Integrated Monitoring Report, Water Years 2012 and 2013: Part A

March 2014

Submitted by:

Contra Costa Clean Water Program

Executive Summary

Part A of the Integrated Monitoring Report (IMR) summarizes the findings of water quality monitoring conducted in accordance with Provision C.8 of the Municipal Regional Permit (MRP) and the corresponding permit issued to East Contra Costa County Permittees, the Central Valley Permit. Key technical findings are summarized below, followed by recommendations relevant to reissuance of the next MRP and the Central Valley Permit.

Creek Status: The health of creeks, as measured by stream surveys, indices of biological integrity scores, physical habitat scores, and water quality indicators, is related to the degree of urbanization or more specifically impervious surfaces that are directly connected to storm drains and local creeks. Urbanization is likely not the only factor, which is why Creek Status monitoring continues to develop a robust baseline regional picture of creek health. The creek condition assessment based on data from monitoring conducted in Water Years 2012 and 2013 appear in Section 4.2 of Appendix A-1 of the IMR Part A. The findings of that condition assessment are consistent with a review of bioassessment data collected from Contra Costa County Creeks during the time frame 2001 – 2010 (CCCWP, 2011).

Recognizing that more heavily urbanized areas tend to have poorer indicators of creek health, the focus of responsive actions will likely be redesign and retrofit of our transportation and drainage infrastructure or the long term with the goal of disconnecting directly connected impervious areas. That approach would be implemented over a 50 year (or longer) time frame, because of the significant capital and long term maintenance costs associated with such a large scale retrofit program. Any such program of retrofits would require new revenues to be feasible. In the next two permit cycles, CCCWP intends to work with permitees to seek funding sources to implement Low Impact Development and Green Street retrofits opportunistically as part of ongoing municipal infrastructure maintenance and rehabilitation.

Biological Condition: The assessment of biological creek health depends in part on the index used. When using Southern California or Central Coast indices, rankings scores for Contra Costa creeks tend to be generally lower than when indices specific to Contra Costa County are used. The Contra Costa County indices provide a wider spread of creek health rankings, which improves the ability to prioritize areas for watershed improvement projects. The comparison of how condition indicators inform assessments is summarized in Section 4.2.3 of Appendix A-1 of IMR Part A.

Toxicity: Toxicity to the benthic amphipod *Hyalella azteca* is commonly observed in water and sediment. Toxicity to *Hyalella Azteca* is thought to result from widespread use of pyrethroid pesticides, which have replaced diazinon and chlorpyrifos as the most commonly applied urban pesticides. Toxicity to water fleas (*Daphnia magna*) is not commonly observed, indicating that restrictions on urban uses of diazinon and chlorpyrifos are providing a benefit to water quality. The observation of toxicity to *Hyallella azteca* triggered a follow-up stressor/source identification study. Results of water toxicity are summarized in Section 3.2.5 of Appendix A-1 of IMR Part A. Results of sediment chemistry and toxicity are summarized in section 3.2.6 of Appendix A-1 of IMR Part A. The stressor assessment discussion appears in section 4.3 of Appendix A-1 of the IMR. The stressor-source identification study proposed as a response to toxicity is described in Appendix A-3 of the IMR Part A.

Temperature and General Water Quality: Local guidelines for temperature as an indicator of warm-water and cold-water fisheries habitat were developed by the Contra Costa Clean Water Program (CCCWP) and proposed in the Water Year 2012 Local Urban Creeks Monitoring Report submitted in March 2013. Attainment of this temperature guideline depends on the degree of channel modification. Streams with more natural channels and shade, such as San Pablo Creek and Pinole Creek, tend to attain temperature guidelines more often than streams with heavily modified channels, such as Walnut Creek and Marsh Creek. Marsh Creek tends to have substantial pH and dissolved oxygen variability during the late summer, often exceeding water quality standards. This may be related to episodic dry-weather flows that promote conditions conducive to algal growth in the creek channel. CCCWP will follow up on this observation by identifying potential sources and causes of dry weather flow. Details of the water quality monitoring results appear in Section 4.2 of Appendix A-2 of the IMR Part A.

Pollutants of Concern (POC) Tributary Loads Monitoring: The POC Loads monitoring Data Progress Report is presented in Appendix A-7 of the IMR Part A. The purpose of monitoring loads of mercury and PCBs (polychlorinated byphenyls) at major tributaries is to provide data to refine a regional watershed spreadsheet model (RWSM) under development by the San Francisco Bay Regional Monitoring Program (RMP). The RWSM is intended to predict how POC loads will be reduced over time in response to implementation of control measures. A recent draft of the RWSM report indicates that modeling uncertainties have not been substantially reduced compared to the state of knowledge prior to implementation of this monitoring project. The POC loads monitoring and related modeling efforts are envisioned by RMP participants as a long-term study that will inform planning decisions in the future. In the short term, the following beneficial information is derived from POC loads monitoring:

- PCB concentrations in Marsh Creek suspended sediments as influenced by local urban runoff are some of the lowest in the Bay Area; this is consistent with the finding that PCB concentrations tend to be higher in older, historically industrialized areas.
- Results from the few events sampled that did capture reservoir releases indicate that when water flows from Marsh Creek Reservoir, transporting suspended sediments from the upper watershed, there is no significant increase in the mercury or methylmercury concentrations of suspended sediments. As the historic Mount Diablo Mercury Mine is located in upper Marsh Creek watershed, this is an important finding.
- PCB and mercury concentrations in suspended sediments at the North Richmond Pump Station are consistent with previous measurements conducted as part of a pilot diversion project funded by the Contra Costa County Public Works Department. The PCB concentrations are typical of older industrialized catchments but do not indicate a particularly unusual or unexpected “high-opportunity area.”
- Establishing a numeric requirement for storms (i.e., average of four storms per year) to be sampled tends to bias the monitoring program to sample smaller storms because they occur with higher frequency. The compliance-oriented focus on smaller, higher frequency storms misses the opportunity to address important questions by sampling larger storms, such as “Does upper Marsh Creek Watershed flow have elevated mercury and methylmercury concentrations related to the Mount Diablo Mercury Mine?”

Recommendations: In the next reissuance of the MRP, Permittees would like to see some of the resources currently devoted to monitoring applied to implementation of projects that improve water quality. Specifically, the POC loads monitoring conducted at Marsh Creek, the

North Richmond Pump Station, and tributaries in other counties may fulfill a useful basic research need, but it does not appear to provide the practical value Permittees need to develop and implement plans to improve water quality.

CCCWP recommends ending the POC loads monitoring requirement in the next reissuance of the MRP. Permittees are prefer to direct resources conserved from loads monitoring to funding projects to improve water quality. Marsh Creek POC monitoring costs approximately $40,000–$45,000 per storm for labor and laboratory charges. North Richmond Pump Station monitoring in Water Year 2012 was funded as a special study of the RMP, and was therefore indirectly funded by CCCWP through its contribution to the RMP. In Water Years 2010 and 2011, monitoring at the North Richmond Pump Station was funded by a USEPA grant provided to the Contra Costa County Department of Public Works. The MRP and the Central Valley Permit require an average of four storms per year to be sampled at each POC loads station. Evolving the POC loads monitoring program to a program of water quality improvement would redirect approximately $200,000 per year. CCCWP has already demonstrated a willingness to support development of grant proposals, which are included as appendices to Part C of the IMR. Over a five-year permit term, if those resources were applied as 20 percent cost match for grant funding, up to $5 million could be applied to water quality improvement projects in Contra Costa.

Creek status monitoring conducted under Provision C.8.c is telling a story that has already been told: urbanization tends to degrade creek health, especially when stormwater is discharged from hardscape areas with no detention, flow attenuation, or treatment measures. Permittees recognize that characterizing creek health across the County helps support planning and funding needed to restore creeks and improve watersheds through disconnecting directly connected impervious surfaces. CCCWP had already generated a 10-year record of creek health in the County before the MRP was issued, and has mapped out opportunity areas through the Contra Costa County Watershed Atlas. CCCWP recommends that any revisions to the creek status monitoring requirements of Provision C.8.c that increase cost per location sampled be balanced with commensurate reductions to achieve cost neutrality.

Based on previous years' activities, CCCWP has budgeted $1,425,000 for FY 2014–2015 for the purposes of fulfilling the requirements of Provision C.8, C.11, and C.12 of the MRP and the Central Valley Permit. The resources are allocated as follows:

- $147,000 San Francisco Bay Regional Monitoring Program (Provision C.8.b of the MRP)
- $788,000 Creek Status and Pollutant of Concern Loads Monitoring (Provision C.8.c – C.8.i) of the MRP and the Central Valley Permit)
- $140,000 As-needed Technical Support Services (Provisions C.8, C.11, and C.12 of the MRP and the Central Valley Permit)
- $50,000 Methylmercury Control Study Plan (Provisions C.11 in Central Valley Permit)
- $50,000 Matching Contribution to the Clean Watersheds for a Clean Bay Grant Program (to support pilot stormwater treatment retrofits required under Provisions C.11 and C.12 of the MRP)
- $250,000 Contribution to a Permittee-led pilot stormwater diversion to sanitary sewers project (Required under Provisions C.11 and C.12)

Of the above expenditures, only the last two items, totaling $300,000 are directly related to implementation of projects to improve water quality. The remaining $1,125,000 is allocated for monitoring, reporting, and program management and coordination necessary to implement regional monitoring projects through collaborative efforts with other Bay Area stormwater programs. For context, for fiscal years 2012-2013, 2013-2014, and 2014-2015, the total projected expenditures on monitoring amounts to $2,964,418. The total projected program expenditures on implementation of water quality improvement projects is $300,000. The CCCWP Permitees, on behalf of the public that funds CCCWP activities, believe that this 10:1 ratio of monitoring to implementation effort should be substantially reduced by replacing monitoring studies with water quality improvement projects.

CCCWP will draw down reserves by $516,377 in FY 2014–2015. This is unsustainable and will require either a reduction in monitoring costs or an increase in CCCWP costs to Permittees, or *both*. Some opportunities to reduce CCCWP costs to comply with Provision C.8 are listed below:

- Reduce the creek status monitoring requirements of Provision C.8.c, either by lowering the number of required sites, or by reducing the assessment requirements at each site such that two sites per day can be completed, consistent with the approach taken by CCCWP during the 2001 – 2010 time frame.
- Look ahead and define how much Creek Status monitoring is enough to establish the current baseline of creek condition. CCCWP believes that between the current Creek Status program under the MRP and baseline bioassessment data collected between 2001 and 2010, we have in hand a reasonably good picture of creek health. For regional consistency, CCCWP could continue Creek Status monitoring during the next permit cycle; however, the information benefits of additional creek status monitoring beyond the next permit cycle should be carefully weighed against the costs and competing needs for program resources.
- Do not require any new stressor/source identification studies in the next permit cycle; instead, allow CCCWP to continue implementation of the follow-up toxicity reduction actions that will result from the current toxicity stressor/source identification study. The stressor / source ID study defined in Appendix A-3 will take time and attention to complete, especially with regards to the most important aspect, which is attempting to effect change in behavior to reduce pesticide toxicity.
- Implement recommendations of the MRP Steering Committee Workgroup that is discussing monitoring provisions of the next reissuance of the MRP, such as these:
    - Match stream survey locations with bioassessment sites and remove the numeric requirement for stream miles surveyed.
    - Remove the geomorphic study requirement of Provision C.8.d.iii. The geomorphic studies completed to fulfil this requirement are shown in Appendix A-5 and Appendix A-6. Although these are useful activities, they are conducted as part of normal operations through CCCWP's participation in the Contra Costa Watershed Forum and through the Flood Control and Water Conservation District's day to day activities. As such, there is no need to require deliverables for these activities through and NPDES permit, nor is there a clear nexus to discharges and potential inmpacts to water quality.
    - Establish a higher trigger value for residual chlorine to focus attention on true discharges of potable water. Results of free and total chlorine summarized in Section 4.3.1, Table 4-23 of Appendix A-1 of the IMR Part A show that detection of residual chlorine at or near the existing trigger level is difficult. The point of this monitoring should be to identify significant potable water discharges, not to chase spurious detections.

- Change the electronic data submittal date from January 15 to February 28.
- Change the Urban Creeks Monitoring Report and Integrated Monitoring Report submittal dates from March 15 to April 30.

The above changes will result in some increased efficiency and will allow for more thoughtful development of monitoring reports.

In summary, the Water Quality Monitoring reported in IMR Part A, the POC Pilot Project Findings reported in IMR Part B, and the POC implementation plans proposed in IMR Part C lead CCCWP to conclude that substantial project work is needed to address existing regulatory drivers. The recommendations in this report are intended to help better prioritize how CCCWP funds are used to study and improve water quality. An important lesson learned from the first five years of the MRP is that funds are needed for actual water quality improvement projects; more studies are not likely to change that finding.

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LIST OF ABBREVIATIONS

BASMAA	Bay Area Stormwater Management Agencies
BMP	best management practice
Board	BASMAA Board of Directors
CEC	contaminant of emerging concern
EMC	event mean concentration
IMR	Integrated Monitoring Report
IMS	Information Management System
MPC	Monitoring and Pollutants of Concern Committee
MRP	Municipal Regional Permit
MYP	Multi-Year Monitoring Plan
NPDES	National Pollutant Discharge Elimination System
PCBs	polychlorinated biphenyls
POC	pollutant of concern
POTWs	publicly owned treatment works
PPCP	pharmaceutical and/or personal care product
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program for Water Quality in San Francisco Bay
RWSM	Regional Watershed Spreadsheet Model
S&T Program	Status and Trends Monitoring Program
SF Bay Water Board	San Francisco Bay Regional Water Quality Control Board
SFEI	San Francisco Estuary Institute
SOP	standard operating procedure
SPoT	Statewide Stream Pollutant Trends
SSID	stressor/source ID
STLS	small tributary loading strategy
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
UC	urban creek
WY	Water Year

SECTION A.1 – INTRODUCTION

This Integrated Monitoring Report (IMR), Part A is being submitted to the San Francisco Bay Regional Water Quality Control Board ("SF Bay Water Board") by the Contra Costa Clean Water Program (the "Program") on behalf of all towns, cities, counties, and flood control agencies represented by the Program (i.e., "Permittees") that are subject to the Municipal Regional Stormwater National Pollution Discharge Elimination System (NPDES) Permit (MRP; Order R2009-0074) issued by the SF Bay 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 Years 2012 (October 1, 2011, through September 30, 2012) and 2013 (October 1, 2012, through September 30, 2013). Monitoring data presented in this report were submitted electronically to the SF Bay Water Board by Regional Monitoring Coalition participants and are accessible via the San Francisco Bay Area Regional Data Center (http://water100.waterboards.ca.gov/ceden/sfei.shtml).

