measurements recorded at 60-minute intervals at the equivalent of eight sites, with some mid-season breaks in record due to dry conditions as noted for specific sites.

Castro Valley and Crow Creeks

Figure 4-1 presents the results of the continuous monitoring results for WY2014, and box plots of the temperature data are shown in Figure 4-2

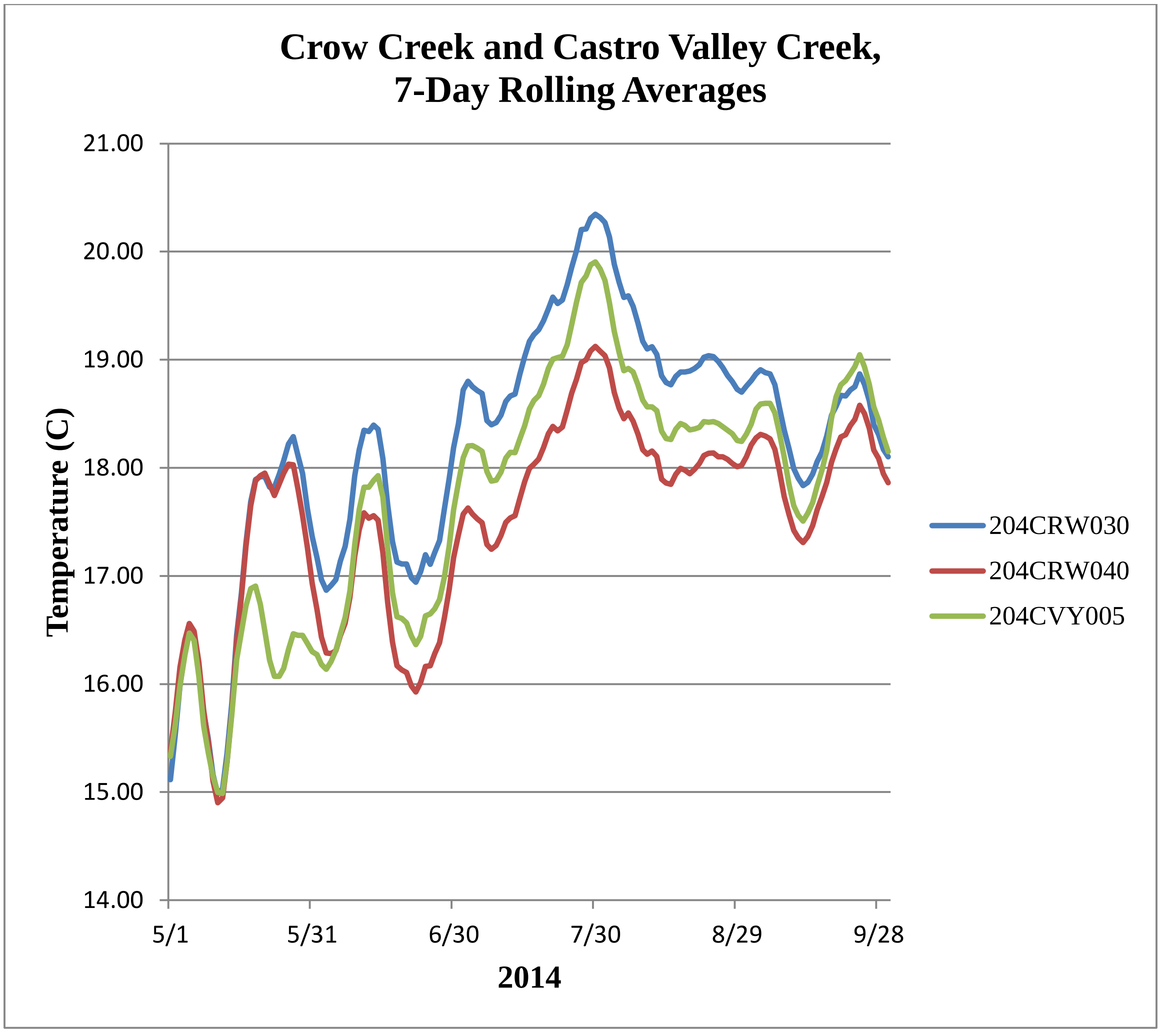


Figure 4-1. Temperature (7 Day Rolling Average Calculated Daily) Line Graph at Castro Valley Creek and Crow Creek, April 25 through September 30, 2014.

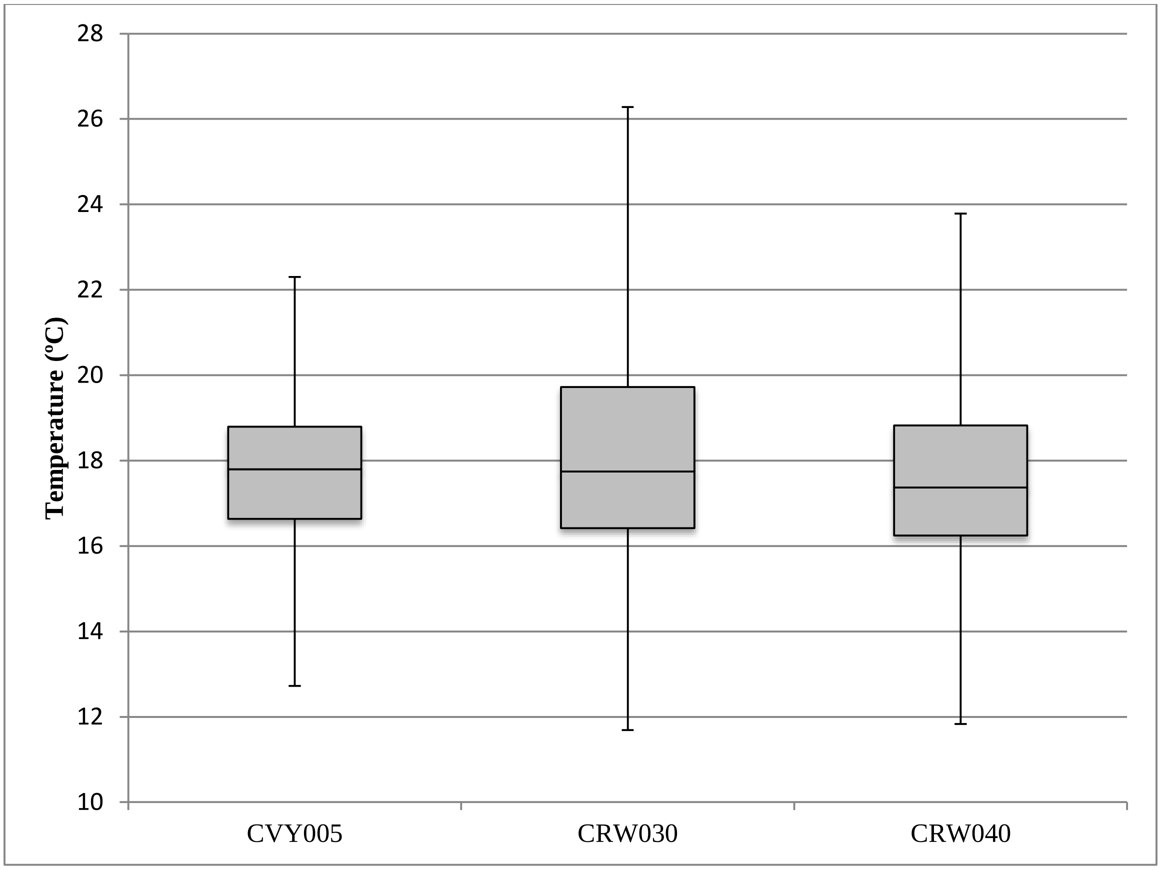


Figure 4-2. Temperature Box Plot at Castro Valley Creek and Crow Creek, April 25 through September 30, 2014.

Summary 2014 results are presented for sampling locations within Castro Valley and Crow Creeks in Table 4-1. The highest temperature was recorded at 204CRW030 on June 9. The lowest temperature was recorded at the same site on April 28. Average temperatures ranged from 17.67°C to 18.15°C.

Table 4-1. Summary of Temperature Data from from WY2014 at Castro Valley Creek and Crow Creek Sampling Locations.

Temperature (ºC)	204CRW030	204CRW040	204CVY005
Min	11.69	11.83	12.73
Max	26.28	23.79	22.30
Range	14.59	11.95	9.57
Mean	18.15	17.48	17.67
St dev	2.64	1.97	1.63

Oakland Creeks

Figure 4-3 presents the results of the continuous monitoring results for Oakland Creeks in WY2014, and box plots of the temperature data are shown in Figure 4-4. As discussed in Section 3.1.1 and shown in these charts and the following table, the usable deployment period for 204AVJ110 was only from April 25 through May 10, 204LIO080 has a gap between May 27 and July 16 when it was repositioned, and 204SAU200 was first deployed on July 25.

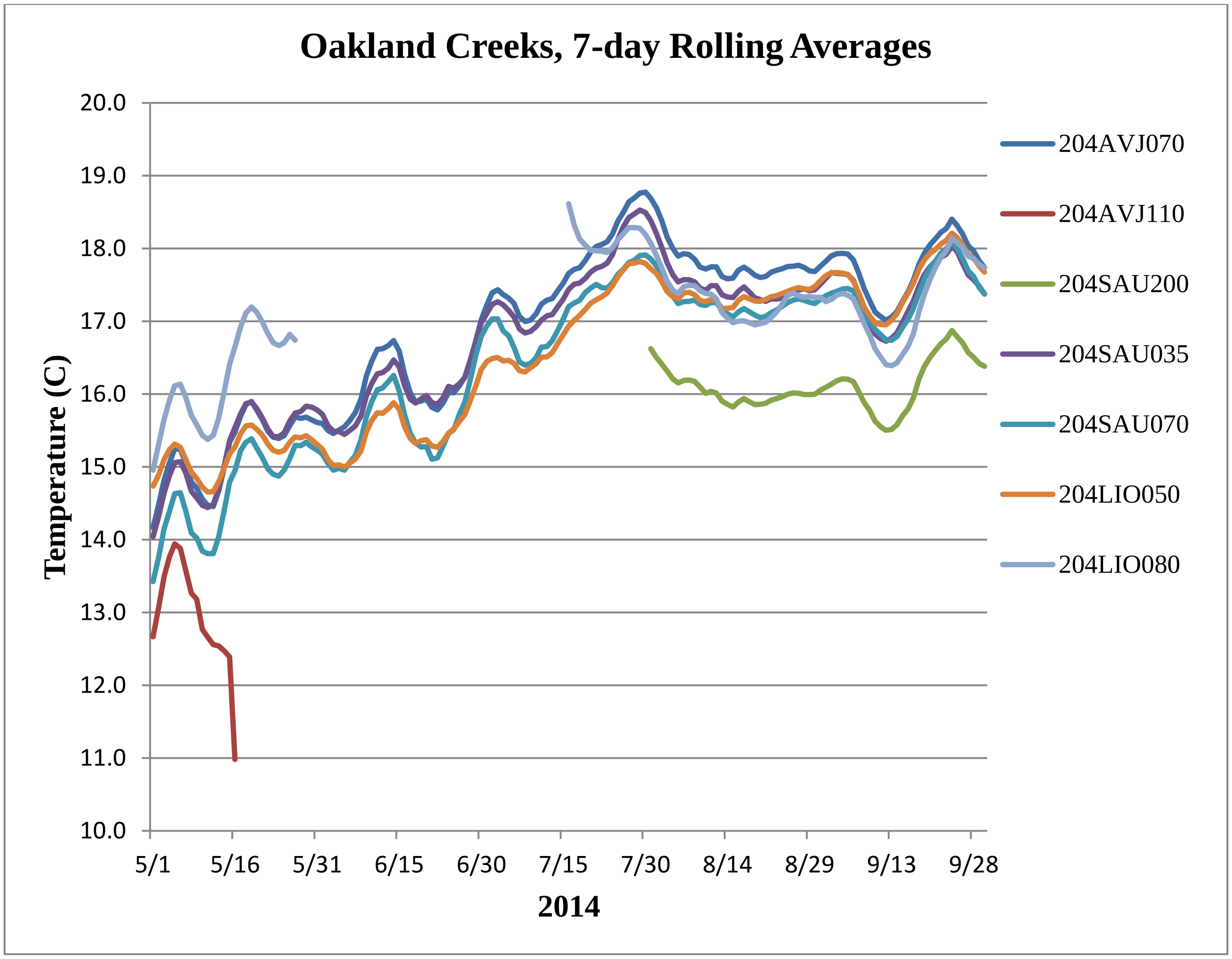


Figure 4-3. Temperature (7-day Rolling Average Calculated Daily) Line Graph for Oakland Creeks, April 25 through September 30, 2014.

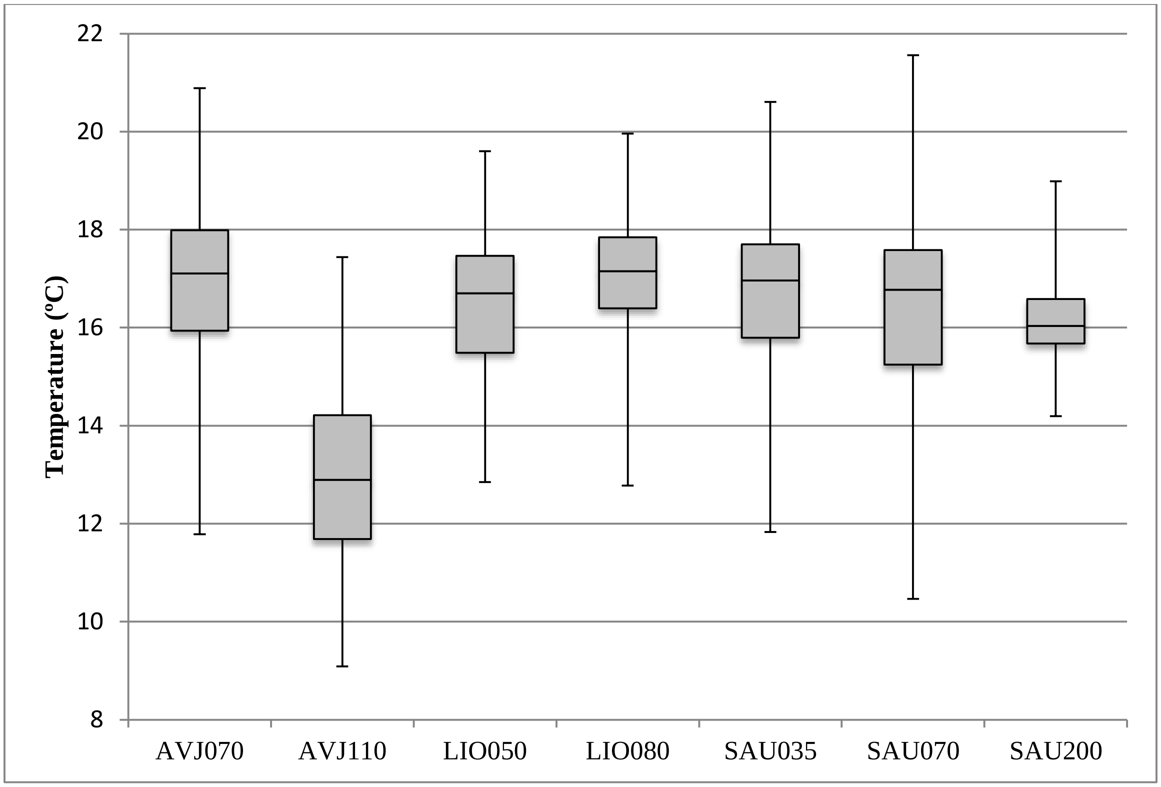


Figure 4-4.Temperature Box Plot for Oakland Creeks, April 25 through September 30, 2014.

Summary results for temperature data from WY2014 are presented in Table 4-2. Average temperatures at the Oakland sites ranged between 13.00°C and 17.04°C. The highest temperatures were recorded at 204SAU070 on June 30 while the lowest temperatures were recorded at 204AVJ110 in June, and at 204SAU070 in April.

Temperature (ºC)	204 AVJ070	204 AVJ110	204 LIO050	204 LIO080	204 SAU035	204 SAU070	204 SAU200
Min	11.78	9.09	12.85	12.78	11.83	10.47	14.19
Max	20.89	17.44	19.60	19.96	20.60	21.56	18.99
Range	9.11	8.35	6.76	7.19	8.77	11.09	4.79
Mean	16.88	13.00	16.50	17.04	16.69	16.37	16.14
St dev	1.56	1.86	1.23	1.22	1.46	1.72	0.66

Table 4-2. Summary of Temperature Data from WY2014 at Oakland Creek Sampling Locations

Temperature (ºC)	204 AVJ070	204 AVJ110	204 LIO050	204 LIO080	204 SAU035	204 SAU070	204 SAU200
Min	11.78	9.09	12.85	12.78	11.83	10.47	14.19
Max	20.89	17.44	19.60	19.96	20.60	21.56	18.99
Range	9.11	8.35	6.76	7.19	8.77	11.09	4.79
Mean	16.88	13.00	16.50	17.04	16.69	16.37	16.14
St dev	1.56	1.86	1.23	1.22	1.46	1.72	0.66

4.3 General Water Quality Measurement

General water quality measurements of temperature, DO, pH and specific conductivity were taken at locations during two periods: spring (May and/or June) and late summer to fall (August and/or September). In WY2014, these data were collected from 3 sites (see Table 3-3):

- 204AVJ080 – Arroyo Viejo near Golf Links Rd. and I-580
- 204CRW040 – Crow Creek above confluence with Cull Creek; and
- 204CRW042 – Crow Creek south of Crow Creek Drive.

In the following pages Table 4-3, Table 4-4 and Table 4-5 summarize the 7-day rolling average results from each site; Figure 4-5, Figure 4-6 and Figure 4-7 show graphical plots of temperature and DO for these sites in the spring and summer/fall periods.

Table 4-3. General Water Quality 7-day Rolling Averages at Site 204AVJ080 in WY2014

June				September			
Date	**Temp (ºC)**	**pH**	**DO (mg/L)**	**Date**	**Temp (ºC)**	**pH**	**DO (mg/L)***
6/2/14	15.23	7.98	9.42	9/15/14	17.26	7.18	0.78
6/3/14	15.16	7.97	9.39	9/16/14	17.28	7.10	0.12
6/4/14	15.20	7.96	9.35	9/17/14	17.35	7.06	0.10
6/5/14	15.25	7.96	9.31	9/18/14	17.44	7.05	0.10
6/6/14	15.30	7.95	9.31	9/19/14	17.54	7.04	0.10
				9/20/14	17.63	7.03	0.10
				9/21/14	17.70	7.03	0.10
				9/22/14	17.76	7.03	0.10
				9/23/14	17.81	7.04	0.10
				9/24/14	17.88	7.04	0.10
				9/25/14	17.94	7.11	0.71

* Not qualified, see discussion in text

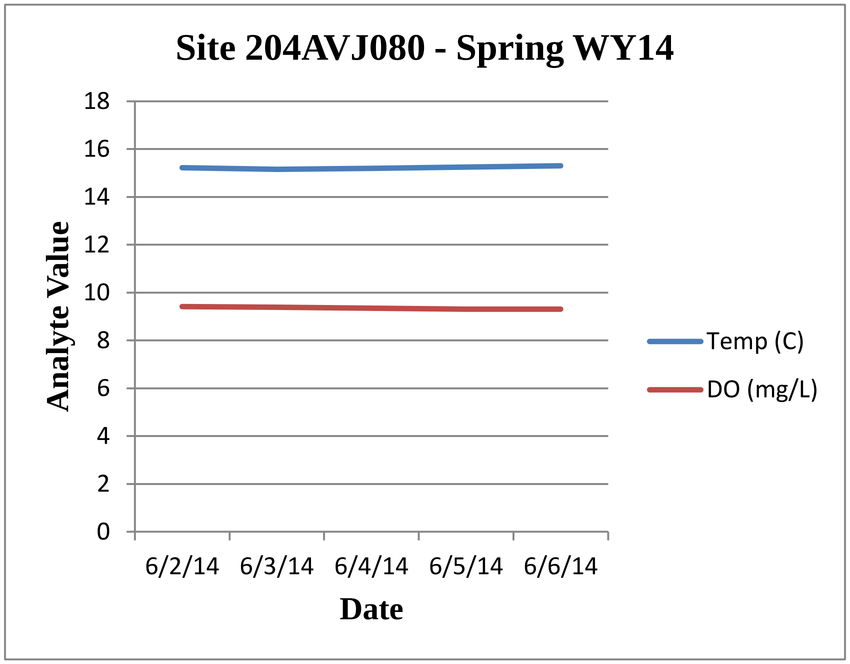
Table 4-4. General Water Quality 7-day Rolling Averages at Site 204CRW040 in WY2014

June				**September**			
Date	Temp (ºC)	**pH**	**DO (mg/L)**	**Date**	**Temp (ºC)**	**pH**	**DO (mg/L)**
5/19/14	16.25	8.09	8.08	9/1/14	17.19	7.86	4.57
5/20/14	16.45	8.11	8.17	9/2/14	17.24	7.85	4.48
5/21/14	16.66	8.13	8.27	9/3/14	17.36	7.86	4.47
5/22/14	16.62	8.13	8.31	9/4/14	17.42	7.86	4.48
				9/5/14	17.41	7.86	4.48
				9/6/14	17.39	7.86	4.51
				9/7/14	17.25	7.87	4.70
				9/8/14	17.19	7.88	4.91
				9/9/14	17.03	7.88	5.16

Table 4-5. General Water Quality 7-day Rolling Averages at Site 204CRW042 in WY2014

June				**September**			
Date	**Temp (ºC)**	**pH**	**DO (mg/L)**	**Date**	**Temp (ºC)**	**pH**	**DO** (mg/L)**
5/19/14	15.72	8.02	8.13	9/1/14	17.07	8.02	NR
5/20/14	15.41	8.03	8.33	9/2/14	17.09	8.02	NR
5/21/14	15.36	8.03	8.35	9/3/14	17.23	8.03	NR
5/22/14	15.21	8.04	8.42	9/4/14	17.28	8.03	NR
				9/5/14	17.28	8.04	NR
				9/6/14	17.24	8.04	NR
				9/7/14	17.09	8.05	NR
				9/8/14	17.01	8.06	NR
				9/9/14	16.79	8.07	NR

** Data for fall deployment censored due to equipment failure, see discussion in text.



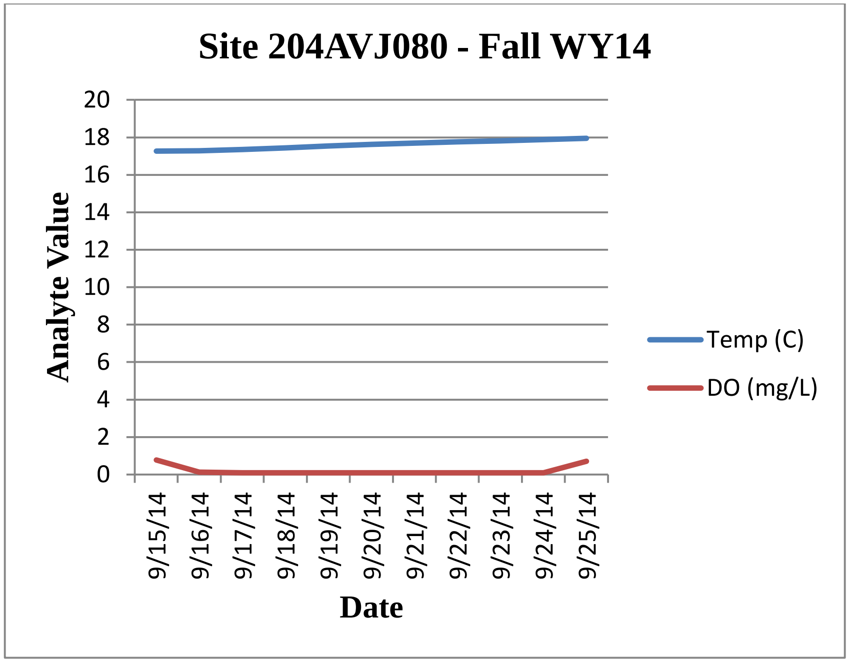


Figure 4-5. General Water Quality Monitoring 7-day Rolling Averages for Temperature and Dissolved Oxygen at 204AVJ080 in Spring and Fall, WY2014

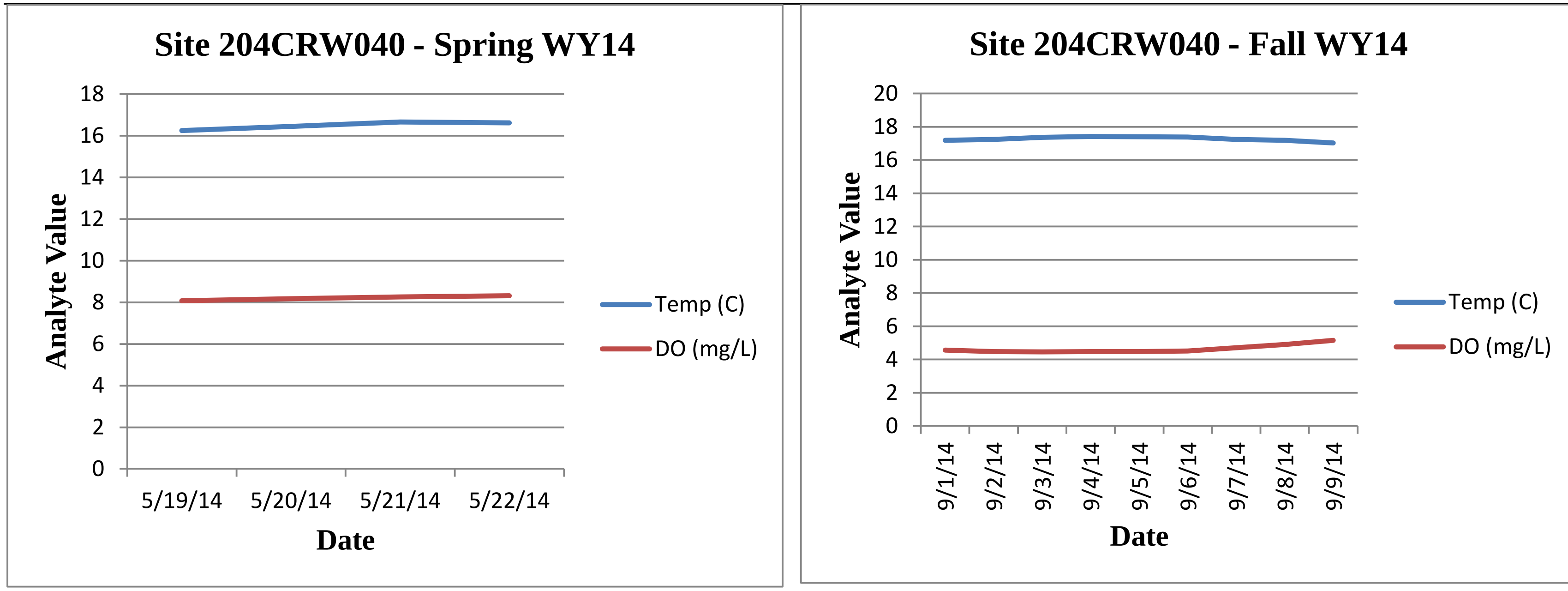
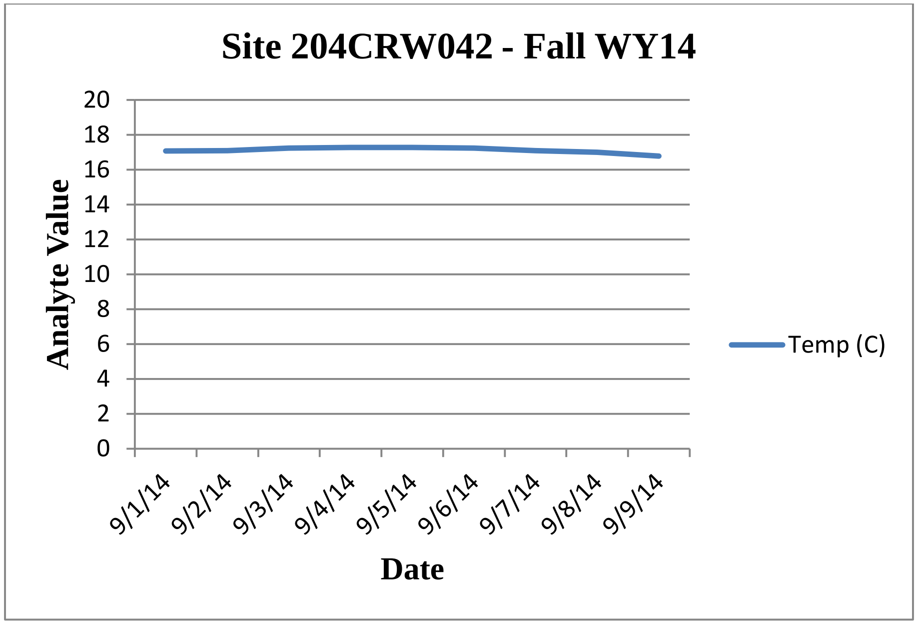


Figure 4-6.General Water Quality Monitoring 7-day Rolling Averages for Temperature and Dissolved Oxygen at 204CRW040 in Spring and Fall, WY2014.



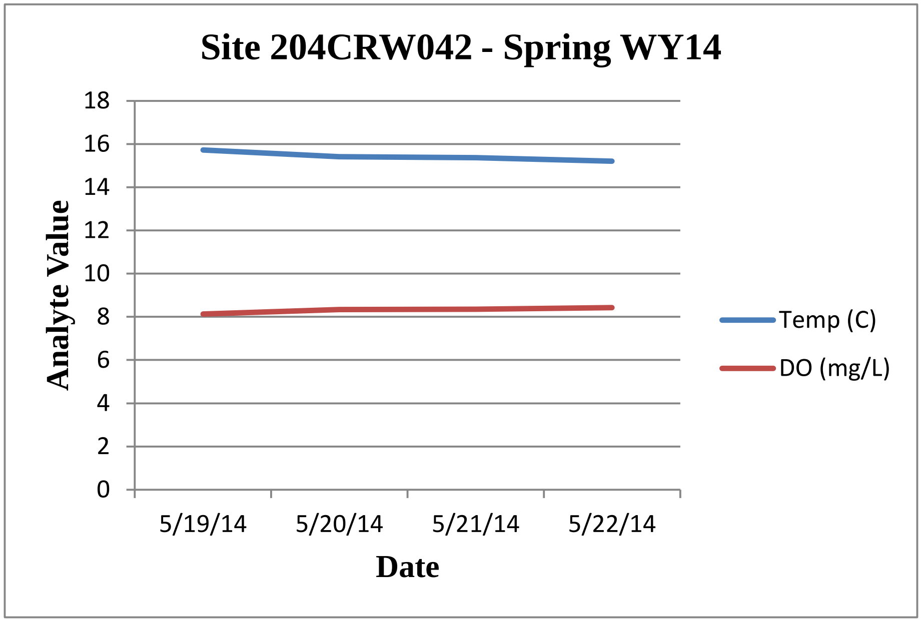


Figure 4-7. General Water Quality Monitoring 7-day Rolling Averages for Temperature and Dissolved Oxygen at 204CRW042 in Spring and Fall, WY2014. (see text for discussion of conductivity probe malfunction that caused Fall DO data recorded to be censored).

4.4 Pathogen Indicators

Single grab water samples for pathogen indicators were taken at five locations in the greater Castro Valley Creek watershed on July 8, 2014. *E. coli* and fecal coliform were enumerated as individual grab samples as presented in Table 4-6.

The highest 2014 concentrations of fecal indicator bacteria were found at 204CVY020 where both fecal coliform and *E.coli* numbers were 2,200MPN/100mL. Similarly elevated concentrations were also found at Sites 204CVY080 (2,200MPN/100mL for *E.coli*) and 204CVY125 (1,700MPN/100mL for fecal coliforms), while both fecal coliform and *E.coli* concentrations were low at 204CVY140 (170MPN/100mL). In comparison, the bacteria concentrations at or near the five sampling sites in July 2012 were almost all greater than or equal to 900MPN/100mL, and elevated fecal indicator bacteria concentrations were found at Site 204CVY140 (greater than or equal to 16,000MPN/100mL).

Table 4-6. Fecal coliform and *E. coli* enumerations at Castro Valley Creek Monitoring Sites in July 2014.

Site ID	Site Description	Creek Name	Fecal Coliform (MPN*/100mL)	*E. coli* (MPN*/100 mL)
204CVY020	Chabot Creek at Carlos Bee Park	Chabot Creek	2,200	2,200
204CVY080	Castro Valley Creek above confluence with Chabot Creek	Castro Valley Creek	130	2,200
204CVY125	Castro Valley Creek below Castro Valley Blvd.	Castro Valley Creek	1,700	700
204CVY140	Castro Valley Creek North side of Berdina Rd	Castro Valley Creek	170	170
204CVY150	Castro Valley Creek North side of Heyer Ave	Castro Valley Creek	900	900

*Most Probable Number

4.5 Stream Survey

In 2014 the Program surveyed approximately 9.2 creek miles within the greater Laguna Creek watershed in Fremont, using the modified Unified Stream Assessment protocol. The field team identified no immediate impacts of concern. The following sections summarize the Stream Survey portions of the Creek Status monitoring data for the following creeks, shown with their Zone-Line designations used by the Alameda County Flood Control and Water Conservation District:

- Laguna Creek, Zone 6 Line E (Section 4.5.1)
- Laguna Creek Bypass, Zone 6 Line G (Section 4.5.2)
- Agua Caliente, Zone 6 Line F (Section 4.5.3)
- Washington Creek, Zone 6 Line K-1 (Section 4.5.4)

Attachments A through D provide more detailed maps of the surveyed reaches.

Surveyed reach characteristics are presented in Tables 1 through 4. Findings generated through the assessments are described in the sections that follow.

Table 4-7. Surveyed Reaches, Laguna Creek

Reach	Geographic Extent	Reach Length (ft)	Valley Slope (%)	General Characteristics
A	North side of 880 to confluence of Line 6_G	549	0.13	Earth
B	Confluence of Line 6_G to North side of S Grimmer Blvd	1515	0.76	Earth and concrete
C	North side of S Grimmer Blvd to confluence of Line 6_H	1598	0.21	Earth
D	Confluence of Line 6_H to confluence of Line 6_J	1135	0.43	Earth
E	Confluence of Line 6_J to North side of Auto Mall Prkwy	1137	0.27	Earth
F	North side of Auto Mall Prkwy to NE side of Fremont Blvd	421	0.93	Earth
G	NE side of Fremont Blvd to confluence of Line 6_I	569	0.84	Earth
H	Confluence of Line 6_I to North side of Delaware Dr	1916	0.39	Earth
I	North side of Delaware Dr. to North side of Blacow Rd	2017	0.41	Concrete
J	North side of Blackow Rd to NE side of Roberts Ave, at confluence of Line 6_K	894	0.46	Earth
K	Confluence of Line 6_K to NW side of Carol Ave	727	0.89	Earth
L	NW side of Carol Ave to North side of Adams Ave	650	0.06	Earth
M	North side of Adams Ave to underground culvert	581	0.94	Earth
N	Beginning of daylighted channel at end of Nolan Terrace to North side of High St	2089	0.10	Earth
O	North side of High St to North side of Paseo Padre Pkwy	1319	0.25	Earth and concrete
P	Beginning of daylighted channel at culvert under parking lot at Fremont Blvd to SW side of park path to Gatewood St	910	0.03	Earth
Q	SW side of park path to Gatewood St to end of daylighted channel at end of Cedarwood Dr	1059	0.39	Earth

Table 4-8. Surveyed Reaches, Laguna Creek Bypass

Reach	Geographic Extent	Reach Length (ft)	Valley Slope (%)	General Characteristics
A	Confluence of Line 6_E near 880 Fwy to large outfall on East bank (near Enterprise St.)	1215	0.53	Earth
B	Large outfall on East bank (near Enterprise St.) to North side of Auto Mall Pkwy	4398	0.19	Earth
C	North side of Auto Mall Pkwy to North side of Yellowstone Park Dr	3211	0.03	Earth
D	North side of Yellowstone Park Dr. to footbridge (across from Clarendon Park Ct)	1409	0.28	Earth
E	Upstream of footbridge (across from Clarendon Park Ct) to North side of Valpey Park Ave	1355	0.38	Earth
F	North side of Valpey Park Ave to North side of Blacow Rd	1650	0.39	Earth
G	North side of Blackow Rd to North side of Carol Ave	1477	0.11	Earth
H	North side of Carol Ave to West side of Grimmer Blvd overpass (to end of concrete banks)	1232	0.56	Earth and concrete
I	West side of Grimmer Blvd overpass (begin at natural banks) to culvert (near Irvington Ave)	792	0.27	Earth
J	North side of Fremont Blvd to North side of Paseo Padre Pkwy	2368	0.22	Earth

Table 4-9. Surveyed Reaches, Agua Caliente

Reach	Geographic Extent	Reach Length (ft)	Valley Slope (%)	General Characteristics
B	NE side of Fremont Blvd to East side of 880 Fwy	1570	0.10	Earth
C	East side of 880 Fwy to concrete channel underneath road crossing	1826	0.21	Earth
D	Beginning of concrete channel underneath road crossing to culvert at railroad tracks	884	1.29	Concrete
E	East side of railroad tracks to East side of Warm Springs Blvd	1022	1.87	Concrete
F	East side of Warm Springs Blvd to culvert at Research Ave	2029	2.09	Earth

Table 4-10. Surveyed Reaches, Washington Creek

Reach	Geographic Extent	Reach Length (ft)	Valley Slope (%)	General Characteristics
A	Confluence with Sabrecat Creek at Sabrecat Creek-B to end of daylighted segment near Osgood Rd (in line with axis of Adams Ave to west of railroad tracks)	2657	1.24	Earth and concrete
B	Beginning of daylighted channel at Driscoll Rd and Washington Blvd to East side of Alice St where banks change from engineered earth to natural.	705	2.49	Earth
C	East side of Alice St to South side of Olive Ave	1431	1.64	Earth

Reach Assessment

Summary results of the USA reach assessments are provided in Table 5 through Table 8 and Figure 6 through Figure 9. The attributes making up the overall reach assessment scores are discussed below.

Instream Habitat

The overall instream habitat scores ranged by reach from 20 to 52. Washington Creek reaches had the highest average score of 39, with the most natural creek mileage and more optimal instream habitat. The highly modified reaches of Laguna Creek and Laguna Creek Bypass had the lowest average score of 33, with poor instream habitat complexity, sparse bank vegetation, and deeply entrenched streams.

Buffer and Floodplain Condition

Overall buffer and floodplain condition reach scores ranged from 4 to 14. Laguna Creek Bypass reaches had the highest average score of 6, while the Laguna Creek, Agua Caliente Creek, and Washington Creek reaches all shared the lowest average scores of 5. These relatively low scores reflect that all of our surveyed reaches were in highly urbanized areas with minimal vegetated buffer width and significant floodplain encroachment.

Overall Reach Assessment

The overall reach assessment scores ranged from 26 to 57. Washington Creek reaches had the highest average score of 44, with slightly more complex instream habitat and vegetated banks. Laguna Creek had the lowest average score of 38, with heavily modified channel reaches and significant floodplain encroachment.

Table 4-11. Reach Assessment Scores, Laguna Creek

Laguna Creek Reach	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Overall Stream Condition																	
Instream Habitat	2	6	8	7	6	7	8	7	4	7	7	7	6	6	6	6	5
Vegetative Protection (LB)	4	4	4	3	3	4	4	4	4	3	4	4	2	5	5	3	4
Vegetative Protection (RB)	4	4	4	3	4	3	4	3	4	4	4	4	2	5	5	3	3
Bank Erosion (LB)	4	7	6	9	7	6	6	7	6	6	7	8	4	9	8	8	6
Bank Erosion (RB)	3	7	6	9	7	7	6	6	6	7	7	8	4	9	8	8	7
Floodplain Connection	3	4	4	3	3	3	3	3	8	5	8	10	6	14	11	8	8
Instream Habitat Total Score	20	32	32	34	30	30	31	30	32	32	37	41	24	48	43	36	33
Overall Buffer & Floodplain Condition																	
Vegetative Buffer Width (LB)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vegetative Buffer Width (RB)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Floodplain Vegetation	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Floodplain Habitat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Floodplain Encroachment	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Floodplain and Buffer Total Score	6	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5	5
Reach Assessment Total Score	26	37	37	39	35	35	36	35	37	37	42	46	29	53	48	41	38

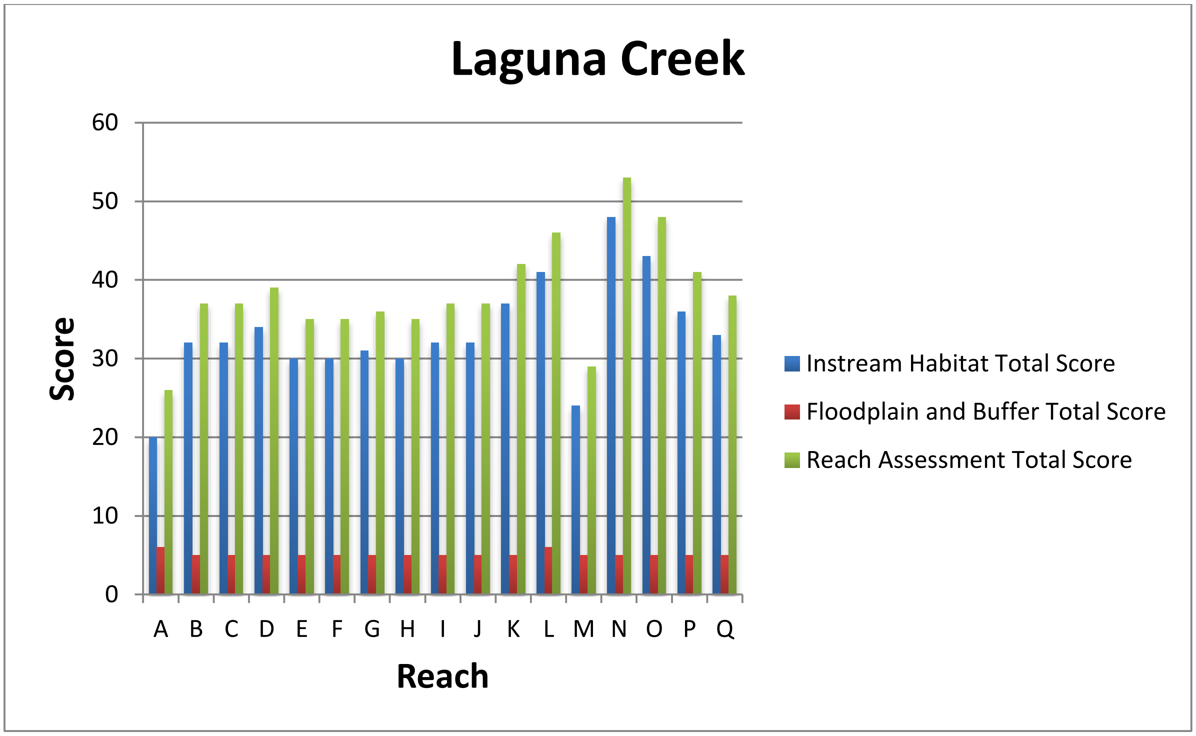


Figure 4-8. Summary of Unified Assessment Scores for Laguna Creek Reaches

Table 4-12. Reach Assessment Scores, Laguna Creek Bypass

Laguna Creek Bypass Reach	A	B	C	D	E	F	G	H	I	J
Overall Stream Condition										
Instream Habitat	4	4	5	5	3	8	13	8	5	10
Vegetative Protection (LB)	1	1	4	4	4	5	4	5	3	5
Vegetative Protection (RB)	1	1	4	4	5	4	4	3	3	4
Bank Erosion (LB)	6	6	7	7	7	8	6	7	6	9
Bank Erosion (RB)	6	6	7	7	6	7	6	6	6	8
Floodplain Connection	5	5	9	9	6	6	5	5	5	3
Instream Habitat Total Score	23	23	36	36	31	38	38	34	28	39
Overall Buffer & Floodplain Condition										
Vegetative Buffer Width (LB)	1	1	1	1	1	1	1	1	1	1
Vegetative Buffer Width (RB)	0	0	1	1	2	1	1	1	1	2
Floodplain Vegetation	1	1	2	2	2	1	1	1	1	6
Floodplain Habitat	1	1	1	1	1	1	1	1	1	2
Floodplain Encroachment	1	1	2	2	1	1	1	1	1	3
Floodplain and Buffer Total Score	4	4	7	7	7	6	5	5	5	14
Reach Assessment Total Score	27	27	43	43	38	44	43	39	33	53

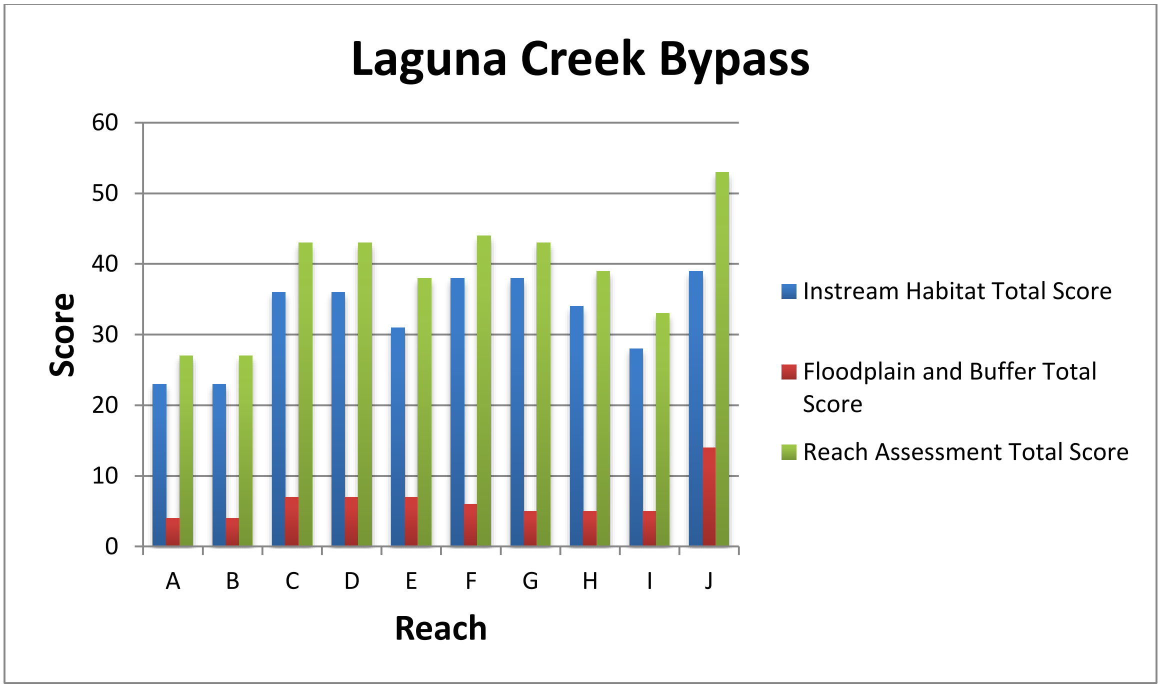


Figure 4-9. Summary of Unified Stream Assessment Scores for Laguna Creek Bypass Reaches

Table 4-13. Reach Assessment Scores, Agua Caliente Reaches

Agua Caliente Creek Reach	**B**	**C**	**D**	**E**	**F**
Overall Stream Condition					
Instream Habitat	10	6	1	0	15
Vegetative Protection (LB)	4	3	0	0	7
Vegetative Protection (RB)	4	3	0	0	7
Bank Erosion (LB)	6	6	10	10	7
Bank Erosion (RB)	7	7	10	10	6
Floodplain Connection	5	6	5	5	10
Instream Habitat Total Score	36	31	26	25	52
Overall Buffer & Floodplain Condition					
Vegetative Buffer Width (LB)	1	1	1	1	1
Vegetative Buffer Width (RB)	1	1	1	1	1
Floodplain Vegetation	1	1	1	1	1
Floodplain Habitat	1	1	1	1	2
Floodplain Encroachment	1	1	1	1	1
Floodplain and Buffer Total Score	5	5	5	5	5
Reach Assessment Total Score	41	36	31	30	57

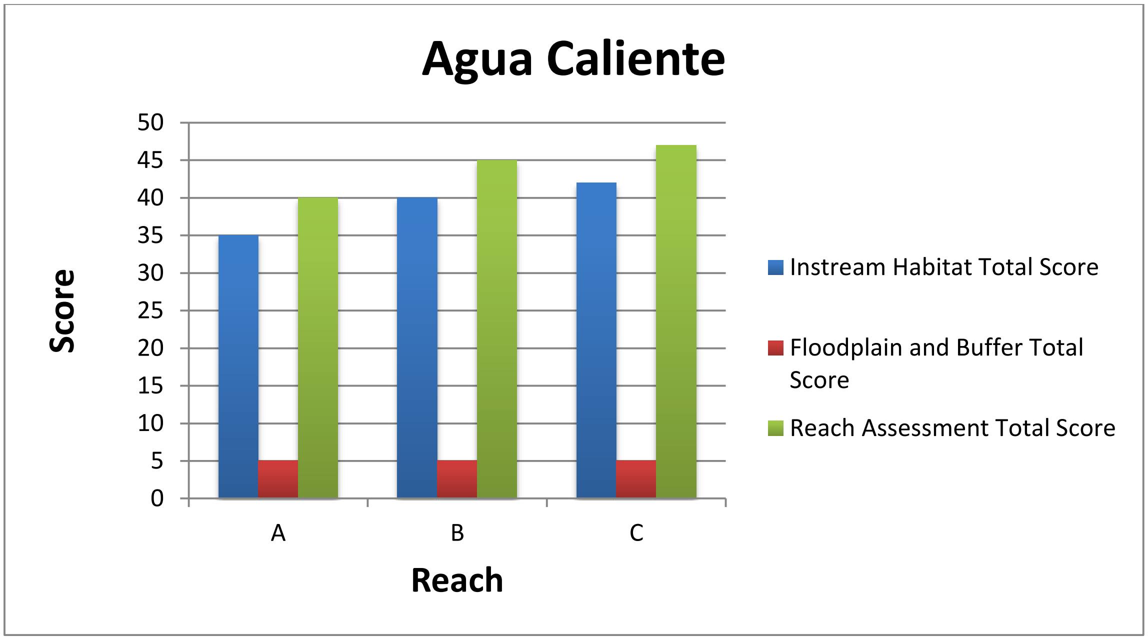


Figure 4-10. Summary of Unified Stream Assessment Scores for Agua Caliente Reaches

Table 4-14. Reach Assessment Scores, Washington Creek Reaches

Washington Creek Reach	**A**	**B**	**C**
Overall Stream Condition			
Instream Habitat	4	14	15
Vegetative Protection (LB)	4	5	5
Vegetative Protection (RB)	4	4	5
Bank Erosion (LB)	7	7	6
Bank Erosion (RB)	7	6	7
Floodplain Connection	9	4	4
Instream Habitat Total Score	35	40	42
Overall Buffer & Floodplain Condition			
Vegetative Buffer Width (LB)	1	1	1
Vegetative Buffer Width (RB)	1	1	1
Floodplain Vegetation	1	1	1
Floodplain Habitat	1	1	1
Floodplain Encroachment	1	1	1
Floodplain and Buffer Total Score	5	5	5
Reach Assessment Total Score	40	45	47

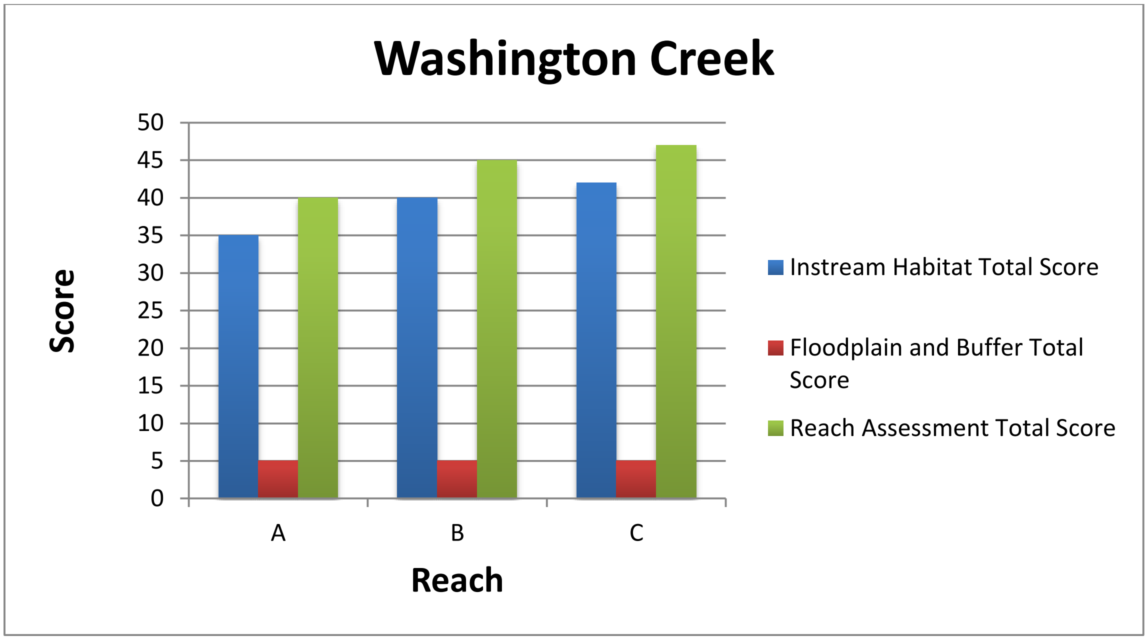


Figure 4-11. Summary of Unified Stream Assessment Scores for Washington Creek Reaches

Impact Assessment Summary

Summary results from the impact assessments are shown in the previous tables. Schematic maps showing location of impacts within each reach are found in the Attachments A-D. Findings relative to individual impact categories are discussed below.

Outfalls

The greatest frequency of outfalls per surveyed mile occurred in Laguna Creek Reach A (approximately 38/mi). In comparison, both Laguna Creek Reach G and Washington Creek Reach C were devoid of outfalls. The majority of outfalls that occurred in all creeks were classified as storm drains, while the remaining outfalls with a 1 – 6" diameter were suspected to be private. Sampling personnel did not investigate potential sources of the suspected private outfalls. Approximately 97% of the outfalls had no dry weather flow, and the remaining outfalls had trickle to moderate flow. Sampling personnel did not observe any suspicious discharges during surveys.
Channel Modification

Within the highly urbanized channels surveyed, Laguna Creek Bypass had the highest degree of distinct structural modification (approx. 5% by length), primarily consisting of bank armoring and one drop structure. Laguna Creek had approximately 4% channel modifications and Agua Caliente Creek and Washington Creek had less than 1%. The low percentage of channel modification reflects that while each stream was channelized and structurally altered, survey reaches were fairly uniform. Only notable changes in the channel's uniformity were recorded. Most of the channel modifications were to banks, and the bank armoring materials typically used were concrete, sandbags and riprap. However one instream trash grate and multiple drop structures were observed.

Erosion

A minimal amount of bank erosion / slope failure was found in the reaches surveyed. Only Laguna Creek and Washington Creek reaches had any notable erosion occurring. The observed erosion was likely from historic channel incision that resulted in steeper channel gradients and steeper bank slopes, as well as storm damage to banks that were sparsely vegetated.

Washington Creek had the highest total percentage of stream crossings (12% by length), due to the fact that the channel flows through a more residential area with a higher density of roads and overpasses. Laguna Creek Bypass had the lowest total percentage of stream crossings (5%), because the channel flows through an industrial area with more space between major road crossings. Most stream crossings encountered were vehicle overpasses, underground culverts, and footbridges. None of the stream crossings encountered in any reaches were fish barriers or performed grade control.

Trash

The only trash observed during our surveys was stacks of tires on the right bank of Agua Caliente Reach F. It was unclear if the tires were originally placed there for bank armoring.

Recreation

Field personnel observed no recreation sites during 2014 surveys.

Utilities

Laguna Creek had the most utility impacts observed in the surveyed reaches (6), while Washington had the fewest observed (1). All impacts were utility pipes. None of the utility pipes appear to pose barriers to fish passage.

5 Stressor Assessment

This section is a preliminary review of targeted monitoring data to identify samples with results that meet the “trigger” conditions for potential further investigation according to Table 8.1 of the MRP (see Table 5-1).

Table 5-1. Description of Triggers for Creek Status Targeted Parameters.

Monitoring Parameter	Trigger Description Per MRP Table 8.1
General Water Quality	20% of results in one water body exceed one or more water quality standards or established thresholds: • Dissolved Oxygen for WARM is 5.0 mg/l: 3-month median for DO shall not be less than 80 percent of the DO content at saturation. • Dissolved Oxygen Coldwater Beneficial Use: 7.0 mg/l • Water Temperature Warmwater Beneficial Use: see below • Water Temperature Coldwater Beneficial Use: see below • Conductivity: NA • pH: > 6.5 and <8.5; and controllable water quality factors shall not cause changes greater than 0.5 units in normal ambient pH levels.
Temperature	20% of results in one water body exceed applicable temperature thresholds: • The temperature of any cold or warm freshwater habitat shall not be increased by more than 5°F (2.8°C) above natural receiving water temperature; for designated COLD reaches, the maximum 7-day mean temperature should not exceed 26°C and should not exhibit spikes with no obvious natural explanation observed.
Pathogen Indicators	Fecal coliform: SFRWQCB (2011) Table 3.1 not applicable [5]. *E. coli:*SFRWQCB (2011) Table 3.2 for Water Contact Recreation in fresh water[6] Steady State: 126 colonies per 100 ml Moderately used area:< 298 colonies per 100 ml Lightly used area:< 406 colonies per 100 ml Infrequently used area:< 576 colonies per 100 ml (USEPA 1986)
Stream Survey	NA

5.1 Continuous Temperature

Continuous temperature 7-day averages were compared to two criteria established by USEPA (Brungs and Jones, 1977) for juvenile rainbow trout (*Onchorhynchus mykiss*)[7]:

[5] Water Quality Objectives listed in Table 3.1 of the Basin Plan for fecal coliform are based on five consecutive samples that are collected over an equally spaced 30-day period, which do not correspond to the sampling frequency in the MRP. The WQOs for Water Contact Recreation include concentrations for the calculated geometric mean (< 200 MPN/100ml) and the 90th percentile (< 400 MPN/100ml).