REPORT ORGANIZATION

This report consists of two main parts, the main body and nine appendices. The main body provides brief summaries of accomplishments in Water Years 2012 and 2013 in compliance with MRP Provision C.8. The summaries are organized by subprovisions of the MRP into the following sections:

A.1 Introduction
A.2 San Francisco Estuary Receiving Water Monitoring
A.3 Creek Status Monitoring
A.4 Monitoring Projects
A.5 Pollutants of Concern and Long-Term Trends Monitoring
A.6 Sediment Delivery Estimate / Budget
A.7 Emerging Pollutants Work Plan
A.8 Citizen Monitoring and Participation
A.9 Monitoring Budget Summary and Recommendations
A.10 Reporting, Monitoring Protocols, and Data Quality

The appendices include data analyses for interpretive reports focused on specific types of water quality monitoring required by the MRP. Appendices are also grouped by subprovision and referenced within the applicable sections of the main body.

This report addresses the following reporting requirements for the annual Urban Creeks Monitoring Report (Provision C.8.g.iii) 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 names of water bodies and latitude and longitude data); sample ID, collection date (and time where relevant), and 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 (“Creek Status Monitoring”).
- 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.
- A signed certification statement.

In addition, this report addresses the following reporting requirements in Provision C.8.g.v (“Reporting”):

- A comprehensive analysis of all data collected pursuant to Provision C.8 during the permit term.
- A budget summary for each monitoring requirement.
- Recommendations for future monitoring.
- Methods, data, calculations, load estimates, and source estimates for each pollutant of concern (POC) monitoring parameter.

REGIONAL MONITORING COALITION

Provision C.8.a (“Compliance Options”) of the MRP allows Permittees to address monitoring requirements either through a “regional collaborative effort,” through their stormwater programs, or individually. In June 2010, Permittees notified the SF Bay Water Board in writing of their agreement to participate in a regional monitoring collaboration to address requirements in Provision C.8.[1] The collaboration is known as the Bay Area Stormwater Management Agencies (BASMAA) Regional Monitoring Coalition (RMC). With notification of participation in the RMC, Permittees were required to begin collecting water quality data by October 2011. In a November 2, 2010, letter to the Permittees, the SF Bay Water Board’s Assistant Executive Officer, Thomas Mumley, acknowledged that all MRP Permittees had opted to conduct monitoring required by the MRP through a regional monitoring collaboration, namely, the BASMAA RMC.

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[1] The Cities of Antioch, Brentwood and Oakley, and portions of Contra Costa County are not subject to the MRP but have similar requirements and, therefore, are participating in the 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 ("Board"). A total of 27 regional projects are identified in the RMC Work Plan, based on the requirements described in MRP Provision C.8.

Regionally implemented activities in the RMC Work Plan are conducted under the auspices of the BASMAA, a 501(c)(3) nonprofit organization comprising 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, which are approved by the BASMAA Board. MRP Permittees, through their stormwater program representatives on the Board and its subcommittees, collaboratively authorize and participate in BASMAA regional projects or tasks. Regional project costs are shared either by all BASMAA members or among those Phase I municipal stormwater programs that are subject to the MRP.

SECTION A.2 – SAN FRANCISCO ESTUARY RECEIVING WATER MONITORING (C.8.B)

As described in MRP Provision C.8.b ("San Francisco Estuary Receiving Water Monitoring"), Permittees are required to contribute funds annually to a program that monitors an estuary receiving water that at a minimum is equivalent to the Regional Monitoring Program (RMP) of the San Francisco Estuary Institute (SFEI). 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 have actively participated in RMP committees and work groups through Permittee and/or stormwater program staff, as described in the following sections.

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.[2] The regulated community includes Permittees, publicly owned treatment works (POTWs), dredgers, and industrial dischargers. The RMP seeks to answer the following core management questions:

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

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[2] RMP Annual Work Plans are available at www.sfei.org/rmp/what.

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

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
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 budget generally applies to two major programs: Status and Trends and Pilot/Special Studies. These programs are discussed briefly below.

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 2013, the S&T Program consisted of the following program elements that collect data to address the RMP management questions described above:

- Water/sediment/biota chemistry and toxicity monitoring
- Sediment benthos monitoring
- Small and large tributary loading studies
- 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 five-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 would be available for pilot and special studies. Additional information on the S&T Program and associated monitoring data is available for downloading using the Status and Trends Monitoring Data Access Tool on the RMP website (www.sfei.org/rmp/data.htm).

RMP PILOT AND SPECIAL STUDIES

The RMP also conducts the 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 work groups identify as priority for further study. These studies are developed through an open selection process at the work-group level and are selected for funding through RMP committees. The results and summaries of the most pertinent P/S Studies can be found on the RMP website (www.sfei.org/rmp/).

In Water Years 2012 and 2013, a considerable amount of RMP and stormwater program staff time was spent on 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 POCs from relatively small tributaries to the San Francisco Bay. Additional information on STLS-related studies is provided under Provision C.8.e (see Section A.5 of this report).

PARTICIPATION IN COMMITTEES, WORK GROUPS, AND STRATEGY TEAMS

In Water Years 2012 and 2013, Permittees actively participated in the following RMP committees and work groups:

- Steering Committee
- Technical Review Committee
- Sources, Pathways and Loadings Workgroup
- Contaminant Fate Workgroup
- Exposure and Effects Workgroup
- Emerging Contaminant Workgroup
- Sport Fish Monitoring Workgroup
- Toxicity Workgroup
- Strategy teams (e.g., PCBs, mercury, dioxins, small tributaries, nutrients)

Committee and work-group representation was provided by Permittees, stormwater program staff, and/or individuals designated by RMC participants and the BASMAA Board. Representation involved participating in meetings, reviewing technical reports and work products, co-authoring or reviewing articles included in the RMP’s *The Pulse of the Estuary*, and providing general program direction to RMP staff. Representatives of the RMC also provided timely summaries and updates and received input from stormwater program representatives (on behalf of Permittees) during MPC and/or BASMAA Board meetings to ensure that Permittees’ interests were adequately represented.

SECTION A.3 – CREEK STATUS MONITORING (C.8.C)

MRP 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 the *Regional Monitoring Coalition Final 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 level (e.g., differences between aquatic life condition in urban and non-urban creeks).[3]

The Contra Costa Clean Water Program submitted its creek status monitoring data for Water Years 2012 and 2013 to the SF Bay Water Board by January 15, 2013, and January 15, 2014, respectively. The analyses of results from creek status monitoring conducted by RMC participants in Water Years 2012 and 2013 are presented in Appendices A.1 and A.2, as are the schedules for next steps. Table A-2 provides a list of the parameters that are included in program-specific and jointly produced appendices.

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

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

	Detailed Data Appendix to IMR	
Biological Response and Stressor Indicators	**Appendix A.1**	**Appendix A.2**
Bioassessment (Benthic Macroinvertebrates and Algae) & Physical Habitat Assessments	X	
Chlorine	X	
Nutrients	X	
Water Toxicity	X	
Sediment Toxicity	X	
Sediment Chemistry	X	
General Water Quality (Continuous)		X
Temperature (Continuous)		X
Pathogen Indicators		X
Stream Survey (USA or CRAM)		X

SECTION A.4 – MONITORING PROJECTS (C.8.D)

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

- SSID projects (C.8.d.i)
- BMP (best management practices) effectiveness investigations (C.8.d.ii)
- 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 Years 2012 and 2013 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 collaboration will be required to initiate no more than 10 Stressor/Source Identification (SSID) projects when monitoring results trigger a follow-up action as indicated in MRP Table 8.1. To ensure consistent interpretation of the SSID requirements (C.8.d.i) and a coordinated approach to compliance with that provision, RMC Permittee efforts in Water Year 2013 included a collaborative evaluation of Water Year 2012 creek status monitoring results and joint decision-making process for selecting sites for SSID follow-up by individual programs. RMC program representatives reviewed the list of candidate SSID projects with SF Bay Water Board staff in the April 2013 meeting of the RMC.

THE CONTRA COSTA CLEAN WATER PROGRAM SSID PROJECTS

In consultation with Permittees, The Contra Costa Clean Water Program developed plans to initiate the first follow-up action for each SSID project in Fiscal Year 2013–2014, and no later than in the second fiscal year after the sampling event that triggered the project. As required by MRP Provision C.8.d.i, the first step is 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. Subsequent SSID follow-up steps involve identification, implementation, and evaluation of controls. CCCWP chose to follow up on observed toxicity for the two SSID studies implemented. Details of the CCCWP SSID Study are presented in Appendix A-3.

THE CONTRA COSTA CLEAN WATER PROGRAM BMP EFFECTIVENESS INVESTIGATION

CCCWP studied the flow-control effectiveness of Integrated Management Practices that are incorporated in CCCWP's Stormwater C.3 Guidebook. Three IMPs (bioretention facilities) at an office building in Pittsburg, and two IMPs (bioretention + downstream vault facilities) at a townhouse development in Walnut Creek, were monitored during the 2011-2012 and 2012-2013 water years. Rainfall data was collected at each location. For the IMPs at the Pittsburg site, the water level in the subsurface storage layer was also continuously monitored.

Results of the comparison show that the IMPs provide considerably greater flow-control effectiveness than predicted by the model. The primary reason is that model inputs underestimated the amount of runoff that would be infiltrated by the IMPs. In addition, it was found that runoff percolated through the IMPs soil/compost planting mix more readily than the model predicted. Following changes to input parameters, including the infiltration rate of underlying soils, the model outputs closely matched observed IMP flows and storage.

Local long-term rainfall records were then input to the calibrated model to analyze how IMPs would perform in comparison to current and potential future permit requirements. The simulation indicates that the IMPs fully control runoff flows between the thresholds specified in the current permit (twotenths of the 2-year pre-project peak flow, or 0.2Q2, and the 10 year pre-project peak flow, or Q10). The Pittsburg bioretention IMPs also control runoff flows within a range extended to the potential future threshold of one-tenth of the 2-year pre-project peak flow, or 0.1Q2. The Walnut Creek bioretention + vault facilities could control flows within the extended range with minor modifications.

Details of the BMP effectiveness investigation are presented in Appendix A-4.

THE CONTRA COSTA CLEAN WATER PROGRAM GEOMORPHIC PROJECTS

CCCWP conducted two geomorphic projects. An inventory of stormwater treatment retrofit opportunities in the Alhambra Creek Watershed addressed the geomorphic project requirement in the MRP (Appendix A-5). A review of geomorphic data in Marsh Creek addressed the same requirement in the CV Permit (Appendix A-6).

SECTION A.5 – POLLUTANTS OF CONCERN AND LONG-TERM TRENDS MONITORING (C.8.E)

POC LOADS MONITORING

POC loads monitoring is required by MRP Provision C.8.e.i. Loads monitoring is intended to (1) assess inputs of POCs to San Francisco Bay from local tributaries and urban runoff, (2) assess progress toward achieving wasteload allocations for total maximum daily loads, and (3) help resolve uncertainties associated with loading estimates for these pollutants. Specifically, four priority management questions need to be addressed through POC loads monitoring:

- Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs?
- What are the annual loads or concentrations of POCs from tributaries to the Bay?
- What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay?
- 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 as required by the MRP and to answer the POC loads management questions listed above, an RMP Small Tributaries Loading Strategy (STLS) was developed in 2009 by the STLS Workgroup, which included representatives from BASMAA and RMP/SFEI, SF Bay Water Board staff, 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 the concurrence of participating SF Bay 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-MYP was appended to the BASMAA RMC's *Regional Urban Creeks Status Monitoring Report* in 2013, with various appendices provided along with previous semiannual monitoring status reports. The main body of the 2013 version describes the primary STLS elements, including recent activities as summarized below.

RMC participant activities associated with POC loads monitoring during Water Years 2012 and 2013 focused on bottom-of-watershed monitoring and the continued development of a watershed pollutant load estimation model, both of which were coordinated through the STLS Workgroup and the associated RMP Sources, Pathways and Loadings Workgroup.

STLS Multi-Year Plan Activities

On the recommendation of the STLS Workgroup, RMC representatives in coordination with SFEI staff created the STLS-MYP to assist Permittees in complying with Provision C.8.e. The MYP 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 MYP provides a more comprehensive description and work plan for STLS activities over the next 5 to 10 years, 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
- Small tributaries monitoring

Previous MYP updates regarding STLS activities were provided in the Monitoring Status Report submitted to the SF Bay Water Board in September 2012, and additional activities after July 2013 were summarized in the Urban Creeks Monitoring Report (BASMAA, 2013). The following paragraphs briefly summarize each of these elements and activities conducted during the period from October 2012 through September 2013:

- **Watershed Modeling** –The STLS and RMP Sources, Pathways and Loadings Workgroup continued to provide oversight in Water Years 2012 and 2013 of the construction and initial testing of the Regional Watershed Spreadsheet Model, which is the primary tool for estimating overall POC loads to San Francisco Bay. Initial modeling efforts focused on developing load estimates for sediment, mercury, and PCBs. For each POC, a submodel architecture will be developed specific to its runoff characteristics and source areas in the Bay Area landscape. An initial test model was constructed for copper for which the submodel is similar to the basic hydrologic version and inputs from other efforts that were readily available. In the second half of 2012, a graphic user interface was also developed that allows for customization and running of submodels by users who are not GIS software experts.
- **Bay Margins Modeling –** In 2012, the RMP released a second draft of the Bay Margins Conceptual Model report that incorporated extensive review comments by the RMP Contaminant Fate Workgroup, which includes representatives from BASMAA. The RMP Steering Committee also authorized the development of a multi-year plan to create a modeling framework with multiple objectives regarding nutrients and other contaminants of interest, which would be used to answer management questions about contaminant processes in the Bay margins. The goals of the modeling strategy pertinent to the STLS include identifying high-leverage watersheds whose POC loadings contribute disproportionately to Bay impacts. Further development of the Bay Modeling strategy planned in 2013 will include convening technical experts, stakeholders, and RMP work groups to produce an initial draft work plan for Bay modeling-related activities.
- **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. On the advice of the Sources, Pathways and Loadings Workgroup, initial RMP studies used alternative approaches to “back-calculate” EMCs from available data as a cost-effective way to support the first iteration of the watershed model. The STLS work group received progress updates on initial modeling results in 2013 and will determine priorities for possible field-data collection source-area runoff in Water Year 2015.