[6]Water Quality Objectives listed in Table 3.1 of the Basin Plan for *E. coli* are maximum values to "provide for a level of production based on the frequency of usage of a given water contact recreation area. For this reason the maximum criterion for "designated beach" and "Steady State" are not applicable to the creeks monitored.

[7] This species, in either the anadromous (steelhead) or resident (rainbow trout) form, is the only salmonid species that naturally occurs in the San Lorenzo and Sausal watersheds.

- Maximum weekly average temperature (MWAT) for juvenile growth - 19°C
- Maximum short-term temperature for juvenile survival - 24°C

While the above thresholds were derived mainly from laboratory studies, they are reasonable in light of habitat characteristics for similar Bay Area salmonid populations (Leidy et al., 2005)[8]. Temperature triggers were observed in the Castro Valley and Crow Creek systems at 204CRW030, with 21% of rolling 7-day averages above the MWAT target threshold of 19°C, 204CVY005 with 11% above, and 204CRW040 with 3% above.

5.2 General Water Quality

Water quality triggers were compared against the results obtained during general water quality monitoring. None of the seven-day rolling averages calculated for temperature pH, or dissolved oxygen (DO) during the spring deployments fell within target ranges beyond trigger thresholds identified in the IMR.

For the summer/fall deployments, no calculated seven-day rolling averages exceeded identified thresholds for temperature or pH. However, 100% of calculated rolling averages for DO fell below the threshold of 5 mg/L at 204AVJ080, and 89% fell below the threshold of 5 mg/L and 100% fell below the threshold of 7 mg/L at 204CRW040. Equipment failure at site 204CRW042 prevented any comparison with DO thresholds in summer/fall.

The only triggers observed were for DO, where. A number of sites were found to be below the respective criterion DO concentrations for COLD and in some cases WARM beneficial uses. Low DO concentrations may have a detrimental impact on aquatic life.

[8]Sullivan et al. (2000) is referenced in Table 8.1 of the MRP as a potential source for applicable thresholds to use for evaluating water temperature data for creeks that have salmonid fish communities, and illustrates the risk-based approach to evaluating temperature effects on salmonid communities in terms of relative reductions in growth at temperatures other than optimum. However, that study established its MWAT thresholds using data from salmonid populations in the Pacific Northwest and is likely overly conservative for steelhead in central California. Since fish growth is a function of both temperature and available food, optimum temperature and the incremental effect of temperature shifts on growth are ration-dependent and affected by other ecosystem factors, (for example see reviews in Myrick and Cech, 2001 and Atkinson et al., 2011). Streams in the Bay Area and Central California in general tend to be higher-nutrient systems than the glacially-derived geology of the Pacific Northwest, and can thus deliver the larger food supplies to support salmonid growth at warmer temperatures.

5.3 Pathogen Indicators

Table 5-1 presents the United States Environmental Protection Agency (USEPA) criteria for ambient water quality bacteria concentrationsas stipulated in Provision C.8 of the MRP. The Basin Plan includes two water quality standards that could potentially be used for comparison in determining triggers.

Table 3.1 of the Basin Plan references a USEPA assessment of public health risk that assumes multiple sampling at recreational bathing beaches and derives a statistical probability of illness from those assumptions. Under the provisions of the MRP, permittees collect single samples, once at each sampling location within that Water Year. As such, the monitoring frequency stipulated within the MRP is not consistent with the sampling requirements of the USEPA WQOs in Table 3, although it is the only comparison offered for fecal coliform bacteria, which may be derived from a wide range of sources and may not be indicative of pathogen risks to human health.

Table 3.2 of the Basin Plan references an alternative USEPA standard that is applicable for single samples of *E. coli* or the enterococci group, which are considered better predictors of human illness. Actual water contact by creek visitors is likely rare to sporadic at many of the sites sampled and does not correspond to the assumptions for human health risk assessment that were used to develop the water quality standard in Table 3.2 of the Basin Plan, which were based on studies of users at bathing beaches that received direct bacteriological contamination from treated human wastewater. These criteria are,however,associated with presumptive recreational uses and so are used as benchmarks to define trigger criteria as required in the MRP; although the results of the monitoring are not an accurate indication of the risk to public healththey may be used to derive coarse assessments of potential fecal pollution sources in watersheds.

Table 5-2presents the results of the pathogen indicator enumeration with comparison against the USEPA criteria in Table 3.2 of the Basin Plan. All sites were found to have bacterial concentrations above the recommended thresholds for lightly and moderately used recreational areas. It should be noted that recreational usage, as defined by the EPA, cannot be directly reflected in appropriate usage within the sampled creeks. As a typical example, Castro Valley Creek is designated for both contact (REC-1) and non-contact (REC-2) recreation, although much of the creek system is inaccessible to the public. One of the monitoring locations (204CVY020) does provide public access through parks and trails but there is little option for immersive swimming or contact recreation. Therefore actual recreational contact in this small creek is extremely limited and is not encouraged. Sites 204CVY140 and 204CVY150 have the least opportunity for public access; if assessed as infrequently used area, 204CVY140 would not be meet the trigger criterion for either fecal coliforms or *E. coli*. The rest of the sites meet the trigger criterion for at least one of the pathogen indicators, whether assessed as lightly or moderately used areas.

Table 5-2. Comparison of WY2014 Pathogen Indicator Concentrations to Water Quality Objectives and Triggers. BOLD font indicates result meets trigger conditions.

Site ID	Site Description	Creek Name	Fecal Coliform (MPN*/100mL)	*E. coli* (MPN*/100 mL)
204CVY020	Chabot Creek at Carlos Bee Park	Chabot Creek	**2,200**	**2,200**
204CVY080	Castro Valley Creek above confluence with Chabot Creek	Castro Valley Creek	130	**2,200**
204CVY125	Castro Valley Creek below Castro Valley Blvd.	Castro Valley Creek	**1,700**	**700**
204CVY140	Castro Valley Creek North side of Berdina Rd	Castro Valley Creek	170	170
204CVY150	Castro Valley Creek North side of Heyer Ave	Castro Valley Creek	**900**	**900**

*Most Probable Number

6 Next Steps

All sites identified in Section 5 as meeting trigger conditions will be reviewed by the Program in conjunction with relevant Permittees and RMC programs to determine potential follow-up actions pursuant to MRP Provision C.8.d.i, Stressor/Source Identification (SSID). ACCWP initiated three SSID projects developed through the RMC selection processs in FY2013-14, which together with those proposed by other RMC participants comprised the regional collaborative limit of 10 projects for the MRP permit term as stipulated in provision C.8.d.i(5) of the MRP. Where triggers or potential trigger conditions have been identified in WY2014 results, ACCWP will also work with local stormwater managers to identify appropriate follow-up activities, which may be either incorporated in WY 2014 Creek Status Monitoring or conducted outside the scope of MRP C.8.c.

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8 Attachments

Attachment A	Laguna Creek Surveyed Reaches
Attachment B	Laguna Creek Bypass Surveyed Reaches
Attachment C	Agua Caliente Surveyed Reaches
Attachment D	Washington Creek Surveyed Reaches

Attachment A – Laguna Creek Surveyed Reaches

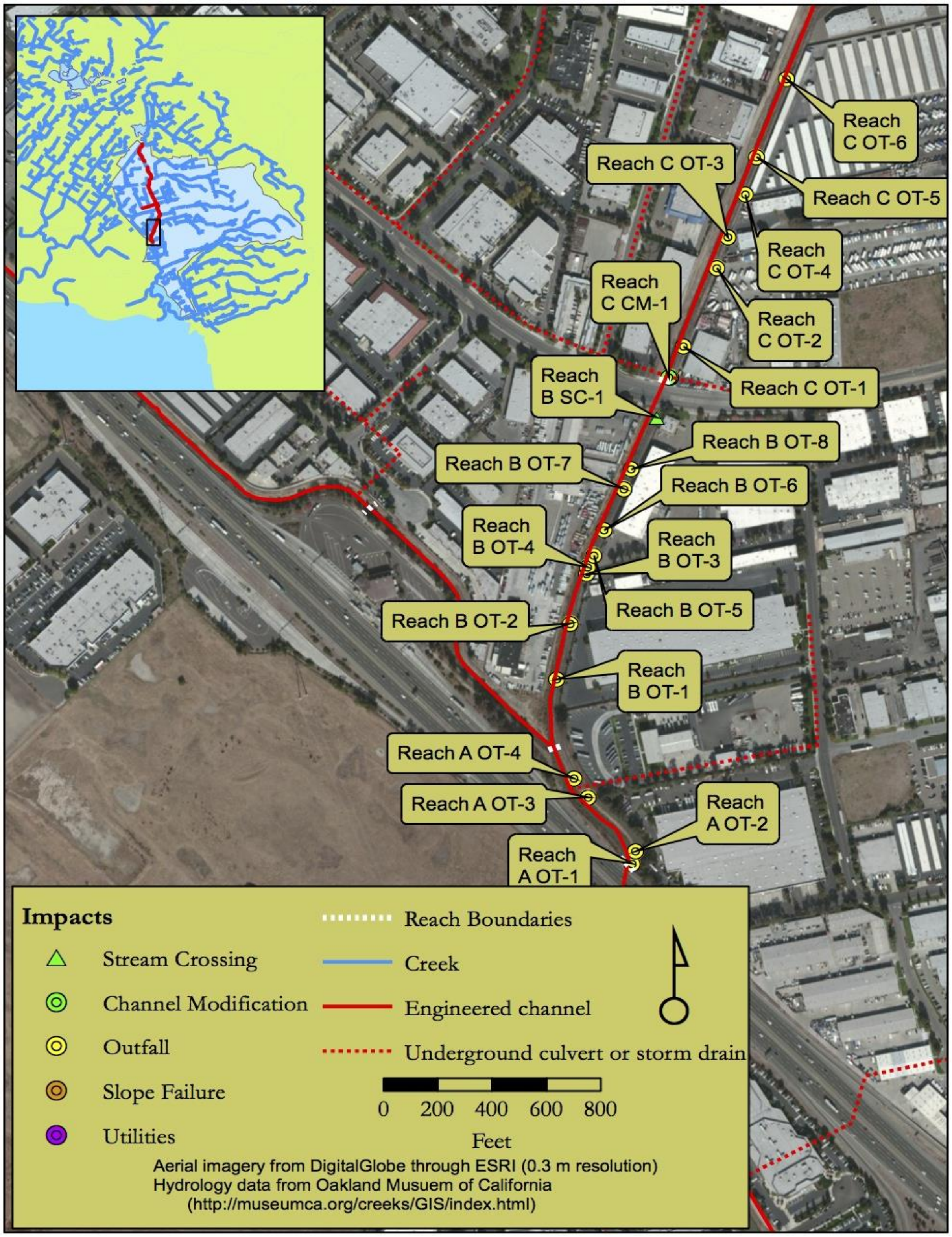

Figure 1. Identified Impacts, Laguna Creek Reaches A, B, and C.

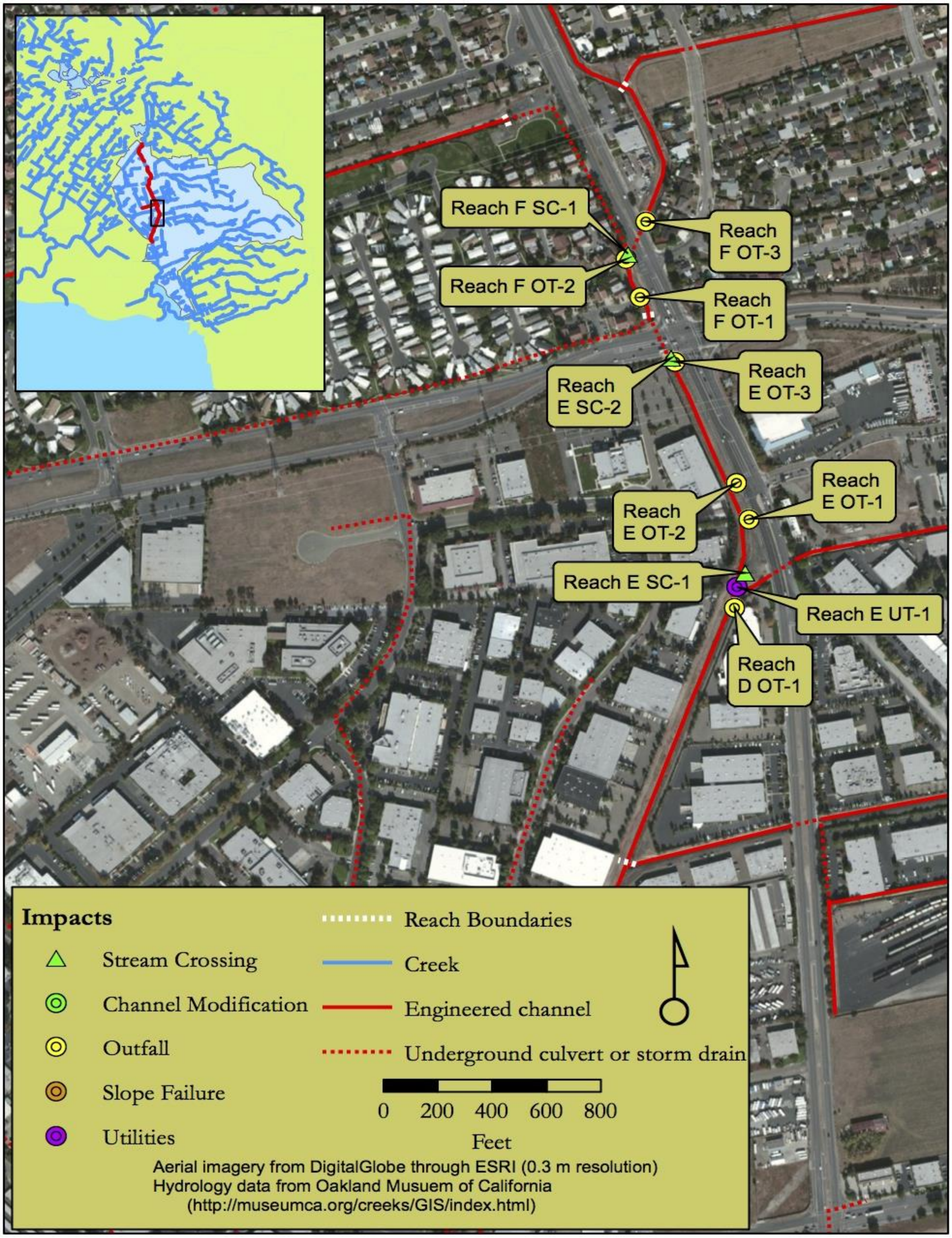

Figure 2. Identified Impacts, Laguna Creek Reaches D, E, and F.

Figure 3. Identified Impacts, Laguna Creek Reaches H, P, and Q.

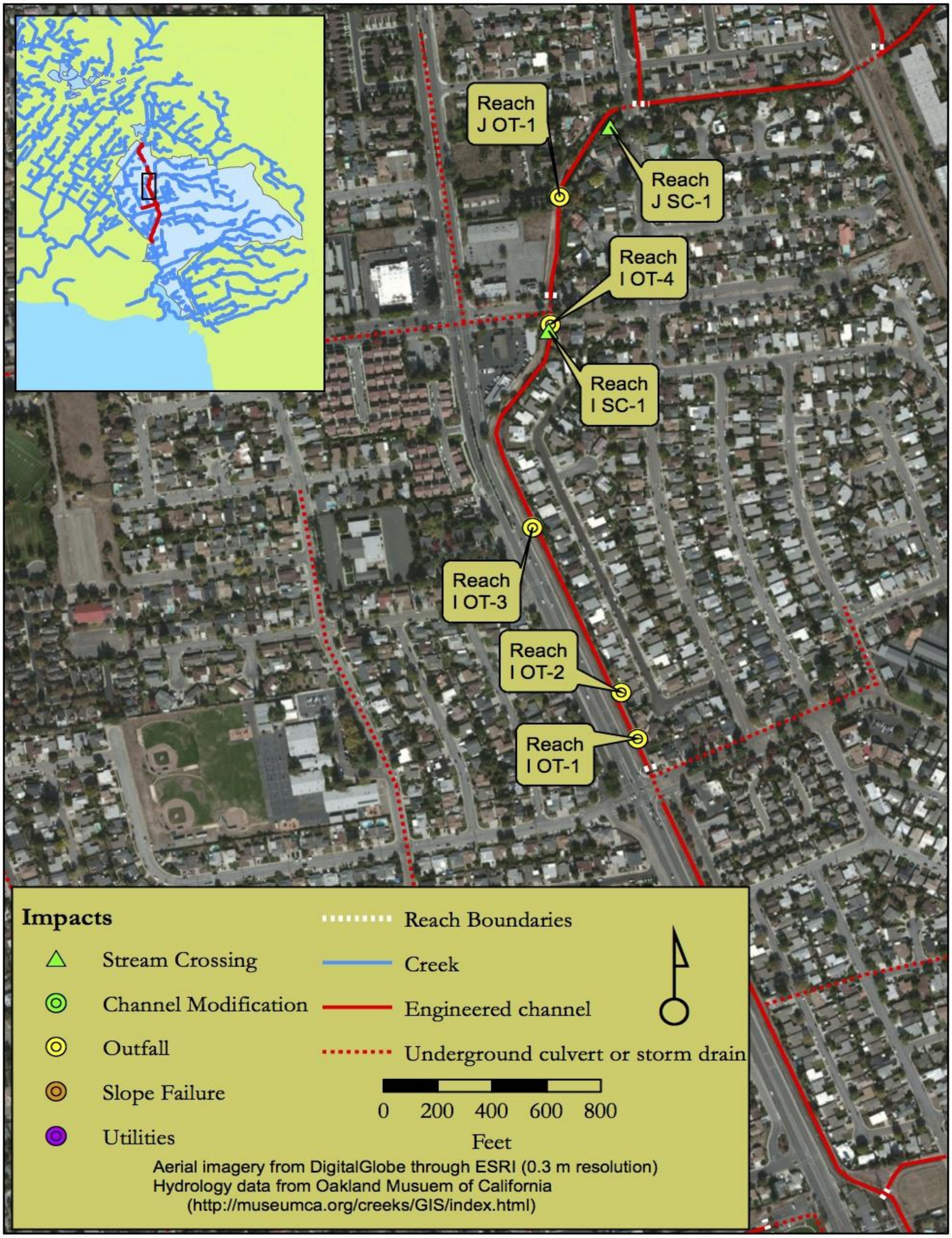

Figure 4. Identified Impacts, Laguna Creek Reaches I and J.

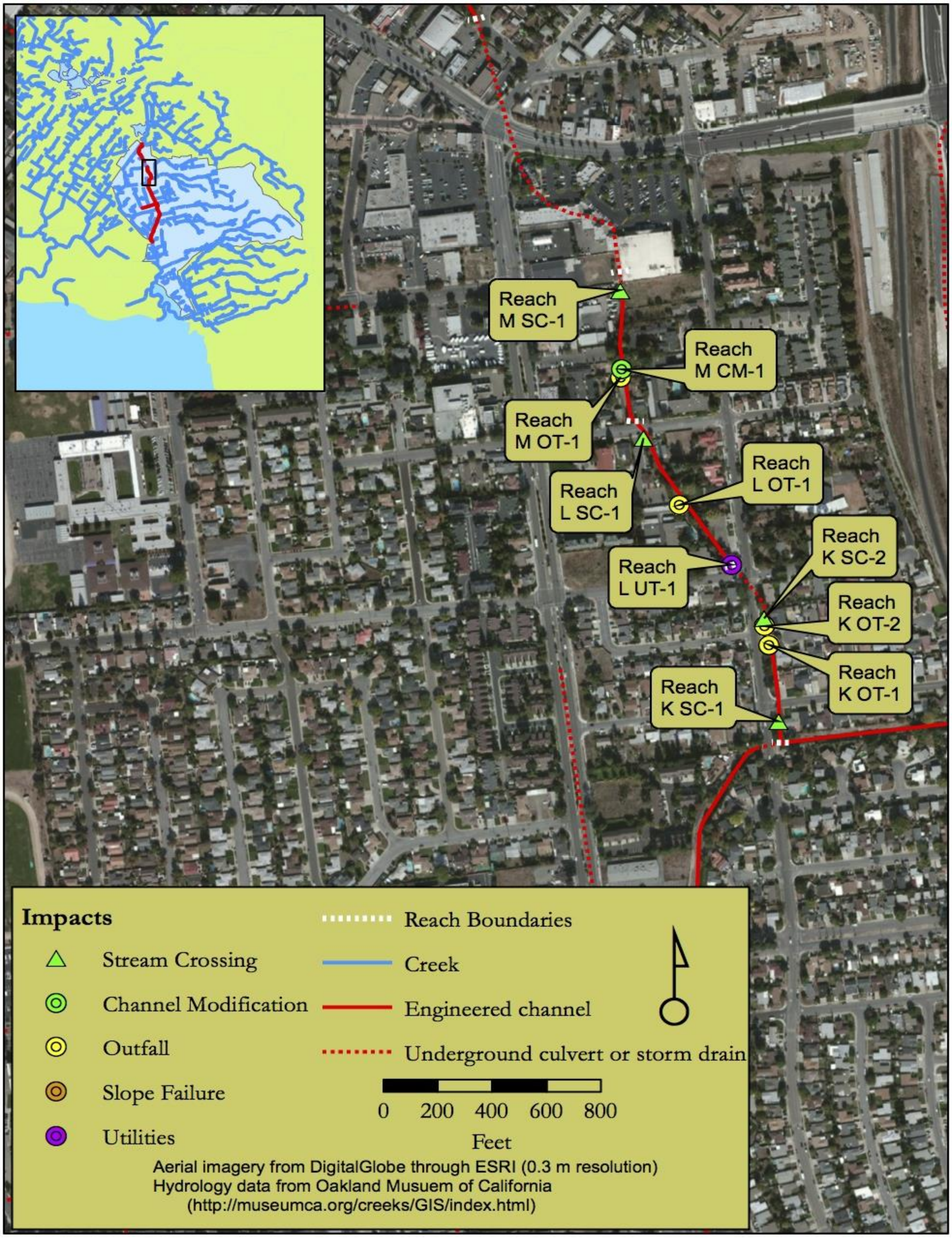

Figure 5. Identified Impacts, Laguna Creek Reaches K, L, and M.

Figure 6. Identified Impacts, Laguna Creek Reaches N and O.

Attachment B - Laguna Creek Bypass Surveyed Reaches

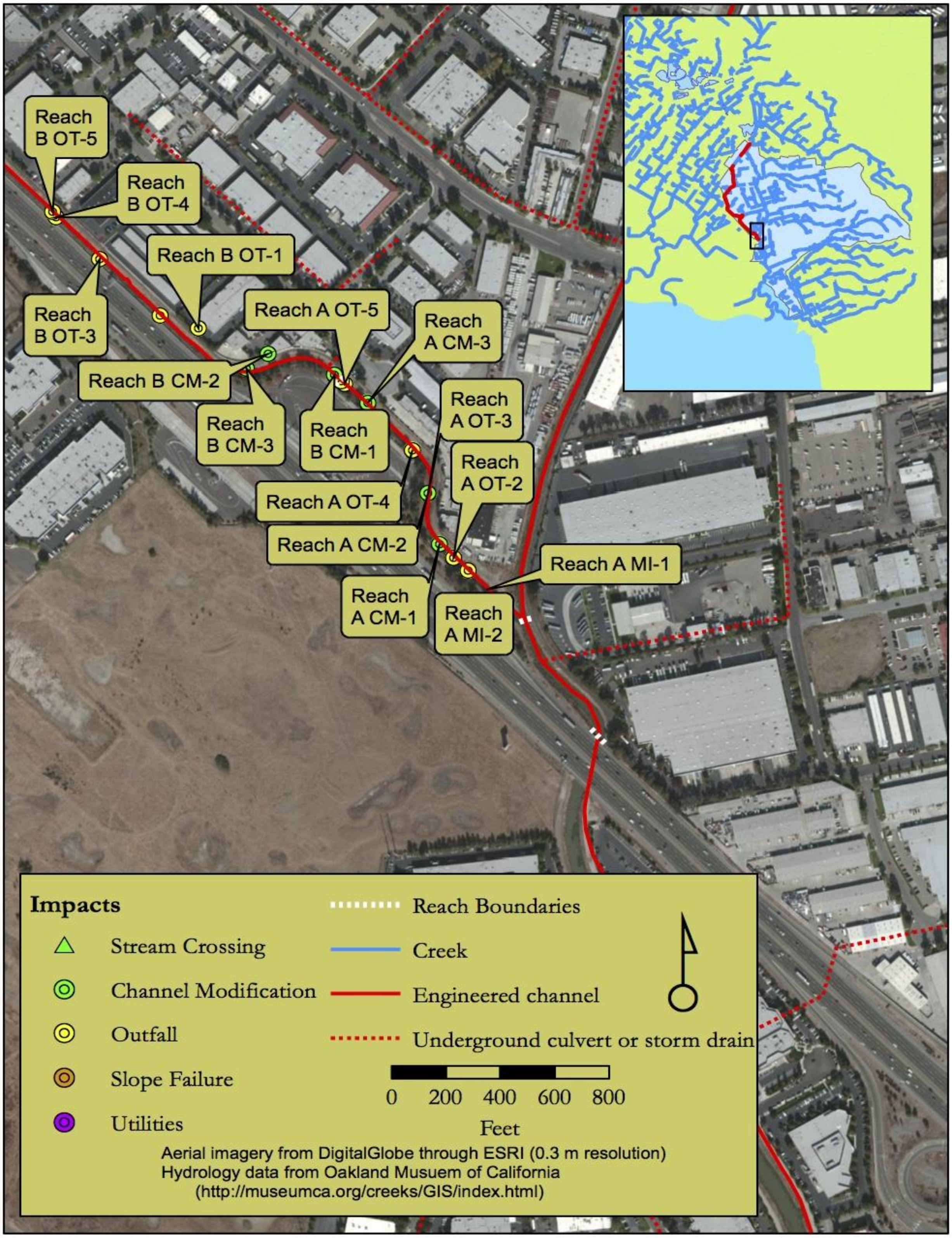

Figure 7. Identified Impacts, Laguna Creek Bypass Reach A.

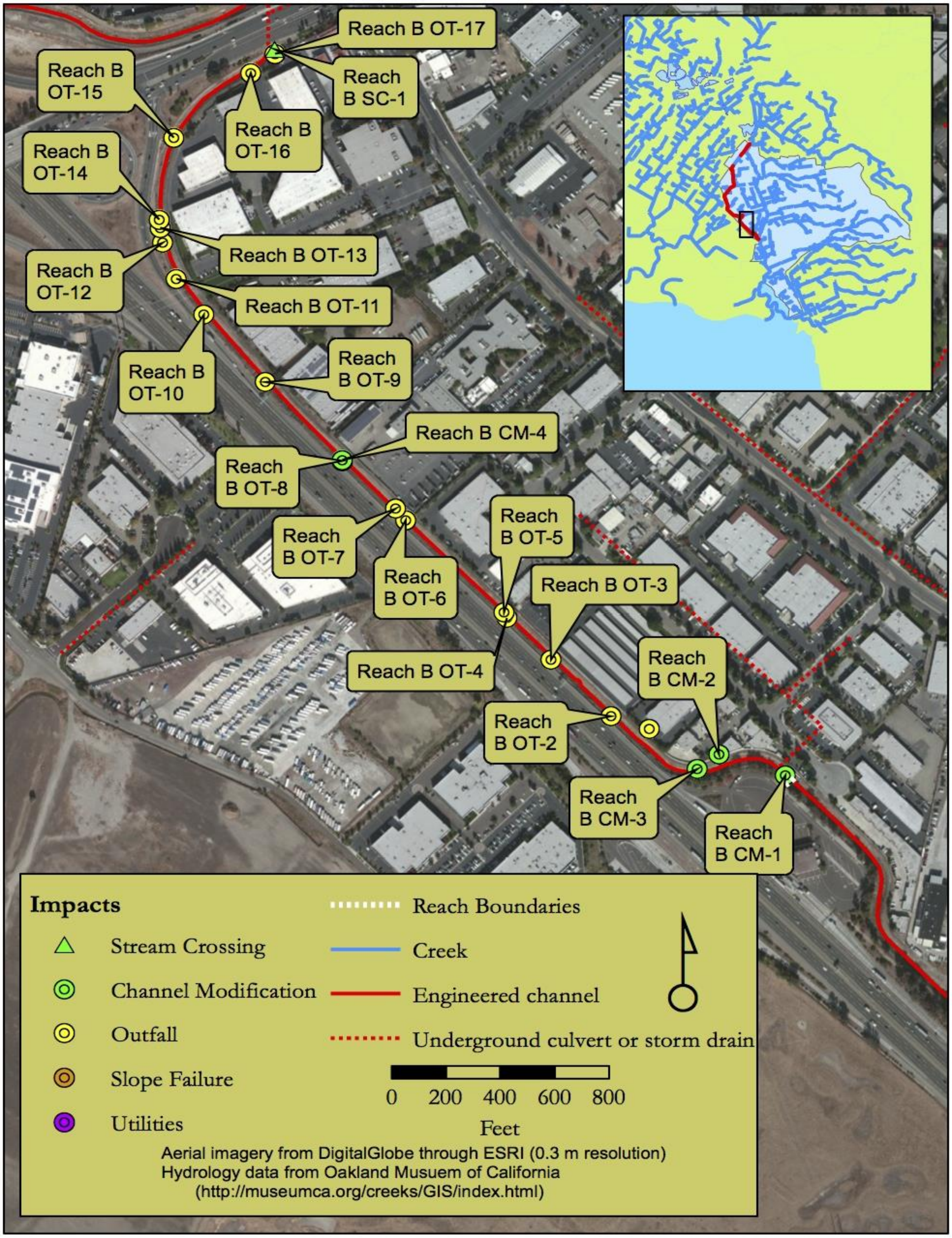

Figure 8. Identified Impacts, Laguna Creek Bypass Reach B.

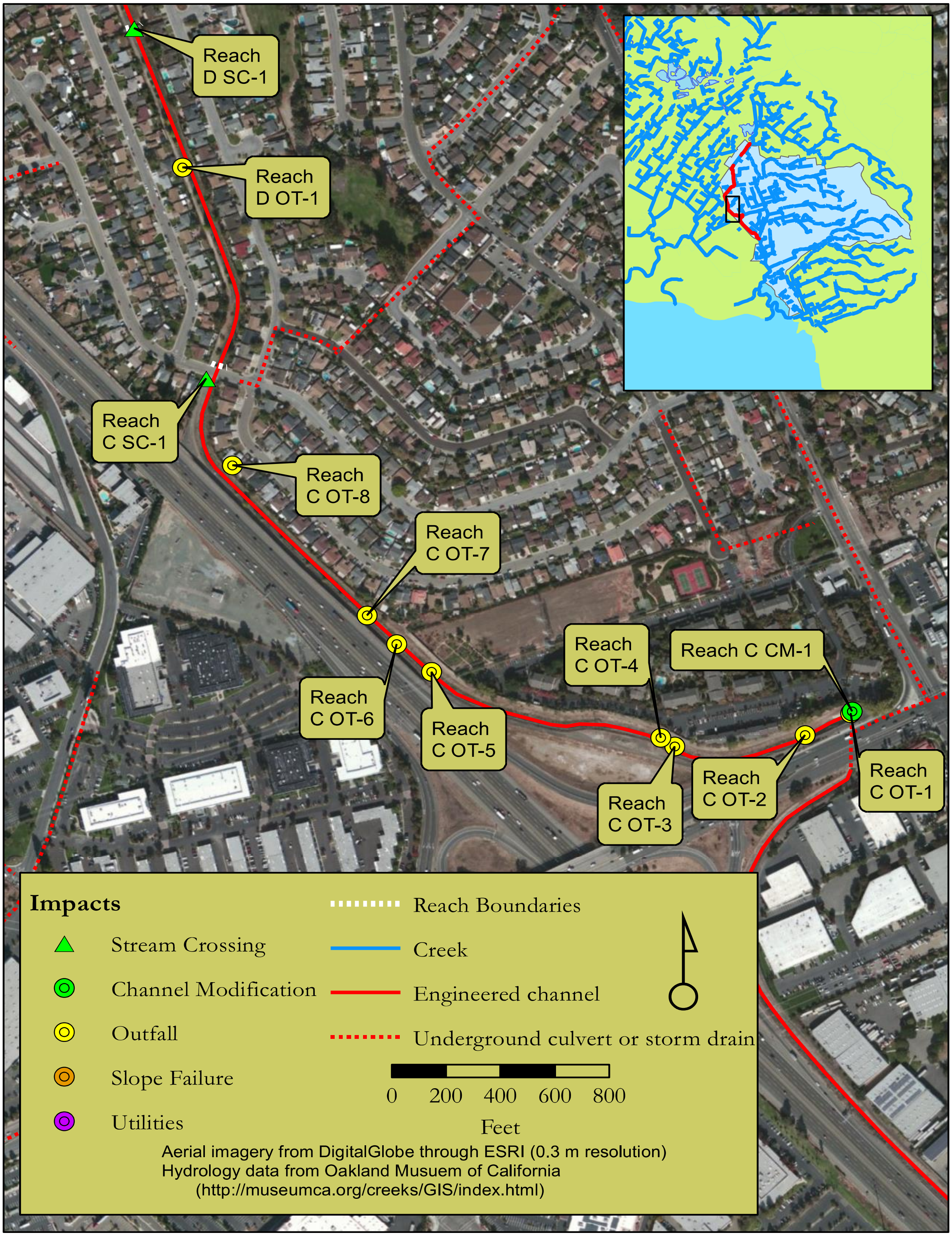

Figure 9. Identified Impacts, Laguna Creek Bypass Reached C and D.

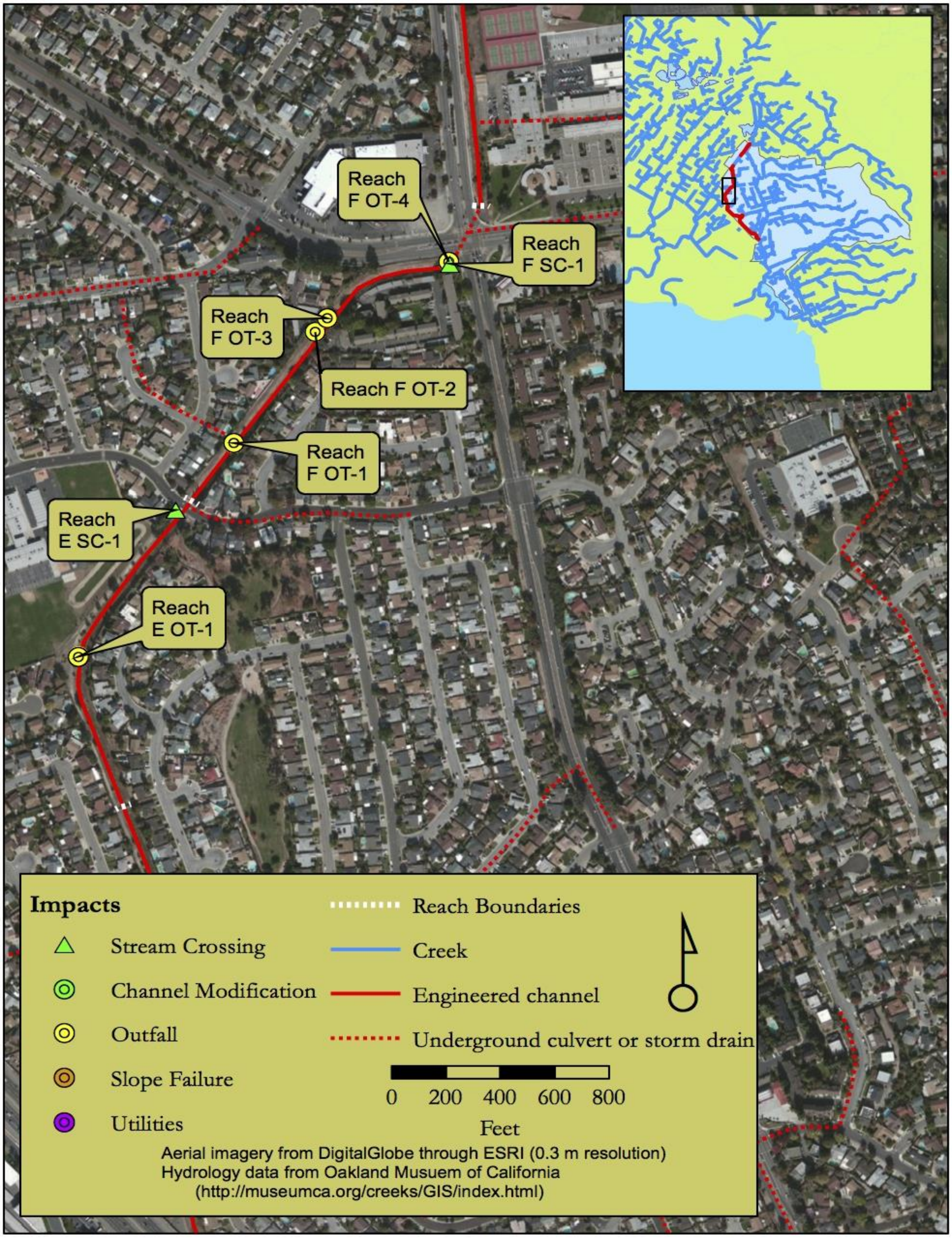

Figure 10. Identified Impacts, Laguna Creek Bypass Reaches E and F.

Figure 11. Identified Impacts, Laguna Creek Bypass Reaches G, H, and I

Figure 12. Identified Impacts, Laguna Creek Bypass Reach J.

Attachment C – Agua Caliente Surveyed Reaches

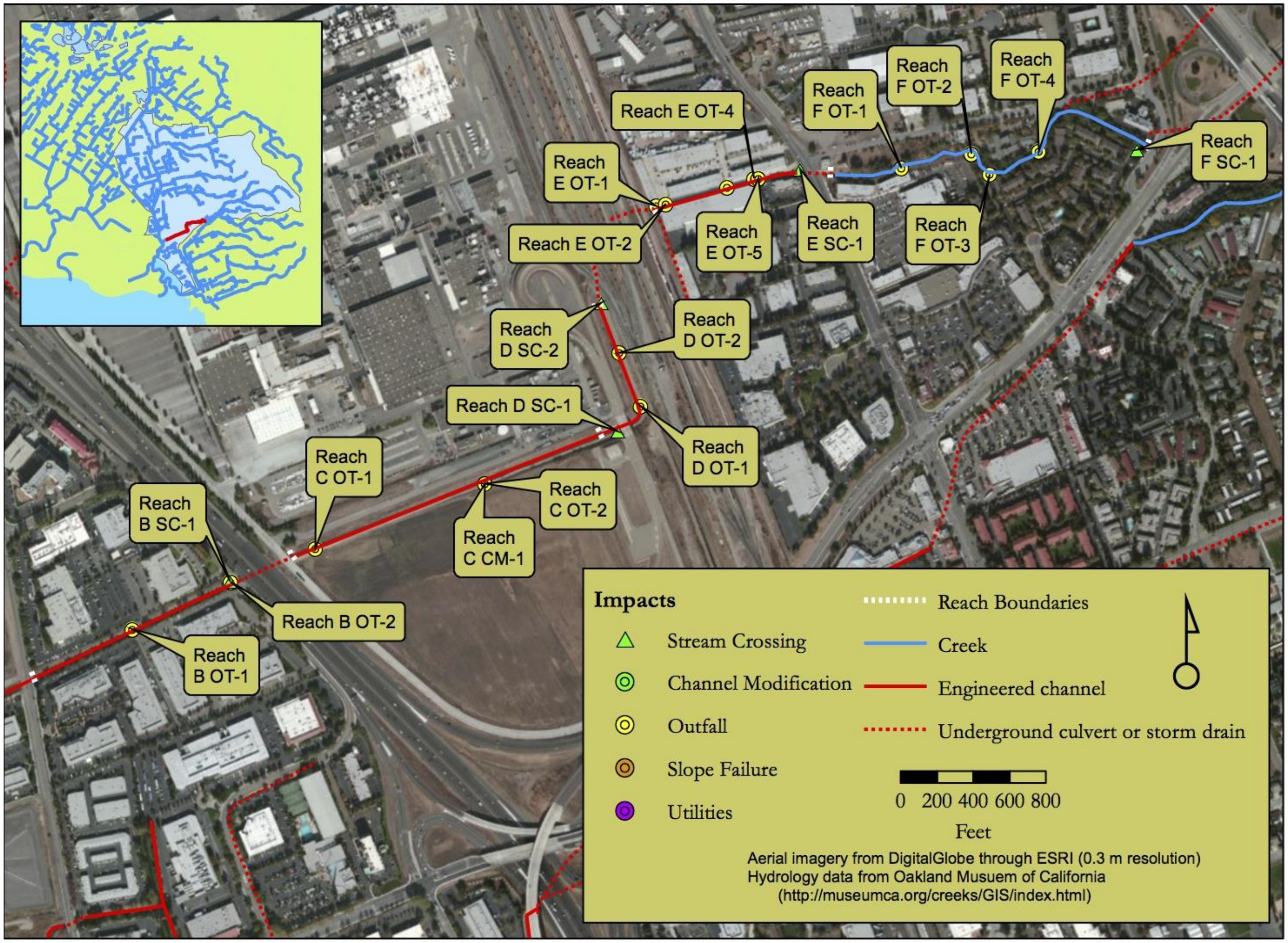

Figure 13. Identified Impacts, Agua Caliente Reaches B, C, D, E, and F.

Attachment D – Washington Creek Surveyed Reaches

Figure 14. Identified Impacts, Washington Creek Reaches A, B, and C.

ALAMEDA COUNTYWIDE CLEAN WATER PROGRAM

URBAN CREEKS MONITORING REPORT

OCTOBER 2013 THROUGH
SEPTEMBER 2014

APPENDIX A.3

Pollutants of Concern (POC) Loads Monitoring Progress Report, Water Years (WYs) 2012, 2013, and 2014

Pollutants of concern (POC) loads monitoring progress report, water years (WYs) 2012, 2013, and 2014

Prepared by

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San Francisco Estuary Institute, Richmond, California

On

January 20, 2015

For

Bay Area Stormwater Management Agencies Association (BASMAA)

And

Regional Monitoring Program for Water Quality in San Francisco Bay (RMP)
Sources Pathways and Loadings Workgroup (SPLWG)
Small Tributaries Loading Strategy (STLS)

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1. Introduction

The San Francisco Regional Water Quality Control Board (Water Board) has determined that San Francisco Bay is impaired by mercury and PCBs due to threats to wildlife and human consumers of fish from the Bay. These contaminants persist in the environment and accumulate in aquatic food webs (SFRWRCB 2006; SFRWRCB, 2008). The Water Board has identified urban runoff from local watersheds as a pathway for pollutants of concern into the Bay, including mercury and PCBs. The Municipal Regional Stormwater Permit (MRP; SFRWRCB, 2009) contains several provisions requiring studies to measure local watershed loads of suspended sediment (SS), total organic carbon (TOC), polychlorinated biphenyl (PCB), total mercury (HgT), total methylmercury (MeHgT), nitrate-N (NO3), phosphate-P (PO4), and total phosphorus (TP) (provision C.8.e), as well as other pollutants covered under provision C.14. (e.g. legacy pesticides, PBDEs, and selenium).

Four Bay Area Stormwater Programs[1], represented by the Bay Area Stormwater Management Agencies Association (BASMAA), collaborated with the San Francisco Bay Regional Monitoring Program (RMP) to develop an alternative strategy allowed by Provision C.8.e of the MRP, known as the Small Tributaries Loading Strategy (STLS) (SFEI, 2009). An early version of the STLS provided an initial outline of the general strategy and activities to address four key management questions (MQs) that are found in MRP provision C.8.e:

> 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; and,
>
> 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.

Since then, a Multi-Year-Plan (MYP) has been written (BASMAA, 2011) and updated twice (BASMAA, 2012; BASMAA, 2013). The MYP provides a comprehensive description of activities that will be implemented over the next 5-10 years to provide information and comply with the MRP. The MYP provides rationale for the methods and locations of proposed activities to answer the four MQs listed above. Activities include modeling using the regional watershed spreadsheet model (RWSM) to estimate regional scale loads (Lent and McKee, 2011; Lent et al., 2012; McKee et al., 2014), and pollutant characterization and loads monitoring in local tributaries beginning Water Year (WY) 2011 (McKee et al.,

[1] Alameda Countywide Clean Water Program, Contra Costa Clean Water Program, San Mateo Clean Water Pollution Prevention Program and Santa Clara Urban Runoff Pollution Prevention Program conduct monitoring and other activities on behalf of MRP Permittees in the four largest Bay Area counties.

2012), that continued in WY 2012 (McKee et al., 2013), WY 2013 (Gilbreath et al., 2014), and was largely completed in WY 2014 (this report).

The purpose of this report is to describe data collected during all three WYs (2012, 2013, and 2014) in compliance with MRP provision C.8.e., following the standard report content described in provision C.8.g.vi. The study design (selected watersheds and sampling locations, analytes, sampling methodologies and frequencies) as outlined in the MYP was developed to assess concentrations and loads in watersheds that are considered to likely be important watersheds in relation to sensitive areas of the Bay margin (MQ1):

- Lower Marsh Creek (Hg);
- North Richmond Pump Station (Hg and PCBs);
- San Leandro Creek below Chabot dam (Hg);
- Guadalupe River (Hg and PCBs);
- Sunnyvale East Channel (PCBs); and
- Pulgas Creek Pump Station South (PCBs).

Loads monitoring provides verification data for the RWSM (MQ2), and is intended to provide baseline data to assess long term loading trends (MQ3) in relation to management actions (MQ4). This report was structured to allow annual updates after each subsequent winter season of data collection. It should be noted that the sampling design described in this report (and modeling design: Lent and McKee, 2011; Lent et al., 2012; McKee et al., 2014) was focused mainly on addressing MQ2. During the next permit term (perhaps beginning in 2015), there will be an increasing focus towards finding high leverage watersheds and source areas within watersheds (MQ 1) for management focus (MQ4). A parallel report (the "POC synthesis report" (SFEI in preparation)) is intended to document progress to date towards addressing management questions and the rationale for changed monitoring design going forward that more carefully addresses MQ1 and MQ4.

2. Field methods

2.1. Watershed physiography, sampling locations, and sampling methods

The San Francisco Bay estuary is surrounded by nine highly urbanized counties with a total population greater than seven million people (US Census Bureau, 2010). Although urban runoff from upwards of 300 small tributaries (note the number is dependent upon how the areas are lumped or split) flowing from the adjacent landscape represents only about 6% of the total freshwater input to the San Francisco Bay, this input has broadly been identified as a significant source of pollutants of concern (POCs) to the estuary (Davis et al., 2007; Oram et al., 2008; Davis et al., 2012; Gilbreath et al., 2012). Four watershed sites were sampled in WY 2012 and two additional watershed sites were added in WY 2013 and WY 2014 (Figure 1; Table 1). The sites were distributed throughout the counties where load monitoring was required by the MRP. The selected watersheds include areas with urban and industrial land uses, watersheds where stormwater programs are planning enhanced management actions to reduce PCB and mercury discharges, and watersheds with historic mercury or PCB occurrences or related management concerns.

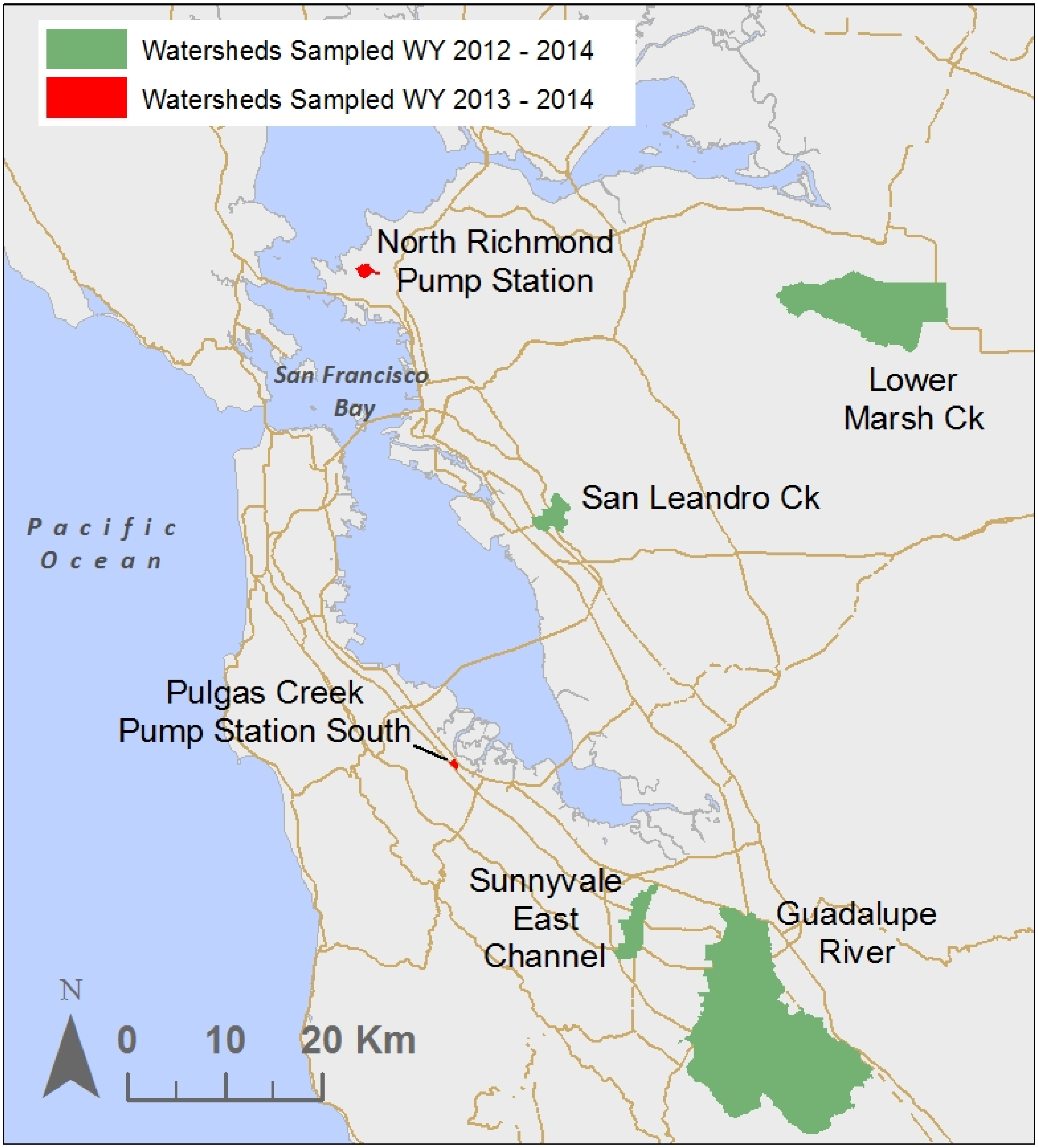

Figure 1. Water year 2012, 2013 and 2014 sampling watersheds.

Table 1. Sampling locations in relation to Countywide stormwater programs and sampling methods at each site.

County program	Watershed name	Water years sampled	Watershed area (km^2)[1]	Sampling location			Operator	Discharge monitoring method	Turbidity	Water sampling for pollutant analysis		
				City	Latitude (WGS1984)	Longitude (WGS1984)				Hg/MeHg collection	Discrete samples excluding Hg species	Composite samples
Contra Costa	Marsh Creek	2012-2014	99	Brentwood	37.990723	-122.16265	ADH	USGS Gauge Number: 11337600[2]; STLS creek stage applied to USGS discharge rating	OBS-500[4]	Manual grab	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Contra Costa	North Richmond Pump Station	2013-2014	2.0	Richmond	37.953945	-122.37398	SFEI	Measurement of pump rotations/ interpolation of pump curve	OBS-500[4]	FISP US D95[7]	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Alameda	San Leandro Creek	2012-2014	8.9	San Leandro	37.726073	-122.16265	SFEI WY2012 ADH WYs 2013-14	STLS creek stage/ velocity/ discharge rating	OBS-500**[4]	FISP US D95[7] WY 2012 ISCO pump sampler WY 2013-14	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Santa Clara	Guadalupe River	2012-2014	236	San Jose	37.373543	-121.69612	SFEI WY2012 Balance WYs 2013-14	USGS Gauge Number: 11169025[3]	DTS-12[5]	FISP US D95[6]	FISP US D95[6]	FISP US D95[6]
Santa Clara	Sunnyvale East Channel	2012-2014	14.8	Sunnyvale	37.394487	-122.01047	SFEI	STLS creek stage applied to SCVWD discharge rating[6]	OBS-500*[4] WY 2012 DTS-12[5] WYs 2013-14	FISP US D95[8]	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
San Mateo	Pulgas Creek South Pump Station[9]	2013-2014	0.6	San Carlos	37.504583	-122.24901	KLI	ISCO area velocity flow meter with an ISCO 2150 flow module	DTS-12[5]	Pole sampler	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]

[1]Area downstream from reservoirs
[2]USGS 11337600 MARSH C A BRENTWOOD CA
[3]USGS 11169025 GUADALUPE R ABV HWY 101 A SAN JOSE CA
[4]Campbell Scientific OBS-500 Turbidity Probe
[5]Forest Technology Systems DTS-12 Turbidity Sensor
[6]This rating curve was verified with discharge velocity measurements in WY 2012
[7]FISP US D-95 Depth integrating suspended hand line sampler
[8]Teledyne ISCO 6712 Full Size Portable Sampler
[9]Both the northern and southern catchments to the Pulgas Creek Pump Station were sampled in the WY 2011 characterization study (McKee et al., 2012)
*OBS-500 malfunctioned during WY 2012 due to low flow water depth. A DTS-12 was installed during WY 2013
**OBS-500 malfunctioned during some WY2014 events

The monitoring design focused on winter season storms between October 1 and April 30 of each water year; the period when the majority of pollutant transport occurs in the Bay Area (McKee et al., 2003; McKee et al., 2006; Gilbreath et al, 2012). At all six sampling locations, measurement of continuous stage and turbidity at time intervals of 15 min or less was the basis of the chosen monitoring design (Table 1). At free flowing sites, stage was used along with a collection of discrete velocity measurements to generate a rating curve between stage and instantaneous discharge. Subsequently this rating curve was used to estimate a continuous discharge record over the wet season by either the STLS team or USGS depending on the sampling location (Table 1). At Richmond pump station, an optical proximity sensor (Omron, model E3F2) was used along with stage measurements and a pump efficiency curve based on the pump specifications to estimate flow. ISCO flow meters were deployed at the Pulgas Creek Pump Station (Table 1). Turbidity is a measure of the “cloudiness” in water caused by suspension of particles, most of which are less than 62.5 µm in size and, for most creeks in the Bay Area, virtually always less than 250 µm (McKee et al., 2003). In natural flowing rivers and urban creeks or storm drains, turbidity usually correlates with the concentrations of suspended sediments and hydrophobic pollutants. In the creek and channel sampling locations, turbidity probes were mounted in the thalweg of each sampling location on an articulated boom that allowed turbidity sampling at approximately mid-depth under most flow conditions (McKee et al., 2004). At North Richmond Pump Station, the turbidity probe was mounted on a boom that extended into the center of the central well. At Pulgas Creek South Pump Station, the turbidity probe was attached to the catch basin wall at a fixed height, which was selected to ensure the probe remained submerged.

Composite and discrete samples were collected for multiple analytes from the water column over the rising, peak, and falling stages of the hydrograph. The sampling design was developed to support the use of turbidity surrogate regression (TSR) during loads computations. This method is deemed one of the most accurate methods for the computation of loads of pollutants transported dominantly in particulate phase such as suspended sediments, mercury, PCBs and other pollutants (Walling and Webb, 1985; Lewis, 1996; Quémerais et al., 1999; Wall et al., 2005; Ruzycki et al., 2011; Gilbreath et al., 2012; Riscassi and Scanlon, 2013). The method involves logging a continuous turbidity record in a short time interval (15 min or less during the study) and collecting a number of discrete samples to support the development of pollutants specific regressions. In this study, although not always achievable (see discussion later in the report), field crews aimed to collect 16 samples per water year during an early storm, several mid-season storms (ideally including one of the largest storms of the season) and later season storm. The use of turbidity surrogate regression and the other components of this sampling design was recommended over a range of alternative designs (Melwani et al 2010), and was adopted by the STLS (BASMAA, 2011).

Discrete samples for analytes used for loads computations (except water samples collected for mercury, methylmercury and a simultaneously collected sample for suspended sediment analysis) were collected using the ISCO autosampler as a slave pump at all the sites except the Guadalupe River site. At the Guadalupe River location, all discretely collected samples were collected using a Teflon coated Federal Interagency Sediment Program (FISP) D-95 depth-integrating water quality sampler due to the large distance between the overhead structure (a road bridge) and the water surface. Discrete samples for analysis of mercury and methylmercury and a simultaneously collected sample for SSC analysis were collected with the D-95 at Guadalupe, Sunnyvale East Channel, North Richmond Pump Station, and San Leandro Creek (WY 2012 only), using a pole sampler at Pulgas Creek Pump Station, by manually dipping an opened bottle from the side of the channel at Lower Marsh Creek (both WYs), and by ISCO manual pump at San Leandro (in WY 2013-2014) (Table 1).

Tubing for the ISCO autosamplers was installed using the clean hands technique, as was the 1 L Teflon bottle for use with the D-95. Composite samples made up of a number of discrete sub-samples were collected using the ISCO autosampler at all of the sites except Guadalupe River. Composite samples and the timing of each individual sub-sample were collected with the intent of representing the average concentrations during a storm runoff hydrograph for each storm event sampled. The concentration of a particular analyte of interest obtained from laboratory analysis of such a composite sample is usually referred to as an event mean concentration (Stone et al., 2000; Ma et al., 2009). However, as will be discussed later for each of the individual sites, the composites collected during this study rarely captured sub-samples from the entire hydrograph. Additionally, these composites were time-weighted (except at North Richmond Pump Station where collection times were limited to times of pump outs) rather than flow-weighted, chosen to better represent the average conditions that an organism would be exposed to over a period of time, which was advantageous to the interpretation of toxicity. At the Guadalupe site, a FISP D-95 depth integrating water quality sampler was used to collect multiple discrete samples over the hydrograph which were manually composited on-site.

All water samples were collected in pre-labeled appropriately sized and cleaned sample bottles and placed on ice in coolers either during the sampling procedure or as soon as practically possible. Samples were transported back to the office and labels were rechecked as they were logged in prior to and in preparation for shipment to the laboratories.

2.2. Loads computational methods

It has been recognized since the 1980s that different sampling designs and corresponding loads computation techniques generate computed loads of differing magnitude and of varying accuracy and precision (e.g. Walling and Webb, 1985). Therefore, how can we know which methodology generates the most accurate load? In all environmental situations, techniques that maintain high resolution variability in concentration and flow data during the field collection and subsequent computation process result in high-resolution loads estimates that are more accurate no matter which loads computation technique is applied. Less accurate loads are generated by sampling designs that do not account for (or adequately describe) the concentration variability (e.g. a daily or weekly sampling protocol would not work for a semi-arid environment like the Bay Area where storm hydrographs are flashy even in larger watersheds) or that use some kind of mathematical average concentration (e.g. simple mean; geometric mean; flow weighted mean) combined with monthly or annual time interval flows (again would not work in the semi-arid environment since 95% of flow occurs during storms).

Since the objective of any type of environmental data interpretation exercise is to neither over nor under interpret the available data, any loads computation technique that employs extra effort to stratify the data as part of the computation protocol will generate the most accurate loading information.

Stratification can be done in relation to environmental processes such as seasonality, flow regime, or data quality. In a general sense, the more resolved the data are in relation to the processes of concentration or flow variation, the more likely it is that computations will result in loads with high accuracy and precision. The data collection protocol implemented through the Small Tributaries Loading Strategy (STLS) was designed to allow for data stratification in the following manners:

1. Early-season ("1st storm") storm flow sampled for pollutants
2. Mid-season ("largest flood") storm flow sampled for pollutants
3. Later-season storm flow sampled for pollutants
4. Early-, mid-, and later-season storm flow when no pollutant sampling took place
5. Dry weather flow

Loads computation techniques differ for each of these strata in relation to pollutants that are primarily transported in dissolved or particulate phase. As subsequent samples were collected each year at the STLS monitoring sites, our knowledge about how concentrations varied with season and flow (improvements of the definition of the strata) and thus about how best to apply loads computation techniques gradually improved. Therefore, with each additional annual reporting year, the loads were recomputed. This occurred in relation to both improved flow information as well as an improved understanding of concentration variation in relation to seasonal characteristics and flow. The loads and interpretations presented here therefore supersede those reported in previous annual reports for WY 2012 (McKee et al., 2013), WYs 2012 and 2013 (Gilbreath et al., 2014).

During the study, concentrations either measured or estimated were multiplied with the continuous estimates of flow (1-15 minute interval) to compute the load on a 1 to 15 minute basis and summed to monthly and wet season loads. Laboratory measured data were retained in the calculations and assumed real for that moment in time. The techniques for estimating concentrations were applied in the following order of preference (and resulting accuracy of loads) as appropriate for each analyte (see summary in Table 2):

Linear interpolation: Linear interpolation was the primary technique used for interpolating concentrations between measured data points when storms were well sampled. It is the most accurate loads computation method for such storms and retains the maximum amount of information about how concentration and flow varies during the storm of interest (Young and DePinto, 1988; Kronvang and Bruhn, 1996). Two linear interpolation approaches were applied:

> **Linear Interpolation using water concentrations (LI_{WC}):** Linear interpolation using water concentrations is the process by which the interpreter estimates the concentrations mathematically between observed measurements using a linear time step (Kronvang and Bruhn 1996). It was appropriately used for pollutants which occur mainly in dissolved phase because it does not incorporate varying turbidity or SSC (Table 2). It can be used for analytes that are primarily transported in particulate phase; although during this study a superior method using particle ratios was applied to those analytes (Table 2).

Linear Interpolation using particle ratios (LI_{PR}): Linear interpolation using particle ratios can be thought of as locally derived regression in three-dimensional space. It is superior to linear interpolation using water concentrations (see above) for pollutants which occur mainly in particulate form because it ensures that the relationship between the derived concentration and varying turbidity that occurs between the two laboratory pollutant measurements results in particle ratios that, at all times, are reasonable (simpler linear interpolation of concentrations between samples may lead to unreasonable particle ratios for example if samples are collected on either side of a turbidity peak leading to lower particle ratios estimated at the turbidity peak). The use of this method was decided upon in concert with the field sampling design and was only possible because of the collection of continuous turbidity measurements. It was ideal for PCBs and Hg (two of the analytes of most interest) as well as other particulate phase analytes like total phosphorus (Table 2).

Regression Estimators: Regression estimator methods for loads calculations involve developing relationships between limited sample concentration data and an unlimited surrogate measure (e.g. turbidity or flow). These relationships are then applied to the unlimited surrogate measure record (e.g. the short time interval records of flow or turbidity) to calculated short time interval estimates of pollutant concentrations. This loads calculation method has been widely applied to estimating suspended sediment loads throughout the world (e.g., Walling and Webb, 1985; Lewis, 1996), demonstrated by SFEI and others to work well for metals (e.g., Quémerais et al., 1999; Wall et al., 2005; David et al. in press; McKee et al., 2010; Ruzycki et al., 2011; Riscassi and Scanlon, 2013), and more recently been demonstrated by SFEI to work well for organic pollutants (McKee et al., 2006; Gilbreath et al., 2012). This study was designed specifically to apply this method for loads calculations of discretely sampled analytes.

Interpolation using unique POC-flow based regression equations (FSR): The flow based surrogate regression interpolation method was applied for pollutants transported dominantly in the dissolved phase and forming a good relationship with flow, or to the more particle associated pollutants during periods when a turbidity probe failed to deliver quality data (yet the relationship with flow was preferred over resorting to a simple ratio or averaging method.

Interpolation using unique POC-turbidity based regression equations (TSR): Turbidity surrogate regression can be considered the default standard for pollutants of concern that are primarily transported in a particulate form. These types of pollutants (for example PCBs and mercury) form strong linear relationships with either turbidity or SSC. For the particle associated pollutants, turbidity surrogate regression was applied to all unsampled flood flow conditions observed at each monitoring site except under rare circumstances when turbidity data were not available due to probe malfunction. This interpolation method is superior to FSR for particle-associated pollutants because takes into account hysteresis in relation to flow (Walling and Webb, 1985; Lewis, 1996). For example concentrations of suspended sediment and pollutants that are strongly associated with suspended sediment often have greater concentrations during the rising stage of the hydrograph for a given flow as compared with concentrations at the same flow magnitude but on the falling stage of a given hydrograph. This occurs because there is more energy in the water column and typically no transport or source limitation during the rising stages of the hydrograph and earlier phases of a storm. Conversely, water transported during the falling stages is typically less turbulent and sources may have been washed clean by this time or, for the larger watersheds or those that have nonurban land-use in the upstream areas, lower concentrations can occur purely because the origin of the water has evolved to include upstream or less impervious components of the watershed.

Ratios and Averages: During unsampled periods of the record and in cases where pollutants did not form strong relationships with surrogate measures (turbidity, flow and other measured pollutants were all explored), or during periods when the surrogate measure record was unavailable, a simple ratio or average estimator method was applied.

Flow Weighted Mean Concentration (FWMC): In the event that flow or turbidity/SSC does not adequately explain the variation in pollutant concentrations, a flow weighted mean concentration can be calculated and applied to the appropriate flow classes. This is a simple ratio method that averages the concentration data but weighted more heavily towards the greatest flow and thus is an improvement over a simple average (Walling and Web, 1985, Birgand et al., 2010). If warranted, the data may be stratified first with a different FWMC applied to each stratum. Stratification in this manner has been previously applied for Chesapeake Bay tributaries and found to improve the accuracy of loading estimates (Lawson et al., 2001). Using a FWMC is the lowest accuracy method applied in this study for estimating storm flow concentrations.

Interpolation assuming a representative concentration (e.g. "dry weather lab measured" or "lowest measured"): To apply this method, an estimate of average concentrations under certain flow conditions is combined with discharge. This is, in effect, a simple average estimator and is the least accurate and precise of all the loads calculation methods. Because this sampling program focuses on characterizing concentration during storm flows, it may be desirable to use this method in addition to one or more of the previously mentioned methods (e.g. this method may better characterize lower flows alongside use of the FWMC to better characterize storm flows).

3. Continuous data quality assurance

3.1. Continuous data quality assurance methods

Prior to the start of WY 2012, the STLS monitoring teams developed the continuous monitoring protocols for the study collaboratively. Basic quality assurance methods were applied to the WY 2012 dataset. In WY 2013, a better documented method for quality assurance was developed and applied to continuous data (turbidity, stage, and rainfall) collected at the POC loads monitoring stations (McKee et al., 2013). QA was performed on WY 2012 data though not as systematically as later years. Quality of

Table 2. Methods predominantly used for loads computations in relation to each pollutant of concern.

Computation method[a]	SS	TOC	PCBs	HgT	MeHgT	NO3	PO4	TP
Linear interpolation water concentrations (LI_{WC})		✓				✓	✓	
Linear interpolation particle ratios (LI_{PR})	✓		✓	✓	✓			✓
Turbidity surrogate regression (TSR)	✓	✓	✓	✓	✓			✓
Flow surrogate regression (FSR)		✓				✓	✓	
Flow weighted mean concentration (FWMC)		✓				✓	✓	
Assumed representative concentration (for dry weather flow)	✓	✓	✓	✓	✓	✓	✓	✓

[a] Exceptions to the methods listed for each analyte include: FWMCs were used for all analytes at Pulgas Creek Pump Station South. Flow Surrogate Regression was used for most analytes at San Leandro Creek when the turbidity sensor was malfunctioning or had been removed to protect it from vandalism (FWMCs had to be used during these periods for TOC, NO3 and PO4), and at Sunnyvale East Channel to estimate SSC during all of WY 2012 and portions of WY 2013 when the turbidity record was impacted by vegetation collecting at the sensor. The estimated SSC was then used in regressions with particulate associated pollutants.

the continuous data record for each monitoring location for all three years are highlighted in the text below and summarized in Tables 3 and 4.

Throughout the season, field staff were responsible for data verification checks after data were downloaded during site visits. The field staff reviewed the data and completed a data transmission record. During the data validation process, individual records were flagged if they didn't meet the criteria developed in the continuous QA protocol. Datasets were evaluated in relation to the validation criteria, including: accuracy of the instruments through calibration, accuracy of the instruments in relation to comparison with manual measurements, dataset representativeness relative to logging interval and the degree of change from one measurement to the next, completeness of the dataset relative to the target monitoring period (October 1 – April 30) and finally our confidence in the corrections applied to the data records (Table 3 and Table 4). For more information on the quality assurance procedures developed and applied for continuous data, the reader is referred to the current version of the draft "*Quality Assurance Methods for Continuous Rainfall, Run-off, and Turbidity Data*" (McKee et al., 2015).

3.2. Continuous data quality assurance summary

The targeted monitoring period for this study was October 1 through April 30 each wet season (totaling 212 days each season). Especially in the first year of monitoring at each location in which the STLS team installed equipment (this excepts all equipment at Guadalupe as well as stage/flow equipment at Lower Marsh for WYs 2012 and 2013), there were often delays to start the season. The delay to start was the sole reason for missing stage data at all sites except for North Richmond Pump Station in WY 2013 when there was a 7 day period of missing record in October 2012 for unknown reasons. In addition to delayed starts, occasionally the rain gauges clogged, leading to data gaps in the rainfall records, and the expensive turbidity sensor at San Leandro Creek was often removed during periods when no rain was

Table 3. Continuous data quality assurance summary for record completeness and accuracy for each monitoring location. Missing days for all three monitoring years are provided, but quality ratings for accuracy of comparison were only developed for WYs 2013 and 2014. When only one rating is provided, it is relevant for both WYs. "NR" indicates that the QA procedure was not completed and "NA" indicates that the QA procedure was not applicable.

	Missing Days in Period of Record[a]			Accuracy of Comparison[b]		
	Rainfall	Stage	Turbidity	Rainfall	Stage	Turbidity
Lower Marsh	58/ 31/ 61	0 / 0 / 36	58 / 31 / 36	Excellent	NR	NR
Richmond	NA/ 61 / 0	NA / 7 / 17	NA / 0 / 0	Poor[1] / Excellent	NR / Excellent	Good[2] /Excellent
San Leandro	38 / 48 / 30	38 / 42 /23	38 / 42 / 37[3]	Excellent	Excellent	Excellent
Guadalupe	Complete	Complete	5 / 5 / 21	NA	NR / Excellent	Excellent
Sunnyvale	61 / 0 / 1	61 / 0 / 0	61 / 0 / 0	Excellent	Excellent	Excellent
Pulgas	NA / 9 / 21	NA / 41 / 21	NA / 117 / 72	Excellent	NR	Poor[4]

[a] Number of missing days is out of total target of 212 days. Number of missing days is provided for each monitoring year (WY 2012 - 2014)
[b] Accuracy of comparison is provided for WYs 2013 and 2014, the years for which this metric was evaluated systematically.
[1] Rainfall tipping bucket clogged during portions of December and January, leading to a poor relationship between the site record and other nearby rain gauge records.
[2] Regression between sensor and manual measurement data $R^2 = 0.85$.
[3] In total, 158 days of this record were missing turbidity in WY 2014. However, much of that time stages were low enough that no flow occurred. The 37 days noted includes the 23 days at the beginning of the record in which stage was not recorded plus 14 days in which flow did occur yet turbidity was not recorded. This equates to approximately half of the storms in WY 2014 which have no turbidity data.
[4] Manual turbidity measurements against sensor measurements had an $R^2 = 0.25$ in WY 2013 and 0.09 in WY 2014; this record fluctuated dramatically and cyclically (presumably in relation to pump outs); additional review of these data is recommended by BASMAA as they believe application of additional smoothing techniques may improve correlation between manual and sensor turbidity readings.

expected in order to prevent vandalism. A complete review of the number of days missing (out of 212) for each continuous record is provided in Table 3.

Overall the continuous rainfall data were acceptable. Rain data were collected at all the sites except for Guadalupe (Note, SCVWD collects high quality rainfall data throughout the Guadalupe River watershed), and the data were collected on the same time interval as stage and turbidity (except at North Richmond and Pulgas pump stations where rainfall data were collected on the 5 minute interval but stage and turbidity intervals were variable). Rain gauges were cleaned before and periodically during the season, but not calibrated. All sites except for the North Richmond Pump Station and Lower Marsh Creek compared well to nearby rain gauges. Clogging of the tipping buckets at these two sites led to discrepancies in the record compared with nearby gauges. The daily data of the site gage was regressed with the daily data of a nearby gage during periods when the site gage was working, and the regression was used to correct the site gage record. The regression was strong for North Richmond ($R^2 = 0.91$) but poor for San Leandro Creek ($R^2 = 0.61$). All sites had rainfall totals during 5-, 10- and 60-minute intervals that aligned with 1-, 2- and 5-year rainfall returns in their respective regions.

Overall the continuous stage data were acceptable. When collected, manual stage measurements compared well with the corresponding record from the pressure transducer ($R^2 > 0.99$ at all sites all years where it was measured). Percent differences between consecutive records were reasonable at all

Table 4. Continuous data quality assurance summary for representativeness and confidence in corrections for each monitoring location. Quality ratings were only developed for WYs 2013 and 2014. When only one rating is provided, it is relevant for both WYs. "NA" indicates that the QA procedure was not applicable.

	Representativeness of the Population[c]			Confidence in Corrections[c]		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Lower Marsh	Excellent	Excellent	Excellent	Excellent / Poor[1]	Excellent	Excellent
Richmond	Excellent	Excellent	Poor / Good[2]	Good[3] / Excellent	Excellent	Excellent
San Leandro	Excellent	Excellent	Excellent	Excellent	Excellent	Poor[4]
Guadalupe	NA	Excellent	Excellent	NA	USGS maintained	Excellent
Sunnyvale	Excellent	Good[5] / Excellent	Excellent	Excellent	Excellent	Poor/Good[6]
Pulgas	Excellent	Excellent / Poor[7]	Good[8]	Excellent	Poor/Good[9]	Poor[10]

[c] Representativeness of the Population and Confidence in Corrections metrics are provided for WYs 2013 and 2014, the years for which this metric was evaluated systematically

[1] During WY 2014, data from 59% of the actual rain days were rejected due to clogging of the tipping bucket. The data were substituted with records from nearby local stations (Weather Underground). The regression of daily total rainfall between one of these substituted gages and the site gage for days when the tipping bucket was working had a coefficient of variation of 0.61; the other site has since been decommissioned and the relationship could not be evaluated.

[2] In WY 2013, 4.2% of the population (251 records) had > 20 NTU absolute value change and ≥15% relative change from the preceding record; 2.9% (171 records) had > 20 NTU absolute value change and >50% relative change from the preceding record. In WY 2014, 3.7% of the population had >20 NTU absolute value change and ≥15% relative change from the preceding record; 2.1% had >20 NTU absolute value change and >50% relative change from the preceding record.

[3] Data missing due to clogging was corrected with the nearby Richmond City Hall gage; the regression of daily total rainfall between the Richmond City Hall gage and the site gage for days when the tipping bucket was working had an $R^2 = 0.91$.

[4] Turbidity could not be measured at flows <0.4 ft. Generally, however, these were likely periods of very low turbidity anyway. However, during WY 2013, 23% of records for stages > 1ft were missing turbidity, and in WY 2014, several entire storms were missed due to the sensor not being installed to prevent vandalism or malfunctioning. For WY 2014, 43% of record for which there was flow did not have corresponding turbidity records.

[5] 4.7% of records at Sunnyvale in WY 2013 showed a >15% change between consecutive readings.

[6] The sensor installed during WY 2012 was not adequate for measuring turbidity at lower flows and the entire record was rejected (noted here but not reflected in the Table 4 rating since only WYs 2013 and 2014 are rated. During the subsequent water years, vegetation frequently got caught on the boom structure within the channel and fouled the turbidity record. During WY 2013, 8.3% of the record was rejected and could not be corrected. In WY 2014, 7% of records required correction but this time there was relatively clear evidence for the method used to fill data gaps.

[7] 14% of the records at Pulgas showed a >15% change between consecutive readings, 7% were >25% change, and 1.3% were >100%change.

[8] In WY 2013, 1.9% of the population (483 records) had > 20 NTU absolute value change and ≥15% relative change from the preceding record; 1.3% (328 records) had > 20 NTU absolute value change and >50% relative change from the preceding record. Recommended action for improvement is to shorten the recording interval from 5 minutes to 1 minute. In WY 2014, 1.6% of the population had > 20 NTU absolute value change and ≥15% relative change from the preceding record; 1.0% had > 20 NTU absolute value change and >50% relative change from the preceding record.

[9] During WY 2013, a large portion of the record was on intervals > 15 minutes and we often had no confidence in a method to correct the data. Equipment issues were improved in WY 2014 and the recording interval was set to 15 min except during times of flow, when it switched to logging on the 1 min interval. However, back-ups into the stormdrain led to zero-flow conditions prompting the measurement interval back to 15 minute intervals. It is unknown what the flow was between these occurrences. In total, this scenario appeared to have happened between 15-25 times and back-of-the-envelope calculations suggest that 2-4 % of the total flow volume was likely not recorded as a result.

[10] The turbidity sensor was placed in a catchbasin near the pump station and the runoff in the catchbasin was vigorously pumped out when the pump station turned on. This led to cyclical large variations in the turbidity record, and BASMAA is currently investigating the pump station on/off times to determine if spikes due to pumping can be identified and discerned from erroneous spikes. Pending additional review, the current comparison to the manual turbidity measurements was poor, and we have little confidence in the corrections that were applied to the dataset. Furthermore, the recording interval for WY 2013 was set to 5 min. This was also the case for WY 2014, except during times of flow, when it logged on the 1 min interval consistent with the stage record. However, back-ups into the stormdrain led to zero-flow conditions prompting the measurement interval back to 5 minutes. It is unknown what the flow and turbidity was between these occurrences.

sites with the exceptions of Sunnyvale in WY 2013 and Pulgas in WY 2014 when there were nearly 5 and 14% of the records at each station in which consecutive records showed greater than a 15% difference in stage measurement. Manual stage measurements were not collected at Pulgas Creek Pump Station at all during the study, and could not be used to verify the accuracy or precision of those stage records.

At the creek and channel sites, flow was calculated from the continuous stage record and therefore the accuracy of the estimated flows was dependent on a quality stage record as well as a quality discharge rating curve. At Lower Marsh Creek and Guadalupe River, the USGS had already developed discharge rating curves. The Santa Clara Valley Water District (SCVWD) provided a discharge rating curve for Sunnyvale Channel, and through measurements over a broad stage range, the STLS team verified the quality of the SCVWD curve. The San Leandro location was a challenging cross section to rate given no bed control, seasonally variable vegetation on the banks, variation in the cross-section morphology within and just upstream of the measurement point under the bridge and a near-field side channel entry just upstream. Given these issues, a flow rating for the site would likely take many years under a very wide variety of storms to verify with certainty. With these challenges in mind, the STLS team began development of a discharge rating curve at San Leandro Creek, which was well-measured in WY 2012 and 2014 at stages <2 feet and with three measurements in WY 2012 at approximately 3.5 feet of stage. Due to the large gap in measurements between 2 and 3.5 feet of stage, as well as no measurements for flows between 3.5 and 4 feet of stage (the maximum stage recorded during that study on 12/23/2012), we could have at best moderate confidence in the flow estimates for this site. Compounding this uncertainty, flow volumes estimated during storms of similar sizes between monitoring years were substantially different from year to year perhaps associated with morphological changes that were not documented. Therefore, despite excellent QA ratings for the continuous stage record at San Leandro, our overall confidence in the flow record for this site is low.

The pump station sampling locations employed alternate methods of flow estimation and therefore additional QA procedures were applied to the flow records. The stage records were evaluated for these sites in the same manner as for the creek and channel locations. Additionally, at North Richmond Pump Station, the optical proximity sensor record was reviewed for consistency of the pump shaft rates during times of operation. At both North Richmond and Pulgas Creek Pump Stations, the storms during each water year monitored were isolated and total flow and precipitation volumes were calculated. Relationships between these metrics were evaluated and used to identify eight storms at Pulgas from WY 2013 when the flow meter was malfunctioning. After censorship of these storms, the rainfall-runoff relation at each site was excellent (r^2=0.96 and r^2=0.98 for North Richmond and Pulgas, respectively).

Continuous turbidity data were rated excellent at Lower Marsh Creek and Guadalupe River throughout the monitoring periods. The San Leandro Creek dataset was relatively free from spikes requiring censorship or correction but had a large portion of missing records due to failure to install the sensor prior to some storm events and delays in correcting sensor loss or malfunction. Sunnyvale East Channel's entire WY 2012 record was censored because the numerous spikes that resulted from the OBS-500 reading the bottom of the channel during low flows could not be corrected. The turbidity record for Sunnyvale East Channel also had numerous spikes in the subsequent two years of monitoring due to vegetation catching on the boom structure and interfering with the turbidity measurement; this record could not be corrected for small portions of WY 2013 but because more frequent maintenance was implemented in WY 2014 to address this problem, the entire record could be used after correction of some records. The two pump station monitoring sites were the most dynamic in terms of turbidity magnitude changes from record to record and presented the most challenging logistics for turbidity measurement, which resulted in diminished quality. At North Richmond Pump Station, for example, the regression between sensor and manual measurements in WY 2013 was slightly less than ideal (r^2 = 0.85) and despite the frequent 1-minute logging interval, 4.2% of the WY 2013 records during pump outs had relative changes in turbidity magnitudes from record to record greater than 15% and 20 NTU, leading to a quality ranking of "Poor" for WY 2013. Field staff noted throughout the season large amounts of trash in the pump station well where monitoring occurred, and this could be the cause of the turbidity fluctuations, though it is also conceivable that the small urban system and unique monitoring configuration could have been so dynamic as to result in these relative changes. At Pulgas Creek South Pump Station the turbidity sensor was placed in a catchbasin near the inlet to the pump station and the runoff in the catchbasin was vigorously pumped out when the pumps turned on. This led to cyclical large variations in the turbidity record, and it was not always possible to discern erroneous spikes in the data record as opposed to the cyclical spikes resulting from the pump outs. BASMAA is undertaking further review of the pump on/off times to determine if spikes due to pumping can be identified and if somehow this information will be useful to estimating loads. Furthermore, the recording interval for WY 2013 was set to 5 min, which was long in duration relative to the dynamically changing system. The logging interval was improved in WY 2014, such that during times of flow turbidity was recorded on the 1 min interval consistent with the stage record. However, the programming logic set to accomplish this changing interval created some periods in which flow and turbidity were likely not recorded on the shorter intervals. The current comparison to the manual turbidity measurements at Pulgas Creek was poor in both water years, and we have little confidence in the corrections that were applied to the dataset. Ultimately, the turbidity record was not used to estimate continuous loads at Pulgas Creek, and a flow-based or flow-weighted mean concentration approach was adopted instead. BASMAA has suggested they may undertake further review of this dataset, including application of smoothing functions to better fit the pollutant data to the turbidity record and potentially improve the usability of these data.

4. Laboratory analysis and quality assurance

4.1. Sample preservation and laboratory analysis methods

All samples were labeled, placed on ice, transferred back to the respective site operator's headquarters, and refrigerated at 4 °C until transport to the laboratory for analysis. Laboratory methods were chosen to ensure the highest practical ratio between method detection limits, accuracy and precision, and costs (BASMAA, 2011; 2012). No changes were made between WYs 2013 and 2014 in laboratories conducting the chemical analyses (Table 5).

An inter-comparison study, started in WY 2013 and continued in WY 2014, was designed to assess any impacts of laboratory change during the study. A subset of samples were collected in replicate in the

Table 5. Laboratory analysis methods for WY 2014 samples.

Water Year	Analyte	Method	Field Filtration	Field Acidification	Laboratory
WY2012	Carbaryl	EPA 632M	No	No	DFG WPCL
WY2013	Carbaryl	EPA 632M	No	No	DFG WPCL
WY2014	Carbaryl	EPA 632M	No	No	DFG WPCL
WY2012	Copper[1]	EPA 1638M	No	No	Brooks Rand Labs LLC
WY2013	Copper[1]	EPA 1638M	No	No	Caltest Analytical Laboratory
WY2014	Copper[1]	EPA 1638M	No	No	Caltest Analytical Laboratory
WY2012	Dissolved OrthoPhosphate	EPA 300.1	Yes	No	EBMUD
WY2013	Dissolved OrthoPhosphate	SM20 4500-P E	Yes	No	Caltest Analytical Laboratory
WY2014	Dissolved OrthoPhosphate	SM20 4500-P E	Yes	No	Caltest Analytical Laboratory
WY2012	Fipronil	EPA 619M	No	No	DFG WPCL
WY2013	Fipronil	EPA 619M	No	No	DFG WPCL
WY2014	Fipronil	EPA 619M	No	No	DFG WPCL
WY2012	Nitrate	EPA 300.1	Yes	No	EBMUD
WY2013	Nitrate	EPA 353.2/SM20 4500-NO3 F	Yes	Yes	Caltest Analytical Laboratory
WY2014	Nitrate	EPA 353.2/SM20 4500-NO3 F	Yes	No	Caltest Analytical Laboratory
WY2012	PAHs	AXYS MLA-021 Rev 10	No	No	AXYS Analytical Services Ltd.
WY2013	PAHs	AXYS MLA-021 Rev 10	No	No	AXYS Analytical Services Ltd.
WY2014	PAHs	AXYS MLA-021 Rev 10	No	No	AXYS Analytical Services Ltd.
WY2012	PBDEs	AXYS MLA-033 Rev 06	No	No	AXYS Analytical Services Ltd.

Water Year	Analyte	Method	Field Filtration	Field Acidification	Laboratory
WY2013	PBDEs	AXYS MLA-033 Rev 06	No	No	AXYS Analytical Services Ltd.
WY2014	PBDEs	AXYS MLA-033 Rev 06	No	No	AXYS Analytical Services Ltd.
WY2012	PCBs	AXYS MLA-010 Rev 11	No	No	AXYS Analytical Services Ltd.
WY2013	PCBs	AXYS MLA-010 Rev 11	No	No	AXYS Analytical Services Ltd.
WY2014	PCBs	AXYS MLA-010 Rev 11	No	No	AXYS Analytical Services Ltd.
WY2012	Pyrethroids	AXYS MLA-046 Rev 04	No	No	AXYS Analytical Services Ltd.
WY2013	Pyrethroids	EPA 8270Mod (NCI-SIM)	No	No	Caltest Analytical Laboratory
WY2014	Pyrethroids	EPA 8270Mod (NCI-SIM)	No	No	Caltest Analytical Laboratory
WY2012	Selenium[1]	EPA 1638M	No	No	Brooks Rand Labs LLC
WY2013	Selenium[1]	EPA 1638M	No	No	Caltest Analytical Laboratory
WY2014	Selenium1	EPA 1638M	No	No	Caltest Analytical Laboratory
WY2012	Suspended Sediment Concentration	ASTM D3977	No	No	EBMUD
WY2013	Suspended Sediment Concentration	ASTM D3977-97B	No	No	Caltest Analytical Laboratory
WY2014	Suspended Sediment Concentration	ASTM D3977-97B	No	No	Caltest Analytical Laboratory
WY2012	Total Hardness	EPA 1638M	No	Yes	Brooks Rand Labs LLC
WY2013	Total Hardness	SM 2340	No	Yes	Caltest Analytical Laboratory
WY2014	Total Hardness	SM 2340 C	No	Yes	Caltest Analytical Laboratory

Water Year	Analyte	Method	Field Filtration	Field Acidification	Laboratory
WY2012	Total Mercury	EPA 1631EM	No	Yes	Moss Landing Marine Laboratories
WY2013	Total Mercury	EPA 1631EM Rev 11	No	Yes	Caltest Analytical Laboratory
WY2014	Total Mercury	EPA 1631EM Rev 11	No	Yes	Caltest Analytical Laboratory
WY2012	Total Methylmercury	EPA 1630M	No	Yes	Moss Landing Marine Laboratories
WY2013	Total Methylmercury	EPA 1630M Rev 8	No	Yes	Caltest Analytical Laboratory
WY2014	Total Methylmercury	EPA 1630M Rev 8	No	Yes	Caltest Analytical Laboratory
WY2012	Total Organic Carbon	SM 5310 C	No	Yes	Delta Environmental Lab LLC
WY2013	Total Organic Carbon	SM20 5310B	No	Yes	Caltest Analytical Laboratory
WY2014	Total Organic Carbon	SM20 5310B	No	Yes	Caltest Analytical Laboratory
WY2012	Total Phosphorus	EBMUD 488 Phosphorus	No	Yes	EBMUD
WY2013	Total Phosphorus	SM20 4500-P E	No	Yes	Caltest Analytical Laboratory
WY2014	Total Phosphorus	SM20 4500-P E/SM 4500-P F	No	Yes	Caltest Analytical Laboratory
WY2012	Toxicity[2]	See Table note 3 below	No	No	Pacific Eco-Risk Labs
WY2013	Toxicity2	See Table note 3 below	No	No	Pacific Eco-Risk Labs
WY2014	Toxicity2	See Table note 3 below	No	No	Pacific Eco-Risk Labs

[1] Dissolved selenium and dissolved copper samples were field filtered and field acidified (HNO_3) at the Lower Marsh Creek (WY 2012, 2013, 2014) and San Leandro Creek stations (WY 2013, 2014).
[2] Toxicity testing includes: chronic algal growth test with *Selenastrum capricornutum* (EPA 821/R-02-013), chronic survival & reproduction test with *Ceriodaphnia dubia* (EPA 821/R-02-013), chronic survival and growth test with fathead minnows, *Pimephales promelas* (EPA 821/R-02-013), and 10-day survival test with *Hyalella azteca* (EPA 600/R-99-064M).

field and sent to the previous and replacement laboratories for analysis. Nutrients, copper, mercury, methylmercury, selenium and pyrethroid samples were analyzed as part of the inter-comparison study. Individual laboratory QA summaries for the WY 2014 inter-comparison analyses are presented in section 5.2 of this report. A review of the inter-comparison study results and laboratory QA can be found in Attachment 2.

4.2. Quality assurance methods for pollutants of concern concentration data

The data quality was reviewed using protocols applied to samples collected for the SF Bay Regional Monitoring Program for Water Quality. Data handling procedures and acceptance criteria may differ among programs. However, underlying data are never discarded; results even for “censored” data are maintained, so impacts of applying different protocols can be assessed if desired.

4.2.1. Holding Times

Holding times are the length of time a sample can be stored after collection and prior to analysis without significantly affecting the analytical results. Holding times vary with the analyte, sample matrix, and analytical methodology used to quantify concentration. Holding times can be extended if preservation techniques are employed to reduce biodegradation, volatilization, oxidation, sorption, precipitation, and other physical and chemical processes.

4.2.2 Sensitivity

The sensitivity review evaluated the percentage of field samples that were non-detects (NDs) as a way to evaluate if the analytical methods employed were sensitive enough to detect expected environmental concentrations of the targeted parameters. In general, if more than 50% of the samples were ND, then the method may not be sensitive enough to detect ambient concentrations. However, review of historical data from the same project/matrix/region (or a similar one) helped to put this evaluation into perspective; in most cases the lab was already using a method that is as sensitive as is possible.

4.2.3 Blank Contamination

Blank contamination was assessed to quantify the amount of targeted analyte in a sample from external contamination in the lab or field. This metric was performed on a lab-batch basis. Lab blanks within a batch were averaged. When the average blank concentration was greater than the method detection limit (MDL), the field samples within each batch were qualified as blank contaminated. If the field sample result (including any reported as ND) was less than 3 times the average blank concentration those results were “censored” and not reported or used for any data analyses. All censored data are made available but are qualified as exceeding QAQC thresholds.

4.2.4 Precision

Rather than evaluation by lab batch, precision was reviewed on a project or dataset level (e.g., a year or season’s data) so that the review took into account variation across batches. Only results that were greater than 3 times the MDL were evaluated, as results near MDL were expected to be highly variable. The overarching goal was to review precision using sample results that were most similar in characteristics and concentrations to field sample results. Therefore the priority of sample types used in this review was as follows: lab-replicates from field samples or field replicates (but only if the field replicates are fairly homogeneous which is unlikely for wet-season runoff event samples unless collected simultaneously from a location). Replicates from Certified Reference Materials (CRMs), matrix spikes, or spiked blank samples were reviewed next with preference to select the samples that most resembled the targeted ambient samples in matrix characteristics and concentrations. Results outside of the project management quality objective (MQO) but less than 2 times the MQO (e.g., ≤50% if the MQO is ≤25% relative percent difference (RPD) or relative standard deviation (RSD)) were qualified; those outside of 2 times the MQO were censored. All censored data are made available but are qualified as exceeding QAQC thresholds.

4.2.5. Accuracy

Accuracy was also reviewed on a project or dataset level (rather than a batch basis) so that the review takes into account variation across batches. Only results that were greater than 3 times the MDL were evaluated. Again, the preference was for samples most similar in characteristics and concentrations to field samples. Thus the priority of sample types used in this review was as follows: CRMs, then Matrix Spikes (MS), then Blank Spikes. If CRMs and MS were both reported in the same concentration range, CRMs were preferred because of external validation/certification of expected concentrations, as well as better integration into the sample matrix (MS samples were often spiked just before extraction). If both MS and blank spike samples were reported for an analyte, the MS was preferred due to its more similar and complex matrix. Blank spikes were used only when preferred recovery sample types were not available (e.g., no CRMs, and insufficient or unsplittable material for creating an MS). Results outside the MQO were qualified, and those outside 2 times the MQO (e.g., >50% deviation from the target concentration, when the MQO is ≤25% deviation) were censored for poor recovery. All censored data are made available in all public data displays but are qualified as exceeding QAQC thresholds.

4.2.6. Comparison of dissolved and total phases

This review was only conducted on water samples that reported dissolved and total fractions. In most cases the dissolved fraction was less than the particulate or total fraction. Some allowance is granted for variation in individual measurements, e.g. with a precision MQO of RPD or RSD<25%, a dissolved sample result might easily be higher than a total result by that amount.

4.2.7. Average and range of field sample versus previous years

Comparing the average range of the field sample results to comparable data from previous years (either from the same program or other projects) provided confidence that the reported data do not contain egregious errors in calculation or reporting (errors in correction factors and/or reporting units). Comparing the average, standard deviation, minimum and maximum concentrations from the past several years of data aided in exploring data, for example if a higher average was driven largely by a single higher maximum concentration.

4.2.8. Fingerprinting summary

The fingerprinting review evaluated the ratios or relative concentrations of analytes within an analysis. For this review, we looked at the reported compounds to find out if there are unusual ratios for individual samples compared to expected patterns from historic datasets or within the given dataset.

Since analyses of organic contaminants at trace levels are often susceptible to biases that may not be detected by conventional QA measures, additional QA review helps ensure the integrity of the reported data. Based on knowledge of the chemical characteristics and typical relative concentrations of organic contaminants in environmental samples, concentrations of the target contaminants are compared to results for related compounds to identify potentially erroneous data. Compounds that are more abundant in the original technical mixtures and are more stable and recalcitrant in the environment are expected to exist in higher concentrations than the less abundant or less stable isomers. For example, PCB congener concentrations follow general patterns of distribution based on the original concentrations in Aroclor mixtures. If an individual congener occurs at concentrations much higher than usual relative to more abundant congeners, the result warrants further investigation.

Furthermore, several contaminants chemically transform into other toxic compounds and are usually measured within predicted ranges of concentrations compared to their metabolites (e.g. heptachlor epoxide/heptachlor), so deviations from such expectations are also further investigated. However, great care should be exercised in using information on congener ratios of common Aroclor mixtures and other such heuristic methods, for some of the same reasons that interpreting environmental PCBs only as mixtures of Aroclors has limitations. Over-reliance on such patterns in data interpretation may lead to inadvertent censoring of data, e.g., for contributions from unknown or unaccounted sources.

When results are reported outside the range of expected relative concentrations, and the laboratory cannot identify the source of variability, values are qualified to indicate uncertainty in the results. If the reported values do not deviate much from the expected range, they are generally allowed to stand and are included in calculations of “sums” for their respective compound classes. However, if the reported concentrations deviate greatly from the expected range and are clearly higher than observed in past analyses or current sample splits, it can be reasonably concluded that the results are erroneous. Again, even “censored” data records are maintained, so any impact of censoring can be reviewed or reversed.

5 Results

The following sections present results from the six monitored tributaries. In the first sub-section, a summary of data quality is initially presented. This is then followed by sub-sections that synthesize climate and flow across the six locations, concentrations of POCs across the six locations, loads across six locations, and a graphical summary of particle concentrations across the six locations.

5.2 Project Quality Assurance Summary

The section below reports on WY 2014 data; for the WY 2012 and 2013 quality assurance summaries refer to previous reports.

Nutrients

Overall the nutrient data were acceptable. Methods were sufficiently sensitive to detect ambient environmental concentrations. Analytes were not detected in any lab blanks, so field samples did not need qualifying for blank contamination. Some analytes (orthophosphate and phosphorus) were detected in field blanks, with the lowest field samples usually at least about 3x higher than the maximum field blank, except for phosphorus, where the field blank (.057) was only ~20% less than the lowest field sample (.067), and only 6x lower than the average field result. Field blank samples with analyte detection were qualified, but field blanks were not included in all field sample batches so were not used for flagging field results on a batch or whole project basis. However, field blanks should be considered in the interpretation of low concentration samples even if not included in all analytical batches.

Precision on field replicates (generally blind) was good, with RSDs on field replicate samples averaging 15% or better for all the nitrogen analytes and <10% for the phosphorus analytes. Results for matrix spikes and blank spikes were consistent, averaging <10% RSD for all analytes. Recoveries were also good, averaging within 10% of expected values or better for all analytes on matrix spikes, and within ~5% or better for all analytes on laboratory control samples (LCS).

Nutrients - Inter-comparison Study

Overall the data were marginal, with moderate to large deviations for some analytes. Method detection limits were acceptable with no NDs reported. Data were reported not blank corrected. No contamination was measured in any of the method blanks. QC sample types were evaluated according to the preferences noted previously (with greatest preference to sample types most similar in matrix and concentration range as reported field samples, if results for those QC sample types were available in a reportable quantitative range). Lab replicates of field samples were used to evaluate precision for nutrients other than total phosphorus. Average RSDs were good, all less than their respective target MQOs (Nitrate 15%; orthophosphate, and total phosphorus 10%). LCS replicates were used to evaluate the precision of Total Phosphorus results, with average RSD of <1% well within the target MQO (10%). LCS recovery RSDs were examined for nitrate as N and orthophosphate as P but not used for qualifying precision on these analytes, since unspiked lab replicates were quantified for those. Orthophosphate (mean RSD 4.28%) was less than the target MQO (10%), but nitrate as N (mean RSD 22.31%) exceeded 15%, with much of the variation due to different spiking levels on different LCS.

Matrix spikes were used to evaluate the accuracy of total phosphorus results. Recoveries were good with the average recovery errors all within their target MQOs (nitrate 15%, orthophosphate, and total phosphorus 10%). LCS samples were used to assess the accuracy of Nitrate as N and orthophosphate, since these analytes were not in matrix spikes. Recoveries were fair for nitrate (mean error 23.25%, qualified with the non-censoring qualifier of "VIU") and poor for orthophosphate (mean error 33.95% qualified with the censoring qualifier of "VRIU"). LCS samples were examined for total phosphorus, but not used for qualifying. Total phosphorus (mean error 9.74%) was less than the target MQO (10%).

Suspended Sediment Concentration

Overall the data were acceptable. Method detection limits (MDLs) were sufficient for estimation or quantitation of most samples, with only ~3% of the results reported as NDs. Data were reported not blank corrected. No blank contamination was found in the field or method blanks. LCS replicates were used to evaluate precision, with the average RSD (3.62%) being well below the target method quality objective (MQO) of 10%. The average RSD for field replicates was not used in the evaluation, but was examined and found to be 7.5%. No qualifiers were added. LCS were used to assess accuracy as they were the only spiked samples analyzed. Recoveries measured were good with the average recovery error of 2.93% being well below the target 10% MQO. No qualifiers were needed.

Suspended Sediment Concentration - Inter-comparison Study

Method detection limits were acceptable with no NDs reported. Data were reported not blank corrected. No contamination was measured in the method blanks. Lacking other sample types analyzed in replicate, CRM recoveries were used to evaluate the precision of Suspended Sediment Concentration results, and had an average RSD of 23.6%. Although this was more than double the target MQO of 10%, they were qualified with the non-censoring qualifier of “VIL” since the CRMs were certified at different target values and thus might not be expected to show similar recoveries. CRMs were used to assess the accuracy of the suspended sediment concentration results. Recoveries measured were fair with the average recovery error of 16.23% being greater than the target MQO of 10%, but less than 20%, so were qualified with the non-censoring qualifier of “VIU”.

Total Organic Carbon

The TOC data were acceptable. MDLs were sufficient with zero NDs reported. Data were reported not blank corrected. Blank contamination was not measured in the method blanks. Equipment and field blanks were examined, but not used in qualifying field sample results in the database. Blank contamination was found in one of the seven equipment blanks at a level ~3% of those found in the field samples (equipment blank contamination 0.51 mg/L compared to mean field sample concentration 15.74 mg/L). No blank contamination was measured in the field blank.

Precision was evaluated using matrix spike replicates. The RSD was good averaging 0.47%; less than the MQO of 10%. No qualifiers were needed. LCS replicates and blind field replicates had an average RSD of 3.87% and 2.97%, respectively. Matrix spike samples were used to assess accuracy as no CRMs were analyzed. Recoveries measured were good with the average recovery error of 6.88% being less than the target MQO of 10%. No qualifiers were needed. LCS recoveries were good with an average recovery error of 2.22%.

Copper, Selenium, and Total Hardness

The copper, selenium, and total hardness data were acceptable. Samples were either field filtered, or lab filtered within 24 hours except for 1 field blank and one sample, qualified for being slightly over (25-26 hours) the target filtering hold time. MDLs were sufficient with zero NDs reported. Data were reported not blank corrected. Blank contamination was not measured in the method blanks.

Equipment and field blanks were examined, but not used in the qualifying of field samples. Blank contamination was found in several of the field blanks for copper (dissolved and total) at a level ~20% of those found in the field samples for dissolved copper (mean field blank contamination 1.4 ug/L compared to mean field sample concentration 7 ug/L), and at a level ~2% of those found in the field samples for total copper (mean field blank contamination 0.6 ug/L compared to mean field sample concentration of 28 ug/L). No blank contamination was measured in the equipment blanks.

Precision was evaluated using the matrix spike replicates, with the average RSDs being well less than the target MQOs (selenium 35%, copper 25%, and hardness 5%); all <2%. Average RSDs for LCS replicates were also less than the target MQOs; all <5%. The average RSDs for field replicates were not used in qualified, but were examined and found to be less than the target MQOs; all <5%. No precision qualifiers were added. Matrix spike samples were used to assess accuracy as no CRMs were analyzed. Recoveries measured were good with average recovery errors less than the target MQOs (selenium 35%, copper 25%, and hardness 5%). LCS recoveries were also good with average recovery errors all less than the target MQOs. No recovery qualifiers were needed. Dissolved and total fractions were reported for copper and selenium. Dissolved/Total ratios were all < 1.35, within the propagated accepted error for precision and accuracy on individual results.

Copper, Selenium, and Total Hardness - Inter-comparison Study

Overall the data were acceptable. MDLs were sufficient with zero NDs reported. One batch had selenium detected in blanks slightly over the MDL, but still well below most field sample concentrations. The data were blank corrected and the blank standard deviation was less than the MDL so no blank qualifiers were added. Lab replicates were used to evaluate precision, with the average RSDs being all <4%, well below the target MQOs (selenium 35%; calcium, copper, and magnesium 25%). Average RSDs for matrix spike/matrix spike replicate samples were all <4%, also less than the target MQOs. No precision qualifiers were added. CRMs were used to assess accuracy. Recoveries measured were good with average recovery errors less than the target MQOs (selenium 35%; calcium, copper, and magnesium 25%); the highest recovery error was 12% for calcium (to calculate hardness). Matrix spike and LCS recoveries were good with average recovery errors all less than the target MQOs. No added qualifiers were needed. Dissolved and total fractions were reported for copper and selenium. Dissolved/Total ratios were all < 1.35, within precision expected propagated error.

Mercury and Methylmercury

The total mercury (Hg) and methylmercury (MeHg) data overall are acceptable. All were analyzed within the recommended 28 day hold time aside from one mercury sample analyzed slightly beyond (35 days) that was qualified for hold time. The methods were sufficiently sensitive to detect MeHg or Hg in nearly all samples, with only 2 MeHg analyses reported not detected. Blank concentrations of MeHg and total Hg were below detection limits for all blank sample types (field, equipment, and lab), so no blank qualifiers were needed.

Precision on field replicates was acceptable, averaging 16% RSD for both total and methyl mercury. Matrix spike/MSD precision averaged 2% RSD, and LCS (spiked blank) precision was similarly good, averaging 4% and 12% for total and methyl mercury, respectively. No CRMs were analyzed, so matrix spikes were the best indicators of recovery available. Although a few individual sample recoveries were outside of the target range (due to spiking less than 2x native concentrations), recovery errors averaged 11% or better for MeHg and total Hg matrix spikes and spike duplicates spiked higher than 2x, and averaged 9% or better for blank spikes, well within target errors of +/-35%. No added qualifiers were needed. The ratios of methyl to total mercury were within an expected reasonable range, with methyl mercury (around 0.2 ng/L) near 1% or less of total mercury (0.05 ug/L = 50 ng/L, around 250x higher).

Mercury and Methylmercury – Inter-comparison Study

Overall the data were quite good. MDLs were sufficient that there were no NDs for field samples. Methylmercury (MeHg) and mercury (Hg) were not detected in most blanks, except 1 just at its MDL, although the blank average for that batch was still <MDL. Precision on an un-spiked lab replicate was good, with an RSD <3%. Precision on repeated measures of CRMs, MS and LCS were similarly good, all averaging <3%, well within the target 35% MQO for Hg and MeHg. Recoveries on CRMs, MSs, and LCS were all good, with average errors <5% for Hg, and <15% for MeHg, well within the target <35%. The ratios of mercury and methylmercury were pretty typical, with methylmercury <1% of total mercury (although they weren't necessarily reported as pairs for a given site and event in the IC samples).

Carbaryl and Fipronil

Overall the carbaryl and fipronil data were acceptable. Methods were sufficient to detect at least some target analytes in most samples. Fipronil was always detected. None of the target analytes were detected in blanks. Precision on field replicates was generally good, with RSDs <35% target for all analytes. Carbaryl had the highest variation (30%) due to concentrations near the MDL. Precision on MS/MSD and LCS replicates was better yet, <20% RSD for all analytes. Recovery errors on all reported analytes averaged less than the 35% target so no added qualifiers were needed

PAHs

Overall the PAH data were marginally acceptable. MDLs were sufficient with 5 of the 44 reported PAHs having NDs (ranging from 6 to 53% ND per PAH congener), with only 1, Benz(a)anthracene having >=50% ND. Blank contamination was measured in at least one of the seven method blanks for many analytes with blank contamination high enough (>1/3 of the field sample result) to qualify many results (88% of Biphenyl, but 29% or less for other PAHs and alkylated PAHs) with the censoring contamination qualifier of "VRIP". Many of these censored results were the alkylated PAHs, not used in generating sums of PAHs; the other censored LPAH and HPAH results typically account for about 10% of total PAHs.

Field blanks were examined, but not used in qualifying field samples in the database. Contamination in the field blanks was found at concentrations mostly 1-4 times that found in the lab blanks, except for 2,6-Dimethylnaphthalene, 2-Methylnaphthalene, 1-Methylnaphthalene, C1-Naphthalenes, and Naphthalene, which were respectively 5, 6, 7, 8 and 8 times greater in the field blanks than the lab blanks. Average field blank contaminant concentrations were generally less than 10% of the average concentrations found in the field samples, notable exceptions were 1-Methylnaphthalene, C1-Naphthalenes, 2-Methylnaphthalene, Biphenyl, and Naphthalene, which were 22%, 24%, 26%, 27% and 58% of the average field sample concentrations, respectively.

Replicates on field samples were used to evaluate precision and were good, less than the target 35% average RSD. LCS replicates were examined and were also all less than the target 35% average RSD (all <10%). The average RSD combining field and lab duplicates were not used in qualifying, but were less than the target MQO of 35%. No precision qualifiers were added. LCS were used to assess the accuracy of PAHs as no CRMs or matrix spikes were reported. Recoveries measured in the LCS were good with recovery errors less than the target 35% for all 44 PAHs measured (all <20%). No recovery qualifiers were added. Alkyalted PAHs were not included in the LCS or other recovery samples so were qualified with the QA code of "VBS" and batch verification code of "VQI" for partial/unknown recovery QA.

PBDEs

The PBDE data were overall acceptable. MDLs were sufficient with 29 of the 49 reported total fraction PBDE congeners having NDs (ranging from 6 to 100% ND), and 27% (13 out of 49) having >=50% ND. PBDE congeners 28, 47, 49, 71, 85, 99, 100, 116, 119, 126, 140, 153, 154, 155, 183, 190, 197, 205, 206, 208, and 209 had some contamination in at least one method blank, but the blank contamination was only bad enough to qualify 58% of PBDE 190 and 205, 41% of PBDE 126, 29% of PBDE 116, 24% of PBDE 140, 12% of PBDE 155, and 6% of PBDE 71 and 199 results with the censoring contamination qualifier of "VRIP" (results with reported concentrations <3x the blank results (by batch) being censored for contamination).

Field blanks were examined, but not used in qualifying. Blank contamination was found in at least one field blank for PBDE congeners 17, 28, 47, 49, 85, 99, 100, 119, 140, 153, 154, 155, 203, 206, 207, and 209. Field blank contamination was found at concentrations mostly 1-4 times that found in the lab blanks, except for PBDE 049 and 085, which were respectively 13 and 10 times greater in the field blanks than the lab blanks. However, this was still well below the concentrations found in the field samples; average field blank contaminant concentrations at most were 2.3% (PBDE 049) of the average concentrations found in the field samples.

Lab replicates on field samples were used to evaluate precision and were generally good, less than the target 35% average RSD (PBDE 008 was just below at 34.9%). Replicates of the eight usable LCS were examined and were all <35% average RSD (all <16%). The average RSD combining all field and lab duplicates were not used in qualifying (since lab replicates alone are more representative of purely analytical issues) but were examined and found to be less than the target MQO of 35%, except for PBDE 138 (RSD 35.6%). No precision qualifiers were added. LCS results were used to assess the accuracy of PBDEs as no CRMs or matrix spikes were reported. Recoveries for the eight PBDEs measured in the LCS were good with recovery errors less than the target 35% for all reported analytes (all <15%). LCS results for PBDE 33 were unusable. No additional qualifiers were needed.

PCBs

Overall the PCB data were acceptable. MDLs were sufficient with NDs being reported for 15.5% (11 out of 71) PCB congeners ranging from 1% to 3.5% ND; none were extensive (>=50% ND). Blank contamination was measured in at least one method blank for many PCBs (8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 87, 95, 99, 101, 105, 110, 118, 128, 132, 138, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, and 187). Contamination was over 1/3 of the field sample result in 1% to 11% of PCB 8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 87, 95, 99, 101, 105, 110, 118, 151, and 177 samples and qualified with the censoring qualifier of "VRIP".

Field blanks were examined, but not used in qualifying results in the database. Blank contamination was found in the field blanks at levels generally less than in the method blanks and at levels well below those found in the field samples (< 1%). Lab replicates of field samples were used to evaluate precision, with the average RSD being less than the target MQO (35%); all <30%. Average RSD for LCS replicates were examined, and were less than the target MQO of 35%; all <10%. The average RSD for field replicates were not used in qualifying, but were examined and found to be less than the target MQO; all <22%. No precision qualifiers were added. LCS results were used to assess accuracy as no CRMs, or matrix spikes were analyzed. Recoveries measured were good with recovery errors less than the target MQO (35%); all <8%. No additional recovery qualifiers were needed.

Pyrethroids

Overall the pesticide data were acceptable. NDs were reported for all 11 pyrethroids ranging from 7% to 100% ND; NDs for Allethrin, Total Esfenvalerate/Fenvalerate, Fenpropathrin, Tetramethrin, and T-Fluvalinate were extensive (>=50% ND). Data were reported not blank corrected. Blank contamination was measured in at least one method blank for Total lambda-Cyhalothrin. Contamination was extensive enough so that 20% of Total lambda-Cyhalothrin results were qualified with the censoring qualifier of "VRIP" (results with reported concentrations <3x the blank results (by batch) being censored for contamination). Field blanks were examined, but not used in qualifying. Blank contamination was found in the field blank for Total lambda-Cyhalothrin at levels ~40% of those found in the method blanks (0.11 ng/L compared to 0.26 and 0.28 ng/L), and at a level below those found in the field samples (average field sample concentration 0.62 ng/L, field blank contamination 0.11 ng/L).

Matrix spike replicates were used to evaluate precision, with the average RSD being well less than the target MQO (35%); all <12%. Average RSD for LCS replicates were examined, and were less than the target MQO of 35%; all <14%. The average RSD for field replicates were not used in qualifying, but were examined and found to be less than the target MQO (35%); all <30%. No precision qualifiers were added. Accuracy was assessed using the matrix spike samples as no CRMs were analyzed. Recoveries measured were generally good with average recovery errors less than the target MQO (35%); except for Total lambda-Cyhalothrin (42%) and T-Fluvalinate (41%) which were qualified with the non-censoring qualifier of "VIU". LCS recoveries were good with average recovery errors all less than 30%.

Pyrethroids – Inter-comparison Study

Overall the data were acceptable. Most pyrethroids were 100% ND, except for Bifenthrin, Deltamethrin/Tralomethrin, and Total Permethrin (Tetramethrin was qualified by the laboratory as an unreportable estimate). Data were reported not blank corrected. No contamination was measured in the one method blank. No replicates of any kind were analyzed so precision could not be evaluated; results were qualified with the QA code of "VBS" for incomplete QC. The LCS was used to assess accuracy as no CRMs or matrix spikes were analyzed. Recoveries measured were generally good with average recovery errors less than the target MQO (35%); all were <24%.

Toxicity

The 36 hour recommended hold times were exceeded for some sets of *Hyalella azteca* (up to 53 hour hold time) and *Pimephales promelas* (up to 74 hours), and up to 1-2 hour slight exceedances for the other species. Results exceeding the recommended 36 hour hold time were qualified. Control survival was acceptable with a minimum 80% survival just meeting the 80% requirement in one batch. Other batches had higher survival up to 100%. Water quality limits for the test species were not exceeded in any tests. Reference toxicant control EC50/IC50 were within the mean+/-2stdev of previous control results ("typical response" range).