- **Small Tributaries Watershed Monitoring** – For this STLS element, the approach outlined in the MYP 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. Water Year 2013 was the second year of monitoring activities at four stations that were set up and mobilized beginning in October 2011. Two additional stations, the North Richmond Pump Station and the Pulgas Pump Station, were established in October 2012 to begin monitoring and complete the phasing in of watershed stations:
    - Lower Marsh Creek (Contra Costa County)
    - Guadalupe River (Santa Clara County)
    - Lower San Leandro Creek (Alameda County)
    - Sunnyvale East Channel (Santa Clara County)
    - North Richmond Pump Station (Contra Costa County)
    - Pulgas Pump Station (San Mateo County)

The stations in Lower Marsh Creek and Guadalupe River and the Pulgas Pump Station are operated by the Contra Costa Clean Water Program, the Santa Clara Valley Urban Runoff Pollution Prevention Program, and the San Mateo Countywide Water Pollution Prevention Program, respectively, on behalf of RMC participants. The Sunnyvale East Channel station and the North Richmond Pump Station are operated by SFEI on behalf of the RMP, as was the Lower San Leandro Creek Station in its first year before being transferred to the Alameda Countywide Clean Water Program in summer 2012 for operation starting in Water Year 2013.

Monitoring methods and laboratory analyses according to the descriptions in the STLS-MYP are documented in a field manual and quality assurance project plan (QAPP), currently under development as a BASMAA regional project.

For Water Year 2012, BASMAA contracted with SFEI to coordinate laboratory analyses, data management, and data quality assurance. The goal was to ensure data consistency among all watershed monitoring stations. BASMAA again recently approved a contract with SFEI to continue to support these activities in Water Year 2013.

Results of Monitoring in Water Years 2012 and 2013

The preliminary results of POC monitoring conducted in Water Years 2012 and 2013 by the STLS Workgroup are presented in Appendix A-6. POC monitoring activities conducted by the Contra Costa Clean Water Program during this period are summarized below. Analytical methods used are summarized in Table A-3 below.

Table A-3. Laboratory analysis methods used by the STLS Workgroup for POC (loads) monitoring in Water Years 2012 and 2013

Analyte	Analytical Method[1]	Analytical Laboratory[1]
Carbaryl	EPA 632M	CA Dept. Fish & Wildlife WPCL
Fipronil	EPA 619M	CA Dept. Fish & Wildlife WPCL
Suspended Sediment Concentration	ASTM D3977	(EBMUD) Caltest Analytical Laboratory
Total Phosphorus	(EBMUD 488 Phosphorus) SM20 4500-P E	(EBMUD) Caltest Analytical Laboratory
Nitrate	(EPA 300.1) EPA 353.2	(EBMUD) Caltest Analytical Laboratory
Dissolved Orthophosphate	(EPA 300.1) SM20 4500-P E	(EBMUD) 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	(AXYS Analytical Services Ltd.) Caltest Analytical Laboratory
Total Methylmercury	EPA 1630M	(Moss Landing Marine Laboratories) Caltest Analytical Laboratory
Total Mercury	EPA 1631EM	(Moss Landing Marine Laboratories) Caltest Analytical Laboratory
Copper	EPA 1638M	(Brooks Rand Labs LLC) Caltest Analytical Laboratory
Selenium	EPA 1638M	(Brooks Rand Labs LLC) Caltest Analytical Laboratory
Total Hardness	EPA 1638M	(Brooks Rand Labs LLC) Caltest Analytical Laboratory
Total Organic Carbon	(SM 5310C) SM20 5310B	(Brooks Rand Labs LLC) Caltest Analytical Laboratory

1 – Methods and laboratories shown in parentheses were used only for data collected in WY 2012.

Comparisons to Numeric Water Quality Objectives/Criteria for Specific Analytes

MRP Provision C.8.g.iii ("Urban Creeks Monitoring Report") requires RMC participants to assess all data collected pursuant to Provision C.8 for compliance with applicable water quality standards. This section of the report provides an assessment of data collected at the Contra Costa Clean Water Program POC monitoring station in Water Years 2012 and 2013.[4]

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 the results do not likely represent long-term (chronic) concentrations of monitored constituents. POC monitoring data collected in Water Years 2012 and 2013 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., one 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 water quality objectives or criteria have been promulgated for only a small set of the analytes collected at POC monitoring stations. These include objectives for trace metals (i.e., copper, selenium, and total mercury) and polychlorinated biphenyls (PCBs). Table A-5 provides a comparison of data collected in Water Years 2012 and 2013 to applicable numeric water quality objectives/criteria for these analytes adopted by the SF Bay Water Board or the State of California. Of these analytes, the MRP contains provisions addressing mercury (Provision C.11), copper (Provision C.13), and selenium (Provision C.14).

All samples collected in Water Year 2012 were below applicable numeric water quality objectives (i.e., freshwater acute objective for aquatic life) for mercury, selenium and copper in both the North Richmond Pump Station watershed (Table A-4) and the Marsh Creek Watershed (Table A-5). For all other analytes measured via POC monitoring in Water Years 2012 and 2013 (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. An assessment of compliance of applicable water quality standards cannot be conducted for these analytes at this time.

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

Table A-4. Comparison of POC (loads) monitoring data for Water Year 2013 collected by the San Francisco Estuary Institute in the North Richmond Pump Station Watershed to applicable numeric water quality objectives and criteria

Year	Analyte	Fraction	Numeric Water Quality Objective/ Criterion	Unit	Type of Objective/ Criterion	Source of Objective/ Criterion	# of Samples > Objective/Criterion
2013	Copper	Dissolved	13	µg/L	Freshwater Acute Water Quality Objective for Aquatic Life (1-hr Average)	San Francisco Bay Water Quality Control Plan (SF Bay Water Board, 2011)	0/3
2013	Selenium	Total	20	µg/L			0/3
2013	Mercury	Total	2.1	µg/L			0/3

* The copper water quality objective is hardness dependent and 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.

Table A-5. Comparison of POC (loads) monitoring data for Water Years 2012 and 2013 collected by **Contra Costa Clean Water Program** in the Marsh Creek Watershed to applicable numeric water quality objectives and criteria

Year	Analyte	Fraction	Numeric Water Quality Objective/ Criterion	Unit	Type of Objective/ Criterion	Source of Objective/ Criterion	# of Samples > Objective/Criterion
2012	Copper	Dissolved	13*	µg/L	Freshwater Acute Water Quality Objective for Aquatic Life (1-hr Average)	Central Valley Regional Water Quality (SF Bay Water Board, 2011)	0/2
2012	Selenium	Total	20	µg/L			0/2
2012	Mercury	Total	2.1	µg/L			0/8
2013	Copper	Dissolved	13	µg/L	Freshwater Acute Water Quality Objective for Aquatic Life (1-hr Average)	San Francisco Bay Water Quality Control Plan (SF Bay Water Board, 2011)	0/4
2013	Selenium	Total	20	µg/L			0/4
2013	Mercury	Total	2.1	µg/L			0/17

* The copper water quality objective is hardness dependent and 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 Years 2012 and 2013 were 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, as follows:

- *Pimephales promelas* (freshwater fish)
- *Hyalella azteca* (amphipod)
- *Ceriodaphnia dubia* (crustacean)
- *Selenastrum capricornutum* (algae)

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 whether 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 MRP Table 8.4, and prescribed long-term monitoring locations are included in MRP 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 Final Creek Status and Long-Term 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. A SPoT program technical report on 2009–2010 data was released to the public in 2013 (Anderson et al., 2013). RMC representatives will continue to coordinate with the SPoT program on long-term monitoring to ensure MRP monitoring and reporting requirements are addressed.[5] Additional information on the SPoT program can be found at http://www.waterboards.ca.gov/water_issues/programs/swamp.

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[5] 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

SECTION A.6 – SEDIMENT DELIVERY ESTIMATE / BUDGET (C.8.E.VI)

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 concluded 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 and Loadings Workgroup and the STLS Workgroup.

The sediment delivery/budget study was designed to be implemented in coordination with the STLS-MYP, with funding from both the RMP and BASMAA regional projects. The following sediment-specific model developments were included:

- Literature-based refinement of land-use-based EMCs.
- Development of a submodel 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.
- 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.

The following BASMAA-funded activities were 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 of 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.
- 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 and provided a June 2013 internal update to BASMAA on the sediment model. In December 2013 distributed for STLS Workgroup review a draft report section with preliminary results of the RWSM models

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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.

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.

SECTION A.7 – EMERGING POLLUTANTS WORK PLAN (C.8.E.V)

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 the endocrine-disrupting compounds PFOS/PFAS (perfluorooctane sulfonates and perfluoroalkyl sulfonates) and NP/NPEs (nonylphenols and nonylphenol esters, which are estrogen-like compounds). The work plan developed by Permittees is to be implemented in the next MRP term.

Consistent with these requirements, Permittees (via Countywide stormwater programs) have and will continue to coordinate the investigation and significance of CECs with the RMP. Permittees have participated in the development and funding of a CEC strategy known as Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations (Sutton et al., 2013). As part of the CEC strategy, Permittees have also participated in the development and implementation of the following work plans, which are consistent with Provision C.8.e.vii:

- *Monitoring Alternative Flame Retardants in SF Bay Water, Sediment and Biota* (Sutton and Sedlak, 2013a).
- *Monitoring Alternative Flame Retardants in SF Bay Water, Sediment, and Biota: Pathway Characterization – Wastewater and Stormwater* (Sutton and Sedlak, 2013b).
- Special two-year study of bioanalytical tools entitled *Linkage of in Vitro Assay Results with in Vivo End Points* (Denslow et al., 2012).

In addition, Permittees have participated and continue to participate in the broader statewide CEC investigation and monitoring efforts through RMP coordination with the State Water Resource Control Board's (SWRCB's) contractor, the Southern California Coastal Water Research Project.

Summary tables that illustrate the relationship of high-priority CECs to the broader statewide effort and the RMP strategy are included as Tables A-6 through A-7. During the next MRP 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. In addition, the need for the development of preliminary loading estimates as well as source analyses will be considered as part of the CEC strategy updates and investigatory results.

Table A-6. San Francisco Bay Regional Monitoring Program's CEC Pilot Monitoring Work Plan Approach – Receiving Waters, Sediment, and Tissue (Relative to SWRCB Panel Guidance)

Compound[1]	**San Francisco Bay Risk Level**[2]	**SWRCB Panel Guidance Embayment Water / Sediment/Tissue**[3]	**RMP Approach**
Bis(2-ethylhexyl) phthalate (PPCP)[4]	I	NA/NA/NA	Widely detected at low levels in surface water, tissue, and sediment. Below available effects thresholds for sediment. Uncertainty regarding the applicability of thresholds to Bay data.
Bisphenol A (PPCP)	I	M/NA/NA	ND samples; Detection Limit (DL) high. Consider resampling using lower DLs. BPA is included in RMP Bioanalytical study.[5]
Bifenthrin (pesticide)	II	M/M/NA	Hydrophobic; based on Bay sediment concentrations, expect ND in water.
Butylbenzyl phthalate (PPCP)	I	NA/NA/NA	Exceed low apparent effects threshold values in sediment but high uncertainty regarding the application of these thresholds to the Bay. ND in mussel tissue.
Permethrin (pesticide)	II	M/M/NA	Hydrophobic; based on Bay sediment concentrations, expect ND in water.
Estrone (hormone)		NA/NA/NA	No Bay data. Included in RMP Bioanalytical study.[5]
Ibuprofen (PPCP)	II	NA/NA/NA	Mostly ND in pilot study. Low priority.
17-beta estradiol (hormone)		M/NA/NA	No Bay data. Include in bioanalytical tools.
Galaxolide – HHCB (PPCP)	II	M/NA/NA	Detected in Bay samples from 1999 and 2000 and in later Bay POCIS passive sampling study. Included in RMP Bioanalytical study.[5] Special study of PPCPs under consideration.
Diclofenac (PPCP)		NA/NA/NA	No data. RMP reviewing as part of PPCP paper.
p-Nonylphenol (PPCP)	III	NA/NA/NA	Detected in water, sediment, and tissue. Included in RMP Bioanalytical study.[5]
PBDE-47 and PBDE-99 (flame retardants)	III	NA/M/M	Analyzed extensively in water, sediment, and tissue. Concentrations declining in multiple species. Prepared summary report on 10 years of RMP data.[6]
Fipronil	III	M/M/NA	Monitored in sediment and water (pilot study).
PFOS (PFAS)	III	NA/M/M	Detected in elevated concentrations in seals and bird eggs. Continue monitoring in tissue (bird/seal). Consider evaluating effluent and sediments.
Triclosan (PPCP)	II	NA/NA/NA	Low to ND in sediment. ND in water and mussels.

Non-PBDE Flame Retardants[7]	I	RMP	RMP special study.[7]

1 – Chlorpyrifos not included in monitoring – see SWRCB Panel September 2013 meeting notes and rationale.
2 – Risk Levels (for San Francisco Bay Receiving Waters): Tier IV (High Concern), Tier III (Moderate Concern), Tier II (Low Concern), and Tier I (Possible Concern); see Sutton et al. (2013).
3 – NA = not applicable, M = monitoring suggested
4 – PPCP = pharmaceutical and/or personal care product
5 – See RMP Detailed Work Plan 2014, December 2013.
6 – PBDE Synthesis Report, Draft 2013.
7 – Additional SF Bay CEC special study; see discussion and rationale in Sutton et al. (2013) and Sutton and Sedlak (2013a, 2013b).

Table A-7. San Francisco Bay Regional Monitoring Program's CEC Pilot Monitoring Work Plan Approach – Wastewater Treatment Plant Effluent (Relative to SWRCB Panel Guidance)

Compound[1]	**San Francisco Bay Risk Level[2]**	**SWRCB Panel Guidance Embayment Water / Sediment/Tissue[3]**	**RMP Approach**
Bis(2-ethylhexyl) phthalate (PPCP)[4]	I	NA	Consider monitoring in concert with butyl benzyl phthalate?
Bisphenol A (PPCP)	I	M	Included in RMP Bioanalytical study[5]
Bifenthrin (pesticide)	II	M	Effluent from 32 facilities have been monitored for pyrethroids. Report pending (Jan. 2014).
Butylbenzyl phthalate (PPCP)	I	NA	Under consideration to analyze?
Permethrin (pesticide)	II	M	Effluent from 32 facilities has been monitored for pyrethroids. Report pending (Jan. 2014).
Estrone (hormone)	I	M	Included in RMP Bioanalytical study[5]
Ibuprofen (PPCP)	II	NA	Mostly ND in pilot study in Bay.
17-beta estradiol (hormone)		NA	No data. Address using bioanalytical tools.
Galaxolide – HHCB (PPCP)	II	M	Included in RMP Bioanalytical study.[5]
Diclofenac (PPCP)		NA	No data. Conducting review of PPCPs.
p-Nonylphenol (PPCP)	III	NA	Included in RMP Bioanalytical study[5]
PBDE-47 and PBDE-99 (flame retardants)	III	M	Declining concentrations; not a high priority to monitor in effluent due to use restrictions.[6]
Fipronil	III	NA	Depending on water results, consider effluent?
PFOS (PFAS)	III	M	Consider monitoring PFOS and precursors in effluent?
Triclosan (PPCP)	II	NA	Not a high priority because only low levels are observed in Bay sediments.
Non-PBDE Flame Retardants[7]	I	RMP	RMP special study.[7]

1 – Chlorpyrifos not included in monitoring – see SWRCB Panel September 2013 meeting notes and rationale.
2 – Risk Levels (for San Francisco Bay Receiving Waters): Tier IV (High Concern), Tier III (Moderate Concern), Tier II (Low Concern), and Tier I (Possible Concern); see Sutton et al. (2013).
3 – NA = not applicable, M = monitoring suggested
4 – PPCP = pharmaceutical and/or personal care product
5 – See RMP Detailed Work Plan 2014, December 2013.
6 – PBDE Synthesis Report, Draft 2013.
7 – Additional SF Bay CEC special study; see discussion and rationale in Sutton et al. (2013) and Sutton and Sedlak (2013a, 2013b).

Table A-7. San Francisco Bay Regional Monitoring Program's CEC Pilot Monitoring Work Plan Approach – Urban Creeks (Stormwater) (Relative to SWRCB Panel Guidance)

Compound[1]	**San Francisco Bay Risk Level[2]**	**SWRCB Panel Guidance Embayment Water / Sediment/Tissue[3]**	**RMP Approach**
Bis(2-ethylhexyl) phthalate (PPCP)[4]	II	NA	NA
Bisphenol A (PPCP)	II	M	NA
Bifenthrin (pesticide)	IV (UC)	M	Monitoring in urban creeks (UC)
Butylbenzyl phthalate (PPCP)	I	NA	NA
Permethrin (pesticide)	IV (UC)	M	Monitoring in urban creeks (UC)
Estrone (hormone)	I	M	NA
Ibuprofen (PPCP)	II	M	NA
17-beta estradiol (hormone)	I	M	NA
Galaxolide –HHCB (PPCP)	II	M	NA
Diclofenac (PPCP)		M	NA
p-Nonylphenol (PPCP)	III	NA	NA
PBDE-47 and PBDE-99 (flame retardants)	III	M	Monitoring in urban creeks (UC)
Fipronil	III	M	Monitoring in urban creeks (UC)
PFOS (PFAS)	III	M	Have monitored in the past (see Houtz and Sedlak, 2012)
Triclosan (PPCP)	II	M	NA
Non-PBDE Flame Retardants[5]	I	RMP	RMP special study[5]

1 – Chlorpyrifos not included in monitoring – see SWRCB Panel September 2013 meeting notes and rationale.
2 – Risk Levels (FOR San Francisco Bay Receiving Waters): Tier IV (High Concern), Tier III (Moderate Concern), Tier II (Low Concern), and Tier I (Possible Concern); see Sutton et al. (2013).
3 – NA = Not Applicable, M = monitoring suggested
4 – PPCP = pharmaceutical and/or personal care product
5 – Additional SF Bay CEC special study; see discussion and rationale in Sutton et al. (2013) and Sutton and Sedlak (2013a, 2013b).

SECTION A.8 – 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 water body function and quality, and to demonstrate within annual reports of their outreach efforts to these groups.

CCCWP staff attends and participate in Contra Costa Watershed Forum (CCWF) meetings, an open committee of some fifty organizations, including state and local agencies, local non-profit environmental and education organizations, community volunteer groups, and private citizens. The CCWF operates on the premise that actions in a watershed are inter-related and, therefore, that broad participation and cooperation is needed to affect change. Members of the CCWF work together in an effort to find common approaches to making our water resources healthy, functional, attractive and safe community assets.

The CCWF impacts the community, environment and decision makers in Contra Costa. Concerned with urban, suburban, and rural areas in the San Francisco Bay Delta area, the CCWF facilitates local agency and citizen collaboration, fosters innovative strategies for stewardship and protection of watershed resources, and encourages regional capacity building in Contra Costa and neighboring areas.

The Contra Costa County Watershed Program funded $80,000 in Community Watershed Stewardship grants in Water Year 2013, matched by $20,000 from CCCWP. Grants awarded in Water Year 2013, are listed in Table A-8 below.

Table A-8. Grant recipients and projects funded by the Contra Costa Community Watershed Stewardship Grant program in Water Year 2013.

Recipient	Project
Contra Costa Resource Conservation District (CCRCD)	Rodeo Creek Community Watershed Stewardship Program
CCRCD	Alhambra Watershed Council watershed coordinator
SPAWNERS	San Pablo Creek Watershed Stewardship Program
Lunchbox International	New Leaf: A Sustainable Living Collaborative Rainwater Harvesting Systems
Friends of Marsh Creek Watershed	Water pollution prevention, restoration of Marsh Creek Watershed, and expansion of FOMCW
Citizens for a Greener El Sobrante	Expansion of membership base and rain garden installation
CREEC	Friends of the Carquinez Watershed Community Stewardship Program
CCRCD	Walnut Creek Watershed part-time coordinator
Bring Back the Natives	Garden Tour Garden Tours
Save Mount Diablo	Creek Restoration and habitat enhancement projects in Kirker, Marsh, and Hess Creeks
Earth Team	Aqua Team
Groundwork Richmond	Tree Planting Program

SECTION A.9 – MONITORING BUDGET SUMMARY AND RECOMMENDATIONS

Based on previous years' activities, CCCWP has budgeted $1,425,000 for FY 2014–2015 for the purposes of fulfilling the requirements of Provision C.8, C.11, and C.12 of the MRP and the Central Valley Permit. The resources are allocated as follows:

- $147,000 San Francisco Bay Regional Monitoring Program (Provision C.8.b of the MRP)
- $788,000 Creek Status and Pollutant of Concern Loads Monitoring (Provision C.8.c – C.8.i) of the MRP and the Central Valley Permit)

- $140,000 As-needed Technical Support Services (Provisions C.8, C.11, and C.12 of the MRP and the Central Valley Permit)
- $50,000 Methylmercury Control Study Plan (Provisions C.11 in Central Valley Permit)
- $50,000 Matching Contribution to the Clean Watersheds for a Clean Bay Grant Program (to support pilot stormwater treatment retrofits required under Provisions C.11 and C.12 of the MRP)
- $250,000 Contribution to a Permittee-led pilot stormwater diversion to sanitary sewers project (Required under Provisions C.11 and C.12)

Of the above expenditures, only the last two items, totaling $300,000 are directly related to implementation of projects to improve water quality. The remaining $1,125,000 is allocated for monitoring, reporting, and program management and coordination necessary to implement regional monitoring projects through collaborative efforts with other Bay Area stormwater programs. For context, for fiscal years 2012-2013, 2013-2014, and 2014-2015, the total projected expenditures on monitoring amounts to $2,964,418. The total projected program expenditures on implementation of water quality improvement projects is $300,000. The CCCWP Permitees, on behalf of the public that funds CCCWP activities, believe that this 10:1 ratio of monitoring to implementation effort should be substantially reduced by replacing monitoring studies with water quality improvement projects.

CCCWP will draw down reserves by $516,377 in FY 2014–2015. This is unsustainable and will require either a reduction in monitoring costs or an increase in CCCWP costs to Permittees, or *both*. Some opportunities to reduce CCCWP costs to comply with Provision C.8 are listed below:

- Reduce the creek status monitoring requirements of Provision C.8.c, preferably by lowering the number of required sites.
- Do not require any new stressor/source identification studies in the next permit cycle; instead, allow CCCWP to continue implementation of the follow-up toxicity reduction actions that will result from the current toxicity stressor/source identification study.
- Implement recommendations of the MRP Steering Committee Workgroup that is discussing monitoring provisions of the next reissuance of the MRP, such as these:
    - Match stream survey locations with bioassessment sites and remove the numeric requirement for stream miles surveyed.
    - Remove the geomorphic study requirement of Provision C.8.d.iii.
    - Establish a higher trigger value for residual chlorine to focus attention on true discharges of potable water.
- Change the electronic data submittal date from January 15 to February 28.
- Change the Urban Creeks Monitoring Report and Integrated Monitoring Report submittal dates from March 15 to April 30.

The above changes will result in some increased efficiency and will allow for more thoughtful development of monitoring reports.

SECTION A.10 – 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. The following data are required;

- Water quality standard exceedances
- Creek status monitoring electronic reporting
- Urban creeks monitoring reporting.

For RMC participants, creek status monitoring electronic data submittals to the SF Bay Water Board were completed by January 15, 2013, for Water Year 2012 data and January 15, 2014, for Water Year 2013 data. Preliminary evaluations of data compared to water quality objectives were included in these submittals. Additional evaluations of data collected pursuant to Provision C.8 are included in this Report and associated appendices.

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 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 1 of these documents (BASMAA, 2012a, 2012b) was completed in Water Year 2012 prior to fieldwork. All interpretative issues or concerns raised during the initial two years of monitoring were resolved through RMC 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 Workgroup and described in the MYP. 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 System (IMS) to provide SWAMP-compatible storage and import/export of data for all RMC programs. A data management subgroup of the RMC met periodically for training and review of data management issues, and suggested enhancements for data checking and to increase efficiency, which were implemented in 2013.

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 management system and performed QA review of the data collected by RMC programs, consistent with the QA for data collected through the RMP.

The IMS's provide standardized data storage formats that allow RMC participants to share data among themselves and to submit data electronically to the SF Bay Water Board per Provision C.8.g.

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CREEK STATUS MONITORING REPORT – REGIONAL/PROBABILISTIC PARAMETERS

Integrated Monitoring Report, Part A – Appendix A.1

Water Years 2012 and 2013
(October 1, 2011 – September 30, 2013)

Prepared for:

Contra Costa Clean Water Program

Prepared by:

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Under subcontract to:

AMEC Environment & Infrastructure

March 14, 2014

Acknowledgments

This report is in large part derived from the Regional Monitoring Coalition Urban Creeks Monitoring Report (UCMR) for Water Year 2012, Appendix A, Regional Urban Creeks Status Monitoring Report, prepared by EOA, Inc. and Armand Ruby Consulting. Analyses contained herein derive in large part from the methods, results and formats presented within the Regional UCMR.

Applied Marine Sciences contributed to this report under contract to the Alameda Countywide Clean Water Program, as part of a BASMAA Task of Regional Benefit (TRB). Participating programs in this BASMAA TRB are the Alameda Countywide Clean Water Program (ACCWP), Contra Costa Clean Water Program (CCCWP), Fairfield-Suisun Urban Runoff Management Program (FSURMP) and City of Vallejo / Vallejo Sanitation and Flood Control District (VSFCD). ACCWP staff acted as BASMAA Project Manager in overseeing the conduct of the TRB.

Staff of the Contra Costa Clean Water Program contributed to the biological analysis and provided review of draft documents. Khalil E.P. Abusaba, Ph.D., served as project manager for AMEC, lead consultant to CCCWP.

Preface

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

The following participants make up the RMC:

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

This report is in part a joint product funded by ACCWP, CCCWP, FSURMP, and Vallejo 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) through the RMC's probabilistic design for certain parameters monitored according to Provision C.8.c. This report is an Appendix to the full IMR submitted by each of the contributing programs on behalf of their respective Permittees.

As described in the *Regional Monitoring Coalition Final Creek Status and Long-Term Trends Monitoring Plan*, RMC participants collected data by implementing standard operating procedures in accordance with the RMC's Quality Assurance Program Plan (QAPP). Analytical laboratory analyses were also conducted under the direction of RMC participants. The quality of all data presented in this report, therefore, is assured by the RMC participants involved in their collection and management, and not the authors.

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

List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
AFDM	ash-free dry mass
BASMAA	Bay Area Stormwater Management Agencies Association
B-IBI	Benthic Index of Biological Integrity
BMI	Benthic Macroinvertebrate
CCCWP	Contra Costa Clean Water Program
CDFW	California Department of Fish and Wildlife
CMC	Criteria Maximum Concentration
CTR	California Toxics Rule
DW	Dry Weight
DQO	Data Quality Objective
EDD	Electronic Data Deliverable
FSURMP	Fairfield Suisun Urban Runoff Management Program
GIS	Geographic Information System
GRTS	Generalized Random Tessellated Stratified
IBI	Index of Biological Integrity
LC50	Lethal Concentration to 50% of test organisms
LIMS	Laboratory Information Management System
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MPC	BASMAA Monitoring and Pollutants of Concern Committee
MQO	Measurement Quality Objective
MRP	Municipal Regional Permit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ND	Non-Detect
NorCal B-IBI	Northern California Benthic Index of Biological Integrity
NPDES	National Pollutant Discharge Elimination System
NT	Non-Target
PAH	Polycyclic aromatic hydrocarbon
PEC	Probable Effect Concentration
PHab	Physical Habitat Assessment
POC	Pollutant of Concern
PRM	Pathogen-Related Mortality
PSA	Perennial Streams Assessment
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RL	Reporting Limit
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program
RPD	Relative Percent Difference
RWB	Reach-Wide Benthos
SCCWRP	Southern California Coastal Water Research Project
SF Bay Water Board	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

STLS	Small Tributaries Loading Strategy
SWAMP	Surface Water Ambient Monitoring Program
TEC	Threshold Effect Concentration
TKN	Total Kjeldahl Nitrogen
TNS	Target Not Sampled
TOC	Total Organic Carbon
TS	Target Sampled
U	Unknown
USEPA	U.S. Environmental Protection Agency
TU	Toxicity Unit
WQ	Water Quality
WY	Water Year

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Appendix A-1 Executive Summary

The Integrated Monitoring Report (IMR), Part A, reports monitoring data collected through implementation of the Regional Monitoring Coalition (RMC) during Water Years (WYs) 2012 (October 1, 2011, through September 30, 2012) and 2013 (October 1, 2012, through September 30, 2013). This Appendix A.1 presents the results for portions of creek status monitoring conducted by a subset of the RMC programs for data collected using a probabilistic monitoring design used by all RMC participants. The RMC was formed by members of the Bay Area Stormwater Management Agencies Association (BASMAA) to assist member agencies in fulfilling requirements of Provision C.8 of the Municipal Regional Stormwater National Pollutant Discharge Elimination System Permit (MRP; SF RWQCB 2009). Certain creek status monitoring parameters were addressed on a regional basis using the probabilistic design and are included in this report for the four Programs contributing to its development (ACCWP, CCCWP, FSURMP, and Vallejo).