5.3 Climate and flow at the sampling locations during water years 2012, 2013, and 2014

The climatic conditions under which observations are made of pollutant concentrations in flowing river systems have a large bearing on concentrations and loads observed. It has been argued that a 30 year period is needed in California to capture the majority of climate related variability of a single site (Inman and Jenkins, 1999; McKee et al., 2003). Given monitoring programs for concentrations or loads do not normally continue for such a long period (except for rare occasions for turbidity and suspended sediment (e.g. Santa Anna River, Southern California: Warrick and Rubin 2007; Casper Creek, northern California: Keppeler, 2012; Alameda Creek at Niles (data for WYs 1957-73 and 2000-present (30 years)), the objective of sampling is usually to try to capture sufficient components of the full spectrum of variability to make inferences from a smaller dataset. When such data are available, they usually reveal complex patterns in relation to rare large events or several periods of rare drought and decadal scale changes to climate and land use or water management (Inman and Jenkins, 1999; McKee et al., 2003; Warrick and Rubin 2007; Keppeler, 2012; Warrick et al., 2013). However, for pollutant data sets in general, data sets are rarely longer than a few years and high magnitude (high intensity or long duration) events occur infrequently and thus are usually poorly represented. Unfortunately, these types of events usually transport the majority of a decadal scale loads (Inman and Jenkins, 1999; Warrick and Rubin 2007). This occurs because the discharge-load relation spans 2-3 orders of magnitude on the discharge axis and often 3-4 orders of magnitude on the sediment load axis and is described best by a power function ($Q_s=aQ_w^b$) where a and b are constants that describe pollutant sources and the erosive power of water. Therefore storms and wet years with larger discharge, if measured, have a profound influence on the estimate of mean annual load for a given site and would likely confound any comparisons of loads between sites unless adequately characterized. However, if it is assumed that this is consistently true for all sites, or loads measured during dry years can be "climatically adjusted", the validity of loads comparisons between sites will be increased.

Conceptually, watersheds that are more impervious, or smaller in area, or have lower pollutant production variability (or sources) should exhibit lower inter-annual variability (lower slope of the power function) and therefore require less sampling to adequately quantify pollutant source-release-transport processes (an example in this group is Marsh Creek which has rural and recent urbanization land uses and few suspected source areas for PCBs). In contrast, a longer sampling period spanning a wider climatic variability would be more ideal to adequately describe pollutant source-release-transport processes in watersheds that are larger, or less impervious, or have large and known pollutant sources. The quintessential example of this category within this study is Guadalupe River in relation to Hg sources, release mechanisms, and loads but San Leandro Creek (both Hg and PCBs) and Sunnyvale East channel and Pulgas Creek (PCBs) also appear to be in this category. Marsh Creek also appears to be in this category in relation to suspended sediment. Concentration variability relative to first flush and storm magnitude-frequency-duration will probably remain unexplainable for these analytes, even after three years of sampling. This will be one factor that may lead to lower confidence in annual loads computations and average annual loads estimates.

Unfortunately, during the three year study, winter seasons have been very dry relative to average annual conditions with all observations to-date made during years of between 38-85% mean annual precipitation and 22-82% mean annual flow (Table 6). For example, San Leandro Creek experienced 75% of mean annual runoff (MAR) in WY 2012, 67% MAR in WY 2013, and 52% MAR in WY 2014. However, there have been some notable storms, particularly those occurring during late November and December of WY 2013, an intense first flush in November 2013 (WY 2014) and another relatively intense storm in late February 2014 (WY 2014). For example, approximately 52% of the total wet season rainfall fell at the Sunnyvale East Channel rain gauge over 11 days during November and December of WY 2013 and 13% on February 28, 2014 (WY2014). Loads of pollutants were disproportionately transported during such events; at Sunnyvale East Channel, 96%, 91% and 84% of the WY 2013 total wet season sediment, PCBs and mercury loads were transported during those larger November and December storms and 30%, 58% and 24% of the total wet season sediment, PCBs, and mercury loads were transported in a single day on February 28 in WY 2014. However, despite these larger individual storm events, the overall drought conditions during the study may result in estimated long-term averages for each site that are biased low due relatively benign flow production, sediment erosion, and transport conditions in all six watersheds. The bias may not be as severe in those watersheds that received slightly wetter conditions and/or that are more impervious.

Table 6. Climate and flow during sampling years at each sampling location.

<table>
<tr><th colspan="2">Water Year (WY)</th><th>Marsh Creek[2]</th><th>North Richmond Pump Station[3]</th><th>San Leandro Creek[4]</th><th>Guadalupe River[5]</th><th>Sunnyvale East Channel[6]</th><th>Pulgas Creek South Pump Station[7]</th></tr>
<tr><td rowspan="4">Rainfall (mm) (% mean annual)</td><td>2012</td><td>320 (71%)</td><td>NA</td><td>486 (75%)</td><td>179 (47%)</td><td>224 (60%)</td><td>NA</td></tr>
<tr><td>2013</td><td>344 (76%)</td><td>493 (85%)</td><td>437 (67%)</td><td>223 (59%)</td><td>307 (82%)</td><td>378 (78%)</td></tr>
<tr><td>2014</td><td>260 (58%)</td><td>327 (57%)</td><td>338 (52%)</td><td>161 (43%)</td><td>207 (55%)</td><td>183 (38%)</td></tr>
<tr><td>Mean Annual</td><td>457</td><td>578</td><td>627</td><td>378</td><td>387</td><td>484</td></tr>
<tr><td rowspan="4">Runoff (Mm^3) (% mean annual)</td><td>2012</td><td>1.87 (22%)</td><td>NA</td><td>7.30</td><td>38.0 (68%)</td><td>1.07</td><td>NA</td></tr>
<tr><td>2013</td><td>6.23 (73%)</td><td>0.74</td><td>7.21</td><td>45.45 (82%)</td><td>1.51</td><td>0.22</td></tr>
<tr><td>2014</td><td>1.17* (15%)</td><td>0.50</td><td>0.24</td><td>16.75* (30%)</td><td>1.01</td><td>0.08</td></tr>
<tr><td>Mean Annual</td><td>8.0</td><td>No long term data</td><td>No long term data</td><td>55.6</td><td>No long term data</td><td>No long term data</td></tr>
</table>

[1] Unless otherwise stated, averages are for the period Climate Year (CY) (Jul-Jun) (rainfall) or Water Year (WY) (Oct-Sep) (runoff) 1971-2010.

[2] Rainfall gauge: Concord Wastewater treatment plant (NOAA gauge number 041967) (CY 1991-2013); Runoff gauge: Marsh Creek at Brentwood (gauge number 11337600) (WY 2001-2013).

[3] Rainfall gauge: This study with mean annual from modeled PRISM data; Runoff gauge: This study.

[4] Rainfall gauge: Upper San Leandro Filter (gauge number 049185); Runoff gauge: This study.

[5] Rainfall gauge: San Jose (NOAA gauge number 047821); Runoff gauge: Guadalupe River at San Jose (gauge number 11169000) and at Hwy 101 (gauge number 11169025).

[6] Rainfall gauge: Palo Alto (NOAA gauge number 046646); Runoff gauge: This study

[7] Rainfall gauge: Redwood City NCDC (gauge number 047339-4); Runoff gauge: This study.

* indicates data missing for the latter few months of the season

5.4 Concentrations of pollutants of concern during sampling to-date

Understanding the concentrations of pollutants in the watersheds is important to both directly answering one of the Small Tributary Loading Strategy management questions (MQ2) as well as forming the basis from which to answer all of the other key management questions identified by the Strategy. The three year sampling program has provided data that, in some cases, indicate surprisingly high concentrations (e.g. Hg in San Leandro Creek; PCBs in Sunnyvale East Channel; PBDEs in North Richmond Pump Station); other cases indicate surprisingly low concentrations (Hg in Marsh Creek). While in other case, sampling has somewhat verified what was expected (North Richmond (PCBs and Hg), Guadalupe (PCBs and Hg) and Pulgas Creek South Pump Station (PCBs)). In some cases NDs and quality assurance issues confound robust interpretations. This section explores these issues through synthesis of data collected across all six sampling locations over the three years.

Concentrations of pollutants typically vary over the course of a storm and between storms of varying magnitudes, and are dependent on antecedent rainfall, soil moisture conditions, related discharge, sediment supply and transport, and pollutant source-release-transport processes. Although these can be fully understood over a long period of sampling that covers a wide range of conditions, shorter sampling programs will fail to capture this variability and therefore concentrations may appear complex or even chaotic and interpretation may remain difficult. Thus, it is important, even during shorter sampling programs, to try sample over a wide range flow conditions both within a storm and over a wide range of storm magnitudes to adequately characterize concentrations of pollutants in a watershed.

The monitoring design for this project aimed to collect pollutant concentration data from 12 storms over the span of three years (except for North Richmond Pump Station and Pulgas Creek South Pump Station with a target of 8 storm events), with priority pollutants sampled at an average of four samples per storm for a total of 48 discrete samples collected during the monitoring term. In order to capture as much variability as possible, the program aimed to sample earlier season storms, several larger (preferably) or “mid-season” storms, and a later season storm each year for each site (Melwani et al 2010; BASMAA, 2011), However, due to dry conditions, these aims were not easily met. Sampling at the six locations over the three water years has included sampling between 7-10 storm events at each location (Table 7). North Richmond Pump Station was the only site that completed the full allotment of storm events (n=8). Given the small sample size and varying sample sizes between sites, and the failure in some cases to collect a full sample set across the desired storm conditions, the following synthesis represents the best available knowledge about these sites; and areas where gaps in knowledge remain are identified.

Overall, detections of concentrations in the priority pollutants (suspended sediment, total PCBs, total mercury, total methylmercury, total organic carbon, total phosphorous, nitrate, and phosphate) were all 90 or higher, as were detections of several of the “tier II” pollutants (total and dissolved copper and selenium, PAHs and PBDEs) (Table 8). Numerous pyrethroids were not detected at any of the sites; whereas, Delta/Tralomethrin, Cypermethrin, Cyhalothrin lambda, Permethrin, Bifenthrin as well as Carbaryl and Fipronil were all detected in one or more samples at each sampling location.

The two highly urban and impervious sampling locations added in WY 2013 and also sampled in WY 2014 (North Richmond and Pulgas Creek South Pump Stations), have the lowest mean SSC; whereas, pollutant concentrations are relatively high for these watersheds (e.g. PCBs at Pulgas Creek South Pump Station). In contrast, Sunnyvale East Channel has high PCB concentrations but also relatively high SSC. As a result, the particle ratio (turbidity or SSC to pollutant; discussed further in section 5.5) rank shows a differing order to the water concentration ranking. Given the high imperviousness and small size of the North Richmond and Pulgas Creek South Pump Station watersheds, although fewer storms have been sampled at these locations, it is unlikely greater variation in SSC would be observed even if they were to be sampled again in the future.

The maximum PCB concentration observed during the three year program (6,669 ng/L) was collected in Pulgas Creek Pump Station, which also has the greatest mean PCB concentration of the six locations; consistent with the high ranking assigned to Pulgas Creek South Pump Station based on the WY 2011 reconnaissance study of 17 watersheds distributed across four Bay Area counties (McKee et al., 2012). This result was an order of magnitude higher than results from any other storm sampled at the station and it is unclear why this storm in particular mobilized such high concentrations given that the storm was relatively small in magnitude (0.42 inches), intensity (maximum 1 hour rainfall 0.11 inches) and the resulting flow peak (8.6 cfs relative to other PCB samples collected at flows as high as 17 cfs). However, sampling at Pulgas Creek South Pump Station during WYs 2013 and 2014 has captured relatively small storm events (one during WY 2013) and the rest during WY 2014 which recorded 38% MAP; given that PCBs are dominantly associated with particles and that particle transport is correlated with rainfall magnitude and intensity (as seen at Zone 4 Line A[2] (Gilbreath et al., 2012)) it is possible that additional sampling during more, and more intense, storm events could reveal even greater concentrations. Guadalupe River had mercury mines in the upper watershed and is a known mercury source to the San Francisco Bay, explaining the relatively high mercury and, possibly, methylmercury concentrations in this watershed (Thomas et al., 2002; Conaway et al., 2003; Davis et al., 2012). Less well understood is San Leandro Creek, which has mercury and methylmercury concentrations nearly as high as Guadalupe River. If sampling in San Leandro Creek were to continue at some point in the future, under more variable storm and climatic conditions, an improved understanding of source-release-transport processes of mercury in this watershed could be generated that would help to isolate natural or anthropogenic mercury sources and also improve our understanding of pollution levels relative to other watersheds and the accuracy of loads estimates. It is also worth noting (with regard to the tier I priority analytes) that phosphorus concentrations in most of the six watersheds appear greater than elsewhere in the world under similar land use scenarios, perhaps attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005). For example, Dillon and Kirchner (1975) found that watersheds of differing geology under the same land use could exhibit loads differing by an order of

[2] Zone 4 Line A is a 4.2 km^2 100% urban tributary located in Hayward, CA. This creek was monitored extensively by the RMP between WYs 2007-2010 using a similar study approach to estimate loads as the one reported here. The creek was discretely sampled during storm events for SSC, Hg species, metals and other trace elements including selenium, organic carbon, PCBs, PBDEs, pyrethroids, OC pesticides, dioxins and furans and nutrients. It presents one of the most robust datasets available in the Bay Area.

Table 7. Number of storms sampled and number of discrete samples collected at each location relative to the program objectives as recommended (Melwani et al 2010) and codified in the multi-year-plan (e.g. BASMAA, 2011).

Water Year	Storm category	Marsh Creek	North Richmond Pump Station	San Leandro Creek	Guadalupe River	Sunnyvale East Channel	Pulgas Creek South Pump Station
2012	Early season or "first flush	No	Study not yet begun	No	No	No	Study not yet begun
	Larger or mid-season	Yes		Yes	Yes	Yes	
	Later season	Yes		Yes	Yes	Yes	
2013	Early season or "first flush	Yes	Yes	Yes	Yes	Yes	No
	Larger or mid-season	Yes	Yes	Yes	Yes	Yes	No
	Later season	Yes	Yes	Yes	Yes	No	Yes
2014	Early season or "first flush	No	Yes	No	Yes	No	Yes
	Larger or mid-season	Yes	Yes	Yes	Yes	Yes	Yes
	Later season	No	No	No	Yes	Yes	Yes
	Total number of discrete samples	31 out of 48	32 out of 32	44 out of 48	39 out of 48	40 out of 48	28 out of 32

magnitude. Bay Area watersheds with geological sources of phosphorus such as appetite minerals may naturally release greater amounts of phosphorus.

Selenium and PBDE concentrations, two analytes being collected at a lesser frequency in this study (intended only for characterization) are particularly notable. In the Guadalupe River, mean selenium concentrations were 2 to 6-fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Across all six sites, Se concentrations averaged 0.6 µg/L. If these concentrations are representative and combined with average annual flow entering the Bay from the nine-county Bay Area (1.5 km^3 based on the RWSM: Lent et al., 2012), the total average annual Se load would be estimated to be 900 kg. Although this is less than the estimated average annual load entering the Bay from the Central Valley Rivers (16,000 kg/yr; David et al., in press), it is still a large component of the Se mass balance for the Bay. Maximum PBDE concentrations in North Richmond Pump Station were 33 to 60-fold greater than the PBDE maxima observed in the five other locations of this current study. These are the highest PBDE concentrations measured in Bay Area stormwater to-date (see section 8.2 for details). Additional investigation into the

Table 8. Synthesis of concentrations of pollutants of concern based on all quality assured data collected over the three sampling years at each location.

Analyte Name	Unit	Number (% detect)	Mean (std.error)	Number (% detect)	Mean (std.error)	Number (% detect)	Mean (std.error)	Number (% detect)	Mean (std.error)	Number (% detect)	Mean (std.error)	Number (% detect)	Mean (std.error)
SSC	mg/L	101 (94%)	108 (97%)	117 (95%)	136 (100%)	137 (98%)	96 (99%)	204 (23.5)	56.8 (5.57)	115 (13.8)	157 (12.3)	232 (31.4)	56.5 (6.27)
ΣPCB	ng/L	22 (100%)	32 (100%)	44 (100%)	39 (100%)	40 (100%)	29 (100%)	1.25 (0.258)	13.8 (1.57)	8.01 (1.16)	14.3 (2.4)	104 (27.5)	505 (261)
Total Hg	ng/L	31 (100%)	32 (100%)	44 (100%)	39 (100%)	40 (100%)	31 (100%)	38.4 (9.62)	39.6 (7.8)	106 (24.2)	212 (35.9)	47.6 (6.68)	18.2 (2.39)
Total MeHg	ng/L	20 (90%)	16 (100%)	30 (100%)	27 (100%)	27 (93%)	20 (100%)	0.291 (0.0741)	0.208 (0.0633)	0.397 (0.0663)	0.504 (0.0677)	0.295 (0.0376)	0.189 (0.033)
TOC	mg/L	30 (100%)	32 (100%)	44 (100%)	40 (100%)	40 (100%)	28 (100%)	7.13 (0.34)	11.2 (1.82)	8.24 (0.462)	12.2 (1.96)	10.1 (1.1)	20.5 (5.54)
NO3	mg/L	28 (96%)	32 (100%)	45 (100%)	36 (100%)	41 (100%)	28 (100%)	0.569 (0.0402)	0.976 (0.143)	0.425 (0.0659)	0.917 (0.099)	0.472 (0.0872)	0.466 (0.0864)
Total P	mg/L	30 (100%)	32 (100%)	44 (100%)	40 (100%)	41 (100%)	28 (100%)	0.415 (0.0441)	0.384 (0.0256)	0.288 (0.024)	0.414 (0.0376)	0.411 (0.0429)	0.29 (0.047)
PO4	mg/L	30 (100%)	31 (100%)	45 (100%)	40 (100%)	41 (100%)	28 (100%)	0.0987 (0.0074)	0.218 (0.0141)	0.1 (0.00412)	0.15 (0.0156)	0.128 (0.00905)	0.124 (0.0189)
Hardness	mg/L	4 (100%)	5 (100%)	8 (100%)	7 (100%)	8 (100%)	6 (100%)	176 (19.3)	129 (38.6)	56.5 (4.94)	138 (12.7)	124 (32.6)	69.8 (12)
Total Cu	ug/L	8 (100%)	8 (100%)	11 (100%)	10 (100%)	10 (100%)	7 (100%)	13.7 (3.59)	22.5 (4.49)	16.2 (3.07)	21.6 (2.87)	17.9 (1.88)	43.9 (10.1)
Dissolved Cu	ug/L	8 (100%)	8 (100%)	11 (100%)	10 (100%)	10 (100%)	7 (100%)	2.74 (0.588)	8.45 (1.53)	5.98 (0.682)	5 (0.939)	5.5 (1.09)	18.6 (3.91)
Total Se	ug/L	8 (100%)	8 (100%)	11 (100%)	10 (100%)	10 (100%)	7 (100%)	0.742 (0.103)	0.409 (0.0638)	0.223 (0.019)	1.31 (0.252)	0.606 (0.147)	0.292 (0.0632)
Dissolved Se	ug/L	8 (100%)	8 (100%)	11 (100%)	10 (100%)	10 (100%)	7 (100%)	0.647 (0.0886)	0.366 (0.0586)	0.166 (0.0149)	1.07 (0.266)	0.519 (0.146)	0.244 (0.0526)
Carbaryl	ng/L	8 (25%)	8 (88%)	12 (50%)	10 (90%)	10 (40%)	7 (100%)	3.63 (2.39)	21.6 (4.72)	5.82 (2.11)	29.5 (6.87)	6.5 (2.78)	105 (26.3)
Fipronil	ng/L	8 (100%)	8 (75%)	11 (91%)	10 (100%)	10 (90%)	7 (86%)	12.2 (1.19)	6.31 (1.92)	10.1 (1.89)	11.3 (1.56)	6.5 (1.13)	3.29 (0.68)
ΣPAH	ng/L	4 (100%)	4 (100%)	5 (100%)	11 (100%)	6 (100%)	6 (100%)	140 (46.5)	527 (279)	1260 (494)	416 (116)	1350 (455)	1660 (1070)
ΣPBDE	ng/L	4 (100%)	5 (100%)	5 (100%)	5 (100%)	6 (100%)	6 (100%)	27 (10.1)	789 (644)	28.5 (11.7)	60.8 (18.3)	47 (16)	45.6 (13.1)
Delta/ Tralomethrin	ng/L	8 (75%)	8 (75%)	10 (40%)	10 (50%)	9 (89%)	7 (43%)	1.5 (0.637)	2.29 (0.818)	0.391 (0.207)	0.852 (0.328)	1.77 (0.469)	0.386 (0.205)
Cypermethrin	ng/L	8 (88%)	8 (100%)	11 (55%)	10 (70%)	10 (80%)	7 (100%)	11.7 (8.24)	4.84 (1.38)	0.368 (0.115)	1.49 (0.512)	3.29 (0.63)	2.42 (0.663)
Cyhalothrin lambda	ng/L	7 (86%)	7 (100%)	9 (56%)	10 (70%)	8 (75%)	6 (83%)	1.23 (0.486)	1.1 (0.228)	0.616 (0.376)	0.556 (0.174)	0.656 (0.296)	0.35 (0.12)
Permethrin	ng/L	8 (75%)	8 (100%)	11 (55%)	10 (80%)	10 (100%)	7 (86%)	6.08 (2.29)	17.7 (5.91)	3.59 (1.24)	10.5 (2.34)	21.8 (3.61)	10.7 (3.03)
Bifenthrin	ng/L	8 (100%)	8 (100%)	11 (91%)	10 (90%)	10 (90%)	7 (100%)	75.2 (29.9)	5.88 (0.796)	8.08 (2.69)	5.29 (1.18)	8.01 (1.95)	5.14 (1.81)

Analyzed but not now I had somedetected: Fenpropathrin, Esfenvalerate/Fenvalerate, Cyfluthrin, Allethrin, Prallethrin, Phenothrin, Resmethrin. All Hardness results in WY 2013 were censored.

source-release processes of PBDE that are specific to Richmond, and lacking in the other watersheds, would be needed to better understand this result.

Concentration sampling during the three water years at the six locations has in part confirmed previously known or suspected high leverage watersheds (i.e. mercury in Guadalupe, PCBs in Sunnyvale East Channel and Pulgas Creek South). Concentration results have also raised some questions about certain pollutants in other watersheds (e.g. upper versus lower watershed Hg concentrations in San Leandro Creek, PBDE concentrations in North Richmond Pump Station). More sampling under a broader range of storm events (early season and first flush, larger storms during the mid-season and later season storms) would improve characterization of pollutants in those watersheds and increase confidence in the relative magnitude between watersheds and average annual loads estimates (baseline concentrations) that might form the basis for assessing trends (MQ3) at some future time. Although not the subject of this report, the RMP has provided funding to support the development of a POC loadings synthesis document (McKee et al. in preparation) and a trends strategy document (slated for preparation in summer 2015). A more thorough evaluation of existing data as a baseline for the trends management questions will be completed through those efforts.

5.5 Loads of pollutants of concern computed for each sampling location

One of the primary goals of this project and a key management question of the Small Tributary Loading Strategy was to estimate the annual loads of POCs from tributaries to the Bay (MQ2). In particular, large loads of POCs entering sensitive Bay margins are likely to have a disproportionate impact on beneficial uses (Greenfield and Allen, 2013). As described in the climatic section (5.2), given that the relationship between climate (manifested as either rainfall or resulting discharge) and watershed loads follows a power function, estimates of long-term average loads for a given watershed are highly influenced by samples collected during wetter than average conditions and rare high magnitude storm events. Comparing loads estimates between the sites was confounded by relatively small sample datasets collected during climatically dry years. However, based on data collected, average annual loads estimates for each sampling location have now been computed. Accepting these caveats, the following observations are made on the total wet season loads estimates at the six locations.

The magnitude of the total loads between watersheds is largely driven by drainage area of each watershed. In terms of total wet season loads from each of the six watersheds, the largest watershed sampled is the Guadalupe River, which also has the largest load for every pollutant estimated in this study. Conversely, Pulgas Creek South Pump Station is the smallest watershed in the study and has the lowest total wet season load (except for PCBs). As another example, methylmercury in San Leandro Creek (8.9 km^2) and Guadalupe River (236 km^2) have similar concentrations but Guadalupe River discharges more than 10x the total mass of methylmercury given the much greater overall discharge of runoff volume and sediments. There is one significant exception. As mentioned, Pulgas Creek Pump Station South exports a disproportionately large PCB load, greater than Lower Marsh Creek (160x larger), North Richmond Pump Station (3.3x larger), San Leandro Creek (15x larger), and Sunnyvale Channel (WY 2013 only, 25x larger) (Table 9).

Table 9. Loads of pollutants of concern during the sampling years at each sampling location.

Site	Water Year	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)	Loads Confidence	Loads Quality
Marsh Creek[a]	2012	1.61	233	11,380	1.34	64.0	0.262	956	175	578	Moderate (PCBs) Low (Hg)	Lack of sample data during storms that cause runoff and sediment transport through the upper watershed reservoir and data during a wet year.
	2013	5.82	2,703	39,500	16.0	408	2.78	3,474	666	4,212		
	2014	1.34	202	9,257	1.20	30.7	0.217	786	148	479		
North Richmond Pump Station[b]	2012	-	-	-	-	-	-	-	-	-	Moderate	Lack of data during wet year.
	2013	0.795	35.7	6,353	8.14	16.0	0.200	761	161	215		
	2014	0.499	20.4	6,197	4.76	15.8	0.117	478	101	186		
San Leandro Creek[c]	2012	7.30	158	40,483	16.4	221	1.57	1,973	571	1,404	Low	Lack of a robust discharge rating curve for higher flows; lack of data during reservoir release and during a wet year.
	2013	7.21	223	52,274	15.0	213	1.58	2,801	674	1,334		
	2014	0.243	28.0	1,840	1.93	25.4	2.89	97.1	23.4	70.6		
Guadalupe River	2012	25.8	2,106[1]	154,379	123	2,039	6.13	20,879	2,498	6,023	High (PCBs) Low (Hg)	Lack of long duration and high intensity storms sampled for Hg release from upper watershed. Confidence in PCB data supported by previous studies.
	2013	35.5	4,464[1]	238,208	309	5,476	13.6	25,775	3,771	10,829		
	2014	16.75	1,094	106,141	97.2	1,519	4.29	13,182	1,723	4,172		
Sunnyvale East Channel[d]	2012	1.31	56.4	8,227	50.9	25.9	0.382	335	139	395	Moderate	Lack of data during wet year. High variability in PCB concentrations between storm events.
	2013	1.51	508	8,685	87.9	87.6	3.26	369	159	689		
	2014	1.01	89.0	12,040	74.4	27.9	0.669	336	135	343		
Pulgas Creek Pump Station[e]	2012	-	-	-	-	-	-	-	-	-	Low	A lower quality (FWMC) approach applied to loads calculations. Lack of data during a wet year. High variability in PCB concentrations between storm events.
	2013	0.165	10.9	1,539	21.8	3.07	0.0291	41.1	12.8	33.0		
	2014	0.08	5.31	764	11.8	1.48	0.0141	20.1	6.31	16.1		

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12, 10/19/12 – 4/18/13 and 11/06/13 – 4/30/14.

[b] North Richmond Pump Station wet season loads are reported for the period of record 11/01/12 – 4/30/13 and 10/16/13 – 4/30/14.

[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12, 11/01/12 – 4/18/13 and 11/01/13 – 4/30/14.

[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12, 10/01/12 – 4/30/13 and 10/01/13 – 4/30/14.

[e] Pulgas Creek South Pump Station loads are estimates provided for the entire wet seasons (10/01/12 – 4/30/13 and 10/01/13 – 4/30/14) however monitoring only occurred during the period 12/17/2012 – 3/15/2012 and 10/22/13 – 4/30/14. Monthly loads for the non-monitored period were extrapolated using regression equations developed for the monthly rainfall and corresponding monthly (or partial month) contaminant load.

Comparison of total wet season loads between water years at the sites highlighted show how loads estimates can be highly variable even during three drier than average years. Additionally, the size and intensity of the storm events in the different regions where the sampling sites were located greatly impacted the load variation from year-to-year and between sampling locations. For example, PCB loads in Guadalupe River and San Leandro Creek were approximately 3- and 7-fold greater in WY 2012 than in WY 2014, whereas loads of PCBs were 13- and 8-fold larger in WY 2013 relative to WY2012 in Lower Marsh Creek and Sunnyvale East Channel, where the late November and December 2012 (WY2013) storms were comparatively larger events. Even when normalized to total discharge (in other words, the flow-weighted mean concentration [FWMC]), Sunnyvale East Channel transported 7-fold as much sediment in WY 2013 than WY 2012, whereas the FWMC of suspended sediment in San Leandro Creek was the same in WYs 2012 and 2013 and 5-fold greater in WY 2014 despite much lower flow. The relationship between FWMC and discharge (either at the annual or individual flood scale) can be used as an indicator of when enough data have been collected to characterize the site adequately to answer our management questions. FWMC should continue to increase relative to storm magnitude until watershed sources are exhausted; locations and analytes that reach that maximum will have sufficient data to compute reliable long term average annual loads. With the data currently in hand, attempts to estimate average annual loads will be biased low.

In light of these climatic considerations as well as the known data quality considerations and challenges at each of the sampling locations, the two far-right columns in Table 9 note the remaining level of confidence in the annual loads estimates as well as the main issues at each site which warrant the confidence level rating. Any future sampling at each of these locations should seek to alleviate these issues and to raise the quality of the data in relation to answering management questions.

5.6. Comparison of regression slopes and normalized loads estimates between watersheds

One of our key activities in relation to the Small Tributary Loading Strategy is improving our understanding of which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from pollutants of concern (MQ1) and therefore potentially represent watersheds where management actions should be implemented to have the greatest beneficial impact (MQ4). Multiple factors influence the treatability of pollutant loads in relation to impacts to San Francisco Bay. Conceptually, a large load of pollutant transported on a relatively small mass of sediment is more treatable than less polluted sediment. Therefore, the graphical function between either sediment concentration or turbidity provides a first order mechanism for ranking relative treatability of watersheds (Figure 2A). This method is valid for pollutants that are dominantly transported in a particulate form (total mercury and the sum of PCBs are good examples but pyrethroid pesticides and PBDEs may also be considered in this group) and when there is relatively little variation in the particle ratios between water years or storms or at least less variation than seen between watersheds. Note data presented at the October 2013 SPLWG meeting demonstrated that this assumption is sometimes violated and influences our perception of relative ranking.

These issues accepted, based on the ratios between turbidity and Hg, runoff derived from less urbanized upper portions of San Leandro Creek watershed and runoff from the Guadalupe River watershed exhibit the greatest particle ratios for total mercury (Figure 2). Sunnyvale East Channel, Marsh Creek and Pulgas Creek South Pump Station appear to have relatively low particle ratios for total mercury, although, Marsh Creek has not been observed under wet conditions when the possibility of mercury release from historic mining sources exists. The relative nature of these rankings has not changed in relation to the previous reports (McKee et al., 2013; Gilbreath et al., 2014).

In contrast, for the sum of PCBs, Pulgas Creek South Pump Station and Sunnyvale East Channel exhibit the highest particle ratios among these six watersheds, with urban sourced runoff from Guadalupe River and North Richmond Pump Station ranked 3rd and 4th as indicated by the turbidity-PCB graphical relation (Figure 2). Marsh Creek exhibits very low particle ratios for PCBs, an observation that is unlikely to change with additional samples given the likelihood of relatively low pollutant sources and relatively low variability of release-transport processes. Unlike for Hg, new data collected during WYs 2013 and 2014 alters the relative PCB rankings based on this graphical analysis providing an example of the influence of either low sample numbers or the random nature of sample capture on the resulting interpretation of particle ratios (as discussed in the October 2013 SPLWG meeting). Given the relatively wide confidence intervals around these lines (not shown) and the collection during relatively dry years, the relative nature of these regression equations may change if there are any future samples completed.

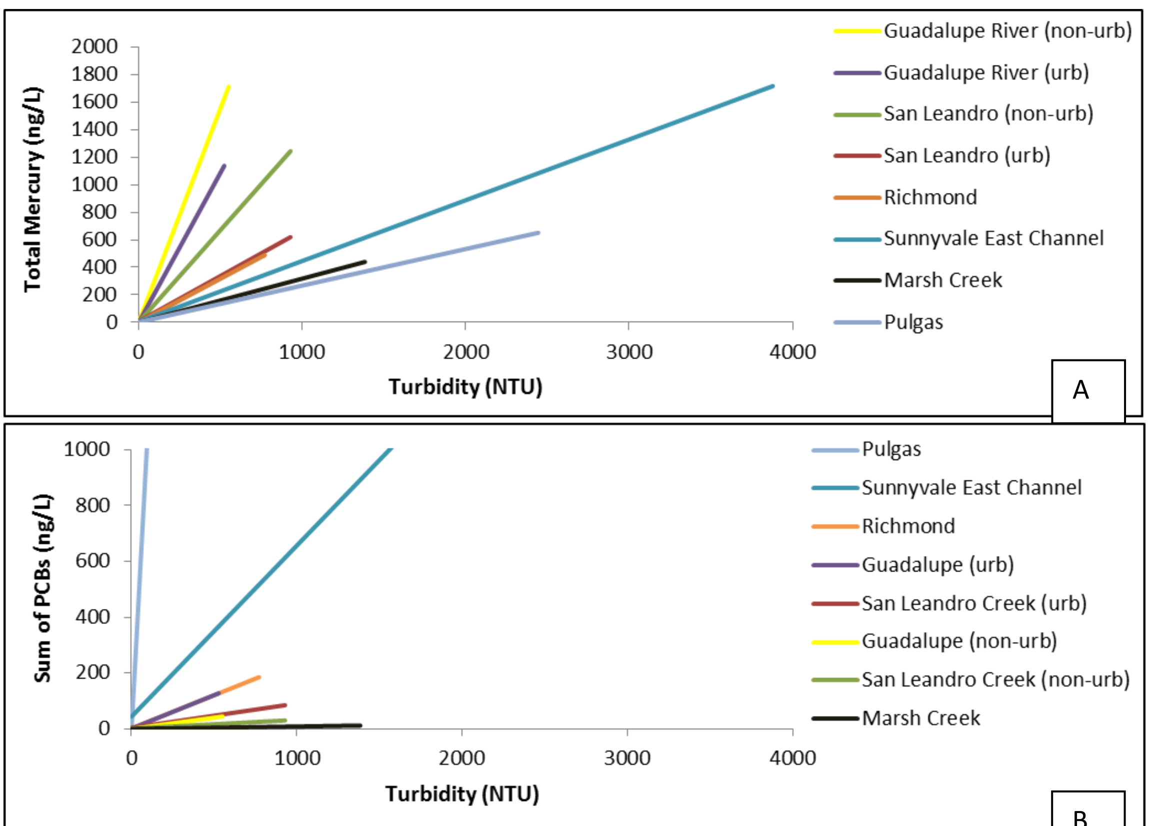

Figure 2. Comparison of regression slopes between watersheds based on data collected during sampling for A) Total Mercury and B) PCBs. Turbidity range shown on graphs represents minimum and maximum turbidities for entire sampling period

Another influence on potential treatability is the size of the watershed. Conceptually, a large load that is transported from a relatively small watershed and therefore in association with a relatively small volume of water is more manageable. Efforts to manage flows from the North Richmond Pump Station watershed exemplify this type of opportunity. Thus, area normalized loads (yields) provide another useful mechanism for first order ranking of watersheds (Table 10) in relation to ease of management. This method is more highly subject to climatic variation than the turbidity function/particle ratio method for ranking and therefore was done on climatically averaged loads. Despite these challenges, in a general sense, the relative rankings for PCBs exhibit a similar ranking to the particle ratio method; Pulgas Creek South Pump Station watershed ranked highest and Marsh Creek watershed ranked lowest. However the relative ranking of the other watersheds is not similar. In the case of mercury, Guadalupe River and San Leandro Creek exhibit the highest currently estimated yields corroborating the evidence from the particle ratio method. Similar to PCBs, the relative ranking of the other four watersheds is not similar to the particle ratio method. Given all our observations were during relatively dry years, it is difficult to know the certainty of the relative nature of the area-normalized estimates. For example, the relative rankings for suspended sediment loads normalized by unit area would likely change substantially with the addition of data from a water year that exceeds the climatic normal for each watershed; total phosphorus unit loads would also respond in a similar manner. For pollutants such as PCBs and total Hg that are found in specific source areas such as industrial and mining areas (Hg only) of these watersheds, release processes will likely be influenced by both climatic factors and sediment transport off impervious surfaces; also factors that are not likely well captured by the sampling that has occurred under relatively dry conditions.

6. Conclusions and next steps

6.1. Current and future uses of the data

The monitoring program implemented during the study was designed primarily to improve estimates of watershed-specific and regional loads to the Bay (MQ2) and secondly, to provide baseline data to support evaluation of trends towards concentration or loads reductions in the future (conceptually one or two decades hence) (MQ3) (see introduction section) in compliance with MRP provision C.8.e. (SFRWRCB, 2009). Multiple metrics have been developed and presented in this report to support these management questions:

- Pollutant loads: Pollutant loading estimates can help measure relative delivery of pollutants to sensitive Bay margin habitats and support calibration and verification of the Regional Watershed Spreadsheet Model and resulting regional scale loading estimates.
- Flow Weighted Mean Concentrations: FWMC can help to identify when sufficient data has been collected to adequately characterize watershed processes in relation to a specific pollutant in the context of management questions.
- Sediment-pollutant particle ratios: Particle ratios can help identify relative watershed pollution levels on a particle basis and relates to treatment potential.
- Pollutant area yields: Pollutant yields can help identify pollutant sources and relates to treatment potential.

Table 10. Climatically averaged area normalized loads (yields) ranked in relation to PCBs based on free flowing areas downstream from reservoirs (See Table 1 for areas used in the computations).

	Unit runoff (m)	SS (t/km^2)	TOC (mg/m^2)	PCBs (µg/m^2)	HgT (µg/m^2)	MeHgT (µg/m^2)	NO3 (mg/m^2)	PO4 (mg/m^2)	Total P (mg/m^2)
Marsh Creek	0.13	80.0	916	0.474	13.8	0.0423	79.7	15.1	76.6
North Richmond Pump Station	0.52	26.1	4,684	5.84	13.7	0.143	497	105	157
San Leandro Creek	0.95	53.3	5,957	3.36	55.4	0.260	317	81.9	216
Guadalupe River	0.24	272	1,926	20.3	282	0.196	169	28.1	116
Sunnyvale East Channel	0.17	33.6	1,220	9.44	5.95	0.116	45.8	19.3	63.9
Pulgas Creek Pump Station	0.63	41.8	5,907	84.6	11.8	0.111	158	49.2	127

- Correlation of pollutants: Finding co-related pollutants helps identify those watersheds with multiple sources and provides additional cost/benefit for management actions.

As discussed briefly in the introduction (section 1), as management effort focuses more and more on locating high leverage watersheds and patches within watersheds, the monitoring (and modeling) design is evolving.

6.2. What data gaps remain at current loads stations?

With regard to addressing the main management endpoints (single watershed and regional watershed loads and baseline data for trends) that influenced the monitoring design recommended by Melwani et al 2010 and described in each iteration of the MYP (BASMAA, 2011; BASMAA, 2012; BASMAA, 2013), an important question that managers are asking is how to determine when sufficient data have been collected. Several sub-questions are important when trying to make this determination. Are the data representative of climatic variability; have storms and years been sampled well enough relative to expected climatic variation? Are the data representative of the source-release-transport processes of the pollutant of interest? In reality, these factors tend to juxtapose and after three years of monitoring during relatively dry climatic conditions, some data gaps remain for each of the monitoring locations.

- Marsh Creek watershed has been sampled for three WYs. Continuous turbidity data were rated excellent at Lower Marsh Creek. Ample lower watershed stormwater runoff data are now available at Lower Marsh Creek, but this site is lacking information on high intensity upper watershed rain events where sediment mobilization from the historic mercury mining area could occur. Any future sampling would ideally be focused on Hg and for storms of greater intensity preferably when spillage is occurring from the upstream reservoir. No further PCB data are recommended. The sampling design to achieve these goals could be revisited with the objective of increased cost efficiency for data gathering to support remaining unanswered management questions.

- North Richmond Pump Station watershed has been sampled for two WYs (although data exist from a previous study [Hunt et al., 2012]). Additional data in relation to early season (seasonal 1st flush or early season storms) would help improve estimates of loads that could be averted from diversion of early season storms to wastewater treatment. Further data collection in relation to high concentrations of PBDEs would increase our understanding of PBDE source(s) in this watershed.
- San Leandro Creek watershed has been sampled for three WYs. San Leandro Creek received poor ratings on the quality of discharge information and completeness of turbidity data. The largest weakness is the scarcity of velocity measurements to adequately describe the stage-discharge rating curve for stages >2 feet and generate a continuous flow record. Additional velocity measurements are necessary to increase the accuracy and precision of discharge data for the site and support the computation of loads. There is currently no information on pollutant concentrations during reservoir releases, yet volumetrically, reservoir releases during WYs 2012 and 2013 were proportionally large but may have been atypical. Sample collection during release would help elucidate pollutant load contributions from the reservoir. Data collection during more intense rainstorms are also desirable for this site given the complex sources of PCBs and mercury in the watershed and the existence of areas of less intense land use and open space lending to likely relatively high inter-annual variability of water and sediment production.
- Guadalupe River watershed has been sampled at the Hwy 101 location during nine water years (WY 2003-2006, 2010-2014) to-date, but data are still lacking to adequately describe high intensity upper watershed rain events when mercury may still be released from sources in relation to historic mining activities. This type of information could help estimate the upper range of mercury loads from the mercury mining district and continue to help focus management attention. Further data collection in Guadalupe River watershed should focus on Hg sampling during high intensity storms. Further sampling of relatively frequent smaller runoff events is unnecessary and transport processes for PCBs are well supported by currently available data. The current sampling design is not cost-effective for gathering improved information to support management decisions in this watershed.
- Sunnyvale East Channel initially received poor quality data ratings for turbidity but this improved substantially in WYs 2013 and 2014. However, more storm event POC data are needed for establishing higher confidence in particle ratios, pollutant loads, FWMCs, and yields. A PCB source was apparently mobilized during the February 28, 2014 storm which had very high PCB concentrations, and this source seemed to continue to flush through the system in subsequent events. Because of this, our PCB regression with turbidity is not strong, creating uncertainty around the accuracy of the total PCB load estimate (e.g. what PCB sources might have moved through the system when we were not sampling?). Further data are needed in this watershed to better understand source-release-transport processes for PCBs.
- Based on the current review of the data, Pulgas Creek South Pump Station received a poor data quality rating for turbidity. Monitoring at this site was complicated by the logistical limitations of monitoring in a highly dynamic storm drain system. The challenging logistics of this site led to delays in the initiation of monitoring in WY 2013 as BASMAA/KLI worked to establish a

monitoring plan and functional instrumentation configuration (e.g., during WY 2013, turbidity data were only collected during three of the seven wet season months due to these challenges). In addition, because this site was located within a storm drain and vault adjacent to a pump station, the periodic operation of the pumps likely contributed to turbidity spikes and generally noisy nature of the data. Following review of WY 2014 observations, it was decided to reject the whole turbidity data set from this site. Although not feasible under the scope of this project, BASMAA has suggested they may undertake further review of this dataset, including application of smoothing functions to better fit the pollutant data to the turbidity record and potentially improve the usability of these data. KLI collected a robust manual turbidity sample set in combination with the pollutant sampling. Although they did not accurately record the times of this sample collection and therefore a relationship between manual turbidity and the sensor turbidity record for discrete times cannot be developed, a relationship between manual collection and smoothed sensor data (e.g. smoothed over 15-30 minutes) could potentially be developed. This could then validate the data quality of the smoothed turbidity data, and allow future use of these data for the development of the turbidity-pollutant regressions. However, because of the dynamic nature of this system (e.g. the sensor record showed changes >500 NTU in a 15 minute period), the likelihood of forming acceptable regressions between pollutant data and smoothed turbidity data seems low. More importantly, the cyclical spiking of the turbidity record suggests resuspension of settled sediments during pump outs. If the turbidity sensor was measuring resuspension of sediment in the vault, the turbidity sensor was measuring the turbidity caused by that sediment when it initially entered the vault, as well as when it was resuspended; in other words, the sensor record includes in some portions twice-measured sediment/turbidity. Therefore, the continuous turbidity record likely does not accurately represent the turbidity within the system, and consequently an accurate, continuous record for any pollutant likely cannot be established using the turbidity surrogate regression method even in the event that a pollutant-turbidity regression could be developed through smoothing. The sampling program began at this location (and North Richmond Pump Station) in WY 2013 as compared to WY 2012 at the other sites, and so despite being one of the most logistically challenging sites to set up for monitoring, BASMAA/KLI also had the least amount of time to execute it (arguably North Richmond Pump Station was also logistically challenging but SFEI had already completed two years of sampling at this location for another project, during which some of the instrumentation set-up challenges had been worked through). Due to both the delay in monitoring initiation at Pulgas combined with the very low rainfall in WY 2013, only a single storm was monitored and therefore very little data was available from WY 2013 in which to assess these issues. In short, although this has been a three-year project, this is really the first year that a substantial dataset has been available to evaluate for the Pulgas Ck Pump Station site. On the positive side, there are nearly two full wet seasons of flow data as well as seven storms worth of pollutant data, including the highest PCB concentrations observed to-date in the Bay Area. Despite challenges with the continuous turbidity record, these other data are valuable and less robust estimates of load are possible based on the FWMC approach. Additionally, because KLI also collected manual turbidity samples during pollutant sample collection, the pollutant data could potentially still be used to estimate loads using turbidity surrogate regression if a high quality relationship between the manually collected turbidity record and a continuous record could be established. Now that the monitoring challenges for this site are better understood, additional effort to improve the continuous turbidity monitoring at this location would be desirable to increase confidence in particle ratios, pollutant loads, FWMCs, and yields.

6.3. Next Steps

Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board in relation to reissuing the MRP (and discussion at the October 2013 and May 2014 SPLWG meetings) have highlighted the increasing focus towards finding watersheds and land areas within watersheds for management focus (MQ4). The monitoring design described in this report is not appropriate for this increasing management focus. There are various alternative monitoring designs that are more cost-effective for addressing the increasing focus in the second MRP permit term towards finding watersheds and land areas within watersheds for management attention while still supporting the other STLS management questions in a programmatic manner. The challenge for the STLS and SPWLG is finding the right balance between the different alternatives within budget constraints. Sampling during WY 2015 is using the following reconnaissance characterization design:

- Collaboration with stormwater Countywide programs to identify locations with possible PCB and/or mercury sources (based on a GIS based analysis)
- Focused sampling in older industrial drainages (some of which are tidally influenced)
- Composite sampling: 1 composite per storm/per analyte for PCB, total mercury, total metals, SSC, grain size, TOC/DOC; 5-15 aliquots per composite sample
- Pilot testing passive sediment samplers

The advantage of the reconnaissance sampling design is flexibility and given recent advances on the development of the RWSM (SFEI in preparation) have indicated the value of the data collected previously using the reconnaissance design (McKee et al., 2012), it seems likely that the reconnaissance design may end up being the most cost-effective going forward over the next three or more years. Data and information gathered over the last 10+ years guided by the SPLWG and STLS will continue to help guide the development of a cost effective monitoring design to adapt to changing management needs.

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8. Detailed information for each sampling location

8.1. Marsh Creek

8.1.1. Marsh Creek flow

The US geological survey has maintained a flow record on Marsh Creek (gauge number 11337600) since October 1, 2000 (13 WYs). Data collection at this site was discontinued after September 30, 2013 due to budget reductions. Flow for WY 2014 was based on a continuous stage record generated by the STLS sampling team combined with the flow rating curve provided by the USGS. Peak annual flows for the 14 years have ranged between 168 cfs (1/22/2009) and 1770 cfs (1/2/2006). For the same period, annual runoff has ranged between 3.03 Mm^3 (WY 2009) and 26.8 Mm^3 (WY 2006). In the Bay Area, at least 30 years of observations are needed at a particular site to get a reasonable understanding of climatic variability (McKee et al., 2003). Since, at this time, Marsh Creek has a relatively short history of gauging, flow record on Marsh Creek were compared with a reasonably long record at an adjacent monitoring station near San Ramon. Based on this comparison, WY 2006 may be considered representative of very rare wet conditions (upper 10th percentile) and WY 2009 is perhaps representative of moderately rare dry conditions (lower 20th percentile) based on records that began in WY 1953 at San Ramon Creek near San Ramon (USGS gauge number 11182500).

A number of relatively minor storms occurred during WYs 2012, 2013, and 2014 (Figure 3). In WY 2012, flow peaked at 174 cfs on 1/21/2012 at 1:30 am and then again 51 ½ hours later at 143 cfs on 1/23/2012 at 5:00 am. Total runoff during the whole of WY 2012 (October 1st to September 30th) was 1.87 Mm^3. During WY 2013, flow peaked at 1300 cfs at 10:00 am on 11/30/2012; total run-off for the water year was 6.26 Mm^3. During WY 2014, flow peaked at 441 cfs on 2/28/2014 at 6:20 am and total runoff was 1.31 Mm^3, the lowest of the 3 years of observations during the study and the lowest in the 14 year record for the site. Although the peak discharge for WY 2013 was the second highest since records began in WY 2001, total annual flow ranked eighth in the last 13 years. Thus, discharge of these magnitudes for all three water years are likely exceeded most years in this watershed. Rainfall data corroborates this assertion; rainfall during WYs 2012, 2013, and 2014 respectively were 70%, 71%, and 61% of mean annual precipitation (MAP) based on a long-term record at Concord Wastewater treatment plant (NOAA gauge number 041967) for the period Climate Year (CY) 1992-2014. Marsh Creek has a history of mercury mining in the upper part of the watershed. The Marsh Creek Reservoir is downstream from the historic mining area but upstream of the current gauging location. During WYs 2012 to 2014, discharge through the reservoir occurred on March, November, and December 2012. It is possible that in the future when larger releases occur, additional Hg loads may be transported down the Creek system but for these dry years, this was not a big component of the flow-source-transport process.

8.1.2. Marsh Creek turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. During WY 2012, turbidity peaked at 532 NTU during a late season storm on 4/13/12 at 7 pm. Relative to flow magnitude, turbidity remained elevated during all storms and was the greatest during the last storm despite lower flow. During WY 2013, turbidity peaked at 1384 NTU during the December storm series on 12/02/12 at 7:05

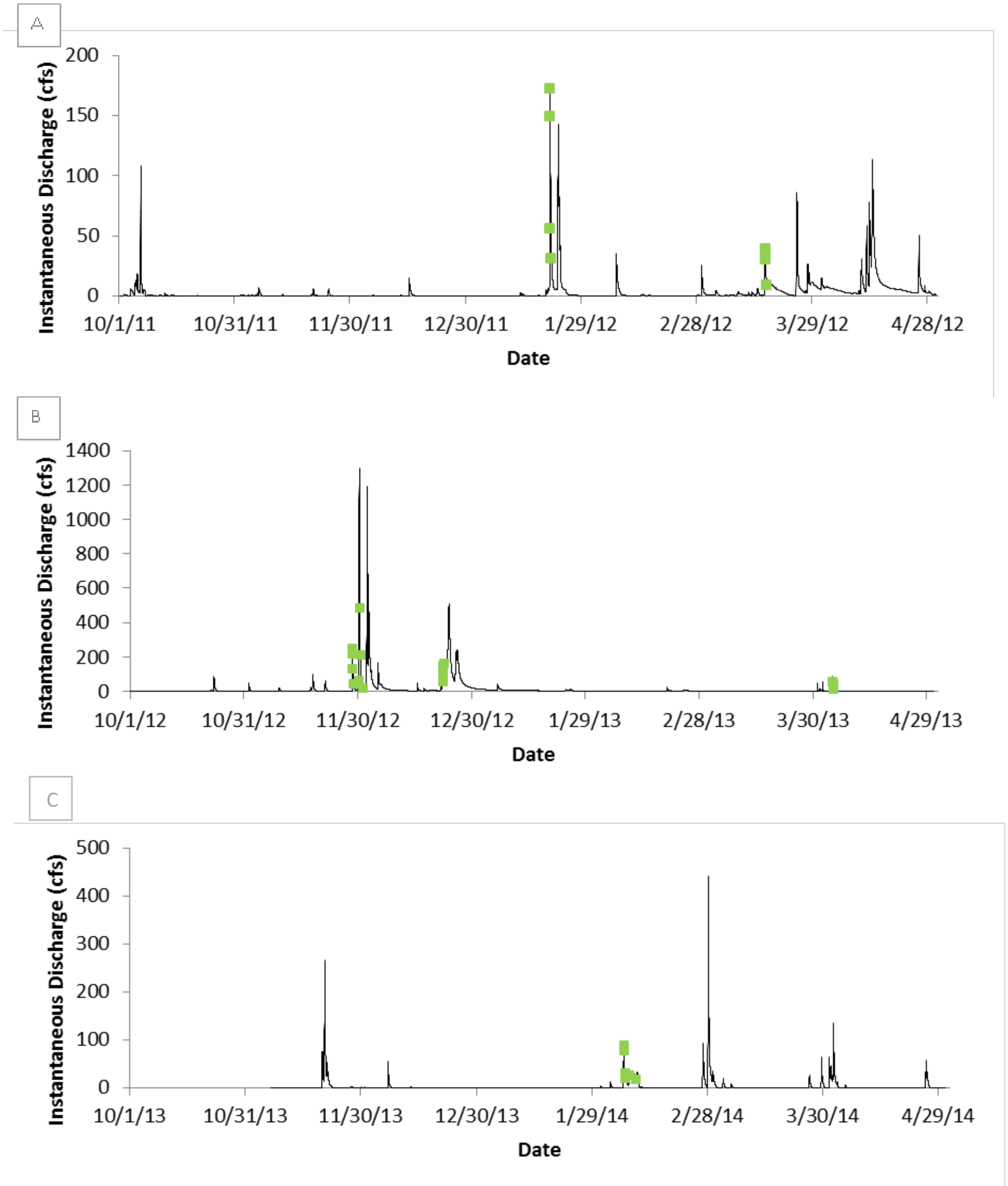

Figure 3. Flow characteristics in Marsh Creek during Water Year 2012 (A) and Water Year 2013 (B) based on published 15 minute data provided by the United States Geological Survey, gauge number 11337600) with sampling events plotted in green. Flow for WY 2014 (C) was based on stage measurements taken by the STLS study team combined with the USGS rating curve for the site.

pm. This occurred during a period when the Marsh Creek Reservoir was overflowing. During WY 2014, turbidity peaked at 458 NTU during the November storm on 11/20/2013 at 2:30 pm, very similar to the peak turbidity (432 NTU) observed later in the year during the storm that yielded the peak flow for the year. These observations, and observations made previously during the RMP reconnaissance study (maximum 3211 NTU; McKee et al., 2012), provide evidence that during larger storms and wetter years, the Marsh Creek watershed is capable of much greater sediment erosion and transport than occurred during observations in the three WYs reported here, resulting in greater turbidity and concentrations of suspended sediment. The OBS-500 instrument utilized at this sampling location with a range of 0-4000 NTU will likely be exceeded during larger storms if such storms are observed during some future sampling effort.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. Computed SSC peaked at 1312 mg/L during the 4/13/12 late season storm, at 1849 mg/L on 12/02/12, and at 682 mg/L on 11/20/2013 at 2:30 pm at the same times as the peaks in turbidity. During WY 2012, relative to flow magnitude, SSC remained elevated during all storms and was the greatest during the last storm despite lower flow. A similar pattern was also observed during WY 2013. Turbidity and computed SSC peaked during a smaller storm in December rather than the largest storm which occurred in late November. Turbidity remained relatively elevated from an even smaller storm that occurred on December 24th. This pattern was not observed in WY 2014 perhaps because storms were minor and few. Observations of increased sediment transport as the season progresses relative to flow in addition to the maximum SSC observed during the RMP reconnaissance study of 4139 mg/L (McKee et al., 2012), suggest that in wetter years, greater SSC can be expected.

8.1.3. Marsh Creek POC concentrations summary (summary statistics)

In relation to the other five monitoring locations, Marsh Creek is representative of a relatively rural watershed with lower urbanization but potentially impacted by mercury residues from historic mining upstream. Summary statistics (Table 11) were used to provide useful information to compare Marsh Creek water quality to other Bay Area streams. The comparison of summary statistics to knowledge from other watersheds and conceptual models of pollutant sources and transport processes provided a further check on data quality.

The maximum PCB concentration (4.32 ng/L) was similar to background concentrations normally found in relatively nonurban areas (Lent and McKee, 2011). For example, maximum concentrations in watersheds with little to no urbanization dominated by agriculture and open space exhibit average concentrations <5 ng/l (David et al., in press; Foster et al., 2000a; Howell et al. 2011; McKee et al., 2012). In instances where urbanization and industrial sources are highly diluted by >75% developed agricultural land concentrations averaging 8.9 ng/L can be observed (Gómez-Gutiérrez et al., 2006). Marsh Creek, at the sampling point, has the lowest percentage imperviousness (10%) of any Bay Area watershed measured to-date for PCBs and exhibits the lowest measured particle ratio of 5 pg/mg. If this is taken to be background for the Bay Area, any rural watershed with little urban land use that has suspended sediment concentrations during flood periods exceeding 1000 mg/L could be expected to exhibit PCB concentrations exceeding 5 ng/L. Of the 23 Bay Area watersheds reviewed by McKee et al. (2003), rural dominated areas including Cull Creek above Cull Creek Reservoir, San Lorenzo Creek above Don Castro Reservoir, Wildcat Creek near the park entrance, and Crow Creek exhibited FWMC > 1000 mg/L and could, if measured, show similar PCB concentrations to those observed in Marsh Creek.

Maximum total mercury concentrations (252 ng/L) were similar to concentrations found in mixed land use watersheds with some urban related influence such as atmospheric burden (McKee et al., 2004; Lent and McKee, 2011). Given global Hg cycling has a large atmospheric component (Fitzgerald et al., 1998; Lamborg et al., 2002; Steding and Flegal, 2002) and background soil concentrations in California are typically on the order of 0.1 mg/kg (equivalent to ng/mg) (Bradford et al., 1996), concentrations of this magnitude in a watershed with higher sediment erosion and higher average suspended sediment concentrations can occur when associated with the transport of low concentration particles (McKee et al., 2012). Thus Bay Area watersheds that exhibit suspended sediment concentrations in excess of 2,000 mg/L during floods should exhibit total Hg concentrations during floods in excess of 200 ng/L, even when no urban or mining sources are present. The particle ratio of Hg in Marsh Creek averaged 0.21 mg/kg for the three years of study, only 3-fold background CA soils concentrations, and was the 5th lowest observed in Bay Area watersheds to-date.