Other parameters were addressed using a targeted design, with regional coordination and common methodologies. These parameters, along with the Bioassessment and physical habitat parameters addressed through the regional design, are reported in separate appendices or portions of the IMR Part A prepared individually by each RMC participating program.

During Water Year 2012, 60 sites were monitored by all RMC member agencies under the probabilistic design for bioassessment, physical habitat, and related water chemistry parameters, including 30 by two programs contributing to this joint report (ACCWP and CCCWP). Ten of the 60 sites were also monitored for water and sediment toxicity and sediment chemistry, including 5 sites monitored by ACCWP and CCCWP. During Water Year 2013, an additional 70 sites were monitored by all RMC member agencies, including 40 by the four programs contributing to this report. Of these 40 sites, 5 were monitored for water and sediment toxicity and sediment chemistry, with an additional two sites monitored for water and sediment toxicity and/or sediment chemistry, but not bioassessment. Water toxicity data and sediment chemistry/toxicity data are available for 12 sites total from Water Years 2012 and 2013 from the four programs contributing to this report.

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 conjuction with the stressor assessment based on sediment chemistry and toxicity. 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 two 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 IMR, 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 water body names and latitudes and longitudes); sample ID, collection date (and time where relevant), and

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.
- A signed certification statement.

The stressor analysis revealed the following potential stressors, based on an analysis of the first two years of RMC data for ACCWP and CCCWP, and the initial year of monitoring data for FSURMP and Vallejo.

- **Nutrients (and Conventional Constituents):** The MRP Table 8.1 trigger criterion for "Nutrients" (20% of results in one water body exceed one or more water quality standards or applicable thresholds) was considered to be exceeded at only three of the 68 monitoring sites.
- **Water Toxicity:** Of the 10 wet and dry season samples collected in 2012, not including retests, three water samples exhibited results "<50% of Control" and therefore were resampled and retested in Water Year 2013, per MRP Table 8.1. Following the retesting, two of the sites again exhibited significant toxicity at levels meeting MRP Table 8.1 trigger criteria.

  In 2013, 2 of 14 samples collected in wet and dry season exhibited results meeting MRP Table 8.1 trigger criteria.
- **Sediment Toxicity:** Of the 12 samples collected cumulatively in Water Years 2012 and 2013, sediment toxicity results were more than 20% less than the control[1] in 5 samples, meeting the MRP Table 8.1 trigger criterion.
- **Sediment Chemistry:** Sediment chemistry results produced evidence of potential stressors in three ways, based on the criteria from MRP Table H-1:
  - At 10 of 12 sites, three or more constituents had TEC quotients greater than or equal to 1.0.
  - At 1 of 12 sites, the mean PEC quotient was greater than 0.5.
  - At 8 of 12 sites, the sum of TU equivalents for all measured pyrethroids was greater than 1.0.

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. 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.

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[1] See body of report for RMC interpretation of MRP trigger criteria.

1.0 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; SF RWQCB, 2009) for creek status monitoring data produced pursuant to MRP Provision C.8.c during Water Years 2012 and 2013 (October 1, 2011 - September 30, 2013) under a regional probabilistic design. The regional probabilistic design was developed and implemented by the Regional Monitoring Coalition (RMC) of the Bay Area Stormwater Management Agencies Association (BASMAA). Provision C.8.c monitoring data collected by CCCWP at targeted sites (not included in the probabilistic design) are reported in Appendix A.2.

The RMC was formed in early 2010 as a collaborative 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[2]. Through its implementation, the RMC allows Permittees and the San Francisco Regional Water Quality Control Board (SF Bay Water Board) 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 county 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 Water Board 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).

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

Table 1-1. Regional Monitoring Coalition Participants

Stormwater Programs	RMC Participants
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Cities of Campbell, Cupertino, Los Altos, Milpitas, Monte Sereno, Mountain View, Palo Alto, San Jose, Santa Clara, Saratoga, Sunnyvale, Los Altos Hills, and Los Gatos; Santa Clara Valley Water District; and Santa Clara County
Alameda Countywide Clean Water Program (ACCWP)	Cities of Alameda, Albany, Berkeley, Dublin, Emeryville, Fremont, Hayward, Livermore, Newark, Oakland, Piedmont, Pleasanton, San Leandro, and Union City; Alameda County; Alameda County Flood Control and Water Conservation District; and Zone 7 Water Agency
Contra Costa Clean Water Program (CCCWP)	Cities 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[3] 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 Water Board[4] and other agencies with common goals.
3. Stabilize the costs of creek monitoring by reducing duplication of effort and streamlining monitoring-related activities.

The RMC addresses the scope of subprovisions specified in MRP Provision C.8 (Table 1-2). This report is a joint product developed by four of the RMC programs (ACCWP, CCCWP, FSURMP, and Vallejo) to present and discuss some of the results of Creek Status Monitoring that were conducted using a regional ambient (probabilistic) monitoring design to comply with Provision C.8.c (Table 1-3). The list of parameters in Table 1-3 derive from the MRP Table 8-1 (SF Bay Water Board, 2009; BASMAA, 2014a, 2014b).

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[3] 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.

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

Table 1-2. Municipal Regional Permit Provisions addressed by the Integrated Monitoring Report

Subprovision	Subprovision Title	Reporting Document
C.8.a	Compliance Options	• Regional Monitoring Coalition Creek Status & Long-Term Trends Monitoring Plan (BASMAA, 2011)
C.8.b	San Francisco Bay Estuary Monitoring	• Regional Monitoring Program Annual Monitoring Results (www.sfei/rmp.org)
C.8.c	**Creek Status Monitoring**	• Integrated Monitoring Report, Part A (main body) • IMR Part A, Appendices (see index of Appendices in main body)
C.8.d	Monitoring Projects	See index of Appendices in main body of IMR Part A, if applicable
	• Stressor/Source Identification (SSID)	• SSID Reports (if applicable)
	• BMP Effectiveness Investigation	• BMP Effectiveness Reports (if applicable)
	• Geomorphic Project	• Geomorphic Project.Report (if applicable)
C.8.e	Pollutants of Concern (Loads) and Long-Term Trends Monitoring	• Pollutants of concern (POC) loads monitoring data progress report, Water Years 2012 and 2013 (see index of Appendices in main body)
C.8.f	Citizen Monitoring and Participation	• Integrated Monitoring Report, Part A (main body)
C.8.g	Data Analysis and Reporting	• Integrated Monitoring Report, Part A (main body) • IMR Part A, Appendices (see index of Appendices in main body)

Table 1-3. Creek Status Monitoring parameters sampled in compliance with MRP Provision C.8.c. and the associated reporting format. A subset of regional parameters is reported jointly for Water Years 2012 and 2013 in this report

	Monitoring Design		Reporting	
Biological Response and Stressor Indicators	**Regional Ambient (Probabilistic)**	**Local (Targeted)**	**Regional WY 2012 (Joint WY 2013)**	**Local**
Bioassessment & Physical Habitat Assessment	X		X	(WY 2013)
Chlorine	X		X (X)	
Nutrients	X		X (X)	
Water Toxicity	X		X (X)	
Sediment Toxicity	X		X (X)	
Sediment Chemistry	X		X (X)	
General Water Quality		X		X
Temperature		X		X
Bacteria		X		X
Stream Survey		X		X

Data presented in this report were collected between October 1, 2011, and September 30, 2013, referred to hereafter as Water Years 2012 and 2013.

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[5] 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?
2. What are the major stressors[6] 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 2.0), data collection and analysis methods (Section 3.0), results and data interpretation (Section 4.0), and conclusions and Next Steps (Section 5.0). 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 1-4. Additional details or discussion may also be found in other Appendices or in the main IMR, Part A.

Table 1-4. 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
3.5	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 IMR, Part A[7]	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

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[5] 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.

[6] Stressors are interpreted per MRP Table 8-1 (SF Bay Water Board, 2009) as results that “trigger” action based upon comparison with an identified threshold.

[7] Data collected by the SF Bay Water Board are not included in this report.

2.0 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 Water Board 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 2012 by RMC participants, with another 70 sites 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.

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 (SF Bay Water Board, 2009). The regional design was developed using the Generalized Random Tessellation Stratified (GRTS) approach developed by the U.S. Environmental Protection Agency (USEPA) and Oregon State University (Stevens and Olson, 2004). GRTS offers multiple benefits for coordinating amongst monitoring entities including the ability to develop a spatially balanced design that produces statistically representative data with known confidence intervals. The GRTS approach has been implemented recently in California by several agencies including the statewide Perennial Streams Assessment (PSA) conducted by SWAMP (Ode et al., 2011) and the Southern California Stormwater Monitoring Coalition's (SMC's) 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 Water Board staff during RMC 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 water body (or water bodies). 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 (SF Water Board, 2009) would be achieved.

The National Hydrography Dataset Plus (1:100,000) was selected as the creek network data layer to provide consistency with both the Statewide PSA and the SMC, and the opportunity for future data coordination with these programs. The RMC sample frame was classified by county and land use (i.e., urban and non-urban) to allow for comparisons between these strata. Urban areas were delineated by combining urban area boundaries and city boundaries defined by the

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[8] Based on discussion during RMC meetings, with SF Bay Water Board 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. Reporting on data collected for that permit, other than those collected via the RMC, however, is outside the scope of this report.

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 meetings, with SF Bay Water Board 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 (Figures 2-2 to 2-4). RMC participants coordinated with the SF Bay Water Board by identifying additional non-urban sites from their respective counties for SWAMP sampling.

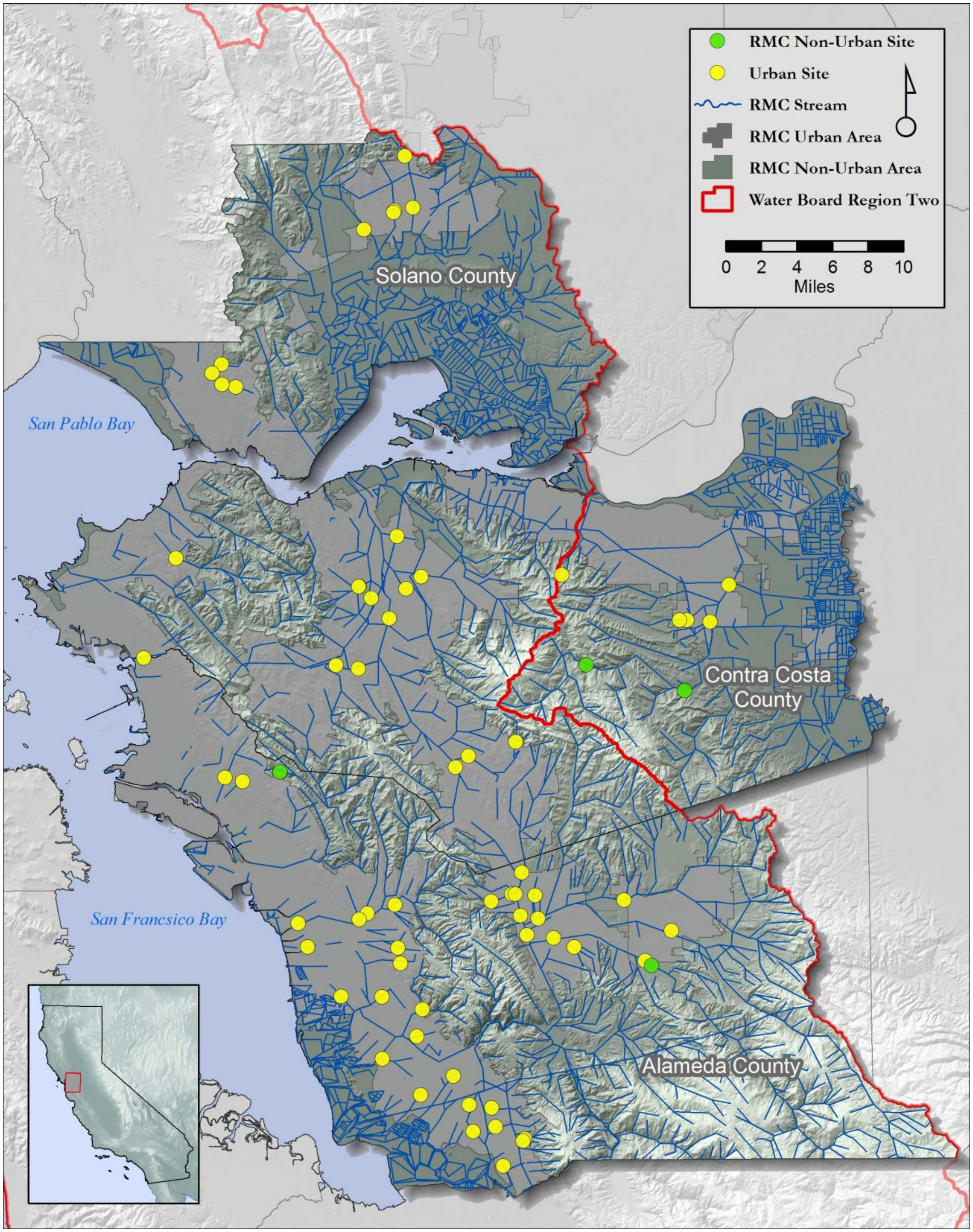

Figure 2-1. BASMAA RMC area, creeks included in the RMC probabilistic monitoring design, and the sites sampled in Water Years 2012 and 2013 by the programs contributing to this report.

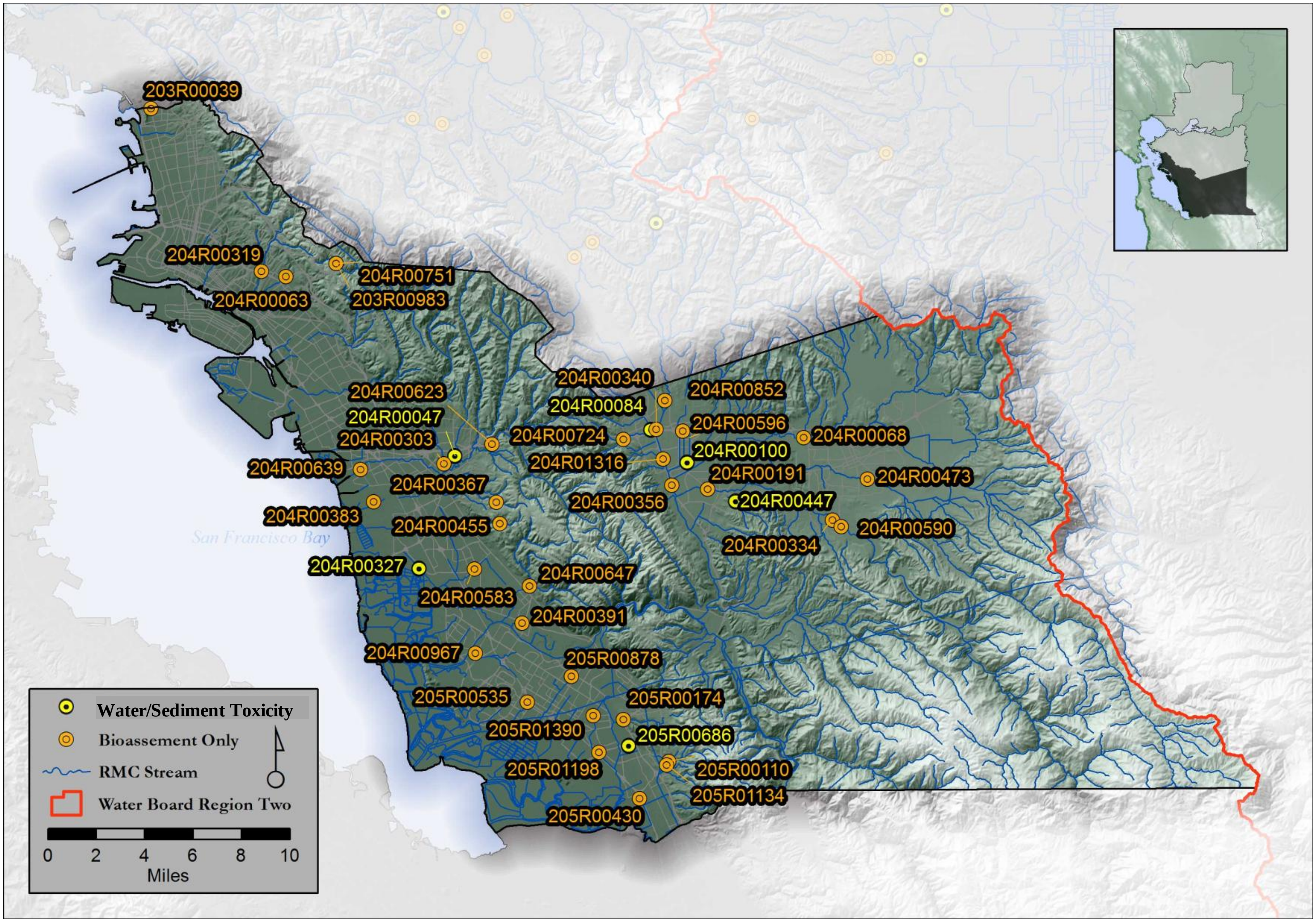

Figure 2-2. Alameda County sites sampled from the RMC probabilistic monitoring design in Water Years 2012 and 2013.

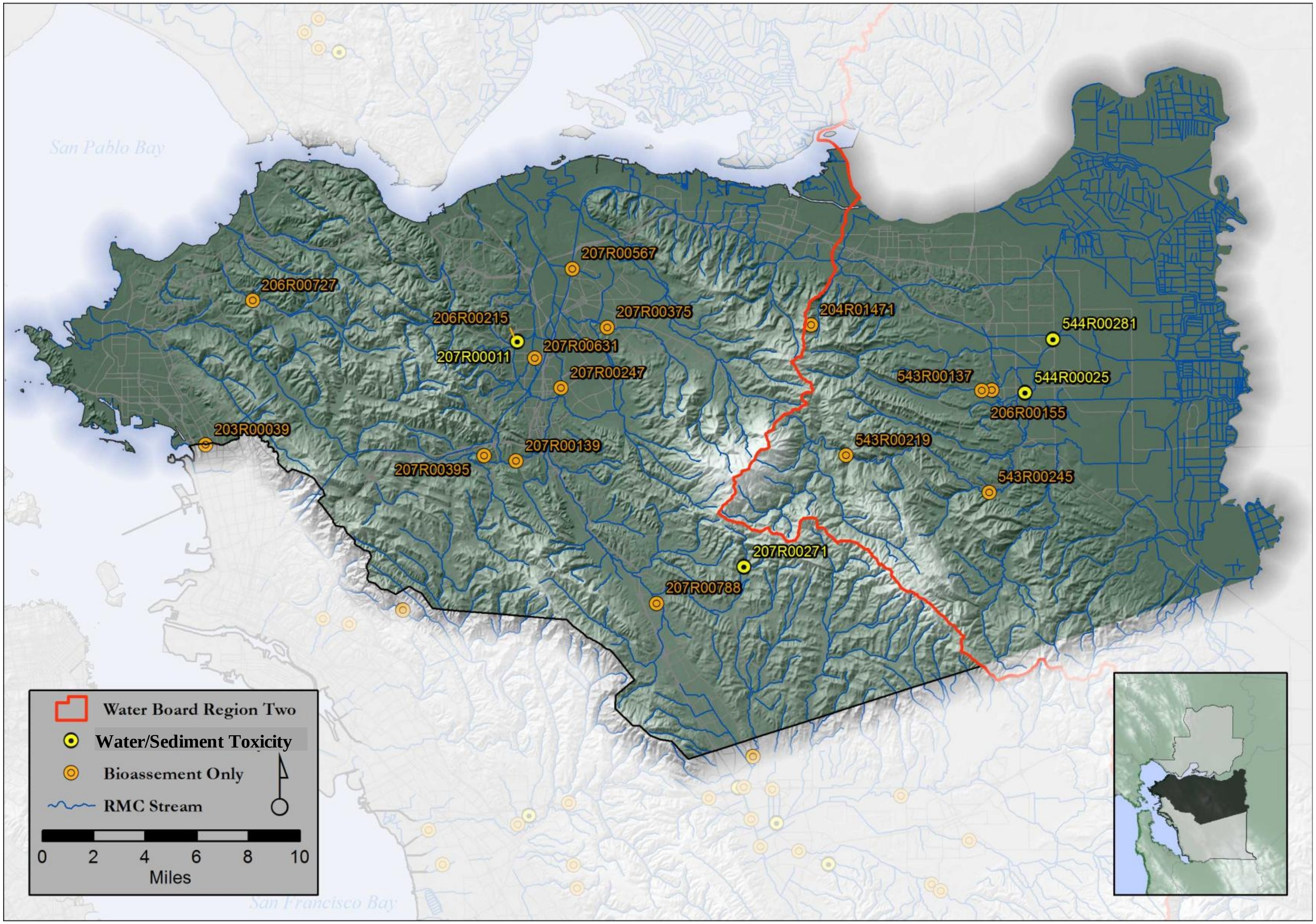

Figure 2-3. Contra Costa County sites sampled from the RMC probabilistic monitoring design in Water Years 2012 and 2013.

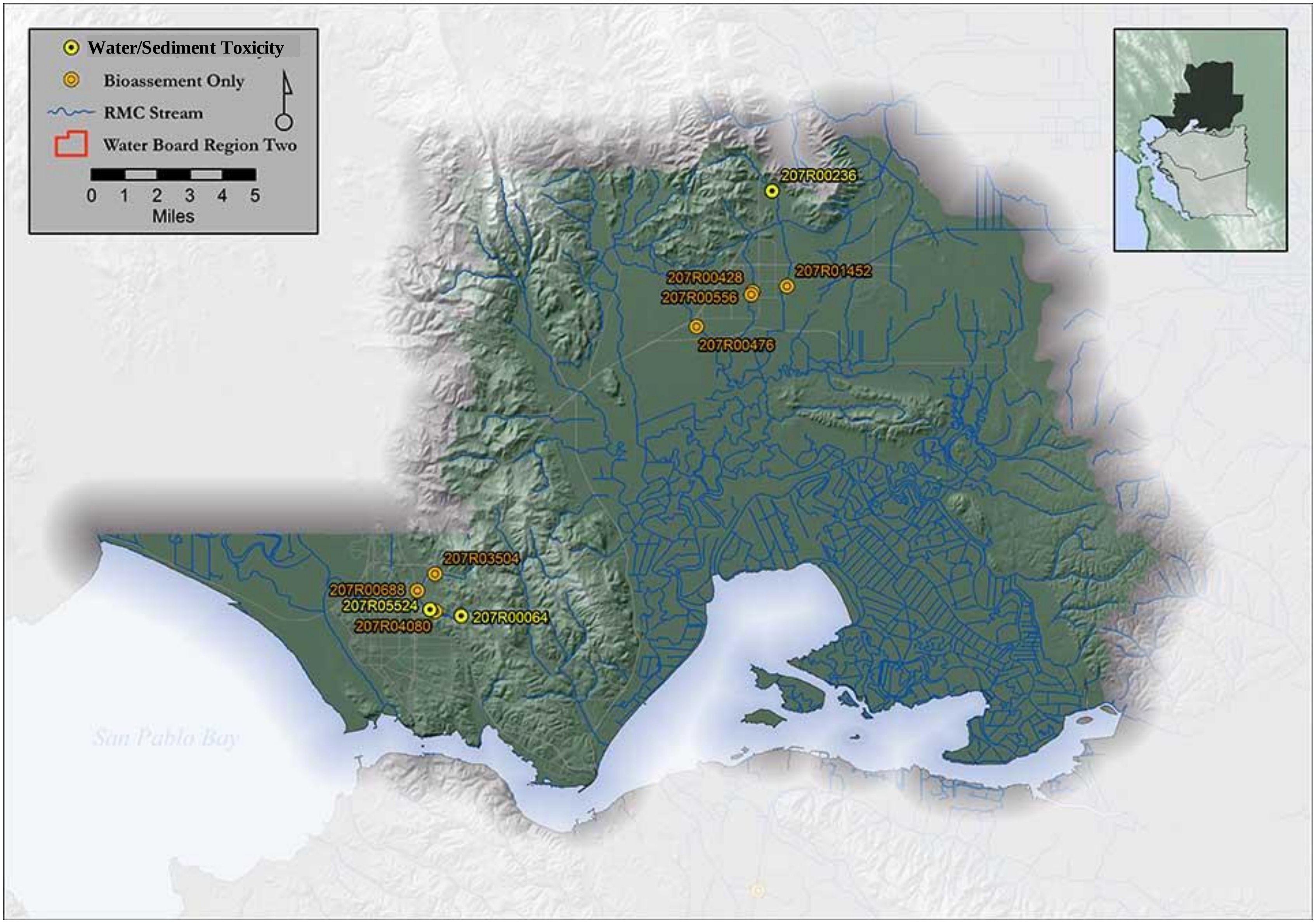

Figure 2-4. Solano County sites sampled from the RMC probabilistic monitoring design by FSURMP and Vallejo in WY 2013.

Table 2-1. Parameters sampled at sites from the RMC Probabilistic Monitoring Design in Water Year 2012 by sampling agency. Water toxicity sampled on 3/17/12 and 7/25/12; sediment toxicity and chemistry sampled on 7/25/12. FSURMP and Vallejo did not initiate RMC monitoring activities until WY 2013

Site ID	Creek Name	Land Use	Latitude	Longitude	Bioassessment, PHab, Chlorine, Nutrients	Water & Sediment Toxicity, Sediment Chemistry	Initial Sampling Date	Sampling Agency
204R00047	Castro Valley	Urban	37.68826	-122.07257	x	x	6/6/2012	ACCWP
204R00068	Collier Channel, Line 7-M	Urban	37.69908	-121.80891	x		5/31/2012	ACCWP
204R00084	Dublin Creek	Urban	37.70104	-121.92542	x	x	5/24/2012	ACCWP
204R00100	Arroyo Mocho	Urban	37.68280	-121.89625	x	x	5/30/2012	ACCWP
204R00191	Arroyo del Valle	Urban	37.66584	-121.87840	x		5/29/2012	ACCWP
204R00303	Chabot Creek	Urban	37.68421	-122.08200	x		6/14/2012	ACCWP
204R00319	Sausal Creek	Urban	37.79923	-122.21818	x		6/7/2012	ACCWP
204R00340	Big Canyon Cr., Line 7-J-1	Urban	37.70218	-121.92074	x		6/11/2012	ACCWP
204R00356	Arroyo de la Laguna	Urban	37.66873	-121.90920	x		6/4/2012	ACCWP
204R00367	Ward Creek	Urban	37.65957	-122.04172	x		6/12/2012	ACCWP
204R00383	Sulphur Creek	Urban	37.65909	-122.13676	x		6/11/2012	ACCWP
204R00391	Line5-M	Urban	37.58682	-122.02358	x		6/6/2012	ACCWP
204R00455	Zeile Creek	Urban	37.64676	-122.03931	x		6/13/2012	ACCWP
204R00583	Line 3A-D	Urban	37.61906	-122.05928	x		6/13/2012	ACCWP
204R00596	Line 7-G-2	Urban	37.70094	-121.90154	x		5/31/2012	ACCWP
204R00639	San Lorenzo Creek	Urban	37.68151	-122.14437	x		6/19/2012	ACCWP
204R00647	Dry Creek	Urban	37.60965	-122.01750	x		6/18/2012	ACCWP
205R00110	Agua Caliente	Urban	37.50273	-121.91225	x		6/18/2012	ACCWP
205R00430	Line 6-D	Urban	37.48229	-121.93782	x		6/5/2012	ACCWP
205R00535	Line 5-F-1	Urban	37.53942	-122.01980	x		6/19/2012	ACCWP
203R00039	Cerrito Creek	Urban	37.89802	-122.30027	x		5/14/2012	CCCWP
206R00155	San Pablo Creek	Urban	37.92408	-121.74088	x		5/16/2012	CCCWP
206R00215	San Pablo Creek	Urban	37.95477	-122.07821	x		5/23/2012	CCCWP
207R00011	Grayson Creek	Urban	37.95485	-122.07829	x	x	5/22/2012	CCCWP
207R00139	Las Trampas Creek	Urban	37.88742	-122.07995	x		5/17/2012	CCCWP
207R00247	Walnut Creek	Urban	37.92833	-122.04745	x		5/22/2012	CCCWP
543R00137	Deer Creek	Urban	37.92408	-121.74807	x		5/15/2012	CCCWP
543R00219	Marsh Creek	Nonurban	37.88654	-121.84347	x		5/21/2012	CCCWP
543R00245	Marsh Creek	Nonurban	37.86732	-121.74947	x		5/21/2012	CCCWP
544R00025	Dry Creek	Urban	37.92611	-121.71722	x	x	5/15/2012	CCCWP