Maximum MeHg concentrations (0.407 ng/L during WY 2012, 1.2 ng/L during WY 2013, and ND during WY 2014 for the single sample collected at low flow) were greater during the first two years of observations than the proposed implementation goal of 0.06 ng/l for methylmercury in ambient water for watersheds tributary to the Central Delta (Wood et al., 2010: Table 4.1, page 40), however concentrations of this magnitude or greater have been observed in a number of Bay Area watersheds (Guadalupe River: McKee et al., 2006; McKee et al., 2010; Zone 4 Line A: Gilbreath et al., 2012; Glen Echo Creek and Zone 5 Line M: McKee et al., 2012). Indeed, concentrations of methylmercury of this magnitude have commonly been observed in rural watersheds (Domagalski, 2001; Balogh et al., 2002) and production has been related to organic carbon transport, riparian processes and percentage of watershed with wetlands (Balogh et al., 2002; Balogh et al., 2004; Barringer et al., 2010; Zheng et al., 2010; Bradely et al., 2011). Although local Hg sources can be a factor in helping to elevate MeHg production and food-web impacts, it is generally agreed that Hg sources are not a primary limiting factor in MeHg production.

Nutrient concentrations appear to be reasonably typical of other Bay Area rural watersheds (McKee and Krottje, 2005; Pearce et al., 2005) but perhaps a little greater for PO4 and TP than concentrations found in watersheds in grazing land use from other parts of the country and world (e.g. three rural dominated watersheds North Carolina: Line, 2013; comprehensive Australian literature review for concentrations bay land use class: Bartley et al., 2012). This appears typical in the Bay Area; phosphorus concentrations appear greater than elsewhere in the world under similar land use scenarios, an observation perhaps attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005; Pearce et al., 2005).

Organic carbon concentrations observed in Marsh Creek were lesser than observed in Z4LA (max = 23 mg/L; FWMC = 12 mg/L: Gilbreath et al., 2012) but compared more closely to Belmont, Borel, Calabazas, San Tomas, and Walnut Creeks (McKee et al., 2012). Indeed, TOC concentrations of 4-12 mg/L have been observed elsewhere in California (Sacramento River: Sickman et al., 2007).

For pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients), concentrations exhibited the typical pattern of median < mean with the exception of organic carbon. A similar style of first order quality assurance based on comparisons to observations in other studies is also possible for analytes measured at a lower frequency. Pollutants sampled at a lesser frequency using composite sampling design (see methods section) and appropriate for characterization only (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) were quite low and similar to concentrations found in watersheds with limited or no urban influences. Carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L: Moran, 2007) (Carbaryl: DL - 700 ng/L: Ensiminger et al., 2012). The Carbaryl concentrations we observed were more similar to those observed in tributaries to Salton Sea, Southern CA (geometric mean ~2-10 ng/L: LeBlanc and Kuivila, 2008). Pyrethroid concentrations of Delta/ Tralomethrin were similar to those observed in Zone 4 Line A, a small 100% urban tributary in Hayward, whereas concentrations of Permethrin and Cyhalothrin lambda were about 10-fold and 2-fold lower and concentrations of Bifenthrin were about 5-fold higher; cypermethrin was not detected in Z4LA (Gilbreath et al., 2012). In summary, the statistics indicate pollutant concentrations typical of a Bay Area non-urban stream and there is no reason to suspect data quality issues.

8.1.2. Marsh Creek toxicity

Composite water samples were collected at the Marsh Creek station during two storm events in WY 2012, four storm events in WY 2013 and two events in WY 2014. No significant reductions in the survival, reproduction and growth of three of four test species were observed during WY 2012 – WY 2014 except two occurrences of fathead minnow testing with 17% mortality rate (WY 2014 sample) and 42% mortality rate (WY 2013). Significant reductions in the survival of the amphipod Hyalella azteca was observed during both WY 2012 storm events while WY 2013 and 2014 had complete mortality of Hyalella Azteca between 5 and 10 days of exposure to storm water during all storm events.

Table 11. Summary of laboratory measured pollutant concentrations in Marsh Creek during WY 2012, 2013, and 2014.

		2012							2013							2014						
Analyte	Unit	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	27	96%	0	930	180	297	276	54	100%	3.3	1040	167	217	230	20	75%	0	161	12	41.9	57
ΣPCB	ng/L	7	100%	0.354	4.32	1.27	1.95	1.61	15	100%	0.24	3.46	0.676	0.927	0.856							
Total Hg	ng/L	8	100%	8.31	252	34.5	74.3	85.2	17	100%	1.9	120	19	32.5	33.9	6	100%	2.4	18	4.55	7.35	6.02
Total MeHg	ng/L	5	100%	0.085	0.406	0.185	0.218	0.12	14	93%	0	1.2	0.185	0.337	0.381	1	0%	0	0	0	0	
TOC	mg/L	8	100%	4.6	12.4	8.55	8.34	2.37	16	100%	4.3	9.5	6.55	6.52	1.6	6	100%	6	8.7	7.05	7.17	1.04
NO3	mg/L	8	100%	0.47	1.1	0.635	0.676	0.202	16	94%	0	1	0.525	0.531	0.222	4	100%	0.28	0.59	0.575	0.505	0.15
Total P	mg/L	8	100%	0.295	1.1	0.545	0.576	0.285	16	100%	0.14	0.95	0.34	0.395	0.21	6	100%	0.097	0.5	0.22	0.255	0.137
PO4	mg/L	8	100%	0.022	0.12	0.0563	0.0654	0.0298	16	100%	0.046	0.18	0.11	0.114	0.0365	6	100%	0.046	0.15	0.108	0.101	0.0415
Hardness	mg/L	2	100%	200	203	202	202	2.12								2	100%	120	180	150	150	42.4
Total Cu	ug/L	2	100%	13.8	27.5	20.6	20.6	9.7	4	100%	3.8	30	12.5	14.7	11	2	100%	4.5	4.7	4.6	4.6	0.141
Dissolved Cu	ug/L	2	100%	4.99	5.62	5.3	5.3	0.445	4	100%	1.3	2.4	1.45	1.65	0.52	2	100%	2.1	2.6	2.35	2.35	0.354
Total Se	ug/L	2	100%	0.647	0.784	0.716	0.716	0.0969	4	100%	0.525	1.4	0.67	0.816	0.395	2	100%	0.44	0.8	0.62	0.62	0.255
Dissolved Se	ug/L	2	100%	0.483	0.802	0.643	0.643	0.226	4	100%	0.51	1.2	0.585	0.72	0.323	2	100%	0.42	0.59	0.505	0.505	0.12
Carbaryl	ng/L	2	50%	0	16	8	8	11.3	4	25%	0	13	0	3.25	6.5	2	0%	0	0	0	0	0
Fipronil	ng/L	2	100%	7	18	12.5	12.5	7.78	4	100%	10	13	10.8	11.1	1.44	2	100%	13	15	14	14	1.41
ΣPAH	ng/L	1	100%	216	216	216	216		2	100%	85.7	222	154	154	96.4	1	100%	37.8	37.8	37.8	37.8	
ΣPBDE	ng/L	1	100%	20	20	20	20		2	100%	11.2	56.4	33.8	33.8	32	1	100%	20.3	20.3	20.3	20.3	
Delta/ Tralomethrin	ng/L	2	100%	0.954	5.52	3.23	3.23	3.23	4	75%	0	2.2	0.75	0.925	0.943	2	50%	0	1.8	0.9	0.9	1.27
Cypermethrin	ng/L	2	50%	0	68.5	34.2	34.2	48.4	4	100%	1.8	13	2.15	4.78	5.49	2	100%	0.6	5.3	2.95	2.95	3.32
Cyhalothrin lambda	ng/L	2	50%	0	2.92	1.46	1.46	2.06	4	100%	0.5	3.2	0.8	1.33	1.27	1	100%	0.4	0.4	0.4	0.4	
Permethrin	ng/L	2	100%	3.81	17.3	10.6	10.6	9.54	4	75%	0	12	6.55	6.28	6.11	2	50%	0	2.4	1.2	1.2	1.7
Bifenthrin	ng/L	2	100%	25.3	257	141	141	163	4	100%	27	150	45	66.8	56.2	2	100%	20	33	26.5	26.5	9.19

Analyzed but not detected: Fenpropathrin, Esfenvalerate/ Fenvalerate, Cyfluthrin, Allethrin, Prallethrin, Phenothrin, and Resmethrin
Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at Marsh Creek was two.
All Hardness results in WY 2013 were censored.

8.1.3. Marsh Creek loading estimates

Site-specific methods were developed for computed loads (Table 12). Methylmercury data was flow-stratified for improved relationships between turbidity and the pollutant under different flow conditions. Preliminary loads estimates generated for WY 2012 and reported by McKee et al. (2013) have now been revised based on additional data collected in WY 2013 and 2014 and an improving understanding of pollutant transport processes for the site. Monthly loading estimates correlate well with monthly discharge (Table 13). There are no data available for October and November 2011 and October 2013 because monitoring equipment was not installed. Monthly discharge was greatest in December 2012 as were the monthly loads for each of the pollutants regardless of transport mode (dominantly particulate or dissolved). The discharge was relatively high for December given the rainfall, an indicator that the watershed was reasonably saturated by this time. The sediment loads are well-aligned with the total discharge and the very high December 2012 sediment load appears real; the watershed became saturated after late November rains such that early December and Christmas time storms transported a lot of sediment. Monthly loads of total Hg appear to correlate with discharge for all months; this would not be the case if there was variable release of mercury from historic mining sources upstream associated with climatic and reservoir discharge conditions. Importantly, if data were to be collected to capture periods when saturated and high rainfall conditions occur along with reservoir releases, new information may emerge about the influence, if any, of Hg pollution associated with historic mining. If these conditions were to result in significant Hg releases, then any estimate of long term average load might be elevated above what can be computed now. Given the very dry flow conditions of WYs 2012, 2013, and 2014 (see discussion on flow above), loads presented here are considered representative of dry conditions.

Table 12. Regression equations used for loads computations for Marsh Creek during water years 2012, 2013 and 2014.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/L/NTU)	Mainly urban	1.49		0.63	Regression with turbidity
Total PCBs (ng/L/NTU)	Mainly urban	0.00878		0.86	Regression with turbidity
Total Mercury (ng/L/NTU)	Mainly urban	0.3174		0.68	Regression with turbidity
Total Methylmercury (ng/L/NTU) - Storm Flows	Mainly urban	0.00136	0.0199	0.86	Regression with turbidity
Total Methylmercury (ng/L/NTU) - Low Flow[a]	Mainly urban	0.0067	0.039	0.94	Regression with turbidity
Total Organic Carbon (mg/L)	Mainly urban	6.9			Flow weighted mean concentration
Total Phosphorous (mg/L/NTU)	Mainly urban	0.00174	0.176	0.71	Regression with turbidity
Nitrate (mg/L)	Mainly urban	0.594			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.111			Flow weighted mean concentration

[a] Includes small storms after extended dry periods.

Table 13. Monthly loads for Lower Marsh Creek during water years 2012 - 2014. Italicized loads are estimated based on monthly rainfall-load relationships.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	33	*0.153*	*9.59*	*1,057*	*0.056*	*1.73*	*0.0224*	*91.0*	*17.0*	*44.2*
	11-Nov	26	*0.0717*	*2.72*	*495*	*0.0159*	*0.50*	*0.0087*	*42.6*	*7.96*	*17.5*
	11-Dec	6	0.0252	0.819	174	0.00483	0.247	0.00466	14.8	2.77	5.38
	12-Jan	51	0.318	77.5	2,443	0.414	19.1	0.0687	190	33.1	158
	12-Feb	22	0.0780	4.56	538	0.0269	1.377	0.00704	46.0	8.58	19.0
	12-Mar	60	0.361	23.5	2,485	0.148	6.64	0.0321	213	38.8	93.8
	12-Apr	59	0.607	114	4,188	0.673	34.5	0.118	358	66.8	240
	Wet season total	257	1.61	233	11,380	1.34	64.0	0.262	956	175	578
2013	12-Oct	23	0.0875	7.98	603	0.0470	1.22	0.0393	51.6	9.62	24.7
	12-Nov	96	0.989	237	6,309	1.42	32.2	0.331	625	132	457
	12-Dec	75	4.00	2,435	27,474	14.4	372	2.32	2,363	444	3,573
	13-Jan	15	0.428	11.1	2,955	0.0655	1.69	0.0256	253	47.1	88.3
	13-Feb	6	0.142	1.39	981	0.00819	0.212	0.0118	83.9	15.6	26.7
	13-Mar	9	0.0721	1.57	497	0.00925	0.239	0.00987	42.5	7.93	14.5
	13-Apr	19	0.0978	8.75	680	0.0476	1.34	0.0412	54.8	10.5	28.0
	Wet season total	243	5.82	2,703	39,500	16.0	408	2.78	3,474	666	4,212
2014	13-Oct	1	*0.0252*	*0.48*	*174*	*0.00280*	*0.0885*	*0.00237*	*15.0*	*2.80*	*4.91*
	13-Nov	41	0.261	49.1	1,800	0.289	7.48	0.0504	154	28.7	103
	13-Dec	6	0.005	0.0185	36.5	0.000109	0.00282	0.000256	3.12	0.582	0.953
	14-Jan	4	0.032	1.39	224	0.00821	0.212	0.00225	19.1	3.56	7.33
	14-Feb	79	0.618	122	4308	0.729	18.5	0.126	363	69.1	259
	14-Mar	24	0.179	9.17	1232	0.0540	1.40	0.0128	105	19.6	42.1
	14-Apr	29	0.215	20.2	1483	0.119	3.07	0.0231	127	23.6	61.4
	Wet season total	184	1.34	202	9,257	1.20	30.7	0.217	786	148	479

[a] April 2012 monthly loads are reported for only the period April 01-26. In the 4 days missing from the record, <0.03 inches of rain fell in the lower watershed.

[b] October 2012 monthly loads are reported for only the period October 19-31. In the 18 days missing from the record, <0.05 inches of rain fell in the lower watershed.

[c] April 2013 monthly loads are reported for only the period April 01-18. In the 12 days missing from the record, no rain fell in the lower watershed.

[d] November 2013 are reported for only the period November 6-30. No rain fell during the missing period.

8.2. North Richmond Pump Station

8.2.1. North Richmond Pump Station flow

Richmond discharge estimates were calculated during periods of active pumping at the station during WYs 2013 and 2014. Discharge estimates include all data collected when the pump rate was operating at greater than 330 RPM, the rate which marks the low end of the pump curve provided by the pump station. This rate is generally reached 30 seconds after pump ignition. For the purposes of this study, flows at less than 330 RPM were considered negligible due to limitations of the pump efficiency curve. This assumption may have resulted in slight underestimation of active flow from the station particularly during shorter duration pump outs but this under estimate was minor relative to storm and annual flows. The annual estimated discharge from the station was 0.74 Mm^3 for WY 2013 and 0.50 Mm^3 for WY 2014 (Table 16). A discharge estimate at the station for WY 2011 was 1.1 Mm^3 (Hunt et al., 2012). The rainfall to runoff ratios between the two studies was similar supporting the hypothesis that the flows and resulting load estimates from the previous study remain valid.

Precipitation in WY 2013 was 89% mean annual precipitation (MAP) based on a long-term record PRISM data record (modeled PRISM data) for the period Climate Year (CY) 1970-2000. Thus it appears WY 2013 was slightly drier than average. Of the total annual rainfall, 74% fell during a series of larger events in the period late November to December. Otherwise, WY 2013 had a number of very small events, three of which were sampled for water quality (Figure 4). The pumps at this pump station operate at a single speed, and therefor flow rates at this location are governed by the number of pumps operating at a given time. Most pump-outs during these storms had one operating pump except for a few storm events where two pumps were in operation. Flow “peaked” during one of these times when two pumps were in operation simultaneously. The peak rate was 210 cfs and occurred on December 2, 2013 after approximately 3.8 inches of rain fell over a 63 hour period.

WY 2014 was even drier than the previous year, with only 62% MAP (12.8 inches of rain). In total, five events were sampled for water quality, including the intense early season first flush on November 19 and 20, 2013, and multiple events in February 2014. Similar to WY 2013, a single pump operated for the majority of pump outs, with only a couple of occasions when two pumps were simultaneously operating. Flow peaked at 191 cfs on March 29th, 2014 after 0.84 inches fell in the previous three hours.

8.2.2. North Richmond Pump Station turbidity and suspended sediment concentration

Maximum turbidity during the study was measured at 772 NTU and which occurred during a dry flow pump out on January 24, 2013 following a low magnitude storm event of 0.22 inches on January 23rd. Maximum turbidity during other storm events ranged up to 428 NTU in WY 2013 and 466 NTU in WY 2014. Storms typically peaked in turbidity between 150 and 500 NTU. The pattern of turbidity variation over the wet season was remarkably similar to that observed during WY 2011 in the previous study (Hunt et al., 2012). The turbidity dataset collected by Hunt et al. (2012) was noisy and contained unexplainable turbidity spikes that were censored. The similarities between the WY 2011 and 2013 datasets suggest that the WY 2011 data set was not over-censored and therefore that pollutant loads based on both flow and turbidity computed by Hunt et al. (2012) remain valid. Suspended sediment concentration was computed from the continuous turbidity data. Computed SSC peaked at 1010 mg/L

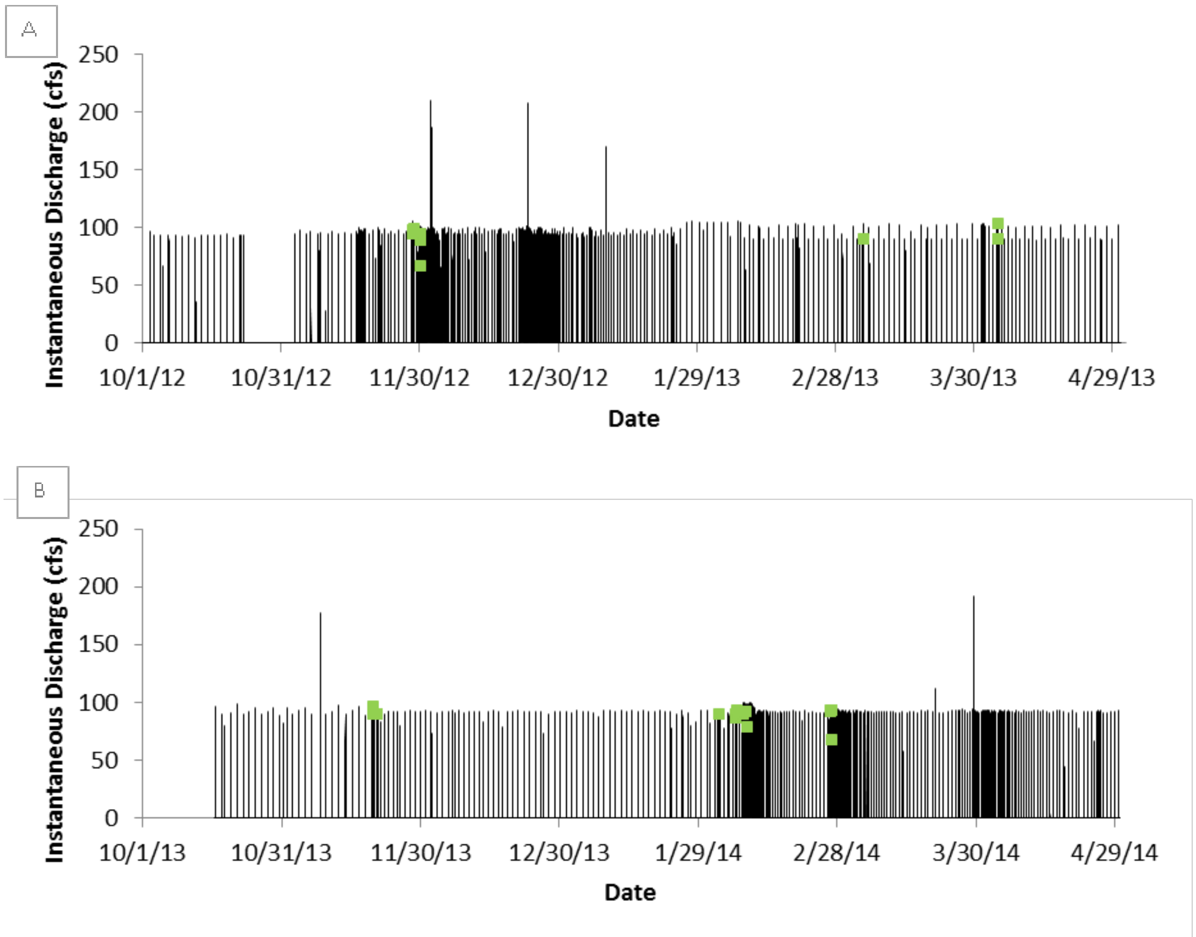

Figure 4. Flow characteristics at North Richmond Pump Station during Water Year 2013 and 2014 with sampling events plotted in green.

during the 1/24/13 low flow pump out when turbidity also peaked. In WY 2014, the peak computed SSC was 579 mg/L during the 3/26/14 event; SSC in most storms peaked between 200 and 600 mg/L.

8.2.3. North Richmond Pump Station POC concentrations (summary statistics)

The North Richmond Pump Station is a 1.6 km watershed primarily comprised of industrial, transportation, and residential land uses. The watershed has a long history of industrial land use and is downwind from the Richmond Chevron Oil Refinery and the Port of Richmond. The land-use configuration results in a watershed that is approximately 62% covered by impervious surface and these land use and history factors help to contribute to potentially high concentrations loads of PCB and Hg. Summary statistics (Table 14) were used to provide useful information to compare Richmond pump station water quality to other Bay Area monitoring locations. The comparison of summary statistics to knowledge from other watersheds and conceptual models of pollutant sources and transport processes provided a further check on data quality.

The maximum PCB concentration measured during the project study period was 38 ng/L. In WY2011, the maximum concentration measured was 82 ng/L (Hunt et al., 2012). PCB concentrations were in the range of other findings for urban locations (range 0.1-1120 ng/L) (Lent and McKee, 2011). Although highly impervious with an industrial history, the North Richmond Pump Station Watershed contains no known PCB sources of specific focus at this time; PCB transport in this watershed could be more generally representative of older mixed urban and industrial land use areas. In contrast, watersheds with known specific industrial sources appear to exhibit average concentrations in excess of about 100 ng/l (Marsalek and Ng, 1989; Hwang and Foster, 2008; Zgheib et al., 2011; Zgheib et al., 2012; McKee et al., 2012) and watersheds with little to no urbanization dominated by agriculture and open space exhibit average concentrations <5 ng/l (David et al., in press; Foster et al., 2000a; Howell et al. 2011; McKee et al., 2012). In instances where urbanization and industrial sources are highly diluted by >75% developed agricultural land concentrations averaging 8.9 ng/L can be observed (Gómez-Gutiérrez et al., 2006). The North Richmond Pump Station Watershed has an imperviousness of 62% and exhibits a PCB particle ratio of 267 pg/mg; the sixth highest observed so far in the Bay Area and well above the background of rural areas (indicated by Marsh Creek in the Bay Area).

Maximum total mercury concentrations (230 ng/L) during WYs 2013 and 2014 were of a similar magnitude with maximum observed concentrations during previous monitoring efforts (200 ng/L) (Hunt et al., 2012). This sample was collected during the February 26, 2014 storm event where approximately 1 inch of rain fell in the watershed. This event followed a 17 day dry period. Mercury concentrations were higher than in the range found in Zone 4 Line-A, another small urban impervious watershed (Gilbreath et al., 2012). Concentrations were also much greater than those observed in three urban Wisconsin watersheds (Hurley et al., 1995), urban influenced watersheds of the Chesapeake Bay region (Lawson et al., 2001), and two sub-watersheds of mostly urban land use in the Toronto area (Eckley and Branfirheun, 2008). Unlike, Marsh Creek, where the maximum Hg concentrations for the most part are attributed to the erosion of high masses of relatively low concentration soils, North Richmond Pump Station Watershed transports relatively low concentrations and mass of suspended sediment (maximum observed from grab samples was just 347 mg/L). Hg sources and transport in this watershed are more likely attributed to local atmospheric re-deposition from historical and ongoing oil refining and shipping and from within-watershed land use and sources. The source-release-transport processes are more likely similar to those of other urbanized and industrial watersheds (Barringer et al., 2010; Rowland et al., 2010; Lin et al., 2012) but not of very highly contaminated watersheds with direct local point source discharge (e.g. 1600-4300 ng/L: Ullrich et al., 2007; 100-5000 ng/L: Picado and Bengtsson, 2012; Kocman et al., 2012; 78-1500 ng/L: Rimondi et al., 2014).

The MeHg concentrations during the two-year study ranged from 0.03-1.1 ng/L compared with WY 2011 maximum concentrations of 0.6 ng/L (Hunt et al., 2012). Concentrations of this magnitude or greater have been observed in a number of Bay Area urban influenced watersheds (Guadalupe River: McKee et al., 2006; McKee et al., 2010; Zone 4 Line A: Gilbreath et al., 2012; Glen Echo Creek and Zone 5 Line M: McKee et al., 2012). However, concentrations of methylmercury of this magnitude have not been observed in urbanized watersheds (Mason and Sullivan, 1998; Naik and Hammerschmidt, 2011; Chalmers et al., 2014). Although local Hg sources can be a factor in helping to elevate MeHg production and food-web impacts, it is generally agreed, at least for agricultural and forested systems with lesser urban influences, that Hg sources are not a primary limiting factor in MeHg production (Balogh et al., 2002; Balogh et al., 2004; Barringer et al., 2010; Zheng et al., 2010; Bradely et al., 2011).

Nutrient concentrations in the North Richmond Pump Station appear to be reasonably typical of other Bay Area more rural watersheds (McKee and Krottje, 2005; Pearce et al., 2005) and compare closely to those observed in Guadalupe River during this study. North Richmond had the highest nitrate concentrations (equivalent to Guadalupe River) and orthophosphate concentrations of the six POC locations in this study. Concentrations also appear typical or slightly greater than for PO4 and TP of found in urban watersheds in other parts of the country and world (e.g. Hudak and Banks, 2006; comprehensive Australian literature review for concentrations by land use class: Bartley et al., 2012). Phosphorus concentrations appear greater here than elsewhere in the world under similar land use scenarios, an observation perhaps attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005; Pearce et al., 2005).

Organic carbon concentrations observed in North Richmond Pump Station were similar to those observed in Z4LA (max = 23 mg/L; FWMC = 12 mg/L: Gilbreath et al., 2012) were similar to Belmont, Borel, Calabazas, and Walnut Creeks (McKee et al., 2012) and Guadalupe and Sunnyvale East Channel. They were much lower than observed in Pulgas Green Pump Station. Indeed, TOC concentrations of 4-12 mg/L have been observed elsewhere in California (Sacramento River: Sickman et al., 2007).

For pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients), concentrations exhibited an unexpected pattern of median < mean except for PAH, PBDE, total copper, and hardness. This is perhaps indicative of some kind of point source for these pollutants in this watershed that is diluted during higher flows. Maximum PBDE concentrations at Richmond were 4200 ng/L which is 85-fold greater than the highest average observed in the five other locations of this current study and 50-fold greater than previously reported for Zone 4 Line A (Gilbreath et al., 2012). These are the highest PBDE concentrations measured in Bay Area stormwater to-date of any study. The North Richmond watershed currently contains an auto dismantling yard and a junk/wrecking yard; possible source areas. Only two peer reviewed articles have previously described PBDE concentrations in runoff, one for the Pearl River Delta, China (Guan et al., 2007), and the other for the San Francisco Bay (Oram et al., 2008) based, in part, on concentrations observed in Guadalupe River and Coyote Creek. Maximum total PBDE concentrations measured by Guan et al. (2007) were 68 ng/L, a somewhat surprising result given that the Pearl River Delta is a known global electronic-waste recycling hot spot. However, the Guan et al. study was based on monthly collection as opposed to storm-based sampling as was completed in a larger river system where dilution of point source may have occurred.

Copper, selenium, carbaryl, fipronil, and pyrethroids were sampled at a lesser frequency using a composite sampling design (see methods section) and were used to characterize pollutant concentrations to help support management questions possible causes of toxicity (in the case of the pesticides). Similar to the other sites, carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L: Moran, 2007) (Carbaryl: DL - 700 ng/L: Ensiminger et al., 2012; tributaries to Salton Sea, Southern CA geometric mean ~2-10 ng/L: LeBlanc and Kuivila, 2008).

Table 14. Summary of laboratory measured pollutant concentrations in North Richmond Pump Station during water year 2013 and 2014.

		2013							2014						
Analyte	**Unit**	**Samples Taken (n)**	**Proportion Detected (%)**	**Min**	**Max**	**Median**	**Mean**	**Standard Deviation**	**Samples Taken (n)**	**Proportion Detected (%)**	**Min**	**Max**	**Median**	**Mean**	**Standard Deviation**
SSC	mg/L	41	95%	0	213	26.5	45.7	54.3	67	99%	0	325	52	63.9	58.1
ΣPCB	ng/L	12	100%	4.85	31.6	10.1	12	7.09	20	100%	2.23	38.5	13.7	15	9.83
Total Hg	ng/L	12	100%	13	98	18.5	27.7	24.6	20	100%	11.5	230	28.5	46.7	51.8
Total MeHg	ng/L	6	100%	0.03	0.19	0.145	0.118	0.0705	10	100%	0.03	1.1	0.16	0.261	0.309
TOC	mg/L	12	100%	3.5	13.5	6.6	7.46	3.36	20	100%	5.2	60	9.85	13.4	12.4
NO3	mg/L	12	100%	0.21	3.1	0.855	1.13	0.848	20	100%	0.32	3.9	0.688	0.882	0.792
Total P	mg/L	12	100%	0.18	0.35	0.27	0.276	0.0449	20	100%	0.3	0.75	0.405	0.448	0.146
PO4	mg/L	11	100%	0.11	0.24	0.16	0.168	0.0424	20	100%	0.15	0.44	0.23	0.245	0.0809
Hardness	mg/L								5	100%	46	260	120	129	86.4
Total Cu	ug/L	3	100%	9.9	20	16	15.3	5.09	5	100%	11	46	30	26.8	14.4
Dissolved Cu	ug/L	3	100%	4.4	10	4.7	6.37	3.15	5	100%	4.7	15.5	7.3	9.7	4.75
Total Se	ug/L	3	100%	0.27	0.59	0.33	0.397	0.17	5	100%	0.24	0.74	0.4	0.416	0.206
Dissolved Se	ug/L	3	100%	0.26	0.56	0.27	0.363	0.17	5	100%	0.16	0.61	0.415	0.367	0.183
Carbaryl	ng/L	3	100%	12	40	19	23.7	14.6	5	80%	0	37	25.5	20.3	14.2
Fipronil	ng/L	3	33%	0	4	0	1.33	2.31	5	100%	5	14	7	9.3	4.35
ΣPAH	ng/L	2	100%	160	1350	754	754	840	2	100%	195	405	300	300	148
ΣPBDE	ng/L	2	100%	153	3360	1760	1760	2270	3	100%	18	241	170	143	114
Delta/ Tralomethrin	ng/L	3	100%	1	3.5	3.05	2.52	1.33	5	60%	0	6.2	0.3	2.16	2.9
Cypermethrin	ng/L	3	100%	2.1	4.35	3.1	3.18	1.13	5	100%	2.1	13	3.4	5.84	4.75
Cyhalothrin lambda	ng/L	3	100%	0.4	1.3	0.6	0.767	0.473	4	100%	0.5	1.9	1.5	1.35	0.619
Permethrin	ng/L	3	100%	6.4	16	13.5	12	4.98	5	100%	7.2	55	7.9	21.1	20.9
Bifenthrin	ng/L	3	100%	3.8	8.05	6.1	5.98	2.13	5	100%	3.4	8.6	5	5.82	2.57

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at the North Richmond Pump Station was two.

Pyrethroid concentrations of Delta/ Tralomethrin were similar to those observed in Zone 4 Line A, Cypermethryn was not detected in Z4LA, whereas concentrations of Permethrin and Bifenthrin were about 2-fold lower (Gilbreath et al., 2012). In summary, the statistics indicate pollutant concentrations typical of a Bay Area urban stream and there is no reason to suspect data quality issues.

8.2.4. North Richmond Pump Station toxicity

At North Richmond Pump Station, no significant effects were observed for the crustacean Ceriodaphnia dubia, the algae Selenastrum capricornutum, or fathead minnows during any tests for either year of monitoring. Two of three WY 2013 samples had a significant decrease in Hyalella Azteca survival. One sample showed an 88% survival rate compared to a 98% lab survival rate. The other sample showed a 12% survival rate compared to a 100% lab survival rate. In the five storm WY 2014 storm events, mortality of Hyalella azteca ranged from 8% to 80%.

8.2.5. North Richmond Pump Station loading estimates

The following methods were applied for calculating loading estimates (Table 15). Given that there were no flows out of the pump station when the pumps were not on, loads were only calculated for periods during active pumping conditions. Regression equations between turbidity and the particle-associated pollutants (SSC, PCBs, total mercury, methylmercury, total organic carbon and total phosphorous) were used to estimate loads (Table 16). Because there was no relation or trend in the concentrations of nitrate and phosphate in relation to flow or turbidity, flow weighted mean concentrations were applied. Monthly loading estimates correlate very well with monthly discharge (Table 16). Monthly discharge was greatest in December 2012 as were the monthly loads for suspended sediment and pollutants. Although there were slight climatic differences that have not been adjusted for, WY 2013 suspended sediment (35.7 t) and PCB (8.14 g) load estimates were comparable to the WY 2011 estimates (29 t and 8.0 g, respectively) even thought it was a wetter year (134% MAP) (Hunt., 2012) providing further support and confidence that the computed loads are reasonable. Due to lessons learned from the previous study, there is much higher confidence in the WY 2013 and 2014 loads estimates due to improvements in both the measurements of turbidity and flow rate using optical sensor equipment. Given the below average rainfall conditions experienced during WY 2013 and 2014, loads from the present study may be considered representative of somewhat dry conditions.

Table 15. Regression equations used for loads computations for North Richmond Pump Station during water year 2013 and 2014.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/L/NTU)	Mainly urban	1.31		0.58	Regression with turbidity
Total PCBs (ng/L/NTU)	Mainly urban	0.237	2.12	0.76	Regression with turbidity
Total Mercury (ng/L/NTU) WY 2013	Mainly urban	0.442		0.89	Regression with turbidity
Total Mercury (ng/L/NTU) WY 2014	Mainly urban	0.733		0.71	Regression with turbidity
Total Methylmercury (ng/L/NTU)	Mainly urban	0.0044	0.0542	0.47	Regression with turbidity
Total Organic Carbon (mg/L/NTU) WY 2013	Mainly urban	-0.0295	8.84	0.09	Regression with turbidity
Total Organic Carbon (mg/L/NTU) WY 2014	Mainly urban	0.0326	11.4	0.01	Regression with turbidity
Total Phosphorous (mg/L/NTU) WY 2013	Mainly urban	0.000754	0.241	0.34	Regression with turbidity
Total Phosphorous (mg/L/NTU) WY 2014	Mainly urban	0.00255	0.293	0.42	Regression with turbidity
Nitrate (mg/L)	Mainly urban	0.958			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.206			Flow weighted mean concentration

Table 16. Monthly loads for North Richmond Pump Station. Italicized loads are estimated based on monthly rainfall-load relationships.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2013	12-Oct	33	*0.0590*	*2.36*	*604*	*0.525*	*1.28*	*0.0129*	*56*	*11.9*	*18.5*
	12-Nov	156	0.152	7.88	1167	1.75	3.48	0.0429	146	30.9	41.2
	12-Dec	232	0.374	20.8	2834	4.56	9.19	0.112	358	75.8	102
	13-Jan	18	0.0640	1.31	537	0.373	0.578	0.00923	61.4	13.0	16.2
	13-Feb	18	0.0438	1.28	358	0.324	0.564	0.00799	42.0	8.89	11.3
	13-Mar	19	0.0418	0.414	360	0.164	0.183	0.00408	40.0	8.48	10.3
	13-Apr	26	0.0602	1.72	493	0.440	0.761	0.0108	57.6	12.2	15.5
	Wet season total	502	0.795	35.7	6353	8.14	16.0	0.200	761	161	215
2014	13-Oct	0	0.0113	0.0184	129	0.0272	0.0142	0.000691	10.8	2.28	3.33
	13-Nov	36	0.0509	2.09	632	0.487	1.61	0.0119	48.7	10.3	19.0
	13-Dec	8	0.0271	0.393	319	0.129	0.304	0.00320	26.0	5.50	8.7
	14-Jan	1	0.0216	0.0739	248	0.0592	0.0571	0.00149	20.6	4.38	6.46
	14-Feb	176	0.224	9.87	2798	2.27	7.63	0.0556	214	45.4	84.8
	14-Mar	74	0.0967	5.64	1243	1.23	4.36	0.0301	92.6	19.6	39.3
	14-Apr	32	0.0676	2.31	829	0.563	1.79	0.0138	64.8	13.7	24.3
	Wet season total	326	0.499	20.4	6,197	4.76	15.77	0.1168	478	101	186

8.3. San Leandro Creek

8.3.1. San Leandro Creek flow

Rainfall at San Leandro Creek during the study was below average all three years. During WY 2012, total rainfall was 19.14 inches, or 75% of mean annual precipitation (MAP = 25.7 in) based on a long-term record at Upper San Leandro Filter (gauge number 049185) for the period 1971-2010 (WY). In WYs 2013 and 2014, rainfall totaled 17.2 and 13.3 inches, respectively, for MAPs of just 67% and 52% in each of those years. Since 1971, 2012-14 were the 14th, 11th, and 3rd driest years on record, respectively, and together had the second lowest 3-year cumulative rainfall, excepting the record dry 1975-1977 drought.

There is no historic flow record on San Leandro Creek. The challenges of developing a rating curve for this site have already been described (see "Continuous data quality assurance summary"). During WY 2012 monitoring, a preliminary rating curve was developed for stages up to 3.65 feet based on discharge sampling. This rating was augmented in WY 2014 with additional discharge measurement at wadeable stages, though gaps in the rating exist between 2 and 3.5 feet of stage as well for stages greater than

3.65 feet. As such, the estimated discharge at this site is of marginal quality. Additionally, the rainfall to runoff relationship during individual storms[3] between WY 2012 and WYs 2013-14 shifts down significantly from 0.38 in WY 2012 to 0.22 in WY 2013 and to 0.12 in WY 2014. We cannot explain this shift, adding further uncertainty to discharge quality.

Total estimated runoff for the monitoring years was 7.3 Mm^3, 7.2 Mm^3, and 0.24 Mm^3 for WYs 2012, 2013 and 2014, respectively. This larger total annual discharge during WYs 2012 and 2013 was mostly a result of reservoir discharge from the upstream Lake Chabot, indicated by the square and sustained nature of the hydrographs during those water years, which may have been atypical[4]. Additionally, a series of relatively minor storms occurred throughout each WY (Figure 5). Flows peaked at 313 cfs in WY 2012, at 344 cfs in WY 2013, and at 152 cfs in WY 2014. San Lorenzo Creek to the south has been gauged by the USGS in the town of San Lorenzo (gauge number 11181040) from WY 1968-78 and again from WY 1988-present. Based on these records, annual peak flow has ranged between 300 cfs (1971) and 10300 cfs (1998). During WY 2012, flow peaked on San Lorenzo Creek at San Lorenzo at 2150 cfs on 1/20/2012 at 23:00; a flow that has been exceeded 54% of the years on record. During, WY 2013, flow in San Lorenzo peaked at 3080 cfs on 12/2/2012 at 11:15 am; a flow of this magnitude has been exceeded 38% of the years on record. And during WY 2014, flow peaked at 1320 cfs, a magnitude which has historically been exceeded 72% of the monitored years. Annual flow for San Lorenzo Creek at San Lorenzo (gauge number 11181040) for WY 2012 - 2014 respectively was 57%, 65% and 27% of normal. Based on this evidence alone, we suggest that storm driven flows in San Leandro Creek were likely much lower than average during this study.

8.3.2. San Leandro Creek turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. During the reservoir release period in the early part of WY 2012, turbidity remained relatively low indicating very little sediment was eroded from within San Leandro Creek at this magnitude and consistency of stream power. A similar phenomenon occurred in January of WY 2013 when again little rainfall occurred and relatively clean runoff devoid of sediment and pollutants was associated with the reservoir release.

Turbidity peaked at 929 NTU during a late season storm on 4/13/12 at 5:15 am. In contrast, during WY 2013, saturated watershed conditions began to occur in late November and sediment began to be released from the upper watershed much earlier in the season. A peak turbidity of 495 NTU occurred on 11/30/12 at 9:45 am. The post new year period was relatively dry and the latter season storm in April was relatively minor. Turbidity in WY 2014 was not well-characterized for a large portion of the season, but the late February through to early April period was measured with a peak of 347 NTU. These observations provide evidence that during larger storms and wetter years, the urbanized lower San

[3] Storms with flow that was augmented with reservoir release were removed from this analysis.

[4] Lake Chabot provides emergency water storage and recreation downstream of the East Bay Municipal Utility District's main Upper San Leandro Reservoir. Downstream releases are episodic and in WYs 2012 and 2013 included lake drawdowns for studies associated with preparation of the December 2013 Environmental Impact Report for planned seismic upgrades of Chabot Dam. http://www.ebmud.com/water-and-wastewater/project-updates/chabot-dam-upgrade

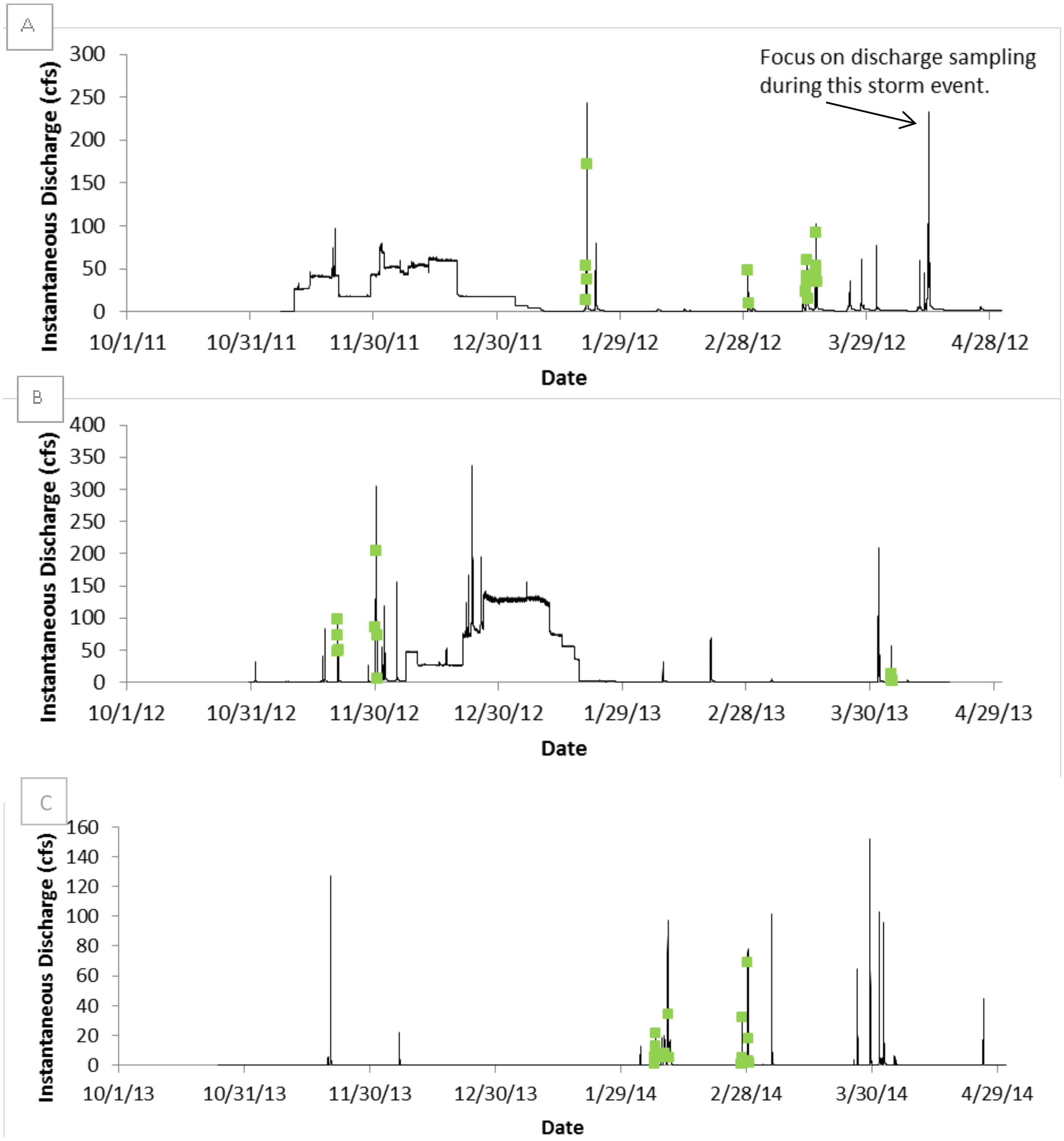

Figure 5. Flow characteristics in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A), WY 2013 (B) and WY 2014 (C) with sampling events plotted in green. Note, flow information could be updated in the future if additional discharge data are collected.

Leandro Creek watershed is likely capable of much greater sediment erosion and transport resulting in greater turbidity and concentrations of suspended sediment.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity. Suspended sediment concentration during WY 2012 peaked at 1106 mg/L during the late season storm on 4/13/12 at 5:15 am; a peak SSC of 898 mg/L occurred on 11/30/12 at 9:45 am for WY 2013; and a peak SSC of 413 mg/L was measured on 2/28/14 at 8:35. The maximum concentration observed during the RMP reconnaissance study (McKee et al., 2012) was 965 mg/L but at this time we have not evaluated the relative storm magnitude between WY 2011 and the current study to determine if the relative concentrations are logical.

8.3.3. San Leandro Creek POC concentrations (summary statistics)

Summary statistics of pollutant concentrations measured in San Leandro Creek during the project provide a basic understanding of general water quality and also allow a first order judgment of quality assurance (Table 17). For pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients), concentrations followed the typical pattern of median < mean for most analytes.

The range of PCB concentrations (0.73-29.4 ng/L) were in the lower range of findings for urban locations (range 0.1-1120 ng/L) (Lent and McKee, 2011). PCB processes are complex in this watershed and appear to be greater in runoff derived from the urban landscape and lower in upper watershed runoff. In contrast, watersheds with known specific industrial sources appear to exhibit average concentrations in excess of about 100 ng/l (Marsalek and Ng, 1989; Hwang and Foster, 2008; Zgheib et al., 2011; Zgheib et al., 2012; McKee et al., 2012) and watersheds with little to no urbanization dominated by agriculture and open space exhibit average concentrations <5 ng/l (David et al., in press; Foster et al., 2000a; Howell et al. 2011; McKee et al., 2012). In instances where urbanization and industrial sources are highly diluted by >75% developed agricultural land concentrations averaging 8.9 ng/L can be observed (Gómez-Gutiérrez et al., 2006). The San Leandro Creek watershed has an average imperviousness of only 38% yet it may be an oversimplification to compare it to less urbanized watersheds since it has a very urban and impervious lower watershed. Indeed, it exhibits a particle ratio for PCBs of 101 pg/mg; the ninth highest observed so far in the Bay Area out of 24 locations and well above the background of rural areas (indicated by Marsh Creek in the Bay Area).

Maximum mercury concentrations (590 ng/L) were greater than observed in Zone 4 Line A in Hayward (Gilbreath et al., 2012) and of a similar magnitude to those observed in the San Pedro stormdrain draining an older urban residential area of San Jose (SFEI, unpublished). Concentrations were also much greater than those observed in three urban Wisconsin watersheds (Hurley et al., 1995), urban influenced watersheds of the Chesapeake Bay region (Lawson et al., 2001), and two sub-watersheds of mostly urban land use in the Toronto area (Eckley and Branfirheun, 2008). Unlike fully urban systems, San Leandro Creek appears to exhibit Hg transport processes in relation to both the erosion of soils and urban processes such as atmospheric deposition and within-watershed urban legacy Hg sources. The source-release-transport processes are not likely similar to those of very highly contaminated watersheds with direct local point source discharge (e.g. 1600-4300 ng/L: Ullrich et al., 2007; 100-5000 ng/L: Picado and Bengtsson, 2012; Kocman et al., 2012; 78-1500 ng/L: Rimondi et al., 2014).

The MeHg concentrations during the three-year study ranged from 0.1-1.48 ng/L. Concentrations of this magnitude or greater have been observed in a number of Bay Area urban influenced watersheds (Guadalupe River: McKee et al., 2006; McKee et al., 2010; Zone 4 Line A: Gilbreath et al., 2012; Glen

Echo Creek and Zone 5 Line M: McKee et al., 2012). However, concentrations of methylmercury of this magnitude have not been observed in urbanized watersheds from other parts of the world (Mason and Sullivan, 1998; Naik and Hammerschmidt, 2011; Chalmers et al., 2014). Although local Hg sources can be a factor in helping to elevate MeHg production and food-web impacts, it is generally agreed, at least for agricultural and forested systems with lesser urban influences, that Hg sources are not a primary limiting factor in MeHg production (Balogh et al., 2002; Balogh et al., 2004; Barringer et al., 2010; Zheng et al., 2010; Bradely et al., 2011).

Nutrient concentrations in the San Leandro Creek watershed appear to be reasonably typical of Bay Area more rural watersheds (McKee and Krottje, 2005; Pearce et al., 2005). Nitrate concentrations appear strikingly similar between San Leandro Creek, Lower Marsh Creek, Sunnyvale East Channel, and Pulgas Creek Pump Station. In contrast, nitrate concentrations were about 2-fold greater in North Richmond and Guadalupe River. Orthophosphate concentrations were similar between San Leandro Creek and Lower Marsh Creek and 1-5-2-fold lower than the other locations in this study. Total P concentrations were similar across the six sites. Concentrations appear typical or slightly greater than for PO4 and TP of found in urban watersheds in other parts of the country and world (e.g. Hudak and Banks, 2006; comprehensive Australian literature review for concentrations by land use class: Bartley et al., 2012). Slightly higher phosphorus concentrations may perhaps be attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005; Pearce et al., 2005).

Organic carbon concentrations observed in San Leandro Creek (4-17 mg/L) were similar to those observed in Z4LA (max = 23 mg/L; FWMC = 12 mg/L: Gilbreath et al., 2012) were similar to Belmont, Borel, Calabazas, and Walnut Creeks (McKee et al., 2012). They were much lower than observed in Pulgas Green Pump Station. TOC concentrations of 4-12 mg/L have been observed elsewhere in California (Sacramento River: Sickman et al., 2007).

A similar style of first order quality assurance is also possible for analytes measured at a lesser frequency using composite sampling design (see methods section) (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) and appropriate for water quality characterization only. The maximum concentration of PBDEs (65 ng/L) was considerably lower than the other sites with the exception of Lower Marsh Creek where observed maximum concentrations were similar. This is possibly due to differences in the randomness of the representativeness of sub-samples of the composites or due to dilution from cleaner water and sediment loads from upstream. Only two peer reviewed articles have previously described PBDE concentrations in runoff, one for the Pearl River Delta, China (Guan et al., 2007), and the other for the San Francisco Bay (Oram et al., 2008) based, in part, on concentration data from Guadalupe River and Coyote Creek. Maximum total PBDE concentrations measured by Guan et al. (2007) were 68 ng/L, a somewhat surprising result given that the Pearl River Delta is a known global electronic-waste recycling hot spot. However, the Guan et al. study was based on monthly interval collection as opposed to storm event-based sampling, and was conducted in a very large river system where dilution of point source was likely to have occurred.

Similar to the other sites, carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil:

70 – 1300 ng/L: Moran, 2007) (Carbaryl: DL - 700 ng/L: Ensiminger et al., 2012; tributaries to Salton Sea, Southern CA geometric mean ~2-10 ng/L: LeBlanc and Kuivila, 2008). The total selenium concentrations in San Leandro Creek appear to be about half those observed in Z4LA (Gilbreath et al., 2012). Pyrethroid concentrations of Delta/ Tralomethrin and Bifenthrin were similar to those observed in Z4LA whereas concentrations of Cyhalothrin lambda and Permethrin were about 3x and 11x lower, respectively (Gilbreath et al., 2012). In summary, mercury concentrations in San Leandro are on the high end of typical Bay Area urban watersheds, whereas concentrations of other POCs are either within the range of or below those measured in other typical Bay Area urban watersheds and appear consistent with or explainable in relation to studies from elsewhere. There do not appear to be any data quality issues.

8.3.4. San Leandro Creek toxicity

Composite water samples were collected at the San Leandro Creek station during four storm events in WY 2012, three storm events during WY 2013, and four storm events during WY 2014. The survival of the freshwater fish species Pimephales promelas was significantly reduced during one of the four WY 2012 and one of the three WY 2013 events. Similar to the results for other POC monitoring stations, significant reductions in the survival of the amphipod Hyalella azteca were observed, in this case in three of the four WY 2012 storm events sampled. In WY 2014 Hyalella azteca had mortality rates ranging from 16% to 98%. No significant reductions in the survival, reproduction and growth of the crustacean Ceriodaphnia dubia or the algae Selenastrum capricornutum were observed during any of these storms.

8.3.5. San Leandro Creek loading estimates

Site specific methods were developed for computed loads (Table 18). This watershed is among the most complex in terms of data interpretation. There were challenges with missing turbidity data, a poorly defined discharge rating, a side channel coming in at the site, reservoir releases potentially including imported water, and complexities associated with urban runoff and non-urban runoff origins of runoff. Loads estimates generated for WYs 2012 and 2013 and reported by Gilbreath et al. (2014) have now been revised based on revisions to the discharge estimates, additional pollutant concentration data collected in WY 2014 and a changing understanding of pollutant transport processes for the site. Monthly loading estimates correlate well with monthly discharge (Table 19). There are no data available for October of each water year because monitoring equipment was not installed. Discharge and rainfall were not aligned due to reservoir release. Monthly discharge was greatest in January 2013 when large releases were occurring from the upstream reservoir. The greatest monthly loads for each of the pollutants regardless of transport mode (dominantly particulate or dissolved) occurred in December 2012 when rainfall induced run-off caused high turbidity and elevated concentrations of suspended sediments and pollutants. The sediment and pollutant loads were less well correlated with the total discharge than for other sampling sites due to reservoir releases and complex sources. When discharge was dominated by upstream flows induced by rainfall, relatively high loads of mercury occurred; conversely, PCB loads were greater relative to rainfall during smaller rainfall events when less runoff occurred from the upper watershed. Given the very dry flow conditions of WY 2012, 2013, and 2014 (see discussion on flow above), loads presented here may be considered representative of dry conditions. Any future sampling should be focus on larger rain storms during wetter years and improving the discharge rating for the site.

Table 17. Summary of laboratory measured pollutant concentrations in San Leandro Creek during water years 2012, 2013, and 2014.

		2012							2013							2014						
Analyte	Unit	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	53	98%	0	590	100	162	144	28	86%	0	904	48	114	202	36	97%	0	178	17.5	46.2	55.1
ΣPCB	ng/L	16	100%	2.91	29.4	10.5	12.3	8.74	12	100%	0.73	15.7	4.15	5.59	4.65	16	100%	1.6	26	2.73	5.48	6.8
Total Hg	ng/L	16	100%	11.9	577	89.4	184	203	12	100%	7.5	590	44	92.8	162	16	100%	4.9	170	17.5	37.4	44.4
Total MeHg	ng/L	9	100%	0.164	1.48	0.22	0.499	0.456	9	100%	0.15	1.4	0.2	0.377	0.397	12	100%	0.1	1	0.24	0.335	0.261
TOC	mg/L	16	100%	4.5	12.7	7.95	7.79	2.12	12	100%	4	14	5.65	6.25	2.55	16	100%	5.75	17	9.53	10.2	3.22
NO3	mg/L	16	100%	0.14	0.83	0.34	0.356	0.194	13	100%	0.13	2.8	0.235	0.546	0.758	16	100%	0.17	0.9	0.27	0.405	0.266
Total P	mg/L	16	100%	0.2	0.76	0.355	0.393	0.176	12	100%	0.0915	0.61	0.205	0.212	0.138	16	100%	0.11	0.495	0.21	0.241	0.094
PO4	mg/L	16	100%	0.057	0.16	0.0725	0.0866	0.0282	13	100%	0.069	0.13	0.0965	0.0962	0.0189	16	100%	0.073	0.17	0.115	0.117	0.0239
Hardness	mg/L	4	100%	33.8	72.5	56.5	54.8	18.5								4	100%	46	69	59	58.3	10.3
Total Cu	ug/L	4	100%	12.3	39.5	20.1	23	11.8	3	100%	5.9	28	11	15	11.6	4	100%	8	14	9.75	10.4	2.75
Dissolved Cu	ug/L	4	100%	6.04	10	8.34	8.18	1.99	3	100%	3.5	4.9	4.1	4.17	0.702	4	100%	3.8	7.2	4.8	5.15	1.47
Total Se	ug/L	4	100%	0.104	0.291	0.216	0.207	0.0885	3	100%	0.18	0.29	0.19	0.22	0.0608	4	100%	0.19	0.29	0.24	0.24	0.0476
Dissolved Se	ug/L	4	100%	0.068	0.195	0.131	0.131	0.0572	3	100%	0.16	0.19	0.17	0.173	0.0153	4	100%	0.16	0.26	0.18	0.195	0.0443
Carbaryl	ng/L	4	50%	0	14	5	6	7.12	3	0%	0	0	0	0	0	5	80%	0	18	11	10	7.44
Fipronil	ng/L	4	100%	6	10	8	8	1.63	3	67%	0	9	2	3.67	4.73	4	100%	15	19	17	17	1.83
ΣPAH	ng/L	2	100%	1530	2890	2210	2210	966	1	100%	1400	1400	1400	1400		2	100%	162	299	231	231	96.6
ΣPBDE	ng/L	2	100%	41	64.9	53	53	16.9	2	100%	1.61	29.7	15.7	15.7	19.9	1	100%	5.19	5.19	5.19	5.19	
Delta/ Tralomethrin	ng/L	3	100%	0.163	1.74	1.41	1.1	0.832	3	33%	0	0.6	0	0.2	0.346	4	0%	0	0	0	0	0
Cypermethrin	ng/L	4	0%	0	0	0	0	0	3	67%	0	0.8	0.7	0.5	0.436	4	100%	0.4	0.9	0.625	0.638	0.25
Cyhalothrin lambda	ng/L	3	33%	0	3.86	0	1.29	2.23	3	33%	0	0.3	0	0.1	0.173	3	100%	0.1	1.1	0.4	0.5	0.424
Permethrin	ng/L	4	100%	3.34	13.1	5.77	7	4.45	3	33%	0	6	0	2	3.46	4	25%	0	4.2	0.675	1.39	1.98
Bifenthrin	ng/L	4	75%	0	32.4	12.1	14.1	13.5	3	100%	2.8	7.1	5.5	5.13	2.17	4	100%	2.85	6.5	3.8	4.24	1.58

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at San Leandro Creek was two.