Table 2-2. Parameters sampled at sites from the RMC Probabilistic Monitoring Design in Water Year 2013 by sampling agency. Wet season water toxicity was sampled on 3/5/13 and 3/6/13 (ACCWP), 3/6/13 and 4/4/13 (CCCWP), and 3/20/13 (FSURMP and Vallejo). Dry-season water toxicity was sampled on 7/9/13 (ACCWP and CCCWP), 7/11/13 (FSURMP and Vallejo). Sediment toxicity and chemistry and dry-season chlorine were sampled 7/9/13 (ACCWP and CCCWP), 7/11/13 (FSURMP), and 7/18/13 (Vallejo)

Site ID	Creek Name	Land Use	Latitude	Longitude	Bioassessment, PHab, Chlorine, Nutrients	Water & Sediment Toxicity, Sediment Chemistry	Initial Sampling Date	Sampling Agency
204R00447	Kottinger Creek	Urban	37.65844	-121.86108	x	x	4/22/13	ACCWP
205R00174	Line 6-K	Urban	37.52816	-121.94772	x		4/23/13	ACCWP
205R00686	Canada Del Aliso	Urban	37.51243	-121.94393	x	x	4/24/13	ACCWP
205R00878	Zone 5 Line B	Urban	37.5544	-121.98651	x		4/24/13	ACCWP
204R00967	Crandall Creek	Urban	37.56895	-122.05885	x		4/25/13	ACCWP
204R00852	Alamo Creek	Urban	37.71961	-121.91376	x		5/6/13	ACCWP
204R00327	Line 3A-A-3	Urban	37.62009	-122.10072	x	x	5/7/13	ACCWP
204R00334	Arroyo Valle	Urban	37.64659	-121.78812	x		5/8/13	ACCWP
204R00590	Arroyo Valle	Nonurban	37.64266	-121.78169	x		5/8/13	ACCWP
204R00473	Arroyo Mocho	Urban	37.67085	-121.76115	x		5/9/13	ACCWP
205R01134	Agua Caliente	Urban	37.50063	-121.91567	x		5/20/13	ACCWP
205R01198	Zone 6 Line G	Urban	37.50878	-121.9666	x		5/20/13	ACCWP
204R00724	Dublin Creek	Urban	37.69649	-121.94548	x		5/21/13	ACCWP
204R01316	Arroyo de la Laguna	Urban	37.68452	-121.91557	x		5/22/13	ACCWP
205R01390	Zone 6 Line G	Urban	37.53087	-121.97042	x		5/23/13	ACCWP
204R00623	San Lorenzo Creek	Urban	37.69461	-122.04478	x		6/3/13	ACCWP
204R00063	Peralta Creek	Urban	37.79651	-122.19966	x		6/4/13	ACCWP
204R00751	Redwood Canyon Creek	Nonurban	37.80408	-122.16134	x		6/5/13	ACCWP
203R00983	Strawberry Creek	Nonurban	37.80404	-122.16136	x		6/6/13	ACCWP
204R01471	Arroyo Mocho	Urban	37.96222	-121.86892	x		5/22/13	ACCWP
206R00727	Pinole Creek	Urban	37.97913	-122.26646	x		5/13/13	CCCWP
207R00271	Sycamore Creek	Urban	37.82651	-121.91876	x	X	4/29/13	CCCWP
207R00375	Galindo Creek	Urban	37.96209	-122.01407	x		5/1/13	CCCWP
207R00395	Las Trampas Creek	Urban	37.89066	-122.10258	x		5/14/13	CCCWP
207R00503	Pine Creek	Urban	37.95234	-122.02984	x		5/2/13	CCCWP
207R00532	Tributary, Sycamore Creek	Urban	37.81527	-121.96726	x		4/29/13	CCCWP
207R00567	Walnut Creek	Urban	37.99528	-122.03836	x		4/30/13	CCCWP
207R00631	Grayson Creek	Urban	37.94515	-122.06595	x		5/16/13	CCCWP
207R00788	San Ramon Creek	Urban	37.80643	-121.98093	x		5/15/13	CCCWP
544R00281	Marsh Creek	Urban	37.95238	-121.69678	x	x	5/15/13	CCCWP
207R00236	Laurel Creek	Urban	38.30557	-122.02620		x	3/20/2013	FSURMP
207R00428	Union Ave. Creek	Urban	38.26096	-122.03772	x		5/21/2013	FSURMP

Site ID	Creek Name	Land Use	Latitude	Longitude	Bioassessment, PHab, Chlorine, Nutrients	Water & Sediment Toxicity, Sediment Chemistry	Initial Sampling Date	Sampling Agency
207R00476	Ledgewood Creek	Urban	38.24580	-122.06958	x		5/23/2013	FSURMP
207R00556	Union Ave. Creek	Urban	38.25963	-122.03854	x		5/15/2013	FSURMP
207R01452	Laurel Creek	Urban	38.26325	-122.01848	x		5/28/2013	FSURMP
207R00064	Blue Rock Springs Creek	Urban	38.11852	-122.20327	x	(X)*	5/28/2013	Vallejo
207R03504	Rindler Creek	Urban	38.13726	-122.21778	x		5/29/2013	Vallejo
207R00688	Blue Rock Springs Creek	Urban	38.12988	-122.22782	x		5/29/2013	Vallejo
207R04080	Blue Rock Springs Creek	Urban	38.12072	-122.21785	x		5/30/2013	Vallejo
207R05524	Blue Rock Springs Creek	Urban	38.12146	-122.22083		X*	7/18/2013	Vallejo

*Site 207R00064 had insufficient sediment to conduct sediment toxicity testing; sediment was thus collected from site 207R05524 the following week and analyzed for sediment chemistry and toxicity.

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

Table 2-3. Cumulative numbers of planned bioassessment samples per monitoring year according to RMC design

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 2012)	**48**	22	16	6	16	6	8	4	8	4	0	2
Year 2 (WY 2013)	**100**	**44**	**32**	12	**32**	12	16	8	16	8	8	0
Year 3[c] (WY 2014)	**156**	**66**	**48**	18	**48**	18	24	12	24	12	12	6
Year 4 (WY 2015)	**204**	**88**	**64**	24	**64**	24	**32**	16	**32**	16	12	8
Year 5 (WY 2016)	**256**	**110**	**80**	**30**	**80**	**30**	**40**	20	**40**	20	16	10

Shaded cells indicate when a minimum sample size (n=30) may be available to develop a statistically representative data set to address management questions related to condition of aquatic life.

[a] Assumes SF Bay Water Board will continue WY 2012-13 monitoring effort of two non-urban sites annually in each RMC county.

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

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

2.3 Monitoring Design Implementation

Monitoring was conducted in accordance with the RMC Multi-year Monitoring Plan (BASMAA, 2011). The Monitoring Plan illustrates the total number of sites that each RMC Permittee plans to sample within the MRP term (SF Bay Water Board, 2009), as shown in Table 2-3 above. Table 2-3 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. Per the RMC Monitoring Plan and the requirements of MRP Provision C.8.c, the RMC creek status monitoring emphasizes monitoring of urban land use sites. RMC participants have set a target of at least 80% of the sites sampled annually to be in urban areas, with up to 20% in non-urban areas. Due to unforeseen field circumstances, however, this percentage may vary by year. For example, some sites may not be samplable due to seasonal drying and/or access issues, thereby altering the relative proportion of urban-to-nonurban sites sampled in a given year. Some sites classified as urban, using data in a geographic information system, may be considered for reclassification as non-urban based on actual land uses of the drainage area, despite their location inside municipal jurisdictional boundaries. Such outcomes can be addressed in subsequent sampling years by adjusting the relative proportion of urban and non-urban sites in regional statistical analyses.

The numbers of probabilistic sites monitored annually in Water Years 2012 and 2013 are shown by land use category for each program contributing to this report in Table 2-4.

Table 2-4. Number of Bioassessment sites sampled by contributing Programs in Water Years 2012 and 2013 by land use and county

Monitoring Year	**Alameda County**		**Contra Costa County**		**FSURMP**		**Vallejo**	
Land Use	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*	*Urban*	*Non-Urban*
WY 2012	20	0	8	2	0	0	0	0
WY 2013	17	3	10	0	4	0	4	0
Total	**37**	**3**	**18**	**2**	**4**	**0**	**4**	**0**

3.0 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 included bioassessments (benthic macroinvertebrates [BMIs], algae, and physical habitat), physicochemical measurements (dissolved oxygen, temperature, conductivity, and pH), chlorine, nutrients, 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] (2012). Each site was evaluated to determine if it met the following RMC sampling location criteria:

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

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

The outcomes of these site evaluations for CCCWP sites are illustrated in Figures 3-1 (Water Year 2012) and 3-2 (Water Year 2013). A relatively small fraction of sites evaluated each year are classified as “target sampleable” sites.

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

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

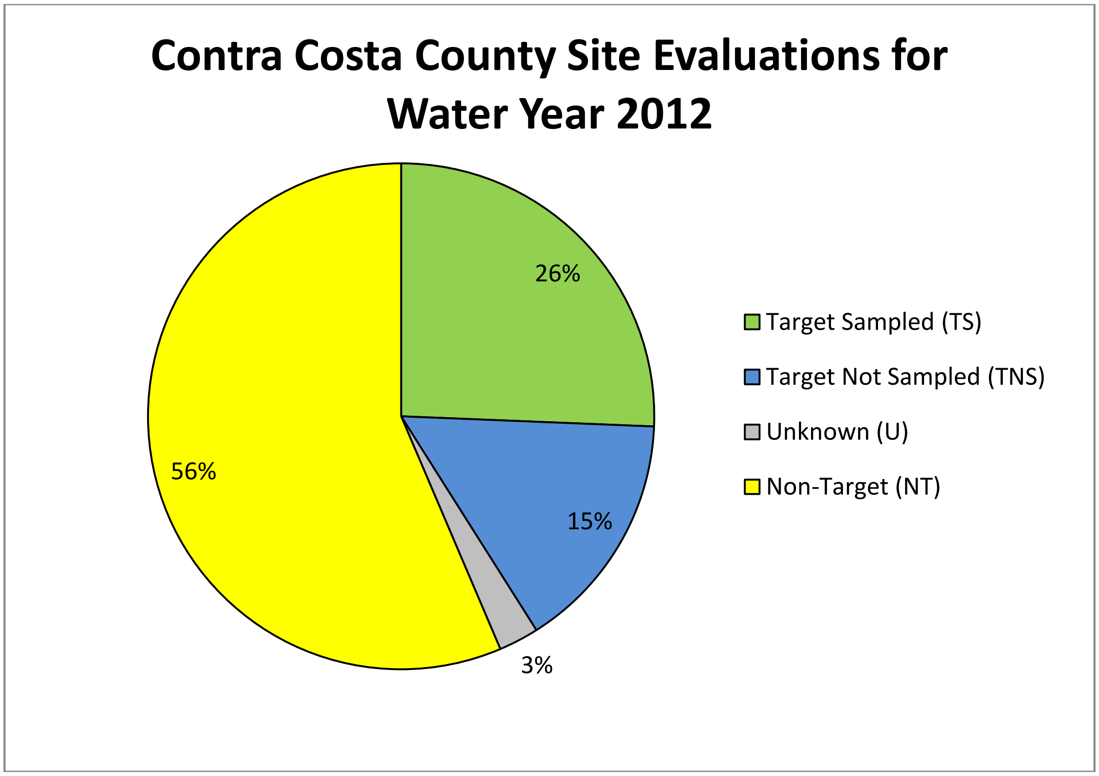

Figure 3-1. Results of CCCWP Site Evaluations for Water Year 2012

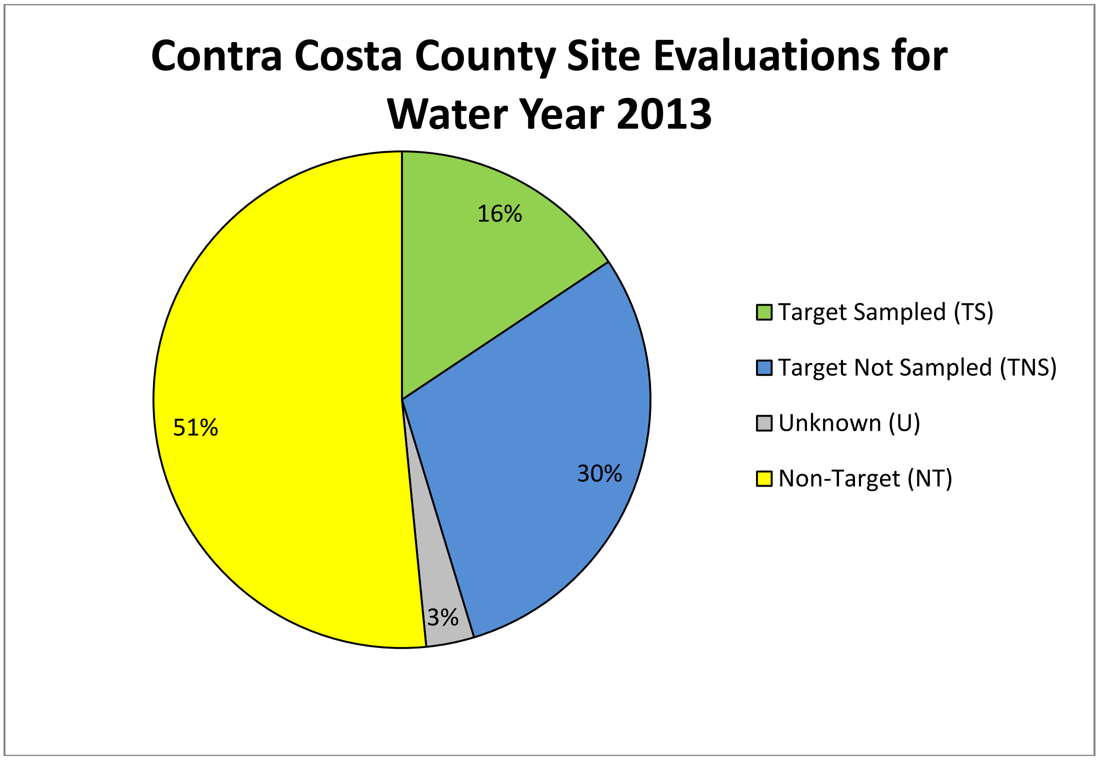

Figure 3-2. Results of CCCWP Site Evaluations for Water Year 2013

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).
- No Water (no surface water present).