Table 18. Regression equations used for loads computations for San Leandro Creek during water years 2012-14.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/L/NTU)	Mainly urban	1.35		0.9	Regression with turbidity
Suspended Sediment (mg/L/NTU)	Mainly non-urban	1.14		0.82	Regression with turbidity
Suspended Sediment (mg/L)	Mainly baseflow	3.39			Avg of 4/4/13 storm (all collected at base flow) and low flow samples
Suspended Sediment (mg/L/CFS)	Mainly urban	3.58	2.57	0.66	Regression with Flow
Suspended Sediment (mg/L/CFS)	Mainly non-urban	2.04		0.8	Regression with Flow
Total PCBs (ng/L/NTU)	Mainly urban	0.0935	3.95	0.58	Regression with turbidity
Total PCBs (ng/L/NTU)	Mainly non-urban	0.0322	0.957	0.87	Regression with turbidity
Total PCBs (ng/L)	Mainly baseflow	1.32			Avg of 4/4/13 storm (all collected at base flow)
Total PCBs (ng/L/CFS)	Mixed	0.121	2.89	0.54	Regression with Flow
Total Mercury (ng/L/NTU)	Mixed	1.13		0.79	Regression with turbidity
Total Mercury (ng/L)	Mainly baseflow	8.9			Avg of 4/4/13 storm (all collected at base flow)
Total Mercury (ng/L/CFS)	Mainly urban	1.8		0.67	Regression with Flow
Total Mercury (ng/L/CFS)	Mainly non-urban	3.13	44.1	0.43	Regression with Flow
Total Methylmercury (ng/L/NTU)	Mixed	0.00257	0.147	0.81	Regression with turbidity
Total Methylmercury (ng/L)	Mainly baseflow	0.217			Avg of 4/4/13 storm (all collected at base flow) and low flow samples
Total Methylmercury (ng/L/CFS)	Mainly urban	0.00225	0.171	0.14	Regression with Flow
Total Methylmercury (ng/L/CFS)	Mainly non-urban	0.00988	0.27	0.81	Regression with Flow
Total Organic Carbon (mg/L)	Mixed	7.28			Flow weighted mean concentration
Total Organic Carbon (mg/L)	Mainly baseflow	5.3625			Avg of 4/4/13 storm (all collected at base flow)
Total Phosphorous (mg/L/NTU)	Mixed	0.00128	0.158	0.67	Regression with turbidity

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Total Phosphorous (mg/L)	Mainly baseflow	0.105			Avg of 4/4/13 storm (all collected at base flow)
Total Phosphorous (mg/L/CFS)	Mixed	0.00252	0.188	0.45	Regression with Flow
Nitrate (mg/L)	Mixed	0.384			Flow weighted mean concentration
Nitrate (mg/L)	Mainly baseflow	0.26			Avg of 4/4/13 storm (all collected at base flow)
Phosphate (mg/L)	Mixed	0.0932			Flow weighted mean concentration
Phosphate (mg/L)	Mainly baseflow	0.0768			Avg of 4/4/13 storm (all collected at base flow)

Table 19. Monthly loads for San Leandro Creek for water years 2012-14. Italicized loads are estimated based on monthly rainfall-load relationships.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
	11-Nov	*3*	*0.00067*	*0.032*	*5.0*	*0.0045*	*0.042*	*0.0045*	*0.24*	*0.061*	*0.15*
	11-Dec	0	4.67	15.8	25,026	6.16	37.6	0.771	1,213	358	780
	12-Jan	73	0.845	33.3	4,959	3.24	34.7	0.192	244	68.4	170
	12-Feb	22	0.101	1.98	621	0.271	2.56	0.0217	30.5	8.20	17.4
	12-Mar	151	0.734	31.2	4,393	2.59	54.5	0.233	213	59.4	182
	12-Apr	85	0.956	76.1	5,484	4.12	92	0.349	272	76.5	255
	Wet season total	334	7.30	158	40,488	16.4	221	1.57	1,974	571	1,405
2013	12-Oct	*25*	*0.035*	*2.3*	*244*	*0.20*	*2.5*	*0.053*	*13*	*3.2*	*8.5*
	12-Nov	121	0.198	38.6	1,263	1.59	29.7	0.105	110	20.6	57.9
	12-Dec	127	3.29	124	23,951	7.92	124	0.796	1,263	307	621
	13-Jan	7	3.63	52.4	26,430	4.95	51.9	0.652	1,394	338	632
	13-Feb	19	0.0290	1.36	211	0.109	1.26	0.00712	11.1	2.70	6.00
	13-Mar	11	0.00752	0.791	54.7	0.0758	0.666	0.00262	2.89	0.701	1.94
	13-Apr[a]	41	0.0505	5.74	364	0.346	5.41	0.0197	19.1	4.68	14.0
	Wet season total	351	7.24	225	52,517	15.2	215	1.64	2,813	677	1,342
2014	13-Oct	*16*	*0.015*	*0.92*	*107*	*0.088*	*1.1*	*0.031*	*5.5*	*1.4*	*3.6*
	13-Nov	24	0.0276	5.19	199	0.311	5.68	0.908	10.4	2.55	10.0
	13-Dec	8	0.00350	0.104	24.9	0.0146	0.203	0.0880	1.30	0	0.746
	14-Jan	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	14-Feb	93	0.103	9.65	839	0.803	6.65	1.52	44.6	10.6	28.2
	14-Mar	78	0.0756	9.83	543	0.586	9.45	0.0326	28.6	6.98	22.6
	14-Apr	36	0.0332	3.24	234	0.212	3.41	0.340	12.2	3.03	9.02
	Wet season total	256	0.258	28.9	1,946	2.02	26.5	2.92	103	24.8	74.3

[a] April 2013 monthly loads are reported for only the period April 01-18. In the 12 days missing from the record, no rain fell in the San Leandro Creek watershed.

8.3. Guadalupe River

8.3.1. Guadalupe River flow

The US Geological Survey has maintained a flow record on lower Guadalupe River (gauge number 11169000; 11169025) since October 1, 1930 (83 WYs; note 1931 is missing). Peak annual flows for the period have ranged between 125 cfs (WY 1960) and 11000 cfs (WY 1995). Annual runoff from Guadalupe River has ranged between 0.422 (WY 1933) and 241 Mm^3 (WY 1983).

During WY 2012, a series of relatively minor storms[5] occurred (Figure 6). A storm that caused flow to escape the low flow channel and inundate the in-channel bars did not occur until 1/21/12, very late in the season compared to what has generally occurred over the past years of sampling and analysis for this system (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011). The flow during this January storm was 1220 cfs; flows of this magnitude are common in most years. Flow peaked in WY 2012 at 1290 cfs on 4/13/2012 at 07:15 and total runoff during WY 2012 based on USGS data was 38.0 Mm^3; discharge of this magnitude is about 85% mean annual runoff (MAR) based on 83 years of record and 68% MAR if we consider the period WY1971-2010 (perhaps more representative of current climatic conditions given climate change). Rainfall data corroborates this assertion; rainfall during WY 2012 was 7.09 inches, or 49% of mean annual precipitation (MAP = 15.07 in) based on a long-term record at San Jose (NOAA gauge No: 047821) for the period 1971-2010 (CY). CY 2012 was the driest year in the past 42 years and the 7th driest for the 138 year record beginning 1875.

Water year 2013 was only slightly wetter, raining 9.43 inches at the San Jose gauge (65% MAP for the period 1971-2010 [CY]). Three moderate sized storms occurred in late November and December which led to three peak flows above 1500 cfs within a span of one month (Figure 6). Flow peaked on the third of these storms at 3160 cfs on 12/23/12 at 18:45, a peak flow which has been exceeded in half of all years monitored (83 years). Total runoff during WY 2013 based on USGS data was 45.8 Mm^3; discharge of this magnitude is about 82% MAR based on 83 years of record and equivalent to the MAR for the period WY1971-2010.

Water year 2014 was drier than the two previous, raining only 6.32 inches (43 % MAP for the period 1971-2010 [CY]). One moderately sized storm occurred in late February 2014, but otherwise only minor storms occurred during the year. Flow peaked on February 28th, 2014 at 07:30 at 2310 cfs, which has historically been exceeded in 59% of all monitored years. Total flow for the water year has not been published by the USGS[6]. However, when just comparing the October-April time period for each water year monitored in this study, WY 2014 was less than the previous two at only 16.7 Mm^3 compared with 25.8 and 35.5 Mm^3 for WYs 2012 and 2013, respectively.

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[5] A storm was defined as rainfall that resulted in flow that exceeds bankfull, which, at this location, is 200 cfs, and is separated by non-storm flow for a minimum of two days.

[6] The USGS normally publishes finalized data for the permanent record in the spring following the end of each Water Year.

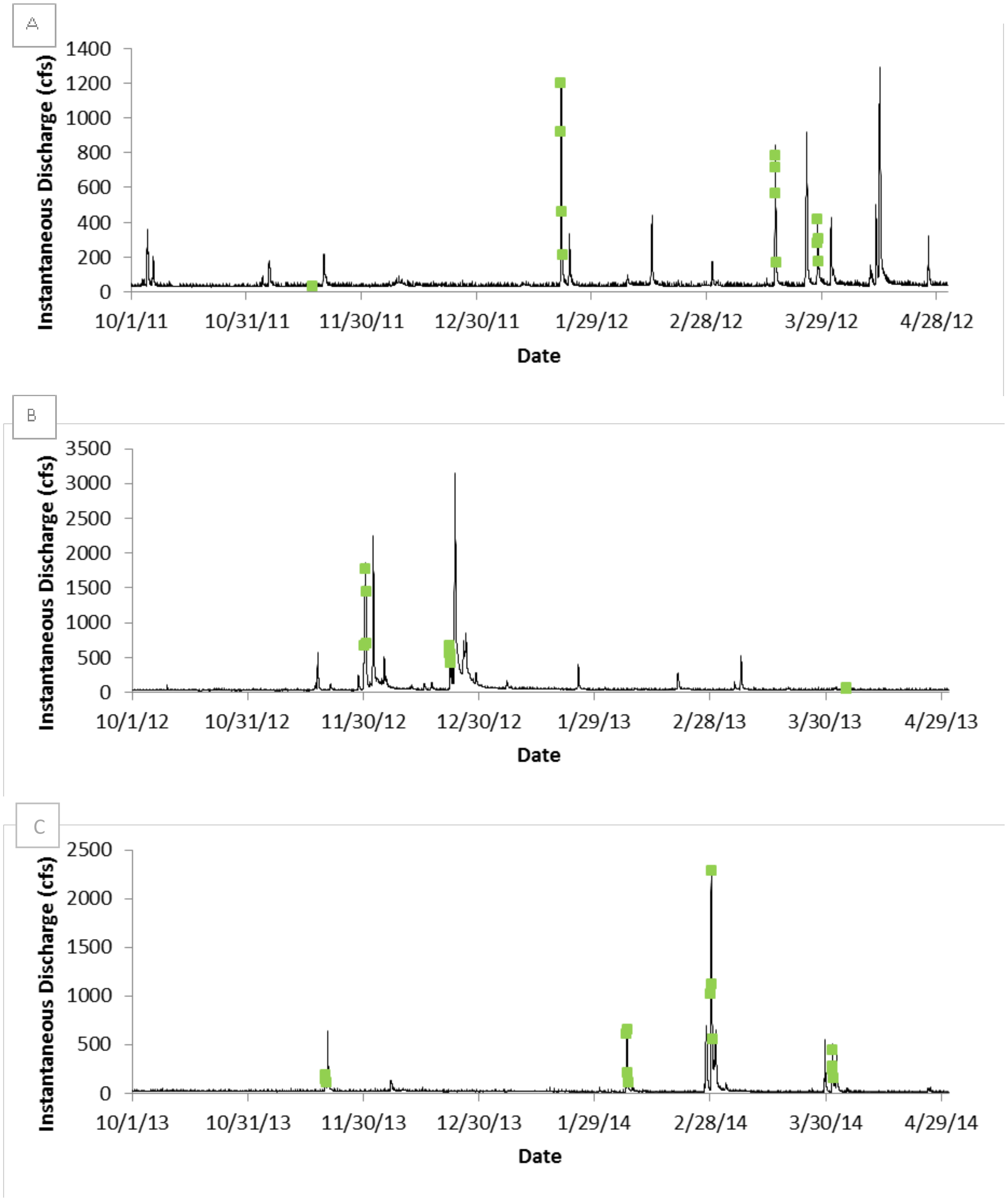

Figure 6. Flow characteristics in Guadalupe River during water year 2012 (A), 2013 (B) and 2014 (C) based on published 15-minute data provided by the USGS (gauge number 11169025), with sampling events plotted in green. The fuzzy nature of the low flow data are caused by baseflow discharge fluctuations likely caused by pump station discharges near the gauge.

8.3.2. Guadalupe River turbidity and suspended sediment concentration

The US Geological Survey also maintains the turbidity sensor at this location. Turbidity generally responded to rainfall events in a similar manner to runoff. Generally, peak turbidities fluctuated throughout the storm season between 150 – 600 FNU for each storm. Based on past years of record, turbidity can exceed 1000 FNU at the sampling location (e.g. McKee et al., 2004), so these monitored years produced turbidity conditions that were generally much lower than the system is capable of. In WY 2012, Guadalupe River exhibited a pronounced first flush during a very minor early season storm when, relative to flow, turbidity was elevated and reached 260 FNU. In contrast, the storm that produced the greatest flow for the season that occurred on 4/13/2012 had lower peak turbidity (185 FNU). A similar pattern occurred in WY 2013, except that the third large storm event on 12/23/12 raised turbidity to its peak for the season (551 FNU). Peak turbidity for WY 2012 was 388 FNU during a storm on 1/21/12 at 3:15 am. Despite higher peak flow in WY 2014 than 2012, turbidity peak only reached 273 FNU during in the intense first flush on 11/20/13 at 15:45.

A continuous record of SSC was computed by SFEI using the POC monitoring SSC data, the USGS turbidity record, and a linear regression model between instantaneous turbidity and SSC for each water year. Based on USGS sampling in Guadalupe River in past years, >90% of particles in this system are <62.5 µm in size (e.g. McKee et al., 2004). Because of these consistently fine particle sizes, turbidity correlates well with the concentrations of suspended sediments and hydrophobic pollutants (e.g. McKee et al., 2004). Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. It is estimated that SSC peaked in WY 2012 at 728 mg/L during the 1/21/12 storm event at 3:15, in WY 2013 at 957 mg/L on 12/23/12 at 19:00, and in WY 2014 at 474 mg/L on 11/20/13 at 15:45. The maximum SSC observed during previous monitoring years was 1180 mg/L in 2002. Rainfall intensity was much greater during WY 2003 than any other year since, leading to the hypothesis that concentrations of this magnitude will likely occur in the future during wetter years with greater and more intense rainfall (McKee et al., 2006).

8.3.3. Guadalupe River POC concentrations (summary statistics)

A summary of concentrations is useful for providing comparisons to other systems and also for doing a first order quality assurance check. Concentrations measured in Guadalupe River during the project are summarized (Table 20). Guadalupe River is unique among the sampling location in that it has been sampled for POCs on and off since November 2002. The results from previous work (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011) are not included in the summary statistics provided here. The interested reader will need to refer to those reports

The range of PCB concentrations are typical of mixed urban land use watersheds (Lent and McKee, 2011) and mean concentrations in this watershed were the 3rd highest measured of the six locations (Pulgas Creek PS > Sunnyvale Channel > Guadalupe River = North Richmond PS > San Leandro Creek >Lower Marsh Creek). However, maximum concentrations measured in Guadalupe River in the past were ~2-fold greater (e.g. McKee et al., 2006). PCB processes are complex in this watershed and are known to be greater in runoff derived from the urban landscape and lower in runoff derived from the upper less urban watershed (McKee et al., 2006). Concentrations in Guadalupe River watershed at the Hwy 101 sampling location appear to be similar to watersheds with industrial sources where concentrations in excess of about 100 ng/L are common (Marsalek and Ng, 1989; Hwang and Foster, 2008; Zgheib et al., 2011; Zgheib et al., 2012; McKee et al., 2012). In contrast, watersheds with little to no urbanization dominated by agriculture and open space exhibit average concentrations <5 ng/l (David et al., in press; Foster et al., 2000a; Howell et al. 2011; McKee et al., 2012). In instances where urbanization and industrial sources are highly diluted by >75% developed agricultural land concentrations averaging 8.9 ng/L can be observed (Gómez-Gutiérrez et al., 2006). The Guadalupe River watershed has an imperviousness of 39% and exhibits a particle ratio of 84 pg/mg (based on all sampling to-date including previous studies); the 10th highest observed so far in the Bay Area out of 24 locations and well above the background of rural areas (indicated by Marsh Creek in the Bay Area).

Maximum mercury concentrations (1000 ng/L measured in WY 2012) are greater than observed in Z4LA (Gilbreath et al., 2012) and the San Pedro stormdrain (SFEI unpublished data), which drains an older urban residential area of San Jose. This maximum concentration was higher than the average mercury concentration (690 ng/L) but much less than the maximum concentration (~18,700 ng/L) observed over the period of record at this location (2002-2010) (McKee et al., 2010). Concentrations were orders of magnitude greater than those observed in three urban Wisconsin watersheds (Hurley et al., 1995), urban influenced watersheds of the Chesapeake Bay region (Lawson et al., 2001), and two sub-watersheds of mostly urban land use in the Toronto area (Eckley and Branfirheun, 2008). The concentrations in Guadalupe River are similar to those of very highly contaminated watersheds with direct local point source discharge or mining influences (e.g. 1600-4300 ng/L: Ullrich et al., 2007; 100-5000 ng/L: Picado and Bengtsson, 2012; Kocman et al., 2012; 78-1500 ng/L: Rimondi et al., 2014).

The MeHg concentrations during the three-year study ranged from 0.04-1.2 ng/L and were lower than maximum concentrations (2.51 ng/L) observed previously for this sampling location (McKee et al., 2010). Concentrations of this magnitude or greater have been observed in a number of Bay Area urban influenced watersheds (Zone 4 Line A: Gilbreath et al., 2012; Glen Echo Creek and Zone 5 Line M: McKee et al., 2012). However, concentrations of methylmercury of this magnitude have not been observed in urbanized watersheds from other parts of the world (Mason and Sullivan, 1998; Naik and Hammerschmidt, 2011; Chalmers et al., 2014). Although local Hg sources can be a factor in helping to elevate MeHg production and food-web impacts, it is generally agreed, at least for agricultural and forested systems with lesser urban influences, that Hg sources are not a primary limiting factor in MeHg production (Balogh et al., 2002; Balogh et al., 2004; Barringer et al., 2010; Zheng et al., 2010; Bradely et al., 2011). Based on previous sampling experience in the system (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011) and these simple comparisons to other studies, there are no reasons to suspect any data quality issues.

Nutrient concentrations were in the same range as measured in in Z4LA (Gilbreath et al., 2012), and typical for the Bay Area, phosphorus concentrations appear greater than elsewhere in the world under similar land use scenarios, perhaps attributable to geological sources (McKee and Krottje, 2005). Nitrate concentrations were highest in Guadalupe River and North Richmond pump station during this study. Nitrate concentrations appear similar between San Leandro Creek, Lower Marsh Creek, Sunnyvale East Channel, and Pulgas Creek Pump Station. In contrast, nitrate concentrations were about 2-fold greater in Guadalupe River and North Richmond Pump Station. Mean orthophosphate concentrations (0.15 mg/L)

Table 20. Summary of laboratory measured pollutant concentrations in Guadalupe River for water years 2012, 2013, and 2014.

		2012							2013							2014						
Analyte	Unit	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	41	100%	8.6	730	82	198	205	41	100%	5.9	342	128	124	104	54	100%	5.8	358	110	150	102
ΣPCB	ng/L	11	100%	2.7	59.1	7.17	17.7	21.5	12	100%	2.04	47.4	6.29	10.6	12.7	16	100%	3.1	33.1	11.4	14.6	11.1
Total Hg	ng/L	12	100%	36.6	1000	125	268	324	12	100%	14.5	360	155	153	119	15	100%	45	740	130	215	193
Total MeHg	ng/L	10	100%	0.086	1.15	0.381	0.445	0.352	7	100%	0.04	0.94	0.49	0.428	0.34	10	100%	0.09	1.2	0.575	0.616	0.366
TOC	mg/L	12	100%	4.9	18	7.45	8.73	4.03	12	100%	5.3	11	6.05	6.36	1.55	16	100%	5.3	56	12.1	19.3	17.1
NO3	mg/L	12	100%	0.56	1.9	0.815	0.917	0.38	8	100%	0.45	2.3	1.43	1.38	0.905	16	100%	0.32	1.8	0.54	0.685	0.403
Total P	mg/L	12	100%	0.19	0.81	0.315	0.453	0.247	12	100%	0.098	0.61	0.355	0.31	0.159	16	100%	0.11	1	0.485	0.464	0.268
PO4	mg/L	12	100%	0.06	0.16	0.101	0.101	0.0321	12	100%	0.061	0.18	0.12	0.109	0.0339	16	100%	0.11	0.5	0.17	0.218	0.125
Hardness	mg/L	3	100%	133	157	140	143	12.3								4	100%	94	200	120	134	46
Total Cu	ug/L	3	100%	10.7	26.3	24.7	20.6	8.58	3	100%	5.9	28	23	19	11.6	4	100%	12	34	25.5	24.3	9.54
Dissolved Cu	ug/L	3	100%	5.07	7.91	5.51	6.16	1.53	3	100%	2.5	3.6	2.5	2.87	0.635	4	100%	2.9	12	4	5.72	4.24
Total Se	ug/L	3	100%	1.16	1.63	1.21	1.33	0.258	3	100%	0.7	3.3	0.78	1.59	1.48	4	100%	0.6	1.8	0.98	1.09	0.506
Dissolved Se	ug/L	3	100%	0.772	1.32	1.04	1.04	0.274	3	100%	0.4	3.2	0.54	1.38	1.58	4	100%	0.34	1.5	0.775	0.847	0.502
Carbaryl	ng/L	3	100%	13	57	54.3	41.4	24.7	3	67%	0	21	17	12.7	11.2	4	100%	12	64	28.5	33.3	21.9
Fipronil	ng/L	3	100%	6.5	20	11	12.5	6.87	3	100%	3	11	9	7.67	4.16	4	100%	8	15	14.5	13	3.37
ΣPAH	ng/L	1	100%	611	611	611	611		8	100%	40.7	736	174	251	245	2	100%	692	1260	978	978	405
ΣPBDE	ng/L	1	100%	23	23	23	23		2	100%	13.1	69.8	41.4	41.4	40.1	2	100%	96.7	101	99	99	3.18
Delta/ Tralomethrin	ng/L	3	100%	0.704	1.9	1.81	1.47	0.667	3	0%	0	0	0	0	0	4	50%	0	2.8	0.65	1.02	1.33
Cypermethrin	ng/L	3	0%	0	0	0	0		3	100%	0.5	3.3	1.7	1.83	1.4	4	100%	1.1	5	1.65	2.35	1.8
Cyhalothrin lambda	ng/L	3	33%	0	0.6	0	0.2	0.346	3	100%	0.3	1.5	0.5	0.767	0.643	4	75%	0	1.46	0.6	0.665	0.606
Permethrin	ng/L	3	100%	16.8	20.5	19.5	18.9	1.91	3	33%	0	5.4	0	1.8	3.12	4	100%	7.2	14	10.6	10.6	3
Bifenthrin	ng/L	3	67%	0	13.3	6.16	6.47	6.63	3	100%	0.9	7.6	5.9	4.8	3.48	4	100%	3.5	6.1	4.75	4.78	1.47

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at Guadalupe River was two.

were slightly lower than observed in the Richmond Pump Station but 20-50% above the other four sample sites. The maximum total P concentration (1 mg/L) was very high in this study relative to the other watersheds; however, average total P concentrations were similar across the six sites. Concentrations appear typical or slightly greater than for PO4 and total P found in urban watersheds in other parts of the country and world (e.g. Hudak and Banks, 2006; comprehensive Australian literature review for concentrations by land use class: Bartley et al., 2012). These elevated phosphorus concentrations, especially the peak concentration observed in Guadalupe River, may perhaps be attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005; Pearce et al., 2005).

Organic carbon concentrations observed in Guadalupe River during WYs 2012-2014 (4-56 mg/L) were higher than those observed in Z4LA (max = 23 mg/L; FWMC = 12 mg/L: Gilbreath et al., 2012). They were greater than but more similar to maximum concentrations observed in Sunnyvale East Channel (30 mg/L) but less than Pulgas Creek South Pump Station (140 mg/L). Although we have not done an extensive literature review of TOC concentrations in the worlds river systems, our general knowledge of the literature would have us hypothesize that concentrations of these magnitudes are very high. These may be contributing to the apparent high methylation rates in the Bay Area.

A similar style of first order quality assurance is also possible for analytes measured at a lesser frequency using composite sampling design (see methods section) (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) and appropriate for water quality characterization only. The maximum concentration of PBDEs (101.2 ng/L) was similar to Sunnyvale East Channel, lesser by 15-fold than North Richmond Pump Station and greater by about 2-fold than the other locations. Only two peer reviewed articles describing PBDE concentrations in runoff have been located, one for the Pearl River Delta, China (Guan et al., 2007), and the other for the San Francisco Bay (Oram et al., 2008) based, in part, on concentration data from Guadalupe River and Coyote Creek taken during WYs 2003-2006. Maximum total PBDE concentrations measured by Guan et al. (2007) were 68 ng/L, a somewhat surprising result given that the Pearl River Delta is a known global electronic-waste recycling hot spot. However, the Guan et al. study was based on monthly interval collection as opposed to storm event-based sampling and was completed in a larger river system where dilution of point source may have occurred.

Copper, which was sampled at a lesser frequency for characterization only, was similar to concentrations previously observed (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006) and similar to those observed in Z4LA (Gilbreath et al., 2012). Maximum selenium concentrations were generally 2-10 fold greater than the other five locations and were generally higher than Z4LA; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Similar to the other sites, carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L: Moran, 2007) (Carbaryl: DL - 700 ng/L: Ensiminger et al., 2012; tributaries to Salton Sea, Southern CA geometric mean ~2-10 ng/L: LeBlanc and Kuivila, 2008). Pyrethroid concentrations of Delta/ Tralomethrin and Bifenthrin were about 2.5-fold less than those observed in Z4LA whereas concentrations of Cyhalothrin lambda and Permethrin were about 8-fold lower (Gilbreath et al., 2012). In summary, mercury concentrations are elevated in the Guadalupe Giver relative to typical Bay Area and other urban watersheds and are more akin to concentrations observed in mining and point source contaminated systems. Concentrations of other POCs are either within the range of or below those measured in other typical Bay Area urban watersheds and appear consistent with or explainable in relation to studies from elsewhere. There do not appear to be any data quality issues.

8.3.4. Guadalupe River toxicity

Composite water samples were collected at the Guadalupe River station during three storm events in WY 2012, three storm events in WY 2013, and four storm events in WY 2014. Similar to the results for other POC monitoring stations, no significant reductions in the survival, reproduction and growth of three of four test species were observed during storms except for fathead minnow growth reductions in two WY 2014 samples and a reduction in fathead minnow survival in one WY 2014 sample. Significant reductions in the survival of the amphipod *Hyalella azteca* were observed during two of the three WY 2012 events sampled and three of the four WY 2014 samples.

8.3.5. Guadalupe River loading estimates

The following methods were applied to estimate loads for the Guadalupe River in WYs 2012, 2013, and 2014. Suspended sediment loads for WY 2012 and 2013 were downloaded from USGS. Since the WY 2014 suspended sediment record has not yet been published, concentrations were estimated from the turbidity record using a linear relation (Table 21). Once the official USGS flow and SSC record is published for WY 2014, the suspended sediment load will be updated. Concentrations during storm flows were estimated using regression equations between the POCs and turbidity, except for nitrate and phosphate, in which a flow-surrogate regression was used (Table 21). As found during other drier periods (McKee et al., 2006), a separation of the data for PCBs to form regression relations based on origin of flow was possible. On the other hand, there was virtually no mining runoff during these very dry years and although a separation was made for Hg in addition to PCBs, very few data points populated the regression between Hg and turbidity for the upper watershed as the source of flow.

Monthly discharge was greatest in December 2012 as were loads of most pollutants. This single wet month transported approximately 50% of the PCB and mercury load of the two wet seasons combined. WY 2013 loads were approximately 3-fold higher than WY 2012 and 4-fold greater than WY 2014. However, compared to previous sampling years (McKee et al., 2004; McKee et al., 2005; McKee et al., 2006; McKee et al., 2010; Owens et al., 2011 [Hg only]), loads of total mercury and PCBs were lower than any previously observed years (Table 22). At this time, all loads estimates for WY 2014 should be considered preliminary. Once available, USGS official records for flow, turbidity, and SSC can be substituted for the preliminary data presented here. Overall, WY 2012, 2013, and 2014 loads may be considered representative of loads during dry conditions in this watershed.

Table 21. Regression equations used for loads computations for Guadalupe River during water year 2012, 2013, and 2014.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/L/NTU)	Mixed	1.69	0.93	0.92	Regression with turbidity
Total PCBs (ng/L/NTU)	Mainly urban	0.236	1.42	0.71	Regression with turbidity
Total PCBs (ng/L/NTU)	Mainly non-urban & baseflow	0.081		0.81	Regression with turbidity
Total Mercury (ng/L/NTU)	Mixed	2.21		0.82	Regression with turbidity
Total Methylmercury (ng/L/NTU)	Mixed	0.00352	0.181	0.6	Regression with turbidity
Total Methylmercury (ng/L)	Baseflow	0.0994			Average
Total Organic Carbon (mg/L/NTU)	Mixed	0.0245	4.9715	0.49	Regression with turbidity
Total Phosphorous (mg/L/NTU)	Mixed	0.00213	0.153	0.72	Regression with turbidity
Nitrate (mg/L/CFS)	Mainly urban	-0.00133	1.99	0.64	Regression with flow
Nitrate (mg/L/CFS)	Mainly non-urban & baseflow	-0.000161	0.732	0.17	Regression with flow
Phosphate (mg/L/CFS)	Mixed	0.0000336	0.0906	0.36	Regression with flow

Table 22. Monthly loads for Guadalupe River for water year 2012, 2013 and 2014.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	19	2.91	167	16,565	9.63	190	0.556	2449	270	628
	11-Nov	15	2.88	104	15,552	6.01	111	0.441	2300	266	548
	11-Dec	1	2.73	76.3	14,016	1.42	38.7	0.272	1984	251	455
	12-Jan	18	3.85	564	28,348	30.9	570	1.33	3077	396	1128
	12-Feb	14	3.15	305	18,361	10.4	243	0.613	2451	294	716
	12-Mar	50	5.08	403	30,542	35.1	433	1.50	4238	495	1314
	12-Apr	44	5.22	486	30,994	29.8	452	1.41	4381	527	1235
	Wet season total	161	25.8	2,106	154,379	123	2,039	6.13	20,879	2,498	6,023
2013	12-Oct	8	2.26	60.5	11,988	3.67	68.5	0.258	1810	207	411
	12-Nov	48	5.23	1092	38,487	53.1	999	2.68	4148	592	1862
	12-Dec	92	14.8	2768	117,823	230	4034	8.90	9301	1745	6174
	13-Jan	15	4.14	204	21,988	8.35	129	0.58	3237	385	756
	13-Feb	11	3.05	85.7	15,999	4.69	76.3	0.398	2355	282	539
	13-Mar	21	3.47	123.4	18,604	7.45	122	0.546	2837	325	648
	13-Apr	5	2.57	130.2	13,319	2.37	47.7	0.279	2087	235	439
	Wet season total	201	35.5	4,464	238,208	309	5,476	13.6	25,775	3,771	10,829
2014	13-Oct	0	1.72	25.5	8,902	1.22	33.2	0.171	1250	157	294
	13-Nov	21	2.25	132	17,545	16.2	169	0.510	2021	246	551
	13-Dec	4	1.96	24.7	10,106	2.23	32.2	0.225	1582	180	331
	14-Jan	3	1.53	15.6	7,837	0.748	20.4	0.152	1115	140	254
	14-Feb	64	4.55	696	34,750	57.6	1009	2.28	3076	538	1797
	14-Mar	35	3.07	148	17,982	13.7	188	0.673	2571	306	627
	14-Apr	17	1.67	50.8	9,020	5.51	66.2	0.274	1566	156	319
	Wet season total	144	16.7	1,094	106,141	97.2	1,519	4.29	13,182	1,723	4,172

8.3. Sunnyvale East Channel

8.3.1. Sunnyvale East Channel flow

Santa Clara Valley Water District (SCVWD) has maintained a flow gauge on Sunnyvale East Channel from WY 1983 to present. Unfortunately, the record is known to be of poor quality (pers. comm., Ken Stumpf, SCVWD), which was apparent when the record was regressed against rainfall (R^2 = 0.58) (Lent et al., 2012). The gauge is presently scheduled for improvement by SCVWD. Despite the poor historical flow record, velocity measurement conducted in WY 2013 confirmed the good quality of the SCVWD discharge-rating curve up to stages of 2.9 ft (corresponding to flows of 190 cfs) for this site. Consequently, flow could be calculated using that curve and the continuous stage record collected during this study.

All three monitored water years were relatively dry years and discharge was likely lower than average. Rainfall during WYs 2012-2014 was 8.82, 12.1 and 8.1 inches, respectively, at Palo Alto (NOAA gauge number 046646). Relative to mean annual precipitation (MAP = 15.5 in) based on a long-term record for the period 1971-2010 (CY), WY 2012 was only 57% MAP, WY 2013 was 78% MAP, and WY 2014 was 52% MAP.

A series of relatively minor storms occurred during WY 2012 (Figure 7). Flow peaked at 492 cfs overnight on 4/12/12- 4/13/12 at midnight. Total runoff during WY 2012 for the period 12/1/11 to 4/30/12 was 1.07 Mm^3 based on our stage record and the SCVWD rating curve. Total annual runoff WY 2013 for the period between 10/01/12 and 4/30/13 was 1.51 Mm^3 and likely below average based on below average rainfall. However, unlike WY 2012 in which the rainfall was spread over several smaller events, the majority of WY 2013 rainfall occurred during three large storm events in late November and December, each of which was of 1-2 year recurrence based on NOAA Atlas 14 partial duration series data for the area. Flow peaked during the third event of this series at 727 cfs on 12/23/12 at 15:15. Given that SCVWD maintains the channel to support a peak discharge of 800 cfs, the December 2012 storms resulted in significant flows for the system. Field observations during sampling of the early December storms corroborate this assertion; stages neared the top of bank and the banks of the channel for the observable reach at and upstream from the sampling location showed evidence of erosion. This is yet another vivid example of why peak discharge often correlates with total wet season load better than total wet season flow (Lewicki and McKee, 2009). The WY 2014 wet season was very similar to the WY 2012 season, both in terms of total annual flow (1.01 Mm3) as well as the relative size of the storms, peaking at 439 cfs on February 28th, 2014 at 3:45 am.

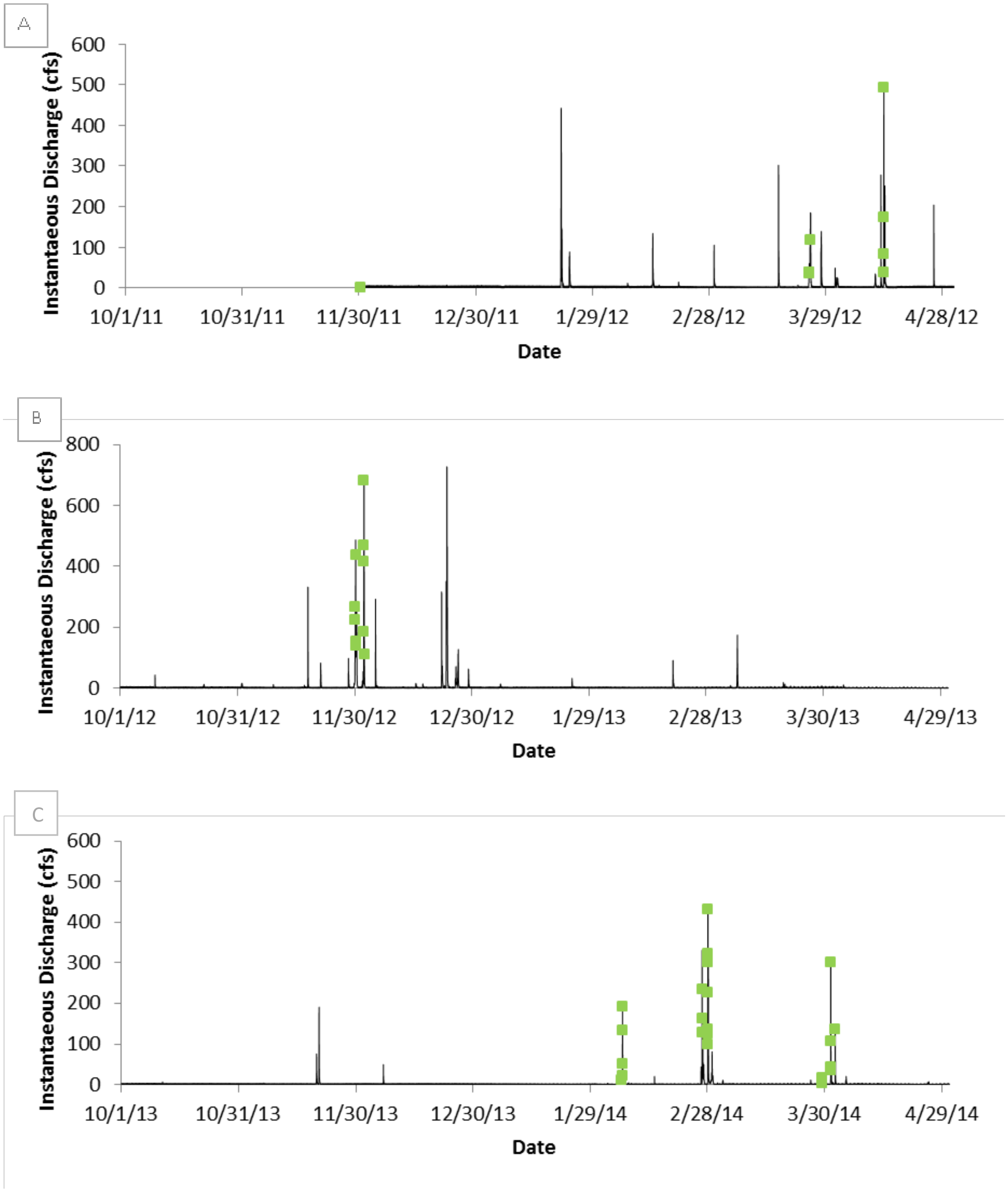

Figure 7. Flow characteristics in Sunnyvale East Channel at East Ahwanee Avenue during WY 2012 (A), WY 2013 (B) and WY 2014 (C) with sampling events marked in green. The flow record is based on the District rating curve for this station as verified by velocity sampling completed during the study in WY 2013.

8.3.2. Sunnyvale East Channel turbidity and suspended sediment concentration

The entire turbidity record for WY 2012 was censored due to problems believed to be with the installation design and the OBS-500 instrument reading the bottom of the channel. In WY 2013, the OBS-500 instrument was replaced with an FTS DTS-12 turbidity probe (0-1,600 NTU range). This instrument performed well through to the first large storm on 11/30/12 and then the turbidity record experienced numerous spikes through the rest of the season. Our observations during maintenance suggested that the three large storm events in late November and December uprooted and dislodged a lot of vegetation and some trash, which slowly passed through the system throughout the season and caught on the boom structure where turbidity was monitored. After field visits to download data and perform maintenance on site including removing the vegetation from the boom, the turbidity record cleared until the next elevated flow. Consequently, 8.3% of the turbidity record was censored due to fouling. In WY 2014, the FTS DTS-12 sensor was used again with more regular field maintenance. Vegetation continued to be a problem throughout the season, fouling the record at times. More regular maintenance and attempts at structural modifications to help deflect vegetation improved the completeness of the record from the previous year, this time with 7% of the record censored and corrected by interpolation.

Given the challenges with the turbidity sensor installation during the first year and vegetation disruptions in the subsequent years, multiple approaches were used for the estimation of SSC. For the portions of the record that were of good quality or deemed to be good quality after correction, turbidity surrogate regression could be used (R^2 = 0.87). For the entire WY 2012 and the portions of the WY 2013 record for which turbidity was not usable, SSC was alternatively computed as a function of flow (with much lower confidence due to the loss of hysteresis in the computational scheme). The relationship was strong in WY 2012 (R^2 = 0.97) and moderately strong in WY 2013 (R^2=0.82).

Turbidity in Sunnyvale East Channel in WY 2013 and 2014 remained low (<40 NTU) during base flows and increased to between 200 and 1000 NTU during storms. Interestingly, turbidity season peaks in both water years occurred during the seasonal first flush, which also happened to corresponded in both years with storms that were short-lived but relatively intense. Turbidity peaked at 1014 NTU early in the season on 10/9/12 in response to a small but intense rainfall in which 0.19 inches fell in 20 minutes. In WY 2014 and turbidity peaked for the season at 424 NTU on the 11/20/13 storm when 0.25 inches fell in one hour. Three large events in November and December 2012 resulted in turbidities in the 600-900 NTU range, and otherwise turbidity for most other events peaked between 200 and 400 NTU.

Computed suspended sediment concentration in WY 2012 peaked at 362 mg/L on 4/13/12 just after midnight, at 3879 mg/L on 10/9/12, and 1148 mg/L on 11/20/13, all in response to the measured peak flow (in WY 2012) or peak turbidity (WY 2013 and 2014) for the given wet season. Although these concentrations are an order of magnitude different, lab measured samples from storm monitoring events in each WY corroborated these results; the maximum sampled lab measured SSC in WY 2012 was 370 mg/L (collected on 4/13/12), 3120 mg/L in WY 2013 (collected on 12/2/12; the 10/9/12 estimated peak SSC occurred during a non-sampled storm event), and 514 mg/L in WY 2014 (collected on 2/26/2014; the 11/20/13 estimated peak SSC also occurred during a non-sampled storm event).

8.3.3. Sunnyvale East Channel POC concentrations (summary statistics)

A summary of concentrations is useful for providing comparisons to other systems and also for doing a first order quality assurance check on the data generated; data that differs from that reported elsewhere may indicate errors or provide evidence for source characteristics. A wide range of pollutants were measured in Sunnyvale East Channel during the three-year project (Table 233). Concentrations for pollutants sampled at a sufficient frequency for loads analysis (suspended sediments, PCBs, mercury, organic carbon, and nutrients) exhibited the typical pattern of median < mean except for some cases where organic carbon, nitrate, phosphate, and PAH where the mean and median were similar.

The range of PCB concentrations were elevated relative to other mixed urban land use watersheds (range 0.1-1120 ng/L: Lent and McKee, 2011) with maximum concentrations observed at 980 ng/L. Highest PCB concentrations were measured during the February 28, 2014 storm event where an estimated 1.3 inches of rain fell in this watershed. This event followed a 0.9 inch rain event 2 days prior. These concentrations were amongst the highest PCB concentration measured to-date in the Bay Area with project site mean PCB concentrations ranking only behind Pulgas Creek South and Santa Fe Channel. PCB concentrations remained elevated throughout other monitored storms during WY 2014 helping to support a hypothesis that there is a large PCB source in this watershed. Concentrations in the Sunnyvale East Channel watershed appear to be similar to watersheds with industrial sources where concentrations in excess of about 100 ng/L are common (Marsalek and Ng, 1989; Hwang and Foster, 2008; Zgheib et al., 2011; Zgheib et al., 2012; McKee et al., 2012). In contrast, watersheds with little to no urbanization dominated by agriculture and open space exhibit average concentrations <5 ng/l (David et al., in press; Foster et al., 2000a; Howell et al. 2011; McKee et al., 2012). In instances where urbanization and industrial sources are highly diluted by >75% developed agricultural land concentrations averaging 8.9 ng/L can be observed (Gómez-Gutiérrez et al., 2006). The Sunnyvale East Channel watershed has an imperviousness of 69% and exhibits a particle ratio of 869 pg/mg (based on all sampling to-date including WY 2011 data); the fourth highest observed so far in the Bay Area out of 24 locations and well above the background of rural areas (indicated by Marsh Creek in the Bay Area).

The range of mercury concentrations were comparable to those observed in Z4LA (Gilbreath et al., 2012) while the maximum total mercury concentration in Sunnyvale East Channel (220 ng/L) was greater than sampled in Z4LA (150 ng/L). Concentrations were also much greater than those observed in three urban Wisconsin watersheds (Hurley et al., 1995), urban influenced watersheds of the Chesapeake Bay region (Lawson et al., 2001), and two sub-watersheds of mostly urban land use in the Toronto area (Eckley and Branfirheun, 2008). Similar to Marsh Creek and San Leandro Creek, where the maximum Hg concentrations are somewhat attributed to the erosion of soils, Sunnyvale East Channel watershed also transports high concentrations of suspended sediment (maximum observed from grab samples was 3120 mg/L). Given the relatively low particle ratio (0.22 mg/kg) not greatly elevated about what might be considered background for CA soils (0.1 mg/kg equivalent to ng/mg: Bradford et al., 1996), Hg sources and transport in this watershed are more likely attributed to local atmospheric deposition or perhaps redeposition from historical and ongoing Lehigh Hanson Permanente Cement Plant (Rothenberg et al., 2010a; Rothenberg et al., 2010b). The source-release-transport processes for Hg in

Table 23. Summary of laboratory measured pollutant concentrations in Sunnyvale East Channel during water years 2012, 2013, and 2014.

		2012							2013							2014						
Analyte	Unit	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	28	96%	0	370	49.5	81.6	100	34	97%	0	3120	301	485	645	75	99%	0	514	125	173	134
ΣPCB	ng/L	8	100%	3.27	119	33.6	41.3	41.5	10	100%	9.16	176	31.3	59.3	64.3	22	100%	2.86	983	90.7	147	223
Total Hg	ng/L	8	100%	6.3	64.1	21.7	27.7	21.7	10	100%	13	220	55.5	72.9	65.2	22	100%	14	120	37	43.1	27
Total MeHg	ng/L	6	83%	0	0.558	0.226	0.25	0.22	6	100%	0.02	0.54	0.22	0.252	0.22	15	93%	0	0.7	0.33	0.332	0.173
TOC	mg/L	8	100%	4.91	8.6	5.94	6.41	1.4	10	100%	4.1	10	5.85	5.85	1.71	22	100%	4.5	30	10.5	13.4	7.94
NO3	mg/L	8	100%	0.2	0.56	0.28	0.309	0.119	10	100%	0.15	0.37	0.28	0.269	0.069	23	100%	0.13	2.6	0.28	0.618	0.714
Total P	mg/L	8	100%	0.19	0.5	0.25	0.277	0.0975	10	100%	0.23	1.7	0.385	0.522	0.434	23	100%	0.11	0.92	0.36	0.408	0.212
PO4	mg/L	8	100%	0.067	0.11	0.079	0.0847	0.0191	10	100%	0.094	0.13	0.12	0.115	0.0098	23	100%	0.006	0.285	0.13	0.148	0.069
Hardness	mg/L	2	100%	51.4	61.2	56.3	56.3	6.93								6	100%	92	340	100	146	97.5
Total Cu	ug/L	2	100%	10.8	19	14.9	14.9	5.79	2	100%	19	31	25	25	8.49	6	100%	11	21	18	16.5	4.09
Dissolved Cu	ug/L	2	100%	4.36	14.8	9.58	9.58	7.38	2	100%	3.1	4.9	4	4	1.27	6	100%	2.8	6.1	4.32	4.63	1.24
Total Se	ug/L	2	100%	0.327	0.494	0.41	0.41	0.118	2	100%	0.49	0.49	0.49	0.49	0	6	100%	0.33	1.9	0.545	0.71	0.593
Dissolved Se	ug/L	2	100%	0.308	0.325	0.317	0.317	0.012	2	100%	0.35	0.39	0.37	0.37	0.0283	6	100%	0.24	1.8	0.47	0.637	0.583
Carbaryl	ng/L	2	100%	11	21	16	16	7.07	2	50%	0	19	9.5	9.5	13.4	6	17%	0	14	0	2.33	5.72
Fipronil	ng/L	2	100%	6	12	9	9	4.24	2	50%	0	6	3	3	4.24	6	100%	3	11	6.5	6.83	2.86
ΣPAH	ng/L	1	100%	289	289	289	289		1	100%	1350	1350	1350	1350		4	100%	382	2770	1660	1620	1260
ΣPBDE	ng/L	1	100%	4.83	4.83	4.83	4.83		1	100%	34.9	34.9	34.9	34.9		4	100%	15.7	103	62	60.6	40.7
Delta/ Tralomethrin	ng/L	1	0%	0	0	0	0		2	100%	3.6	3.8	3.7	3.7	0.141	6	100%	0.6	3.25	1.13	1.42	0.947
Cypermethrin	ng/L	2	0%	0	0	0	0		2	100%	3.2	5.2	4.2	4.2	1.41	6	100%	2.6	6	4.13	4.08	1.16
Cyhalothrin lambda	ng/L	1	0%	0	0	0	0		2	100%	1.2	2.5	1.85	1.85	0.919	5	80%	0	0.6	0.3	0.31	0.213
Permethrin	ng/L	2	100%	5.7	20.9	13.3	13.3	10.8	2	100%	22	48	35	35	18.4	6	100%	11	29	18.8	20.2	6.45
Bifenthrin	ng/L	2	50%	0	8	4	4	5.66	2	100%	8.7	18	13.3	13.3	6.58	6	100%	2	18	5.3	7.56	5.94

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation at Sunnyvale East Channel was two.

this watershed do not appear to be similar to those of very industrial watersheds with direct local point source discharge (e.g. 1600-4300 ng/L: Ullrich et al., 2007; 100-5000 ng/L: Picado and Bengtsson, 2012; Kocman et al., 2012; 78-1500 ng/L: Rimondi et al., 2014).

The MeHg concentrations during the three-year study ranged from DL-0.7 ng/L. Concentrations of this magnitude or greater have been observed in a number of Bay Area urban influenced watersheds (Zone 4 Line A: Gilbreath et al., 2012; Glen Echo Creek Santa Fe Channel, San Leandro Creek, and Zone 5 Line M: McKee et al., 2012). However, concentrations of methylmercury of this magnitude have not been observed in urbanized watersheds from other parts of the world (Mason and Sullivan, 1998; Naik and Hammerschmidt, 2011; Chalmers et al., 2014). Although local Hg sources can be a factor in helping to elevate MeHg production and food-web impacts, it is generally agreed, at least for agricultural and forested systems with lesser urban influences, that Hg sources are not a primary limiting factor in MeHg production (Balogh et al., 2002; Balogh et al., 2004; Barringer et al., 2010; Zheng et al., 2010; Bradely et al., 2011). Based on plenty of previous sampling experience in numerous Bay Area watershed systems there are no reasons to suspect any data quality issues. Bay Area methylmercury concentrations appear to be elevated, perhaps associated with arid climate seasonal wetting and drying and high vegetation productivity in riparian areas of channels systems with abundant supply of organic carbon each fall and winter.

Nutrient concentrations were also in the same range as measured in Z4LA (Gilbreath et al., 2012) and like the other watersheds reported from the current study, phosphorus concentrations appear to be greater than elsewhere in the world under similar land use scenarios perhaps attributable to geological sources (McKee and Krottje, 2005). Nitrate concentrations appear strikingly similar between Sunnyvale East Channel and San Leandro Creek, Lower Marsh Creek, and Pulgas Creek Pump Station. In contrast, nitrate concentrations were about 2-fold greater in Guadalupe River and North Richmond Pump Station. Mean orthophosphate concentrations (0.128 mg/L) were similar to Pulgas Creek Pump Station but much lower than observed in the Richmond Pump Station and about 30% elevated above Lower Marsh and San Leandro Creeks. The maximum total P concentration (1.7 mg/L) should be considered very high for an urban watershed however average total P concentrations were similar across the six sites. Concentrations appear typical or slightly greater than for PO4 and TP of found in urban watersheds in other parts of the country and world (e.g. Hudak and Banks, 2006; comprehensive Australian literature review for concentrations by land use class: Bartley et al., 2012). Higher phosphorus concentrations especially the peak concentration observed in Sunnyvale East Channel may perhaps be attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005; Pearce et al., 2005).

Organic carbon concentrations observed in Sunnyvale East Channel during WYs 2012-2014 (4.1-30 mg/L) were higher than those observed in Z4LA (max = 23 mg/L; FWMC = 12 mg/L: Gilbreath et al., 2012). It turned out that these were the 3rd greatest observed in the Bay Area to-date. They were greater than but more similar to maximum concentrations observed in Guadalupe River (56 mg/L) but less than Pulgas Green Pump Station (140 mg/L). Although we have not done an extensive literature review of TOC concentrations in the worlds river systems, our general knowledge of the literature would have us hypothesize that concentrations of these magnitudes are very high. These may be contributing to the apparently high methylation rates in the Bay Area.

Of the pollutants sampled at a lesser frequency using a composite sampling design (see methods section) appropriate for characterization only, copper and selenium were similar to concentrations observed in Z4LA (Gilbreath et al., 2012) while PAHs and PBDEs were on the lower end of the range observed in Z4LA.

The maximum concentration of PBDEs (102.7 ng/L) was similar to Guadalupe River during this study (note greater concentrations have been observed in Guadalupe River at Hwy 101 previously: McKee et al., 2006) but lesser by 15-fold than North Richmond Pump Station and greater by about 2-fold than the other locations. Only two peer reviewed articles have previously described PBDE concentrations in runoff, one for the Pearl River Delta, China (Guan et al., 2007), and the other for the San Francisco Bay (Oram et al., 2008) based, in part, on concentration data from Guadalupe River and Coyote Creek taken during WYs 2003-2006. Maximum total PBDE concentrations measured by Guan et al. (2007) were 68 ng/L, a somewhat surprising result given that the Pearl River Delta is a known global electronic-waste recycling hot spot. However, the Guan et al. study was based on monthly interval collection as opposed to storm event-based sampling as was completed in a larger river system where dilution of point source may have occurred.

Similar to the other sites, carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L: Moran, 2007) (Carbaryl: DL - 700 ng/L: Ensiminger et al., 2012; tributaries to Salton Sea, Southern CA geometric mean ~2-10 ng/L: LeBlanc and Kuivila, 2008). Project mean Permethrin concentrations at Sunnyvale East Channel were amongst the highest measured to-date ranking only behind Zone 4 Line A. Concentrations of Delta/ Tralomethrin were similar to observed in Lower Marsh Creek and Richmond Pump Station. Bifenthrin were similar to all the other locations except Lower Marsh Creek where they were about 10-fold greater. Concentrations of Cyhalothrin lambda were similar in across San Leandro Creek, Guadalupe River, Sunnyvale East Channel, and Pulgas Creek Pump Station and about 2-fold greater in Marsh Creek and Richmond Pump Station. In general, the mix of pyrethriods used in each watershed appears to differ remarkably and is perhaps associated with local applicator and commercially available product preferences in home garden stores.

In summary, PCB concentrations are elevated in the Sunnyvale East Channel relative to typical Bay Area and other urban watersheds, Hg appears to be relatively low, whereas concentrations of other POCs are either within the range of or below those measured in other typical Bay Area urban watersheds and appear consistent with or explainable in relation to studies from elsewhere. Based on these first order comparisons, we see no quality issues with the data.

8.3.4. Sunnyvale East Channel toxicity

Composite water samples were collected in the Sunnyvale East Channel during two storm events in WY 2012, two storm events in WY 2013, and six storm events in WY 2014. No significant reductions in the survival, reproduction and growth of three of four test species were observed during storms. Significant reductions in the survival of the amphipod Hyalella azteca were observed during all WY 2012, WY 2013, and WY 2014 storm events.

8.3.5. Sunnyvale East Channel loading estimates

Given that the turbidity record in WY 2012 was unreliable due to optical interference from bottom substrate (a problem rectified in 2013), and gaps that existed in the WY 2013 record due to vegetation interference throughout the season, continuous suspended sediment concentration was estimated from the discharge record using a linear relation for the period of record in which turbidity was censored, and otherwise using the power relation with turbidity during the period in which the turbidity record was acceptable (Table 24). Concentrations of other POCs were estimated using regression equations between the pollutant and either flow or estimated SSC, whichever relation was stronger. Total organic carbon and the dissolved nutrients did not have a strong relation with either suspended sediment or flow and therefore a flow weighted mean concentration was applied to estimate the loads reported in Table 25. This table highlights how monthly loads can be dominated by a few large storm events. Relative to discharge, suspended sediment load showed quite high variability relative to some of the other sampling locations in the study. Although just one month (December 2012) discharged 17% of the total volume for WYs 2012, 2013, and 2014 combined, 62% of the suspended sediment load was transported during this month as well as approximately 22% of the PCB and 45% of the mercury loads. Given the context that WYs 2012, 2013, and 2014 were relatively dry years, we may be likely to see an even broader range of rainfall-runoff-pollutant transport processes in Sunnyvale East Channel if wetter seasons are sampled in the future – this could be something to consider also if this station were to be chosen as a trend indicator station.

Table 24. Regression equations used for loads computations for Sunnyvale East Channel during water year 2012-2014. Note that regression equations will be reformulated upon future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (WY2012) (mg/L/CFS)	Mainly urban	0.97		0.97	Regression with flow
Suspended Sediment (WY2013) (mg/L/CFS)	Mainly urban	$0.129x^{1.485}$		0.82	Regression with flow
Suspended Sediment (WY2013&14) (mg/L/NTU)	Mainly urban	$0.24x^{1.40}$		0.87	Regression with turbidity
Total PCBs (ng/mg) prior to Feb 28, 2014	Mainly urban	0.0704	34.4079	0.413	Regression with estimated SSC
Total PCBs (ng/mg) post Feb 28, 2014	Mainly urban	1.05	12.91	0.23	Regression with estimated SSC
Total PCBs (ng/L) Fows < 40 CFS	Mainly urban	15.6			Average Low Flow Concentration
Total Mercury (ng/mg)	Mainly urban	0.149	12.49	0.92	Regression with estimated SSC
Total Methylmercury (ng/mg)	Mainly urban	0.000911	0.144	0.69	Regression with estimated SSC
Total Organic Carbon (WYs 2012-13) (mg/L)	Mainly urban	5.7917568			Flow weighted mean concentration
Total Organic Carbon (WY 2014) (mg/L)	Mainly urban	11.870684			Flow weighted mean concentration
Total Phosphorous (mg/mg)	Mainly urban	0.000503	0.277	0.75	Regression with estimated SSC
Nitrate (WYs 2012-13) (mg/L)	Mainly urban	0.245			Flow weighted mean concentration
Nitrate (WY 2014) (mg/L)	Mainly urban	0.323			Flow weighted mean concentration
Phosphate (WYs 2012-13) (mg/L)	Mainly urban	0.104			Flow weighted mean concentration
Phosphate (WY 2014) (mg/L)	Mainly urban	0.133			Flow weighted mean concentration

Table 25. Monthly loads for Sunnyvale East Channel during water years 2012, 2013 and 2014. Italicized loads are estimated based on monthly rainfall-load relationships.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2012	11-Oct	14	*0.128*	*4.10*	*1053*	*5.20*	*2.65*	*0.0965*	*37.4*	*15.1*	*39.9*
	11-Nov	9	*0.110*	*2.80*	*939*	*4.40*	*2.01*	*0.0865*	*33.6*	*13.4*	*33.7*
	11-Dec	2	0.148	0.383	855	5.110	1.90	0.0210	36.2	15.4	41.1
	12-Jan	37	0.254	18.2	1473	10.03	5.90	0.0516	62.3	26.5	79.6
	12-Feb	22	0.151	1.85	875	5.333	2.17	0.0228	37.0	15.7	42.8
	12-Mar	69	0.260	10.78	1528	9.14	4.76	0.0442	65.1	26.9	76.4
	12-Apr	39	0.260	18.2	1503	11.65	6.55	0.0594	63.2	26.2	81.8
	Wet season total	192	1.31	56.4	8,227	50.87	25.9	0.382	335	139	395
2013	12-Oct	13	0.122	5.29	709	4.584	2.32	0.4595	30.0	12.7	36.6
	12-Nov	61	0.357	89	2020	20.5	15.1	0.541	92	38.5	146
	12-Dec	101	0.610	402	3541	47.7	63.2	1.979	144	63.9	385
	13-Jan	8	0.114	1.82	660	4.052	1.70	0.0853	27.9	11.9	32.5
	13-Feb	10	0.100	4.46	582	3.770	1.92	0.0809	24.6	10.4	30.1
	13-Mar	20	0.138	5.13	799	5.11	2.49	0.1040	33.8	14.3	40.8
	13-Apr	6	0.065	0.129	376	2.241	0.830	0.013	15.9	6.75	18.0
	Wet season total	219	1.51	508	8,685	87.9	87.6	3.263	369	159	689
2014	13-Oct	0	0.115	0.519	1374	4.008	1.52	0.0425	37.3	15.4	32.2
	13-Nov	14	0.141	21.1	1683	6.35	4.91	0.2039	45.7	18.8	49.8
	13-Dec	4	0.096	1.55	1140	3.406	1.43	0.0514	31.0	12.7	27.3
	14-Jan	2	0.072	0.253	861	2.507	0.94	0.0355	23.4	9.62	20.2
	14-Feb	65	0.315	50.9	3771	44.7	13.3	0.2055	90.9	42.9	137
	14-Mar	38	0.164	12.5	1942	9.7	4.16	0.0818	55.7	22.4	47.9
	14-Apr	12	0.107	2.18	1269	3.62	1.66	0.0481	52.0	13.5	29.4
	Wet season total	136	1.01	89.0	12,040	74.4	27.9	0.669	336	135	343

8.6. Pulgas Creek South Pump Station

8.6.1. Pulgas Creek South Pump Station flow

Flow from the southern catchment of the Pulgas Creek Pump Station was monitored for two wet seasons. An ISCO area velocity flow meter situated in the incoming pipe (draining to the catch basin prior to entering the pump station) was used to measure stage and flow in WY 2013 and 2014. A monthly (or partial monthly for December 2012 and March 2013) rainfall to runoff regression (R^2 = 0.97) was applied to estimate total discharge during the missing period of the record. Based on this regression estimator method, coarse estimates of total runoff during WYs 2013 and 2014 were 0.22 Mm^3 and 0.08 Mm^3, respectively.

Runoff from the Pulgas Creek South Pump Station watershed is highly correlated with rainfall due to its small drainage area and high imperviousness. Mean Annual Precipitation (MAP) for the nearby Redwood City NCDC meteorologic gauge (gauge number 047339-4) was 78% and 35% of normal in WYs 2013 and 2014, respectively. Total runoff for both years at Pulgas Creek was also likely below normal, and probably more so than the rainfall since total annual discharge generally varies more widely than total annual rainfall. Indeed, the total annual discharge in the nearby USGS-gauged Saratoga Creek was 48% and 9% of normal in WYs 2013 and 2014, respectively.

During the two years of recorded data at Pulgas Creek South Pump Station, the largest storm series, and subsequently the largest discharge period, occurred in December 2012. Flow peaked during this storm at 50 cfs, while the peak flow in WY 2014 was 33 cfs and occurred during a short but relatively intense storm on 11/20/2013 (Figure 8). December 2012 was only partially monitored (record began on Dec 17, 2012), though by estimating total monthly discharge based on the rainfall-runoff regression, estimated discharge for December 2012 was higher than the entire WY 2014 season's estimated discharge. San Francisquito Creek to the south has been gauged by the USGS at the campus of Stanford University (gauge number 11164500) from WY 1930-41 and again from 1950-present. Annual peak flows in San Francisquito over the long term record have ranged between 12 cfs (WY 1961) and 7200 cfs (WY1998). During WY 2013, flow at San Francisquito Creek peaked at 5400 cfs on 12/23/12 at 18:45, a flow that has been exceeded in only two previous years on record. On the other extreme, during WY 2014 flow peaked at 100 cfs on 4/1/2014 at 22:00. Flow peaks at San Francisquito Creek during these two water years show the contrast in precipitation events between the two years monitored at this site. It is noted, however, that the December 23, 2012 event at Pulgas Creek South Pump Station was likely not equivalent in magnitude as that which occurred at San Francisquito since the smaller, highly impervious Pulgas Creek South Pump Station watershed would be less affected by antecedent saturation conditions than San Francisquito Creek and more by hourly and sub-hourly rainfall intensities. The maximum 1-hour rainfall intensity at Pulgas Creek in WY 2013 was 0.43 inches per hour on 12/23/12 and 0.28 inches per hour on 11/20/2013 in WY 2014, both concurrent with the peak flow for the respective year. Relative to the Redwood City NCDC meteorological gauge and based on the partial duration series, the maximum WY 2013 1-hour rainfall intensity at Pulgas has approximately a 1-year recurrence interval, and therefore much less than a 1-year recurrence for the most intense WY 2014 storm. Based on this rainfall intensity recurrence, we suggest peak flows in Pulgas Creek South Pump Station watershed were approximately average for WY 2013 and below average in WY 2014.

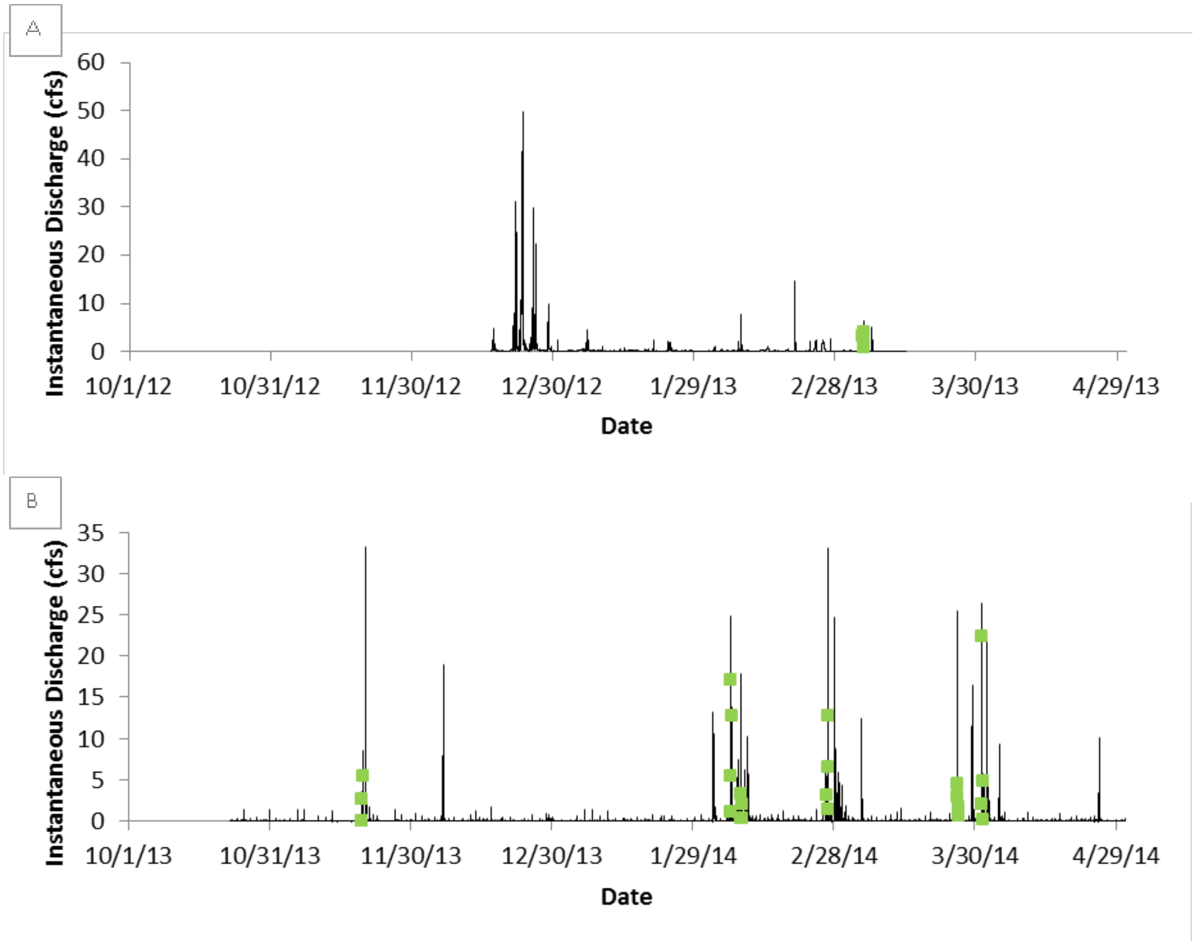

Figure 8. Flow characteristics at Pulgas Creek South Pump Station during Water Year 2013 and 2014 with sampling events plotted in green.

8.6.2. Pulgas Creek South Pump Station turbidity and suspended sediment concentration

Turbidity in Pulgas Creek South Pump Station watershed generally responded to rainfall events in a similar manner to runoff. During non-storm periods, turbidity generally fluctuated between 2 and 20 NTU, whereas during storms, maximum turbidity for each event reached between 100 and 600 NTU. Near midnight on 12/30/12, during flow conditions slightly elevated above base flows but not associated with rainfall, turbidity spiked above the sensor maximum[7] and did not return to readings below 20 NTU for 18 hours. After the first year of sampling, we noted that during all storm events after the 12/30/12 spike, storm maximum turbidities were all greater than maximum turbidities in the large storm series

[7] Note the reported DTS-12 turbidity sensor maximum is 1600 NTU. Maximum sensor reading during this spike was 2440 NTU. Given this is beyond the accurate range of the sensor, we do not suggest this reading is accurate but rather reflects that a significant spike in turbidity occurred in the system at this time.

around 12/23/12. We proposed two hypotheses to explain these observations: a) during larger storm events such as the 12/23/12 storm, turbidity becomes diluted, or b) that the signal of particles released into the watershed and measured on 12/30/12 continued to present at lower magnitudes through the remainder of the season. It remains challenging to tease out which of these hypotheses is more likely correct; turbidity in WY 2014 ranged up to 596 NTU and did peak in most storms higher that the large event on 12/23/12. This would suggest that these turbidities are typical in this watershed. However, WY 2014 was also a very dry year and so it remains possible that the particles released into the watershed and measured on 12/30/12 were still flushing through the system throughout WY 2014.

Turbidity measurements during storms were very spiky, possibly due to the combined factors of the location of the sensor in the catch basin vault and the cyclical pump out from the adjacent pump station. The turbidity record could not be used in regression with manually collected SSC to estimate SSC continuously and therefore it is not possible to estimate the peak SSC during the monitoring period. The highest manually collected SSC was 333mg/L and sampled on 11/19/13 at 16:12. This occurred during a sampled storm in which the continuous turbidity sensor was malfunctioning.

8.6.3. Pulgas Creek South Pump Station POC concentrations (summary statistics)

A summary of concentrations is useful for providing comparisons to other systems and also for doing a first order quality assurance check. Summary statistics of pollutant concentrations measured in Pulgas Creek South Pump Station in WY 2013 and 2014 are presented in Table 26. Samples were collected during one storm event in WY 2013 and 6 storm events in WY 2014 (except for dry weather methylmercury sample collection).

The range of WY 2013 PCB concentrations measured during one storm event were generally typical of mixed urban land use watersheds previously monitored in the San Francisco Bay Area (i.e. Guadalupe River, Zone 4 Line A, Coyote Creek, summarized by Lent and McKee, 2011). However, concentrations in WY 2014 were indicative of PCB watershed sources and were the highest concentrations measured in Bay Area stormwater. Maximum concentrations were measured during the storm event on 11/19/2013 and were quantified at 6669 ng/L. Approximately 0.5 inches of rain fell during this storm event and it was one of the earliest events of the WY 2014 season. The previous highest concentration measured (Santa Fe Channel in WY 2011 at 470 ng/L: McKee et al., 2012) was one order of magnitude lower. For the three-year project, mean PCB concentrations were highest at Pulgas Creek South (Pulgas Creek South > East Sunnyvale Channel > Guadalupe River = Richmond Pump Station > San Leandro Creek > Lower Marsh Creek). Concentrations in the Pulgas Creek Pump Station watershed appear to be similar to watersheds with industrial sources where concentrations in excess of about 100 ng/L are common (Marsalek and Ng, 1989; Hwang and Foster, 2008; Zgheib et al., 2011; Zgheib et al., 2012; McKee et al., 2012) and in fact are amongst the highest reported in peer-reviewed literature for urban systems. In contrast, watersheds with little to no urbanization dominated by agriculture and open space exhibit average concentrations <5 ng/l (David et al., in press; Foster et al., 2000a; Howell et al. 2011; McKee et al., 2012). In instances where urbanization and industrial sources are highly diluted by >75% developed agricultural land concentrations averaging 8.9 ng/L can be observed (Gómez-Gutiérrez et al., 2006). The Pulgas Creek South Pump Station watershed has an imperviousness of 87% and exhibits a particle ratio of 1079 pg/mg, the second highest

Table 26. Summary of laboratory measured pollutant concentrations in Pulgas Creek South Pump Station during water year 2013 and 2014.

		2013							2014						
Analyte	Unit	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation	Samples Taken (n)	Proportion Detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	15	100%	4.3	110	24	33.3	33.1	81	99%	0	333	37	60.8	64.5
ΣPCB	ng/L	4	100%	15.1	62.7	30.5	34.7	20.1	25	100%	16.9	6670	69.5	581	1500
Total Hg	ng/L	6	100%	4.2	23	7.45	10.5	6.9	25	100%	4.2	69	16	20	13.9
Total MeHg	ng/L	6	100%	0.04	0.28	0.215	0.178	0.1	14	100%	0.02	0.66	0.155	0.193	0.167
TOC	mg/L	4	100%	7.3	17	8.35	10.3	4.53	24	100%	4.1	140	11	22.2	31.4
NO3	mg/L	4	100%	0.24	0.49	0.35	0.357	0.102	24	100%	0.1	2.3	0.3	0.484	0.491
Total P	mg/L	4	100%	0.1	0.25	0.125	0.15	0.0707	24	100%	0.067	1.2	0.23	0.313	0.261
PO4	mg/L	4	100%	0.0505	0.0935	0.059	0.0655	0.0195	24	100%	0.056	0.47	0.092	0.133	0.105
Hardness	mg/L								6	100%	40	110	63.5	69.8	29.4
Total Cu	ug/L	1	100%	30	30	30	30		6	100%	22.5	99	36.5	46.3	28.5
Dissolved Cu	ug/L	1	100%	20	20	20	20		6	100%	12	41	13.5	18.3	11.3
Total Se	ug/L	1	100%	0.18	0.18	0.18	0.18		6	100%	0.14	0.6	0.242	0.311	0.175
Dissolved Se	ug/L	1	100%	0.17	0.17	0.17	0.17		6	100%	0.1	0.48	0.19	0.257	0.148
Carbaryl	ng/L	1	100%	204	204	204	204		6	100%	41	189	65.5	88.5	59.4
Fipronil	ng/L	1	0%	0	0	0	0		6	100%	3	6	3.5	3.83	1.17
ΣPAH	ng/L	4	100%	211	1140	552	614	389	2	100%	552	6970	3760	3760	4540
ΣPBDE	ng/L	4	100%	5.18	89.8	32.5	40	39.7	2	100%	52.1	61.4	56.7	56.7	6.59
Delta/ Tralomethrin	ng/L	1	0%	0	0	0	0		6	50%	0	1.2	0.2	0.45	0.565
Cypermethrin	ng/L	1	100%	0.9	0.9	0.9	0.9		6	100%	0.8	5.65	2.7	2.68	1.78
Cyhalothrin lambda	ng/L	1	0%	0	0	0	0		5	100%	0.2	0.8	0.3	0.42	0.268
Permethrin	ng/L	1	100%	2.9	2.9	2.9	2.9		6	83%	0	20	14.3	12	7.94
Bifenthrin	ng/L	1	100%	1.3	1.3	1.3	1.3		6	100%	1.4	15	4.7	5.78	4.92

Zeroes were used in the place of non-detects when calculating means, medians, and standard deviations.
The minimum number of samples used to calculate standard deviation Pulgas Creek South Pump Station was four.

observed so far in the Bay Area out of 24 locations (Only Pulgas Creek North is higher) and well above the background of rural areas (indicated by Marsh Creek in the Bay Area).

The range of total mercury concentrations (4-69 ng/L; mean = 15 ng/L) were lower than observed in any of the other watersheds in this study and on the very low end of concentrations sampled in Z4LA (Gilbreath et al., 2012). Pulgas Creek South Pump Station watershed also exhibits relatively low SSC compared to the other six locations. Of the six POC loads stations monitored during this study, total Hg concentrations in Pulgas Creek were most similar to those observed in three urban Wisconsin watersheds (Hurley et al., 1995), urban influenced watersheds of the Chesapeake Bay region (Lawson et al., 2001), and two sub-watersheds of mostly urban land use in the Toronto area (Eckley and Branfirheun, 2008). Unlike Marsh Creek, San Leandro Creek, or Sunnyvale East Channel where the maximum Hg concentrations could be either mostly or somewhat attributed to the erosion of upper watershed soils, Pulgas Creek South Pump Station Watershed transports relatively low Hg concentrations that are most likely attributable to local atmospheric deposition and minor within-watershed sources areas associated with industrial and commercial land uses. Despite low Hg concentrations in water, the particle ratio for total Hg relative to suspended sediment in this watershed (0.8 mg/kg) is the same as observed in Richmond Pump Station watershed and the 3rd highest behind San Leandro Creek and Ettie St. Pump Station watersheds (discounting Guadalupe River and its mining impacted tributaries which all rank higher still). The source-release-transport processes are likely similar to those of other urbanized and industrial watersheds (Barringer et al., 2010; Rowland et al., 2010; Lin et al., 2012) but not likely similar to very highly contaminated watersheds with direct local point source discharge (e.g. 1600-4300 ng/L: Ullrich et al., 2007; 100-5000 ng/L: Picado and Bengtsson, 2012; Kocman et al., 2012; 78-1500 ng/L: Rimondi et al., 2014).

The MeHg concentrations during the two-year study ranged from 0.04-0.66 ng/L. Concentrations of this magnitude or greater have been observed in a number of Bay Area urban influenced watersheds (Zone 4 Line A: Gilbreath et al., 2012; Glen Echo Creek Santa Fe Channel, San Leandro Creek, Zone 5 Line M, Borel Creek, and Pulgas Creek North: McKee et al., 2012). However, concentrations of methylmercury of this magnitude have not been observed in urbanized watersheds from other parts of the world (Mason and Sullivan, 1998; Naik and Hammerschmidt, 2011; Chalmers et al., 2014). Although local Hg sources can be a factor in helping to elevate MeHg production and food-web impacts, it is generally agreed, at least for agricultural and forested systems with lesser urban influences, that Hg sources are not a primary limiting factor in MeHg production (Balogh et al., 2002; Balogh et al., 2004; Barringer et al., 2010; Zheng et al., 2010; Bradely et al., 2011). Based on plenty of previous sampling experience in numerous Bay Area watershed systems, there are no reasons to suspect any data quality issues. Bay Area methylmercury concentrations appear to be elevated perhaps associated with arid climate seasonal wetting and drying and high vegetation productivity in riparian areas of channels systems with abundant supply of organic carbon each fall and winter. Although there is no riparian corridor in the Pulgas Creek South Pump Station catchment, the pipes nearly always contain water-logged sediment that is deep enough in some areas to create anoxic conditions.

Nutrient concentrations in Pulgas Creek South Pump Station watershed were also generally in the same range as measured in Z4LA (Gilbreath et al., 2012) and like the other watersheds reported from the current study, phosphorus concentrations appear to be greater than elsewhere in the world under similar land use scenarios perhaps attributable to geological sources (McKee and Krottje, 2005). Nitrate concentrations appear lower in Pulgas Creek Pump Station compared to Guadalupe River and Richmond Pump Station but similar Sunnyvale East Channel, San Leandro Creek, and Lower Marsh Creek. Mean orthophosphate concentrations (0.124 mg/L) were similar to Sunnyvale East Channel but much lower than observed in the Richmond Pump Station and about 30% elevated above Lower Marsh and San Leandro Creeks. The maximum total P concentration (1.2 mg/L) should be considered very high for an urban watershed, however average total P concentrations were similar across the six sites. Concentrations of PO4 and TP appear typical or slightly greater than observations in urban watersheds in other parts of the country and world (e.g. Hudak and Banks, 2006; comprehensive Australian literature review for concentrations by land use class: Bartley et al., 2012). Higher phosphorus concentrations, especially the peak concentration observed in Pulgas Creek may perhaps be attributable to geological sources (Dillon and Kirchner, 1975; McKee and Krottje, 2005; Pearce et al., 2005).

Organic carbon concentrations observed in Pulgas Creek Pump Station during WYs 2013-2014 (4.1-140 mg/L) were much greater than those observed in Z4LA (max = 23 mg/L; FWMC = 12 mg/L: Gilbreath et al., 2012). It turned out that these were the greatest concentrations observed in the Bay Area to-date. They were greater than but more similar to maximum concentrations observed in Guadalupe River and Sunnyvale East Channel (56 and 30 mg/L respectively). Although we have not done an extensive literature review of TOC concentrations in the worlds river systems, our general knowledge of the literature would have us hypothesize that concentrations of these magnitudes are very high. High organic carbon concentrations may be contributing to the apparent high methylation rates in Bay Area urban storm drains, creeks, and rivers.

Pollutants sampled at a lesser frequency using a composite sampling design (see methods section) and appropriate for water quality characterization only (copper, selenium, PAHs, carbaryl, fipronil, and PBDEs) were similar to concentrations observed in Z4LA (Gilbreath et al., 2012). PAH concentrations at Pulgas Creek South were almost 2 times higher than the next highest concentration (San Leandro Creek) and were more similar to the previous highest PAH concentration measured (Santa Fe Channel) (McKee et al., 2012). The maximum PBDE concentration (89.9 ng/L) was lower than the other 5 locations in this study with the exception of Lower Marsh Creek. It is possible that low sample numbers and very dry conditions (38% MAP in WY 2014) for this watershed biased the concentrations low; only a future sampling effort would verify the relatively low concentration in comparison to the other highly urban and impervious watersheds in this study. Only two peer reviewed articles have previously described PBDE concentrations in runoff, one for the Pearl River Delta, China (Guan et al., 2007), and the other for the San Francisco Bay (Oram et al., 2008) based, in part, on concentration data from Guadalupe River and Coyote Creek taken during WYs 2003-2006. Maximum total PBDE concentrations measured by Guan et al. (2007) were 68 ng/L, a somewhat surprising result given that the Pearl River Delta is a known global electronic-waste recycling hot spot. However, the Guan et al. study was based on monthly interval collection as opposed to storm event-based sampling as was completed in a larger river system where dilution of point source may have occurred.

Similar to the other sites, carbaryl and fipronil (not measured previously by RMP studies) were on the lower side of the range of peak concentrations reported in studies across the US and California (fipronil: 70 – 1300 ng/L: Moran, 2007) (Carbaryl: DL - 700 ng/L: Ensiminger et al., 2012; tributaries to Salton Sea, Southern CA geometric mean ~2-10 ng/L: LeBlanc and Kuivila, 2008). However, carbaryl concentrations at Pulgas Creek South, although still very low, were 5 to 15 times higher than other POC sites. Concentrations of Cypermethrin were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were about 5x and 2x lower, respectively (Gilbreath et al., 2012). In general, the mix of pyrethroids used in each watershed appears to differ remarkably and is perhaps associated with local applicator and commercially available product preferences in home garden stores. For example, concentrations of Cyhalothrin lambda were similar across the Pulgas Creek Pump Station, San Leandro Creek, Guadalupe River, and Sunnyvale East Channel sampling sites and about 2-fold greater in Marsh Creek and Richmond Pump Station. Bifenthrin was similar across all six sites with the exception of Lower Marsh Creek where concentrations were observed to be 10-fold greater.

In summary, PCB concentrations are extremely elevated in the Pulgas Creek South Pump Station relative to other Bay Area watersheds and urban watersheds in other parts of the world. Hg appears to be relatively low when considering water concentrations alone but elevated in relation to the amount of sediment transported. Whereas concentrations of other POCs are either within range or below those measured in other typical Bay Area urban watersheds and appear consistent with or explainable in relation to studies from elsewhere. Based on these first order comparisons, we see no quality issues with the data.

8.6.4. Pulgas Creek South Pump Station toxicity

The Pulgas Creek South site was sampled over one storm event in WY 2013 and six discrete storm events in WY 2014. There was no observed toxicity in the WY 2013 event. In WY 2014, Hyalella azteca had reduced survival in all the events sampled. The reductions ranged from 6% to 88%. Additionally the first storm sampled in WY 2014, on November 19, 2013, had a significant reduction in the growth of both S. capricornutum and the fathead minnow by 96% and 45%, respectively. The second WY 2014 storm sampled on February 2, 2014 had a reduction in growth of the fathead minnow by 18% while S. capricornutum was unaffected. No other significant reductions in survival or growth were reported in any of the species for any other samples.

8.6.5. Pulgas Creek South Pump Station loading estimates

Continuous concentrations of suspended sediment, PCBs, total mercury and methylmercury, and total phosphorous were computed using a simple FWMC estimator (Table 27). This method differs from the previous report (Gilbreath et al., 2014) when a regression estimator method was used. This occurred because more information revealed complex patterns that could not be explained using regression. If the dataset for this site were to improve in the future, these estimates could be recalculated and improved. With these caveats, preliminary monthly loading estimates are dominated by the three wet months (November and December, 2012 and February 2014) during which time 62% of the total discharge volume and load passed through the system. Pulgas Creek exhibited the highest concentrations and unit area normalized loads of the six loading stations for PCBs (Table 28).

Table 27. Regression equations used for loads computations for Pulgas Creek South during water years 2013-2014.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/L)	Mainly urban	66.1			Flow weighted mean concentration
Total PCBs (ng/L)	Mainly urban	132			Flow weighted mean concentration
Total Mercury (ng/L)	Mainly urban	18.6			Flow weighted mean concentration
Total Methylmercury (ng/L)	Mainly urban	0.1761756			Flow weighted mean concentration
Total Organic Carbon (mg/L)	Mainly urban	9.32			Flow weighted mean concentration
Total Phosphorous (mg/L)	Mainly urban	0.2			Flow weighted mean concentration
Nitrate (mg/L)	Mainly urban	0.249			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.0776			Flow weighted mean concentration

Table 28. Monthly loads estimated for Pulgas Creek South Pump Station during water year 2013-2014.

Water Year	Month	Rainfall (mm)	Discharge (Mm^3)	SS (t)	TOC (kg)	PCBs (g)	HgT (g)	MeHgT (g)	NO3 (kg)	PO4 (kg)	Total P (kg)
2013	12-Oct	25	0.0100	0.659	92.9	1.32	0.185	0.00176	2.48	0.774	1.99
	12-Nov	121	0.0515	3.41	480	6.80	0.959	0.00908	12.8	4.00	10.3
	12-Dec	183	0.0829	5.48	773	10.94	1.54	0.0146	20.6	6.43	16.6
	13-Jan	8	0.0034	0.227	32.0	0.453	0.0639	0.000605	0.855	0.266	0.687
	13-Feb	10	0.0039	0.256	36.1	0.512	0.0721	0.000683	0.965	0.301	0.775
	13-Mar	20	0.0073	0.480	67.7	0.959	0.135	0.00128	1.81	0.564	1.45
	13-Apr	18	0.0062	0.407	57.5	0.814	0.115	0.00109	1.53	0.478	1.23
	Wet season total	386	0.165	10.9	1539	21.8	3.07	0.0291	41.1	12.8	33.0
2014	13-Oct	0	0.0004	0.0283	4.00	0.0566	0.00798	0.0000756	0.107	0.0333	0.0858
	13-Nov	24	0.0085	0.611	108	2.69	0.164	0.00160	2.55	0.770	1.96
	13-Dec	8	0.0047	0.309	43.6	0.617	0.0870	0.000824	1.16	0.363	0.935
	14-Jan	0	0.0008	0.0541	7.63	0.108	0.0152	0.000144	0.204	0.0635	0.164
	14-Feb	90	0.0400	2.61	364	5.09	0.745	0.00701	9.79	3.10	8.10
	14-Mar	41	0.0160	1.09	152	2.00	0.290	0.00283	4.06	1.26	3.03
	14-Apr	21	0.0092	0.605	85.3	1.21	0.170	0.00161	2.28	0.711	1.83
	Wet season total	185	0.0796	5.31	764	11.8	1.48	0.0141	20.1	6.31	16.1

Attachment 1. Quality Assurance information

Table A1: Summary of QA data at all sites. This table includes the top eight PAHs found commonly at all sites , the PBDE congeners that account for 75% of the sum of all PBDE congeners, the top nine PCB congeners found at all sites, and the pyrethroids that were detected at any site.

Analyte	Unit	AverageLabBlank	Detection Limit (MDL) (range; mean)	Average Reporting Limit (RL)	RSD of Lab Duplicates (% range; % mean)	RSD of Field Duplicates (% range; % mean)	Percent Recovery of CRM (% range; % mean)	Percent Recovery of Matrix Spike (% range; % mean)
Carbaryl	ng/L	0	9.9-10; 10	20	75.71-75.71; 75.71	1.39-83.55; 42.47	NA	66.64-120.25; 94.99
Fipronil	ng/L	0	0.5-5; 0.945	4.34	NA	0.00-141.42; 28.84	NA	51.52-150.00; 86.24
NH4	mg/L	0	0.015-0.04; 0.024	0.0486	NA	0.00-11.79; 4.47	NA	80.00-120.00; 102.41
NO3	mg/L	0	0.002-0.05; 0.0113	0.0488	0.00-0.00; 0.00	0.00-42.43; 2.51	NA	90.00-105.00; 98.98
PO4	mg/L	0	0.0035-0.06; 0.00599	0.0112	0.00-1.61; 0.90	0.00-5.29; 1.51	NA	83.50-126.06; 97.94
Total P	mg/L	0	0.007-0.1; 0.016	0.01	0.00-2.40; 0.79	0.00-33.17; 3.90	NA	86.00-113.00; 97.30
SSC	mg/L	0	0.23-6.8; 2.28	3	NA	0.00-85.48; 12.61	80.99-114.49; 100.72	NA
Benz(a)anthracenes/Chrysenes, C1-	ng/L	0.245	0.0364-75.5; 2.64	NA	NA	NA	NA	NA
Benz(a)anthracenes/Chrysenes, C2-	ng/L	0.177	0.046-	NA	NA	NA	NA	NA

Analyte	Unit	AverageLabBlank	Detection Limit (MDL) (range; mean)	Average Reporting Limit (RL)	RSD of Lab Duplicates (% range; % mean)	RSD of Field Duplicates (% range; % mean)	Percent Recovery of CRM (% range; % mean)	Percent Recovery of Matrix Spike (% range; % mean)
			43.1; 1.98					
Fluoranthene	ng/L	0.152	0.0382-2.58; 0.446	NA	NA	NA	NA	NA
Fluoranthene/Pyrenes, C1-	ng/L	0.531	0.103-25.4; 2.08	NA	NA	NA	NA	NA
Fluorenes, C3-	ng/L	1.42	0.0451-29.4; 1.47	NA	NA	NA	NA	NA
Naphthalenes, C4-	ng/L	1.86	0.0461-3.54; 0.751	NA	NA	NA	NA	NA
Phenanthrene/Anthracene, C4-	ng/L	1.44	0.0891-27.1; 2.72	NA	NA	NA	NA	NA
Pyrene	ng/L	0.133	0.0376-5.96; 0.562	NA	NA	NA	NA	NA
PBDE 047	ng/L	0.0363	0.000368-0.000872; 0.000414	NA	NA	NA	NA	NA
PBDE 099	ng/L	0.0379	0.000472-0.0124; 0.00366	NA	NA	NA	NA	NA
PBDE 209	ng/L	0.101	0.0127-0.24; 0.0771	NA	NA	NA	NA	NA
PCB 087	ng/L	0.00147	0.000184-0.0337; 0.00142	NA	NA	NA	NA	NA

Analyte	Unit	AverageLabBlank	Detection Limit (MDL) (range; mean)	Average Reporting Limit (RL)	RSD of Lab Duplicates (% range; % mean)	RSD of Field Duplicates (% range; % mean)	Percent Recovery of CRM (% range; % mean)	Percent Recovery of Matrix Spike (% range; % mean)
PCB 095	ng/L	0.0013	0.000184-0.0372; 0.0016	NA	NA	NA	NA	NA
PCB 110	ng/L	0.00184	0.000184-0.029; 0.00122	NA	NA	NA	NA	NA
PCB 138	ng/L	0.0018	0.000214-0.149; 0.00441	NA	NA	NA	NA	NA
PCB 149	ng/L	0.00101	0.00022-0.151; 0.00469	NA	NA	NA	NA	NA
PCB 151	ng/L	0.000445	0.000184-0.0195; 0.00115	NA	NA	NA	NA	NA
PCB 153	ng/L	0.00178	0.000209-0.132; 0.00392	NA	NA	NA	NA	NA
PCB 174	ng/L	0.0000338	0.000184-0.0118; 0.00106	NA	NA	NA	NA	NA
PCB 180	ng/L	0.000603	0.000184-0.00952; 0.000908	NA	NA	NA	NA	NA
Bifenthrin	ng/L	0.0457	0.05-5.52; 0.761	1.53	NA	NA	NA	NA
Cypermethrin	ng/L	0	0.1-5.29; 0.815	1.53	NA	NA	NA	NA

Analyte	Unit	AverageLabBlank	Detection Limit (MDL) (range; mean)	Average Reporting Limit (RL)	RSD of Lab Duplicates (% range; % mean)	RSD of Field Duplicates (% range; % mean)	Percent Recovery of CRM (% range; % mean)	Percent Recovery of Matrix Spike (% range; % mean)
Delta/Tralomethrin	ng/L	0.155	0.1-1; 0.258	3.05	NA	NA	NA	NA
Total Cu	ug/L	0	0.042-0.421; 0.114	0.527	0.20-2.68; 0.88	0.00-3.72; 1.06	100.66-106.15; 102.50	80.00-200.00; 97.76
Dissolved Cu	ug/L	0	0.042-0.421; 0.096	0.5	NA	0.00-12.65; 3.92	NA	85.50-98.00; 92.24
Total Hg	ng/L	0	0.2-2; 0.234	0.526	2.12-2.12; 2.12	0.00-63.15; 13.84	91.93-106.84; 99.17	92.99-119.87; 104.34
Total MeHg	ng/L	0.00354	0.01-0.02; 0.0177	0.0401	0.97-5.87; 3.35	0.00-37.52; 8.84	NA	58.99-137.27; 95.64
Total Se	ug/L	0.0094	0.024-0.06; 0.0503	0.0925	0.29-26.96; 5.76	0.00-33.12; 6.97	92.56-103.84; 100.00	80.78-121.22; 95.67
Dissolved Se	ug/L	0	0.024-0.06; 0.0523	0.124	6.18-6.18; 6.18	0.00-6.18; 3.03	NA	87.20-96.22; 91.35
TOC	mg/L	0.0197	0.035-0.3; 0.249	0.481	NA	0.00-15.71; 3.49	NA	0.03-123.00; 96.59

Table A2: Field blank data from all sites.

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Carbaryl	ng/L	10	20	ND	ND	ND
Fipronil	ng/L	0.714	3.14	ND	ND	ND
NO3	mg/L	0.0123	0.047	ND	0.039	0.00279
PO4	mg/L	0.00583	0.01	ND	0.008	0.001
Total P	mg/L	0.00719	0.01	ND	0.057	0.00519
SSC	mg/L	2	3	ND	ND	ND
Acenaphthene	ng/L	0.31	-	ND	ND	ND
Acenaphthylene	ng/L	0.0803	-	ND	0.0663	0.0133
Anthracene	ng/L	0.143	-	ND	ND	ND
Benz(a)anthracene	ng/L	0.0394	-	ND	0.0406	0.00812
Benz(a)anthracenes/Chrysenes, C1-	ng/L	0.0293	-	ND	0.173	0.0814
Benz(a)anthracenes/Chrysenes, C2-	ng/L	0.0515	-	ND	0.393	0.186
Benz(a)anthracenes/Chrysenes, C3-	ng/L	0.0457	-	ND	0.389	0.174
Benz(a)anthracenes/Chrysenes, C4-	ng/L	0.0478	-	ND	1.03	0.329
Benzo(a)pyrene	ng/L	0.111	-	ND	ND	ND
Benzo(b)fluoranthene	ng/L	0.0509	-	ND	0.121	0.0407
Benzo(e)pyrene	ng/L	0.102	-	ND	0.0695	0.0139
Benzo(g,h,i)perylene	ng/L	0.0671	-	ND	ND	ND
Benzo(k)fluoranthene	ng/L	0.11	-	ND	ND	ND
Chrysene	ng/L	0.0407	-	ND	0.151	0.0704
Dibenz(a,h)anthracene	ng/L	0.0693	-	ND	ND	ND
Dibenzothiophene	ng/L	0.0688	-	ND	0.289	0.0974
Dibenzothiophenes, C1-	ng/L	0.089	-	ND	ND	ND
Dibenzothiophenes, C2-	ng/L	0.052	-	0.266	0.71	0.486
Dibenzothiophenes, C3-	ng/L	0.0524	-	0.484	0.782	0.637
Dimethylnaphthalene, 2,6-	ng/L	0.247	-	ND	0.854	0.327

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Fluoranthene	ng/L	0.0333	-	0.104	0.343	0.238
Fluoranthene/Pyrenes, C1-	ng/L	0.113	-	0.0828	0.716	0.387
Fluorene	ng/L	0.103	-	ND	0.229	0.098
Fluorenes, C2-	ng/L	0.122	-	1.39	3.5	2.37
Fluorenes, C3-	ng/L	0.133	-	2.95	4.13	3.58
Indeno(1,2,3-c,d)pyrene	ng/L	0.0417	-	ND	ND	ND
Methylnaphthalene, 2-	ng/L	0.233	-	ND	5.56	1.7
Methylphenanthrene, 1-	ng/L	0.119	-	ND	0.12	0.0419
Naphthalene	ng/L	0.145	-	1.7	22.4	10.5
Naphthalenes, C1-	ng/L	0.093	-	ND	8.71	2.69
Naphthalenes, C3-	ng/L	0.167	-	0.601	3.94	2.15
Perylene	ng/L	0.116	-	ND	ND	ND
Phenanthrene	ng/L	0.0885	-	0.436	0.717	0.543
Phenanthrene/Anthracene, C1-	ng/L	0.119	-	ND	0.533	0.256
Phenanthrene/Anthracene, C2-	ng/L	0.068	-	0.0581	0.843	0.485
Pyrene	ng/L	0.0323	-	0.0763	0.229	0.164
Trimethylnaphthalene, 2,3,5-	ng/L	0.11	-	ND	0.385	0.176
PBDE 007	ng/L	0.000474	-	ND	0.00164	0.000328
PBDE 008	ng/L	0.000434	-	ND	0.0013	0.00026
PBDE 010	ng/L	0.000561	-	ND	ND	ND
PBDE 011	ng/L	-	-	-	-	-
PBDE 012	ng/L	0.000417	-	ND	0.000793	0.000159
PBDE 013	ng/L	-	-	-	-	-
PBDE 015	ng/L	0.000401	-	ND	0.00416	0.000832
PBDE 017	ng/L	0.000483	-	ND	0.0236	0.00503
PBDE 025	ng/L	-	-	-	-	-
PBDE 028	ng/L	0.000772	-	ND	0.029	0.00609
PBDE 030	ng/L	0.000457	-	ND	ND	ND

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PBDE 032	ng/L	0.00042	-	ND	ND	ND
PBDE 033	ng/L	-	-	-	-	-
PBDE 035	ng/L	0.000939	-	ND	ND	ND
PBDE 047	ng/L	0.000478	-	0.0156	1.04	0.266
PBDE 049	ng/L	0.0009	-	ND	0.0863	0.0187
PBDE 051	ng/L	0.000521	-	ND	0.00865	0.00173
PBDE 066	ng/L	0.00136	-	ND	0.0494	0.00988
PBDE 071	ng/L	0.000579	-	ND	0.0143	0.00286
PBDE 075	ng/L	0.00102	-	ND	ND	ND
PBDE 077	ng/L	0.000537	-	ND	ND	ND
PBDE 079	ng/L	0.000484	-	ND	ND	ND
PBDE 085	ng/L	0.00151	-	ND	0.0578	0.0137
PBDE 099	ng/L	0.000743	-	0.0295	1.2	0.308
PBDE 100	ng/L	0.000564	-	0.00597	0.281	0.0726
PBDE 105	ng/L	0.0012	-	ND	ND	ND
PBDE 116	ng/L	0.00189	-	ND	0.0113	0.00226
PBDE 119	ng/L	0.00109	-	ND	0.00686	0.00149
PBDE 120	ng/L	-	-	-	-	-
PBDE 126	ng/L	0.000751	-	ND	0.00121	0.000242
PBDE 128	ng/L	0.00495	-	ND	ND	ND
PBDE 140	ng/L	0.000817	-	ND	0.00677	0.00154
PBDE 153	ng/L	0.000892	-	0.00334	0.135	0.0316
PBDE 155	ng/L	0.000608	-	ND	0.00943	0.00207
PBDE 166	ng/L	-	-	-	-	-
PBDE 181	ng/L	0.00218	-	ND	ND	ND
PBDE 183	ng/L	0.00253	-	ND	0.0437	0.00874
PBDE 190	ng/L	0.00454	-	ND	ND	ND
PBDE 197	ng/L	0.00387	-	0.00236	0.0973	0.0498

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PBDE 203	ng/L	0.00308	-	ND	0.123	0.0266
PBDE 204	ng/L	-	-	-	-	-
PBDE 205	ng/L	0.00563	-	ND	ND	ND
PBDE 206	ng/L	0.0222	-	ND	1.4	0.287
PBDE 207	ng/L	0.0177	-	ND	2.33	0.488
PBDE 208	ng/L	0.0265	-	ND	1.69	0.338
PBDE 209	ng/L	0.0512	-	ND	22.9	4.99
PCB 008	ng/L	0.00134	-	ND	0.0204	0.00303
PCB 018	ng/L	0.000722	-	ND	0.109	0.0112
PCB 020	ng/L	-	-	-	-	-
PCB 021	ng/L	-	-	-	-	-
PCB 028	ng/L	0.000465	-	0.00121	0.065	0.00967
PCB 030	ng/L	-	-	-	-	-
PCB 031	ng/L	0.000515	-	ND	0.0477	0.00667
PCB 033	ng/L	0.000523	-	ND	0.0115	0.00202
PCB 044	ng/L	0.000904	-	ND	0.0494	0.00645
PCB 047	ng/L	-	-	-	-	-
PCB 049	ng/L	0.00102	-	ND	0.0245	0.00277
PCB 052	ng/L	0.000668	-	ND	0.0431	0.0062
PCB 056	ng/L	0.00056	-	ND	0.00776	0.00112
PCB 060	ng/L	0.000608	-	ND	0.0013	0.000306
PCB 061	ng/L	-	-	-	-	-
PCB 065	ng/L	-	-	-	-	-
PCB 066	ng/L	0.000699	-	ND	0.00817	0.00176
PCB 069	ng/L	-	-	-	-	-
PCB 070	ng/L	0.000534	-	0.00121	0.02	0.00467
PCB 074	ng/L	-	-	-	-	-
PCB 076	ng/L	-	-	-	-	-

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 083	ng/L	-	-	-	-	-
PCB 086	ng/L	-	-	-	-	-
PCB 087	ng/L	0.000815	-	ND	0.00809	0.00283
PCB 090	ng/L	-	-	-	-	-
PCB 093	ng/L	-	-	-	-	-
PCB 095	ng/L	0.000997	-	ND	0.0115	0.00335
PCB 097	ng/L	-	-	-	-	-
PCB 098	ng/L	-	-	-	-	-
PCB 099	ng/L	0.000777	-	ND	0.00753	0.00189
PCB 100	ng/L	-	-	-	-	-
PCB 101	ng/L	0.00155	-	ND	0.00392	0.00246
PCB 102	ng/L	-	-	-	-	-
PCB 105	ng/L	0.000877	-	ND	0.0033	0.000927
PCB 108	ng/L	-	-	-	-	-
PCB 110	ng/L	0.00099	-	ND	0.0113	0.00416
PCB 113	ng/L	-	-	-	-	-
PCB 115	ng/L	-	-	-	-	-
PCB 118	ng/L	0.000824	-	ND	0.00796	0.00237
PCB 119	ng/L	-	-	-	-	-
PCB 125	ng/L	-	-	-	-	-
PCB 128	ng/L	0.000753	-	ND	0.00127	0.000397
PCB 129	ng/L	-	-	-	-	-
PCB 132	ng/L	0.00104	-	ND	0.00272	0.00113
PCB 135	ng/L	-	-	-	-	-
PCB 138	ng/L	0.00124	-	ND	0.012	0.00353
PCB 141	ng/L	0.000792	-	ND	0.00096	0.000246
PCB 147	ng/L	-	-	-	-	-
PCB 149	ng/L	0.00126	-	ND	0.00828	0.00237

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 151	ng/L	0.000754	-	ND	0.00463	0.00103
PCB 153	ng/L	0.00193	-	ND	0.00341	0.00154
PCB 154	ng/L	-	-	-	-	-
PCB 156	ng/L	0.000731	-	ND	0.000581	0.000132
PCB 157	ng/L	-	-	-	-	-
PCB 158	ng/L	0.000607	-	ND	0.000602	0.000117
PCB 160	ng/L	-	-	-	-	-
PCB 163	ng/L	-	-	-	-	-
PCB 166	ng/L	-	-	-	-	-
PCB 168	ng/L	-	-	-	-	-
PCB 170	ng/L	0.000802	-	ND	0.00131	0.000401
PCB 174	ng/L	0.000818	-	ND	0.00139	0.000347
PCB 177	ng/L	0.000731	-	ND	0.000988	0.000278
PCB 180	ng/L	0.00137	-	ND	0.00274	0.000713
PCB 183	ng/L	0.000725	-	ND	0.00208	0.000442
PCB 185	ng/L	-	-	-	-	-
PCB 187	ng/L	0.00096	-	ND	0.00509	0.000853
PCB 193	ng/L	-	-	-	-	-
PCB 194	ng/L	0.000832	-	ND	0.000731	0.0000522
PCB 195	ng/L	0.000803	-	ND	0.000261	0.0000186
PCB 201	ng/L	0.000633	-	ND	ND	ND
PCB 203	ng/L	0.000903	-	ND	ND	ND
Allethrin	ng/L	0.465	1.5	ND	ND	ND
Bifenthrin	ng/L	0.202	1.5	ND	ND	ND
Cyfluthrin, total	ng/L	1.14	1.5	ND	ND	ND
Cyhalothrin,lambda, total	ng/L	0.24	1.5	ND	0.11	0.0157
Cypermethrin, total	ng/L	0.276	1.5	ND	ND	ND
Delta/Tralomethrin	ng/L	0.21	3	ND	ND	ND

Analyte	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Esfenvalerate/Fenvalerate, total	ng/L	0.254	3	ND	ND	ND
Fenpropathrin	ng/L	0.386	1.5	ND	ND	ND
Permethrin, total	ng/L	1.37	15	ND	ND	ND
Phenothrin	ng/L	0.525	-	ND	ND	ND
Prallethrin	ng/L	7.02	-	ND	ND	ND
Resmethrin	ng/L	0.653	-	ND	ND	ND
Total Cu	ug/L	0.066	0.444	ND	1.4	0.45
Dissolved Cu	ug/L	0.066	0.444	ND	1.4	0.297
Total Hg	ng/L	0.199	0.482	ND	4.4	0.271
Total MeHg	ng/L	0.0192	0.04	ND	0.021	0.00162
Dissolved Se	ug/L	0.0549	0.096	ND	ND	ND
Total Se	ug/L	0.0549	0.096	ND	ND	ND
Total Hardness (calc)	mg/L	1.46	4.3	ND	ND	ND
TOC	mg/L	0.3	0.5	ND	ND	ND

Table A3: Average RSD of field and lab duplicates at each site.

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Carbaryl	-	-	-	-	-	-	83.50%	75.70%	-	-	1.40%	-
Fipronil	53.00%	-	31.40%	-	9.20%	-	10.90%	-	10.90%	-	-	-
NO3	0.00%	0.00%	9.90%	0.00%	0.50%	-	0.00%	0.00%	1.80%	-	0.40%	-
PO4	0.50%	0.80%	1.90%	0.90%	0.30%	-	1.40%	1.10%	1.50%	-	3.70%	-
Total P	3.60%	0.00%	0.90%	0.00%	3.00%	2.40%	12.40%	0.00%	1.70%	-	2.70%	-
SSC	11.00%	-	6.20%	-	11.90%	-	36.20%	-	12.40%	-	10.00%	-
Acenaphthene	20.10%	-	6.30%	3.70%	-	-	10.00%	0.40%	2.10%	1.50%	-	-
Acenaphthylene	10.70%	-	8.50%	5.00%	-	-	31.80%	18.10%	5.70%	5.50%	-	-
Anthracene	14.20%	-	14.10%	5.00%	43.40%	-	39.10%	23.40%	5.60%	4.10%	-	-
Benz(a)anthracene	15.30%	-	18.70%	11.40%	-	-	-	-	-	-	-	-
Benz(a)anthracenes/Chrysenes, C1-	5.70%	-	6.70%	2.30%	2.90%	-	17.30%	6.80%	1.30%	1.30%	-	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Benz(a)anthracenes/Chrysenes, C2-	4.30%	-	7.80%	7.70%	6.00%	-	19.00%	16.40%	2.80%	1.70%	-	-
Benz(a)anthracenes/Chrysenes, C3-	23.60%	-	15.80%	13.50%	11.10%	-	40.20%	8.90%	2.50%	3.40%	-	-
Benz(a)anthracenes/Chrysenes, C4-	5.90%	-	23.90%	26.40%	10.60%	-	16.70%	7.00%	4.00%	0.40%	-	-
Benzo(a)pyrene	16.70%	-	11.80%	5.10%	20.80%	-	23.60%	6.50%	3.60%	4.80%	-	-
Benzo(b)fluoranthene	9.30%	-	9.70%	6.70%	26.60%	-	17.50%	5.20%	4.60%	4.70%	-	-
Benzo(e)pyrene	13.50%	-	7.50%	7.20%	9.90%	-	28.40%	5.90%	2.00%	1.00%	-	-
Benzo(g,h,i)perylene	16.60%	-	5.50%	0.60%	4.60%	-	14.20%	5.30%	3.50%	3.20%	-	-
Benzo(k)fluoranthene	36.40%	-	20.60%	1.80%	-	-	33.00%	2.80%	-	-	-	-
Chrysene	8.40%	-	8.90%	3.50%	9.50%	-	19.00%	7.50%	4.00%	5.00%	-	-
Dibenz(a,h)anthracene	39.90%	-	25.20%	10.90%	-	-	-	-	2.00%	1.20%	-	-
Dibenzothiophene	-	-	7.20%	5.20%	-	-	15.90%	13.00%	-	-	-	-
Dibenzothiophenes, C1-	8.90%	-	5.90%	3.90%	5.10%	-	24.60%	2.90%	7.00%	2.60%	-	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Dibenzothiophenes, C2-	4.50%	-	7.20%	5.70%	10.20%	-	12.20%	2.90%	4.40%	4.90%	-	-
Dibenzothiophenes, C3-	4.80%	-	8.90%	2.30%	8.00%	-	14.70%	0.80%	3.70%	3.80%	-	-
Dimethylnaphthalene, 2,6-	22.20%	-	5.10%	3.70%	0.40%	-	12.20%	13.80%	4.20%	3.90%	-	-
Fluoranthene	16.00%	-	10.60%	3.30%	33.20%	-	17.20%	16.00%	5.50%	3.50%	-	-
Fluoranthene/Pyrenes, C1-	16.30%	-	9.90%	2.80%	8.70%	-	17.40%	2.90%	2.00%	2.30%	-	-
Fluorene	15.30%	-	15.00%	4.00%	-	-	15.80%	9.10%	2.70%	2.90%	-	-
Fluorenes, C2-	14.00%	-	7.30%	8.90%	0.80%	-	9.40%	1.20%	3.30%	4.30%	-	-
Fluorenes, C3-	7.00%	-	11.30%	2.80%	9.00%	-	12.30%	0.10%	2.00%	2.50%	-	-
Indeno(1,2,3-c,d)pyrene	21.90%	-	8.80%	2.30%	14.90%	-	18.10%	5.30%	6.70%	6.70%	-	-
Methylnaphthalene, 2-	9.30%	-	4.10%	2.60%	2.10%	-	10.60%	6.30%	2.40%	1.90%	-	-
Methylphenanthrene, 1-	16.70%	-	14.40%	9.50%	11.60%	-	14.60%	10.70%	0.80%	0.80%	-	-
Naphthalene	10.30%	-	5.20%	1.90%	3.20%	-	2.10%	3.80%	2.40%	0.50%	-	-
Naphthalenes, C1-	14.50%	-	6.40%	3.70%	0.50%	-	7.50%	5.70%	2.30%	1.70%	-	-
Naphthalenes, C3-	17.20%	-	7.80%	7.90%	0.60%	-	8.90%	11.20%	5.30%	5.80%	-	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Perylene	17.60%	-	13.70%	5.80%	5.00%	-	25.60%	8.60%	3.50%	4.30%	-	-
Phenanthrene	5.80%	-	20.20%	5.30%	29.00%	-	21.30%	26.50%	2.50%	2.10%	-	-
Phenanthrene/Anthracene, C1-	28.70%	-	10.30%	3.00%	13.70%	-	13.00%	0.20%	2.60%	2.00%	-	-
Phenanthrene/Anthracene, C2-	15.60%	-	9.10%	7.30%	7.10%	-	12.90%	8.10%	2.80%	2.80%	-	-
Pyrene	16.70%	-	9.00%	3.00%	19.50%	-	19.20%	14.40%	4.60%	3.90%	-	-
Trimethylnaphthalene, 2,3,5-	22.10%	-	7.80%	3.40%	2.30%	-	17.60%	9.00%	3.30%	4.50%	-	-
PBDE 007	-	-	-	-	-	-	-	11.20%	15.40%	15.60%	2.00%	2.00%
PBDE 008	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 010	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 012	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 015	11.20%	9.50%	0.70%	-	-	-	3.20%	4.30%	12.30%	15.40%	7.50%	7.50%
PBDE 017	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 028	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 030	-	-	-	-	-	-	-	-	-	-	-	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PBDE 032	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 035	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 047	8.30%	1.20%	4.40%	-	-	-	13.80%	18.20%	6.40%	0.70%	4.60%	4.60%
PBDE 049	4.10%	0.70%	1.50%	-	-	-	10.20%	8.60%	5.40%	3.20%	12.40%	12.40%
PBDE 051	5.70%	5.70%	0.70%	-	-	-	-	-	10.50%	6.70%	15.30%	15.30%
PBDE 066	2.00%	0.50%	1.10%	-	-	-	13.80%	14.10%	6.30%	2.80%	8.40%	8.40%
PBDE 071	1.90%	1.90%	2.30%	-	-	-	-	-	18.20%	19.60%	32.70%	32.70%
PBDE 075	0.70%	0.70%	9.80%	-	-	-	-	-	0.80%	0.60%	22.00%	22.00%
PBDE 077	15.80%	15.80%	-	-	-	-	-	-	-	-	-	-
PBDE 079	16.40%	16.40%	-	-	-	-	-	-	21.80%	15.60%	-	-
PBDE 085	12.50%	5.20%	5.00%	-	-	-	4.60%	5.70%	12.40%	3.70%	2.90%	2.90%
PBDE 099	8.90%	3.90%	3.30%	-	-	-	8.10%	9.90%	9.30%	2.40%	4.80%	4.80%
PBDE 100	5.20%	0.30%	3.80%	-	-	-	9.20%	11.70%	8.90%	1.10%	6.00%	6.00%
PBDE 105	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PBDE 116	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 119	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 126	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 128	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 140	-	-	30.00%	-	-	-	12.10%	12.50%	15.70%	2.70%	9.80%	9.80%
PBDE 153	11.20%	6.60%	9.90%	-	-	-	6.20%	7.10%	9.50%	3.80%	3.50%	3.50%
PBDE 155	9.20%	12.50%	-	-	-	-	6.40%	7.80%	17.60%	3.70%	6.00%	6.00%
PBDE 181	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 183	16.40%	1.50%	18.50%	-	-	-	27.40%	32.60%	15.40%	6.10%	11.00%	11.00%
PBDE 190	-	-	-	-	-	-	-	-	-	-	1.70%	1.70%
PBDE 197	34.70%	12.30%	15.80%	-	-	-	-	-	-	-	-	-
PBDE 203	25.10%	17.60%	14.80%	-	-	-	-	3.30%	22.40%	12.70%	4.60%	4.60%
PBDE 205	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 206	18.40%	23.90%	10.60%	-	-	-	6.10%	7.60%	21.90%	10.50%	37.30%	37.30%

Analyte	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PBDE 207	24.20%	25.50%	8.30%	-	-	-	2.00%	2.10%	24.70%	14.30%	28.20%	28.20%
PBDE 208	23.50%	23.70%	11.30%	-	-	-	3.50%	4.10%	24.60%	14.50%	30.50%	30.50%
PBDE 209	21.60%	19.40%	1.60%	-	-	-	2.10%	2.20%	19.90%	5.10%	42.30%	42.30%
PCB 008	14.40%	10.40%	13.70%	13.60%	20.00%	-	5.00%	0.30%	23.50%	9.70%	6.90%	11.90%
PCB 018	-	-	-	-	-	-	-	-	26.60%	5.20%	4.70%	-
PCB 028	-	-	-	-	-	-	-	-	20.30%	3.60%	5.10%	-
PCB 031	10.80%	9.10%	8.80%	7.50%	8.50%	-	4.70%	0.70%	17.10%	2.60%	4.90%	0.80%
PCB 033	-	-	-	-	-	-	-	-	24.40%	7.00%	6.50%	-
PCB 044	-	-	-	-	-	-	-	-	13.10%	8.60%	-	-
PCB 049	-	-	-	-	-	-	-	-	15.50%	12.80%	-	-
PCB 052	8.90%	13.80%	12.30%	10.40%	9.90%	-	7.00%	14.40%	18.60%	15.60%	11.40%	6.60%
PCB 056	6.20%	5.10%	13.90%	7.30%	2.20%	-	5.50%	12.00%	13.40%	1.70%	16.20%	3.80%
PCB 060	5.60%	4.30%	14.50%	7.80%	2.00%	-	6.10%	13.60%	11.30%	1.70%	14.60%	3.20%
PCB 066	7.00%	8.00%	11.40%	8.90%	1.50%	-	8.20%	15.00%	11.20%	2.80%	16.00%	1.60%

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PCB 070	-	-	-	-	-	-	-	-	6.00%	9.90%	-	-
PCB 087	-	-	-	-	-	-	-	-	18.40%	22.40%	9.30%	-
PCB 095	-	-	-	-	-	-	-	-	21.10%	29.80%	16.10%	-
PCB 099	-	-	-	-	-	-	-	-	20.60%	24.70%	22.30%	-
PCB 101	-	-	-	-	-	-	-	-	17.10%	23.90%	20.10%	-
PCB 105	7.40%	7.90%	19.30%	11.00%	13.40%	-	7.70%	19.20%	14.90%	11.40%	17.30%	22.50%
PCB 110	-	-	-	-	-	-	-	-	16.60%	20.90%	11.00%	-
PCB 118	7.70%	8.60%	21.00%	8.70%	15.00%	-	8.10%	20.80%	15.20%	13.60%	16.30%	27.90%
PCB 128	19.80%	19.80%	-	-	-	-	-	-	7.20%	15.00%	3.30%	-
PCB 132	9.70%	9.20%	20.00%	4.70%	18.50%	-	11.80%	25.80%	13.20%	18.40%	5.30%	11.40%
PCB 138	-	-	-	-	-	-	-	-	6.60%	10.80%	1.40%	-
PCB 141	9.40%	10.30%	19.40%	3.50%	14.80%	-	14.00%	22.90%	15.50%	15.60%	7.70%	15.90%
PCB 149	-	-	-	-	-	-	-	-	4.80%	10.40%	3.90%	-
PCB 151	-	-	-	-	-	-	-	-	3.00%	5.90%	3.50%	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
PCB 153	-	-	-	-	-	-	-	-	6.40%	7.60%	2.70%	-
PCB 156	-	-	-	-	-	-	-	-	8.00%	18.60%	-	-
PCB 158	8.90%	11.00%	18.50%	3.80%	16.70%	-	11.10%	24.80%	15.60%	16.00%	9.40%	16.70%
PCB 170	7.30%	4.70%	15.90%	1.40%	11.30%	-	13.20%	24.70%	20.80%	7.90%	5.30%	7.70%
PCB 174	5.60%	1.70%	14.20%	2.20%	11.50%	-	21.80%	36.30%	13.80%	1.50%	6.30%	7.20%
PCB 177	6.00%	3.70%	13.30%	3.40%	18.90%	-	20.10%	-	16.60%	4.30%	4.90%	6.00%
PCB 180	-	-	-	-	-	-	23.70%	29.50%	15.00%	4.40%	-	-
PCB 183	-	-	-	-	-	-	33.10%	31.60%	13.40%	5.50%	-	-
PCB 187	5.20%	3.80%	11.00%	3.90%	6.40%	-	23.80%	34.90%	15.00%	5.00%	8.60%	10.50%
PCB 194	7.40%	3.30%	19.00%	5.60%	14.40%	-	16.10%	38.70%	22.70%	12.20%	5.90%	8.20%
PCB 195	5.50%	2.00%	18.10%	3.40%	29.70%	-	15.30%	26.90%	24.80%	12.70%	4.30%	3.80%
PCB 201	8.80%	2.40%	13.20%	1.10%	10.10%	-	23.30%	-	13.20%	6.80%	8.00%	8.20%
PCB 203	7.70%	6.70%	15.50%	5.40%	14.30%	-	18.20%	44.10%	17.80%	17.10%	9.60%	12.90%
Allethrin	-	-	-	-	-	-	-	-	-	-	-	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Bifenthrin	18.70%	-	11.10%	-	8.50%	-	4.80%	-	9.70%	-	0.00%	-
Cyfluthrin, total	14.60%	-	17.90%	-	-	-	-	-	4.30%	-	6.60%	-
Cyhalothrin,lambda, total	-	-	-	-	-	-	-	-	-	-	0.00%	-
Cypermethrin, total	-	-	30.40%	-	27.60%	-	-	-	1.60%	-	1.30%	-
Delta/Tralomethrin	-	-	39.50%	-	32.40%	-	23.00%	-	58.00%	-	12.90%	-
Esfenvalerate/Fenvalerate, total	-	-	10.10%	-	-	-	-	-	24.40%	-	-	-
Fenpropathrin	-	-	-	-	-	-	-	-	-	-	-	-
Permethrin, total	12.90%	-	10.90%	-	10.60%	-	2.10%	-	5.20%	-	4.00%	-
Phenothrin	-	-	-	-	-	-	-	-	-	-	-	-
Prallethrin	-	-	-	-	-	-	-	-	-	-	-	-
Resmethrin	-	-	-	-	-	-	-	-	-	-	-	-
Total Cu	0.90%	1.10%	0.10%	0.20%	0.40%	0.80%	-	-	0.00%	-	3.40%	-
Dissolved Cu	6.30%	-	1.60%	-	-	-	-	-	3.80%	-	-	-

	San Leandro Creek		East Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek	
Analyte	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD	Avg Field RSD	Avg Lab RSD
Total Hg	18.70%	2.10%	11.80%	-	4.50%	-	12.30%	-	9.70%	-	16.90%	-
Total MeHg	10.00%	4.10%	11.90%	-	2.70%	-	10.60%	2.60%	10.70%	-	1.40%	-
Dissolved Se	3.10%	6.20%	1.60%	-	-	-	-	-	5.20%	-	-	-
Total Se	11.60%	10.10%	0.00%	-	4.10%	1.50%	1.40%	1.40%	0.00%	-	6.40%	-
Total Hardness (calc)	1.20%	-	8.30%	-	-	-	-	-	0.00%	-	6.30%	-
TOC	1.50%	-	3.00%	-	3.80%	-	6.10%	-	6.40%	-	1.50%	-

Attachment 2. Intercomparison Studies

Due to the change in analytical labs for 2013 and 2014 from those used previously in loading studies, a limited number of split samples were analyzed for intercomparison with results from laboratories contracted in previous years.

In general, the intra-lab variation from replicate analyses performed on these samples for both the current and previous contract labs, was much smaller than the inter-lab variation. This is to be expected; analytical biases (e.g., from mis-calibration, incomplete extraction, matrix interferences, etc.) will tend to recur and be more consistent within a lab than among labs. Even if both labs perform within typical acceptance limits for CRMs or other performance tests, the net difference between labs can sometimes be exacerbated by biases in opposite directions, or interferences present in specific field matrices but not reference materials, and in limited studies, it may be possible only to estimate a typical difference, not establish which lab's results are more accurate. Differences in results between years and between sites analyzed by different labs that are smaller than or similar to the inter-lab measurement differences may not be real or significant and may only reflect measurement differences between labs.

Even in larger intercomparison exercises with multiple labs, there is no assurance provided that the certified or consensus value is absolutely accurate, only a weight of evidence that more or most labs get a similar result. Such a consensus may in part reflect a common bias among labs encountering a similar interference or bias of choosing a particular extraction or analytical method.

The following section will discuss results on split samples analyzed for this project in 2013 and 2014 for various analytes. In most cases the differences among labs were within common precision acceptance limits (e.g., 25% RPD for intra-lab replicates for trace metals in RMP or SWAMP) or within the expected combined (propagated) error for separate measurements of recovery (e.g. within 25% of target values for 2 independent labs for reference materials or matrix spikes for trace elements; propagated error = square root $((25\%)^{\wedge 2} + (25\%)^{\wedge 2}) = \sim 35\%$). In cases where the results between labs show a consistent bias, it may be possible to adjust for the bias in evaluating interannual or inter-site differences, but in cases where the inter-lab differences appear more randomly distributed, smaller interannual or inter-site differences may not be distinguishable from measurement uncertainty.

In cases where more random or less systematic differences were found between the labs' results, it is often difficult to diagnose the cause without extensive investigation. Causes of the discrepancies may be particular to specific samples, or sporadic and hard to reproduce. However, because the data in this study are compiled to develop overall pictures of concentrations and loads from the various watersheds, the impact of measurement errors or variations in any individual samples is lessened; random errors will partially offset and the aggregate statistics will reasonably allow estimation of the central tendency of the data. For many of the analytes, the results were often in good agreement (near a 1:1 line) for all but 1 of the split sample pairs, so the data can, in many cases, be compared with acknowledgement of measurement uncertainty but without requiring adjustment, which is suitable only for cases of systematic bias. Results for specific analytes are discussed below.

Trace Elements

Copper

Copper was measured by Caltest (the "Target Lab") in 2013 and 2014, and by Brooks Rand (the "IC Lab") in previous years. Three samples each of dissolved and total copper were split and analyzed by both labs in the course of the study. For both labs, the within lab RPDs were within 5% or better for these split samples, suggesting that individually, neither of the labs had noticeable issues with subsampling the provided samples uniformly for replicate analysis. In general, the IC lab reported concentrations higher than the target lab for any given sample (Figure 9). For dissolved copper, the average difference in slope (fitting a linear regression through the origin, vs. an "ideal" 1:1 line) was 28%, and for total copper, the average difference in slope was 15%. For individual result pairs, the target lab result was always lower, ranging 65% to 89% (average 74%) of the IC lab result for dissolved samples and 83% to 95% (average 87%) for total samples; average RPD was 31% for dissolved copper, and 14% for total copper. These data hint at a systematic bias, but because of the small number of samples in the comparison and differences between labs within or nearly within common acceptance limits for within lab variation (e.g., 25% RPD for metals) more evidence of a systematic bias would be recommended before attempting to develop an adjustment factor between labs.

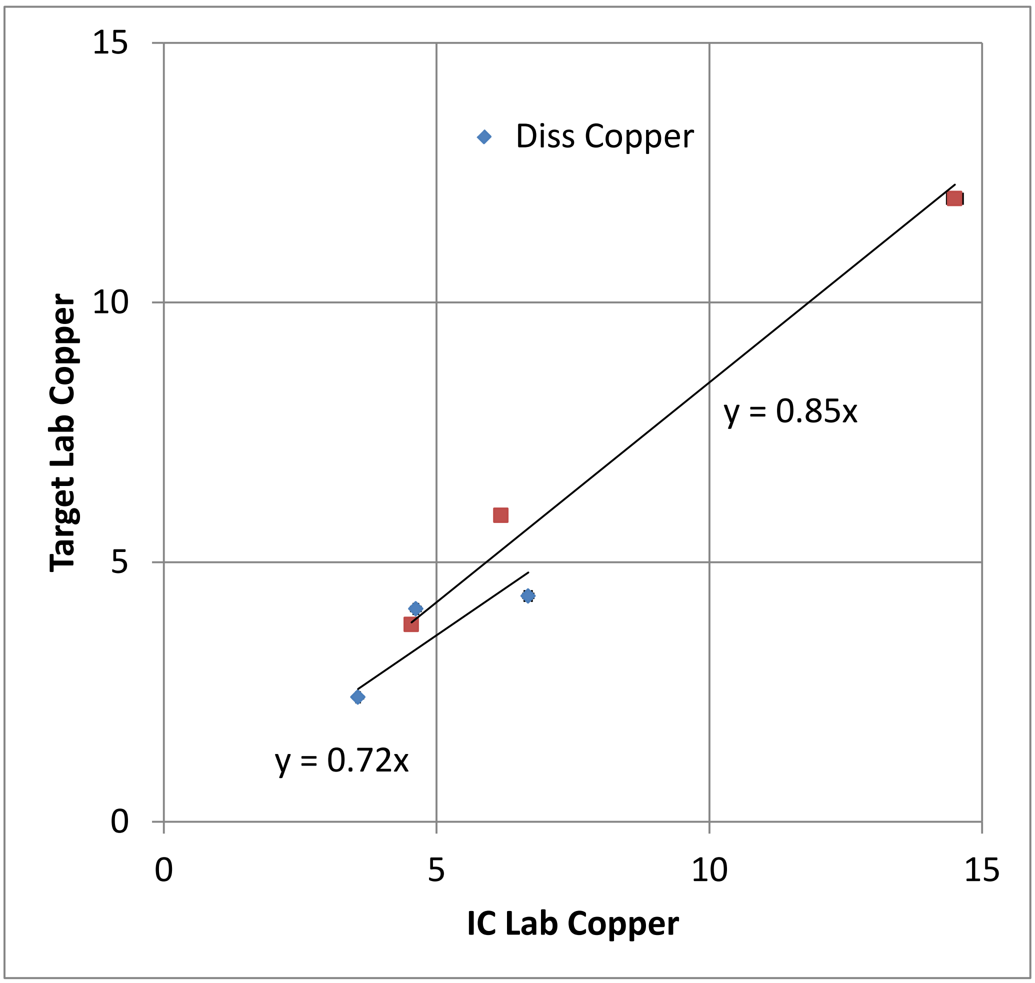

Figure 9 Target versus IC lab dissolved and total copper in split water samples for 2013 to 2014.

Total Mercury

Total mercury was measured by Caltest (the “Target Lab”) in 2013 and 2014, and by Moss Landing Marine Labs (the “IC Lab”) in previous years. Seven total (unfiltered) water samples were split and analyzed for total mercury by both labs in the course of the study. For both labs, none of these split samples were analyzed as lab replicates, but precision on lab replicate analyses averaged 16% RSD in 2014 for the target lab and 3% in 2014 for the IC lab. Similar to copper, the IC lab generally reported concentrations higher than the target lab for any given sample (Figure 10), although the bias is less consistent. For total mercury, the target lab result ranged 51% to 105% (average 82%) of the IC lab result; the average RPD was 25%. Much of this difference was driven by a single result pair in 2014, where the IC lab result was nearly double that of the target laboratory; without that pair, the slope would have been near 1:1 (1.03), so correction is not warranted given the overall deviation depending largely on that one sample pair.

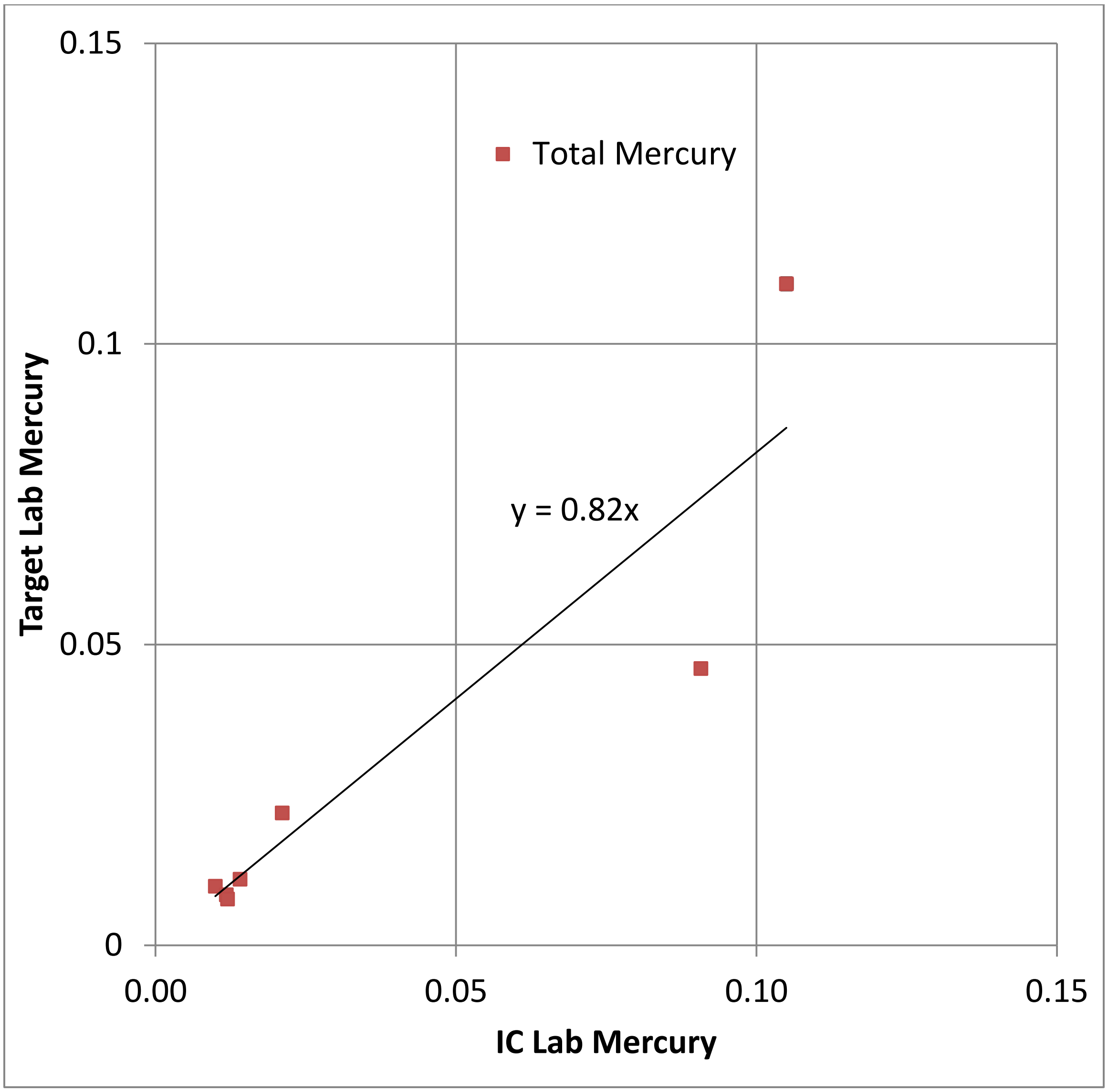

Figure 10 Target versus IC lab total mercury in split water samples for 2013 to 2014.

Methylmercury

Methyl mercury was measured by Caltest (the "Target Lab") in 2013 and 2014, and by Moss Landing Marine Labs (the "IC Lab") in previous years. Four total (unfiltered) water samples were split and analyzed for methylmercury by both labs in the course of the study. Only the IC lab analyzed one of these split samples directly in lab replicates, with <1% RSD, but the target lab also had acceptable precision with average 16% RSD in 2014 for other samples in the project. Unlike the other metals, the results for the IC lab averaged slightly lower than the target lab (Figure 11). For methylmercury, the target lab ranged 90% to 132% (average 105%) of the IC lab result. The average RPD was 12%, with some points both above and below the 1:1 line. Similar to copper, the differences are neither large enough nor consistent enough to warrant a correction factor.

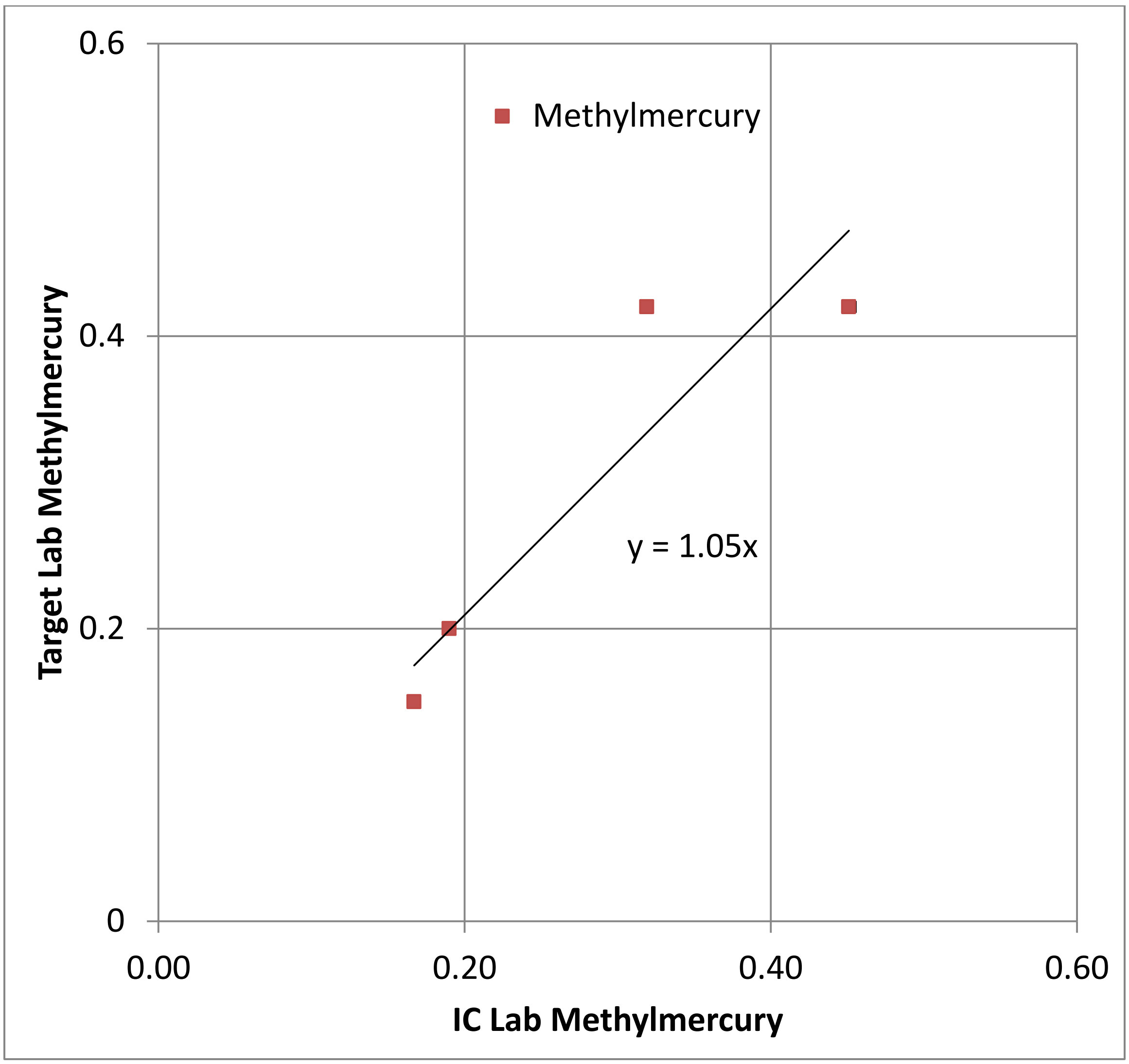

Figure 11 Target versus IC lab methylmercury in split water samples for 2013 to 2014.

Selenium

Selenium was measured by Caltest (the "Target Lab") in 2013 and 2014, and by Brooks Rand (the "IC Lab") in previous years. Two samples each of dissolved and total selenium were split and analyzed by both labs in the course of the study. For both labs, the within lab replicate RPDs were good, within 10% or better for these split samples. In general, the IC lab reported concentrations very slightly higher than the target lab for any given sample (Figure 12), but results were nearly identical among labs, and very similar between dissolved and total phase for any given sampling event. For dissolved selenium, the target lab results were 89% to 97% (average 92%) of the IC lab, and for total selenium 88% to 98% (average 95%). Averages of individual result pair RPDs were 9% for dissolved selenium, and 5% for total selenium. Corrections for selenium are clearly not warranted given the very good agreement.

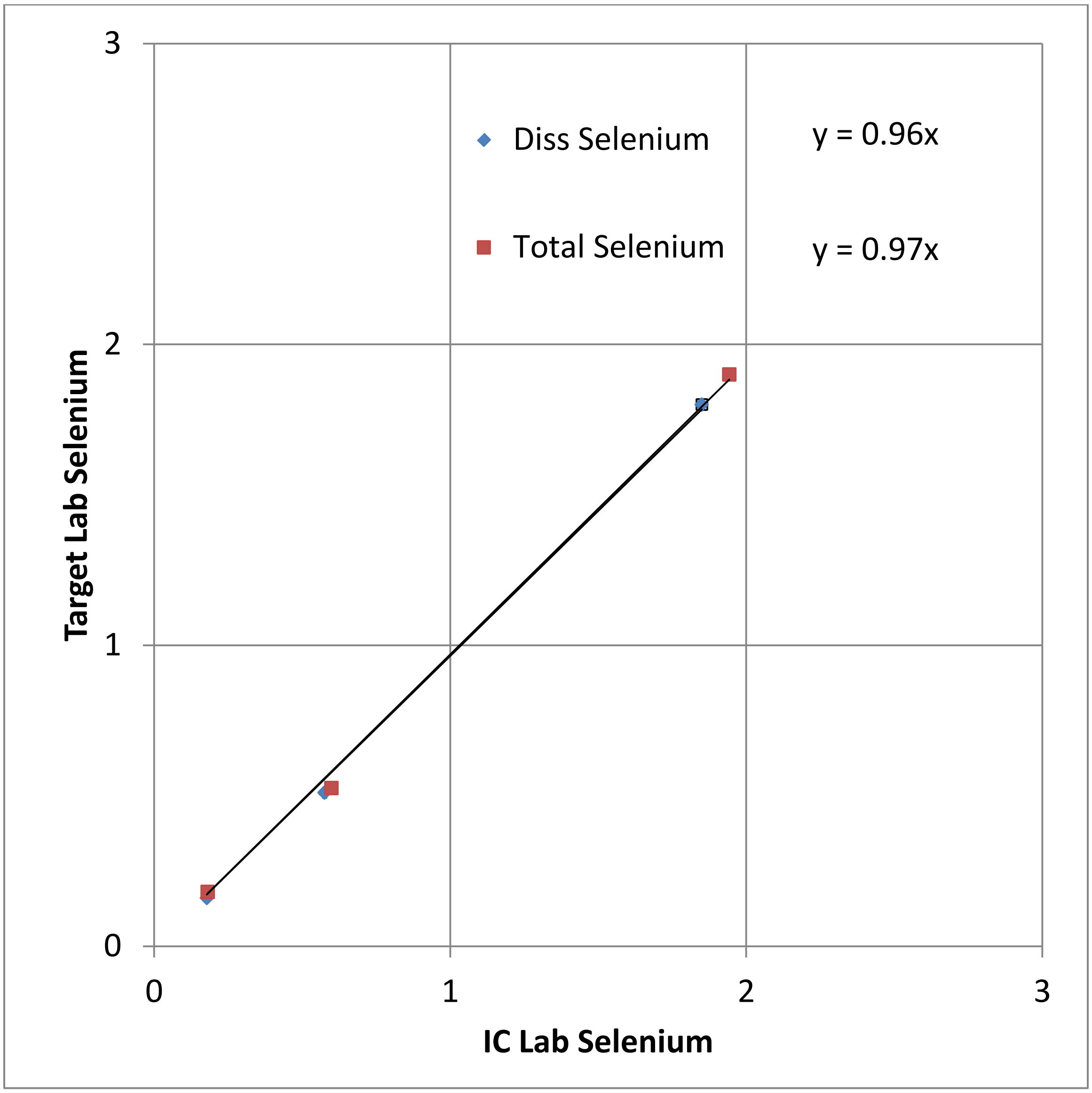

Figure 12 Target versus IC lab dissolved and total selenium in split water samples for 2013 to 2014.

Hardness

Hardness was measured by Caltest (the "Target Lab") in 2013 and 2014, and by Brooks Rand (the "IC Lab") in previous years by a calculation from Ca and Mg concentrations. Three samples were split for analysis by both labs in the course of the study. For the target lab, the within lab replicate RPDs or RSDs were 6% to 12% for these split samples, and for the IC lab 3% on the one sample they analyzed in replicate. There was no consistent bias, with the target lab reporting 85% to 116% (average 100%) of the IC lab result. Although recovery errors in lab control samples (a clean lab matrix) by the target lab were generally within 10% or better of the target value, for field sample matrix spikes, recoveries were highly variable, as low as 30% recovery (70% error), averaging over 20% error. The moderately large average recovery error and sporadic large excursions suggest uncertainties in the target lab hardness data, leading 2013 results to be censored (although raw results remain in the database, and are plotted in Figure 13 here). The IC lab did not report recovery on hardness directly, but recovery was good on Ca and Mg, with modest errors (from 8% to 12%). Given a lack of consistent bias, a correction factor is not warranted for hardness measurements.

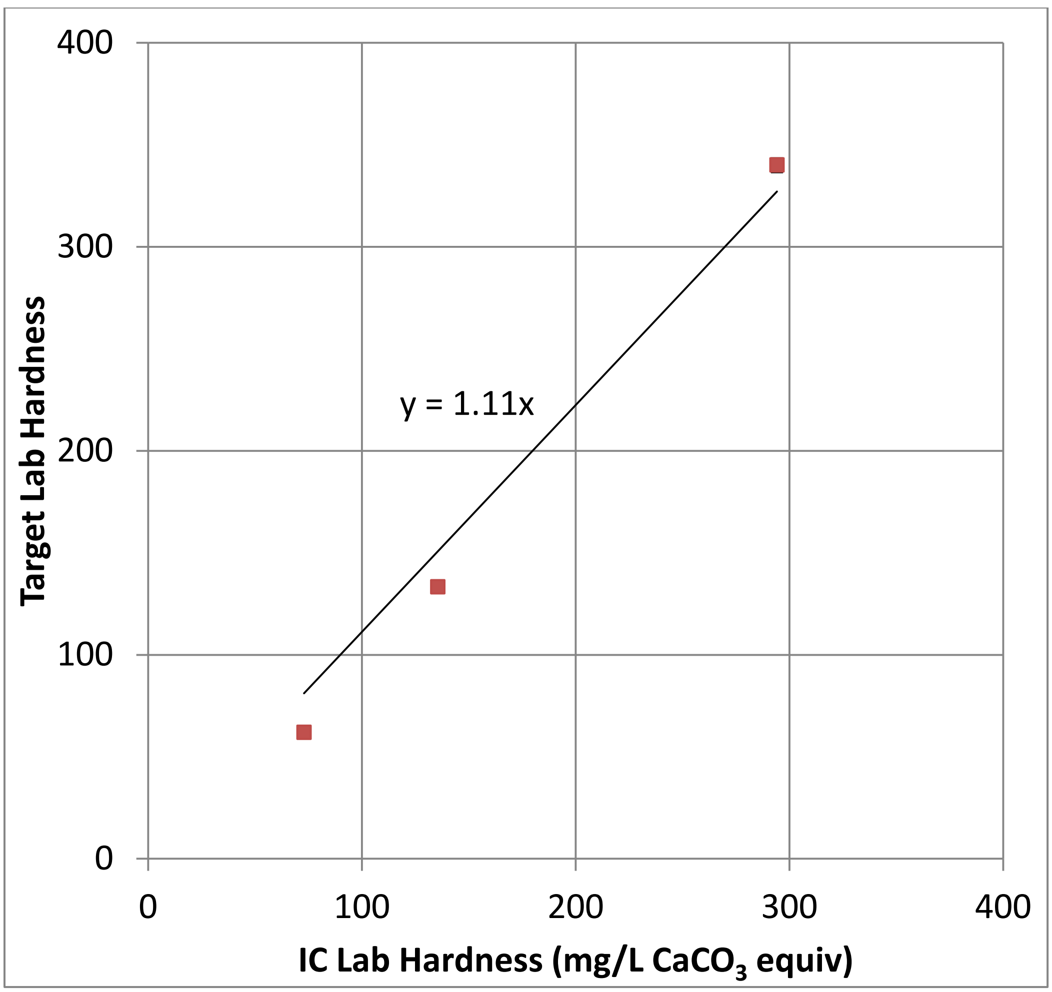

Figure 13 Target versus IC lab hardness in split water samples for 2013 to 2014.

Suspended Sediment Concentration

Suspended sediment concentration (SSC) was measured by Caltest (the "Target Lab") in 2013 and 2014, and by EBMUD (the "IC Lab") in previous years. Three samples were split for analysis by both labs in the course of the study. For the target lab, the lab replicate RSDs were 6% to 12% for these split samples, and for the IC lab 3% on the one sample they analyzed in replicate. There was no consistent bias between labs (Figure 14). The target lab reported results 41% to 150% (average 101%) those of the IC lab, with the largest relative differences on the lower concentration samples. Recoveries on LCS samples by the target lab were within 10% of the expected values. The IC lab reported recovery on performance testing reference materials, with recovery errors for different materials of 1% to 19%. Despite the large variations in the comparison of results between labs, the differences were not consistently biased and thus would not justify application of a correction factor.

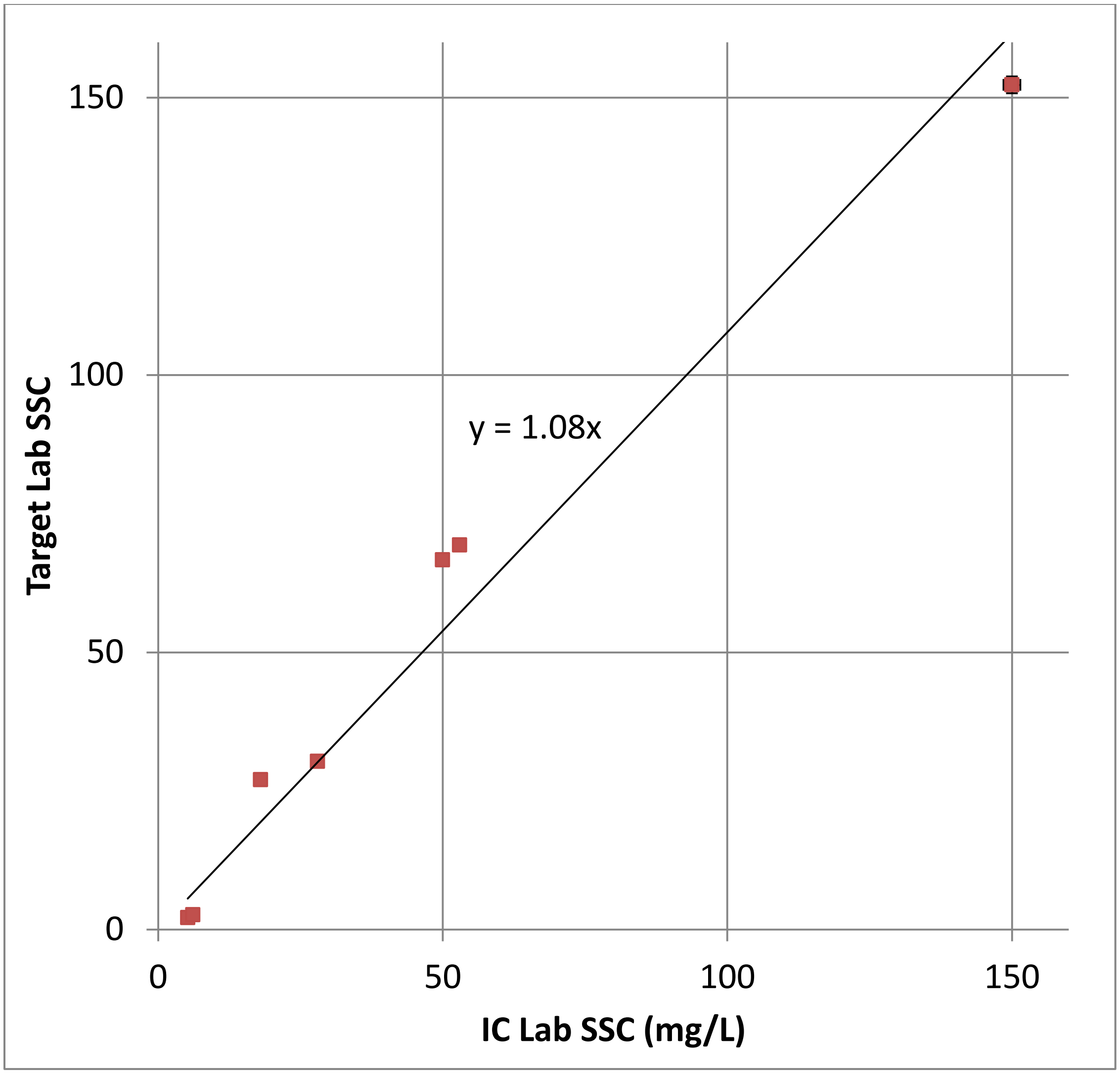

Figure 14 Target versus IC lab SSC in split water samples for 2013 to 2014.

Nutrients

Nutrients were measured by Caltest (the "Target Lab") in 2013 and 2014, and by EBMUD (the "IC Lab") in previous years. Seven samples were split for analysis of nitrate by both labs. For the IC lab, the lab replicate RSDs were 1% or better for these split samples. The target lab did not analyze any of these split samples in replicate, but RSDs for lab replicates on other field samples averaged 5%. The target lab generally reported lower concentrations except for the highest sample (Figure 14), ranging 76% to 108% (average 90%) of those from the IC lab, with the largest relative differences mostly on the lowest concentration samples (RPDs on paired splits of 2% to 28%, averaging 15%). Recoveries on LCS samples by the target lab averaged within 3% of the expected values, while the IC lab LCS sample recovery errors averaged 24%. The IC lab spiked at much lower levels however (around 0.05 mg/L vs ~4 for the target lab) which may in large part explain the seemingly poorer recoveries. Differences among the labs results were not systematic and do not warrant a correction factor for comparison.

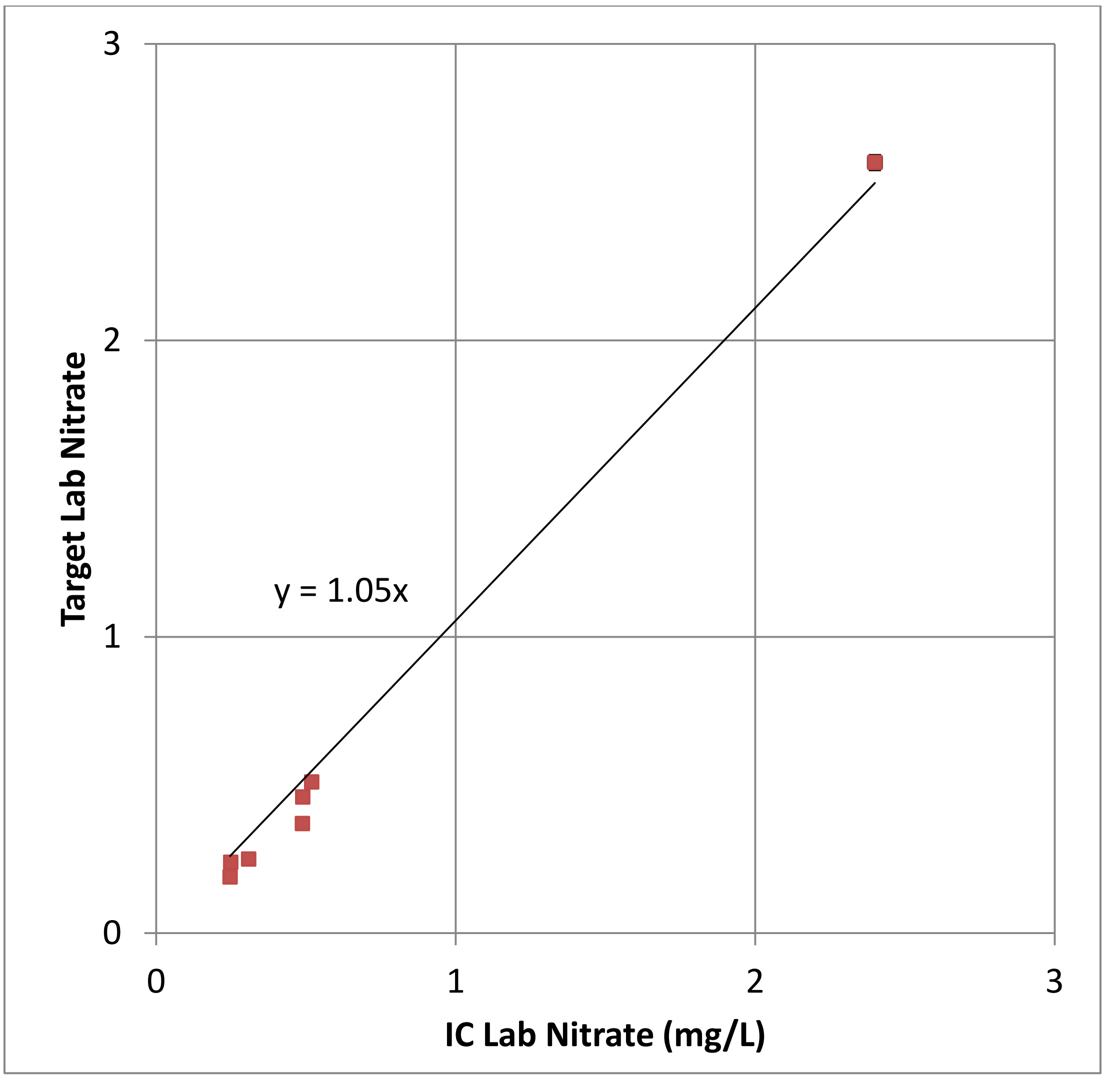

Figure 15 Target versus IC lab nitrate in split water samples for 2013 to 2014.

Orthophosphate was measured in seven split samples by both labs. For both labs, lab replicate RSDs were <1% for these split samples. The target lab reported a much lower concentration (69% of the IC lab result on one sample), but otherwise had similar results (Figure 16), around 92% to 101% of those from the IC lab (average 93% including all samples). Reported as RPDs on paired splits, the differences ranged from 0% to 37%, averaging 8%. Recoveries on IC lab LCS samples were biased high an average 14%, which may explain in part the differences among labs, but without the one sample with the target lab at 69% of the IC results, results would be near 1:1 between the labs.

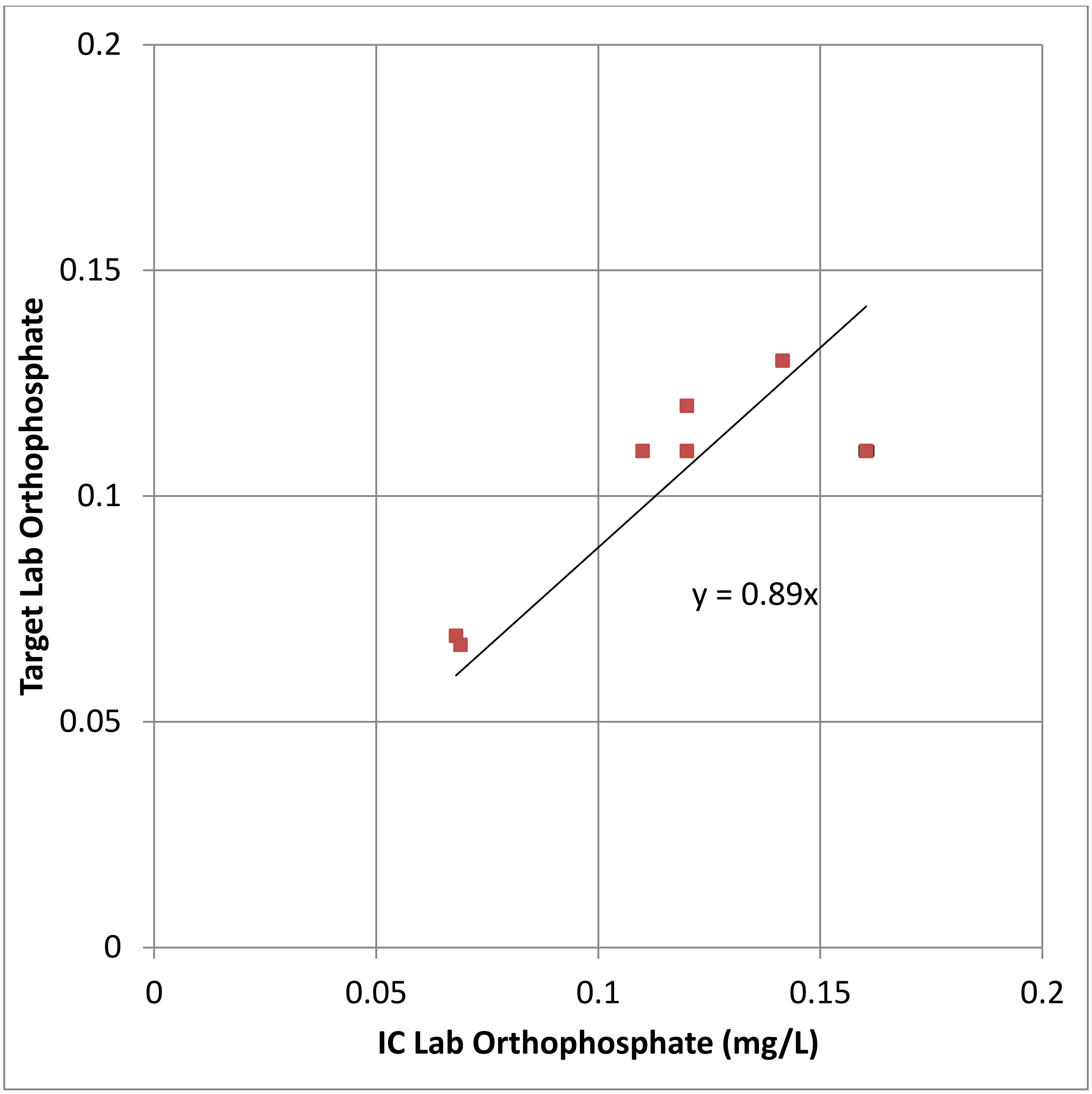

Figure 16 Target versus IC lab orthophosphate in split water samples for 2013 to 2014.

Phosphorus was reported for four split samples. For 3 of the 4 samples results generally agreed (target lab results 70% to 96% of the IC lab's), but for one, the concentration for the target lab was 4x lower (Figure 17). RPDs ranged from 140% for the latter sample pair, to 4% for the best paired results. Although the IC lab 2013 sample batch was flagged for low recovery (86%), below the target MQO of 10% error (90% recovery), that would not explain the discrepancy between the labs since the IC lab result was biased high relative to the target lab. The lab replicate precision was good for both the target and IC labs for these split samples (RSDs <5%), so measurement variation also seems unlikely to explain the difference, but the specific pair with the largest difference was not analyzed in replicate by either lab. Field sampling variation (more likely with total phase samples) might also contribute to differences in inter-lab splits, which are taken sequentially in the field rather than by truly splitting a larger sample. Again, aside from the poor agreement on one pair, the results show no clear bias among labs and do not require any adjustment.

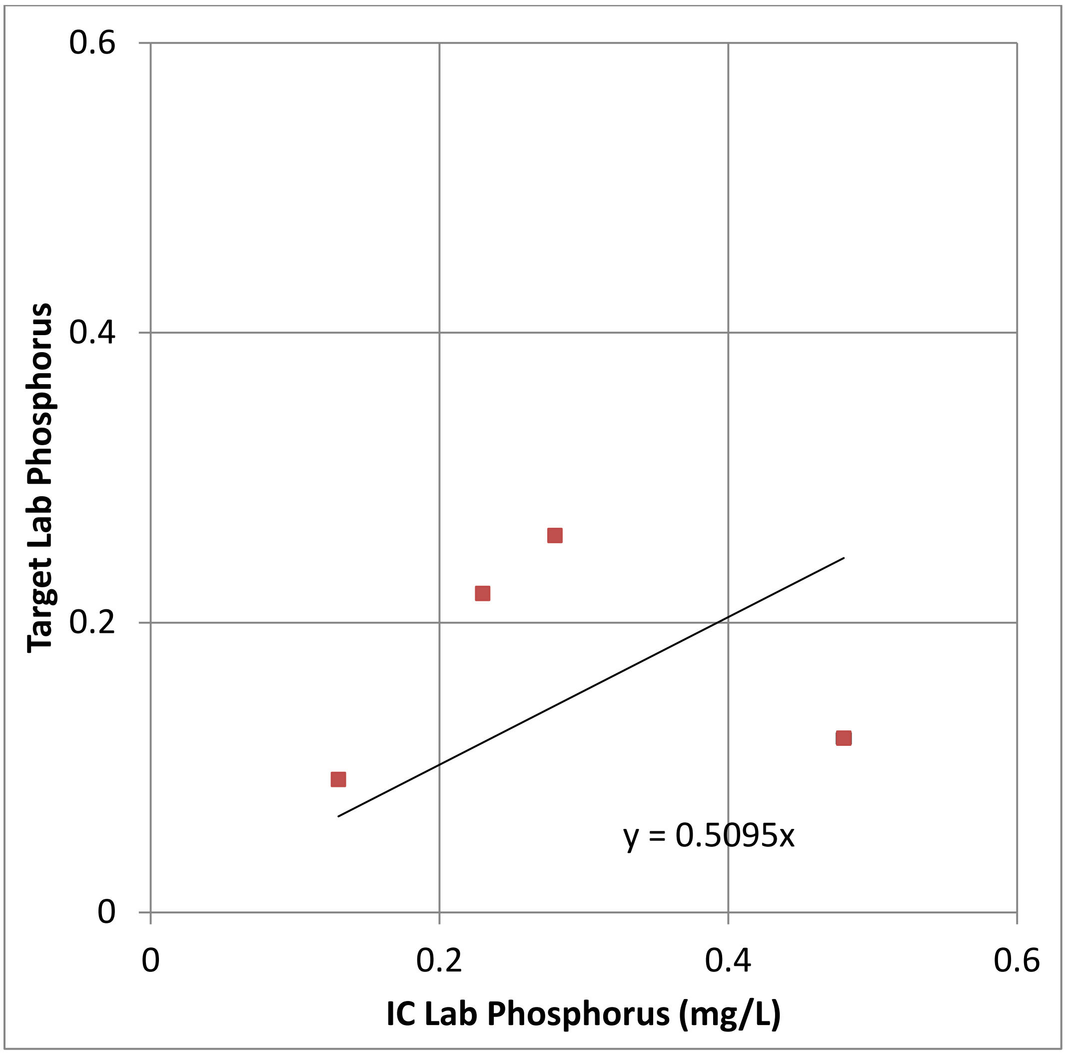

Figure 17 Target versus IC lab orthophosphate in split water samples for 2013 to 2014.

Pyrethroids

Pyrethroids were measured by Caltest (the "Target Lab") in 2013 and 2014, and by Axys Analytical (the "IC Lab") in previous years. Three water samples were split and analyzed for pyrethroids by both labs in the course of the study. For both labs, none of these split samples were analyzed as lab replicates. Some field replicates were analyzed by the target lab with RSDs 31% or better for analytes detected over 3x the MDL; the IC lab reports an ongoing precision and recovery (LCS) sample replicated across batches, with recovery errors 23% or less in 2014 samples. Only three analytes were detected in at least two of the split samples: bifenthrin, deltamethrin/tralomethrin, and total cypermethrin (Figure 18). The target lab reported higher concentrations slightly over half the time, but the ratio of target to IC lab concentrations was highly variable between samples for any given analyte; 54% to 120% for bifenthrin, 38% and 86% for deltamethrin/tralomethrin, and 105% and 149% for total permethrin. These differences are equivalent to an RPD range of 5% to 90%; as would be expected, the worst correspondence occurred in lower concentration samples where the relative impact of a nominal difference is larger. A larger number of samples would be needed to state with certainty, but within this small set of samples there does not appear to be any consistent bias, with the few results with concentrations above 10,000 pg/L (10 ng/L) being generally very similar between labs.

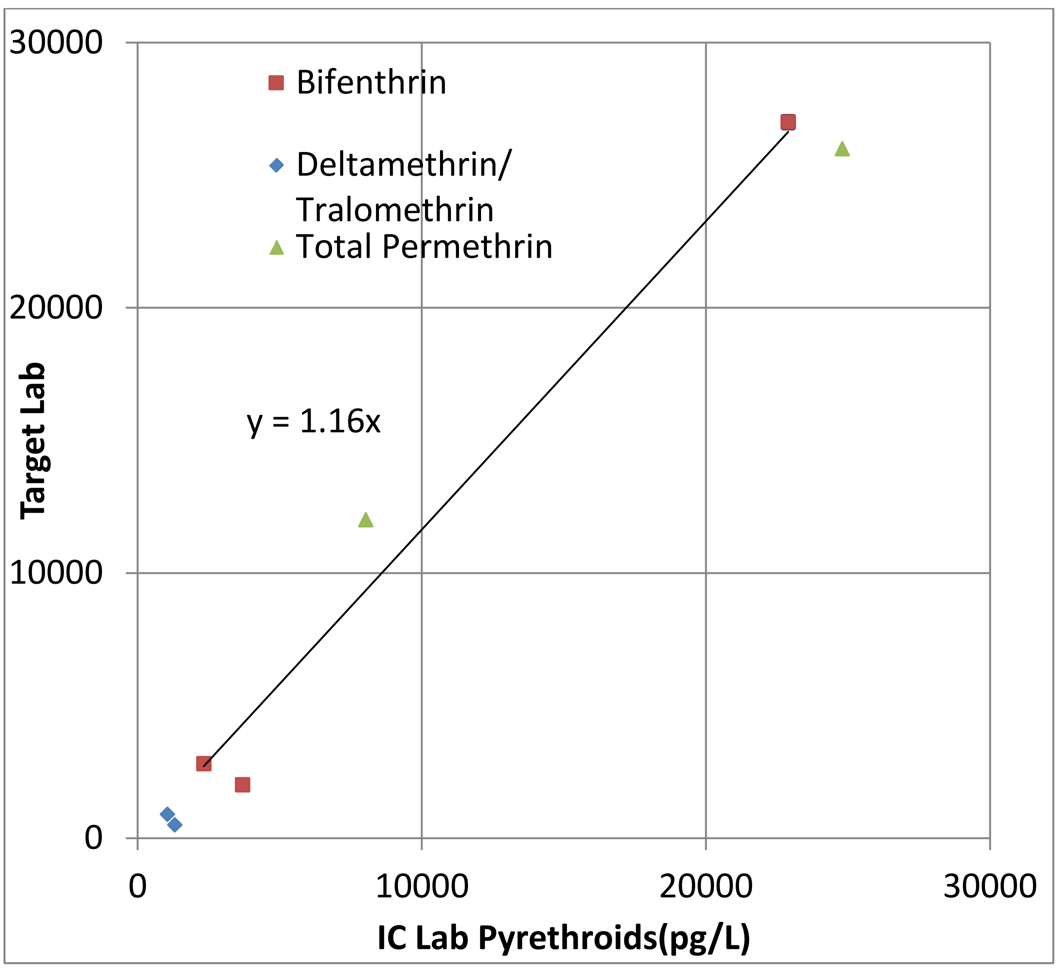

Figure 18 Target versus IC lab pyrethroids in split water samples for 2013 to 2014.

Overall the results of these intercomparison samples show general agreement between labs. For most analytes, there was not consistent bias between the labs; even where there seemed to be some bias, many of the results still showed nearly a 1:1 correspondence, so with the small number of split samples reported for most analytes, one or two random measurement errors could create the appearance of a net bias. If there are needs to more definitively quantify differences in sites or among events reported by different labs in different years, a greater number of split samples would be needed to assure a lack of bias from changing labs, but the current data suggest other than for sporadic excursions for individual samples, the data generally agree between labs, within the usual intra-lab acceptance ranges for precision and recovery for the various analytes. As noted before, most of the field sample data for this study will be considered in aggregated statistics, so even in cases where sporadic large differences appeared, the net impact will be small so long as these excursions are not the rule rather than the exception. Data subsampling techniques (e.g., including and excluding subsets of the best or worst data) can be used to further explore the need to reduce uncertainty of inter-lab differences for decision-making, before devoting time and resources to more rigorously quantify these differences.