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

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

3.2 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) (BASMAA, 2014a) and the associated Standard Operating Procedures (BASMAA, 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	BMI and algae bioassessments and physical habitat assessments
FS-2	Water quality sampling for chemical analysis, pathogen indicators, and toxicity testing
FS-3	Field measurements, manual
FS-6	Collection of bedded sediment samples
FS-7	Field equipment cleaning procedures
FS-8	Field equipment decontamination procedures
FS-9	Sample container, handling, and chain-of-custody procedures
FS-10	Completion and processing of field data sheets
FS-11	Site and sample naming convention
FS-12	Ambient Creek Status Monitoring Site Evaluation
FS-13	QA/QC Data Review

3.2.1 Bioassessments

In accordance with the RMC QAPP (BASMAA, 2014a), bioassessments were conducted during the spring index period (approximately April 15 to July 15) and at a minimum of 30 days after any significant storm (roughly defined as at least 0.5 inch[11] of rainfall within a 24-hour period). During Water Year 2012, the last significant storm occurred April 12–13, 2012. As a result, bioassessments began during the week of May 14, 2012.

In comparison, for Water Year 2013 monitoring there was no region-wide, late season significant precipitation event that required delay of sampling, and bioassessment monitoring was performed during the normal index period. The last significant storm event of the season occurred on April 1 and, for the four programs participating in this report, precipitation exceeded the RMC criterion as defined above for only the northwestern section of Alameda County (i.e., Oakland and north). Monitoring stations were therefore prioritized so that non-affected portions of the four collaborating programs were monitored first, and the affected area of Alameda County was monitored after May 1.

Each bioassessment monitoring site consisted of an approximately 150 m stream reach that was divided into 11 equidistant transects placed perpendicular to the direction of flow. The sampling position within each transect alternated between 25%, 50%, and 75% distance of the wetted width of the stream (see SOP FS-1, BASMAA, 2014b).

Benthic Macroinvertebrates

BMIs were collected via kick-net sampling using the Reach-wide Benthos (RWB) method described in RMC SOP FS-1 (BASMAA, 2014b). Samples were collected from a 1-square-foot area approximately 1 m downstream of each transect. The benthos were disturbed by manually rubbing areas of coarse substrate, followed by disturbing the upper layers of finer substrate to a depth of 4–6 inches to dislodge any remaining invertebrates into the net. Slack water habitat procedures were used at transects with deep and/or slow-moving water (Ode, 2007). Material collected from the 11 subsamples was composited in the field by transferring the entire sample into one to two 1,000 mL wide-mouth jar(s), and the samples were preserved with 95% ethanol. The laboratory then performed taxonomic identification nominally on a minimum of 600 BMI individuals for each sample according to standard taxonomic effort Level 1 as established by the Southwest Association of Freshwater Invertebrate Taxonomists.

Algae

Filamentous algae and diatoms also were collected using the Reach-wide Benthos (RWB) method described in SOP FS-1 (BASMAA, 2014b). Algae samples were collected synoptically with BMI samples. The sampling position within each transect was the same as used for BMI sampling, except that algae samples were collected six inches upstream of the BMI sampling position and following BMI collection from that location. The algae were collected using a range of methods and equipment, depending on the particular substrate occurring at the site (i.e., erosional, depositional, large and/or immobile, etc) per RMC SOP FS-1. Erosional substrates included any material (substrate or organics) that was small enough to be removed from the stream bed, but large enough in size to isolate an area equal in size to a rubber delimiter (12.6 cm^2 in area). When a sample location along a transect was too deep to sample, a more suitable location was selected, either on the same transect or from one further upstream. Algae samples were collected at each transect prior to moving on to the next transect. Sample material (substrate and water) from all 11 transects was combined in a sample bucket, agitated, and a suspended algae sample was then poured into a 500 mL cylinder, creating a composite

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[11] This number was erroneously reported as 0.25 inch over a 24-hour period in UCMR (BASMAA, 2013).

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

Physical Habitat

Physical habitat assessments (PHab) were conducted at each BMI bioassessment sampling event using the PHab protocols described in Ode (2007) (see SOP FS-1, BASMAA, 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).

3.2.2 Physicochemical Measurements

Dissolved oxygen, temperature, conductivity, and pH were measured 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.

3.2.3 Chlorine

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

3.2.4 Nutrients and Conventional Analytes

Water samples were collected for nutrient analyses using the standard grab sample collection method as described in SOP FS-2 (BASMAA, 2014b), associated with bioassessment monitoring conducted. Sample containers were rinsed, as appropriate, using ambient water and completely filled and recapped below water surface whenever possible. An intermediate container was used to collect water for all sample containers with preservative already added in advance by laboratory. Sample container size and type, preservative type and associated holding times for each analyte are described in Table 1 of FS-9 (BASMAA, 2014b). Syringe filtration method was used to collect samples for analyses of dissolved orthophosphate and dissolved organic carbon. All sample containers were labeled and stored on ice for transport to the analytical laboratory, with the exception of analysis of AFDM and chlorophyll-a samples, which were field-frozen on dry ice by some sampling teams where appropriate.

3.2.5 Water Toxicity

Samples were collected using the Standard Grab Sample Collection Method described above, filling the required number of 2.25-L labeled amber glass bottles with ambient water, putting them on ice to cool to 4°C ± 2°C, and delivering to the laboratory within the required hold time. Bottle labels include station ID, sample code, matrix type, analysis type, project ID, and date and time of collection. The laboratory was notified of the impending sample delivery to meet the 24-hour sample delivery time requirement. Procedures used for sampling and transporting samples are described in SOP FS-2 (BASMAA, 2014b).

3.2.6 Sediment Chemistry and Sediment Toxicity

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

3.3 Laboratory Analysis Methods

RMC participants agreed to use the same laboratory for individual parameters, developed standards for contracting with the labs, and coordinated quality assurance issues. All samples collected by RMC participants that were sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods as described in the RMC QAPP (BASMAA, 2014a). Analytical laboratory methods, reporting limits and holding times for chemical water quality parameters are also reported in BASMAA (2012a). The following analytical laboratory contractors were used for chemical and toxicological analysis:[12]

- BioAssessment Services, Inc. – BMI identification
- EcoAnalysts, Inc. – algae identification
- CalTest, Inc. – sediment chemistry, nutrients, chlorophyll-a, AFDM
- Pacific EcoRisk, Inc. – water and sediment toxicity

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[12] BioVir Laboratories, Incorporated was similarly contracted for Pathogen Indicators. These data are reported in CCCWP IMR Part A, Appendix A.2.

3.4 Data Analysis

This section describes methods used to analyze the data collected during bioassessment monitoring, as well as water and sediment toxicity, and sediment chemistry data. The bioassessment data are then used to evaluate stream conditions, and the associated physical, chemical and toxicity testing data are then analyzed to identify potential stressors that may be impacting water quality and biological conditions. As the cumulative RMC sample sizes increase through monitoring conducted in future years (per 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.iii.

This report includes analysis of regional/probabilistic data generated per MRP Provision C.8.c during Water Years 2012 and 2013 in the following presentation format:

- CCCWP only:
    - Biological data (BMI and algae taxonomy)
    - PHab data
- ACCWP, CCCWP, Fairfield-Suisun, and Vallejo jointly:
    - Water chemistry data associated with bioassessment
    - Water toxicity
    - Sediment chemistry and toxicity

Analysis of Provision C.8.c monitoring data generated by CCCWP at local/targeted sites (not included in the probabilistic design) is reported in Appendix A.2.

3.4.1 Biological Condition

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

In this report the biological condition of each probabilistic site monitored by CCCWP in Water Years 2012 and 2013 was evaluated principally through analysis of BMI and algal taxonomic metrics, and calculation of associated benthic index of biological integrity (B-IBI) and algal index of biological integrity (A-IBI) scores. An IBI is an analytical tool involving calculation of a site condition score based on a compendium of biological metrics.

Benthic Macroinvertebrate Data Analysis

Biological metrics associated with BMI assemblages are typically characterized by the following five categories (Ode et al., 2005):

- Richness measures (numbers of distinct taxa within the assemblage or taxonomic groups).
- Composition measures (distribution of individuals among taxonomic groups; includes measures of diversity).
- Tolerance/Intolerance measures (relative sensitivity of the observed taxonomic groups to disturbance).
- Functional feeding groups (relative preponderance of types of feeding strategies in the aquatic assemblage).
- Abundance (estimates of the total number of organisms in a sample based on a 9 square-foot sampling area).

An array of such BMI metrics were computed for the CCCWP data for Water Years 2012 and 2013 using methods developed and tested extensively for both Southern California (Ode et al., 2005) and Northern California (Rehn et al., 2005). Benthic IBI scoring schemes have been developed using selected BMI metrics for Southern California (SoCal B-IBI; Ode et al., 2005) and Northern California (NorCal B-IBI; Rehn et al., 2005).

SoCal and NorCal B-IBI scores were both computed for the Water Year 2012 RMC regional BMI data and compared in the 2012 UCMR (BASMAA, 2013) to evaluate their merits as condition indicators. The B-IBI scores calculated using these two tools were well correlated based on the Water Year 2012 data for the RMC region (Figure 3-3). Because the ecoregions represented by the SoCal B-IBI are more similar to those in the majority of the RMC area than the NorCal ecoregions (with the exception of coastal streams in San Mateo County), the SoCal B-IBI was selected as the primary index used to evaluate biological condition. For consistency with the 2012 UCMR and other RMC programs, the SoCal B-IBI score is the primary tool used for condition assessment in this report.

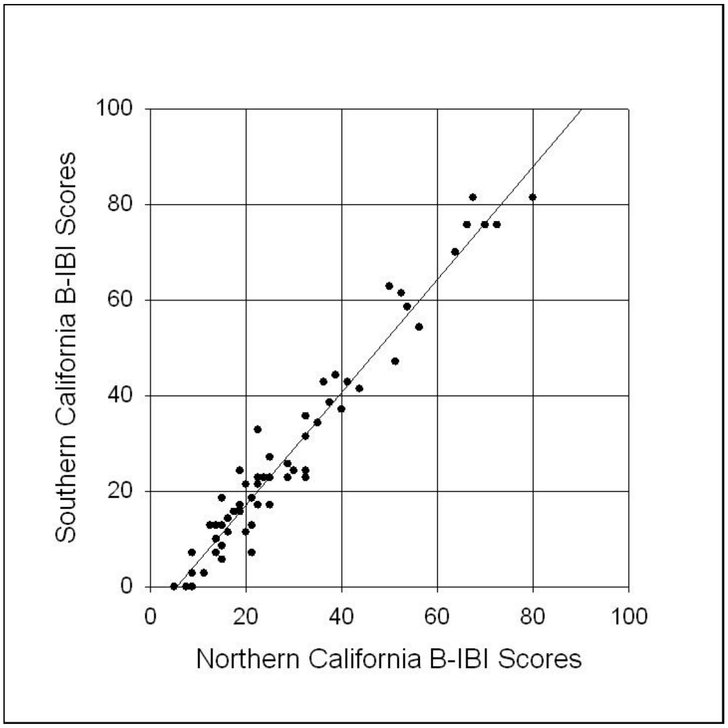

Figure 3-3. Results of regressing the Northern and Southern California B-IBIs for RMC sites sampled in WY 2012 ($r^2 = 0.9518$, $p<0.05$).

The scores calculated using the SoCal B-IBI were classified according to condition categories established for the SoCal B-IBI (Table 3-2).

Table 3-2. Condition categories for Southern California B-IBI scores for BMI taxonomy data

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

The SoCal and NorCal B-IBIs were developed in perennial streams in their respective regions. The majority of sites sampled by the RMC in Water Year 2012 and by CCCWP in Water Year 2013 were classified as perennial steams. Although no statistical analysis comparing perennial and non-perennial stream is possible, these classifications were considered for interpretations of biological condition.

Work was initiated on a San Francisco Bay Region B-IBI in a collaborative effort by BASMAA participants and others, and the results were provisionally tested previously in Contra Costa (CCCWP, 2007) and Santa Clara (SCVURPPP, 2007) Counties. The Contra Costa County version of the Bay Area B-IBI was subsequently used in analysis and reporting of BMI data for the annual Contra Costa Monitoring and Assessment Program (CCMAP) bioassessment monitoring (c.f., Ruby, 2012). Calculation of the preliminary Contra Costa B-IBI is also presented for CCCWP's BMI data in this report, to allow for comparisons with the historical CCMAP data set.

The scores calculated using the preliminary Contra Costa B-IBI were classified according to condition categories as shown in Table 3-3.

Table 3-3. Condition categories for preliminary Contra Costa B-IBI scores for BMI taxonomy data

Condition Category	Contra Costa B-IBI Scores
Very Good	43–50
Good	35–41
Fair	23–34
Marginal	11–22
Poor	0–10

Aquatic life use support at CCCWP sites sampled in Water Years 2012 and 2013 was evaluated by comparing the SoCal and preliminary Contra Costa B-IBI scores and associated condition categories to warm water (WARM) and cold water (COLD) aquatic life uses as designated by the SF Bay Water Board (2011).

Algae Data Analysis

Algal taxonomy has more recently been actively investigated for use as a biological indicator, and IBI development in California is less well-established for algae than for BMIs. Recently algal IBIs (A-IBIs) have been developed for Southern California (Fetscher et al., 2013) and the California Central Coast (Rollins et al., undated), but these have not been tested for Bay Area waters. However, because the Central Coast A-IBI has not been fully peer reviewed, and because there is a version of the SoCal A-IBI that relies only on diatoms and is thought to be more transferable to other areas of the state (Marco Sigala, pers. comm.), it was determined that the SoCal A-IBI “D18” (per Fetscher et al. 2014) could be used provisionally for assessment of stream conditions for this report.

As with BMI data, an array of biological metrics can be derived for algal taxonomic data. The following characteristics were considered in the recent development of the algae IBI for Central Coast rivers and streams (Rollins et al., undated), according to the methods described in Stoddard et al. (2008):

- Autecological Preferences, such as species-level preferences in pH, salinity, nitrogen uptake metabolism, oxygen requirements, saprobity, trophic state, and moisture.
- Community Structure, including metrics pertaining to presence, relative individual abundance, relative species abundance, dominance, evenness, and measures of diversity.
- Ecological Guilds, including metrics derived from motility and morphological classifications.
- Tolerance and Intolerance, including metrics derived from the pollution tolerance index developed by Bahls (1993), as well as metrics developed from central coast data specific to taxa whose abundance most effectively discriminated between sites with the least human disturbance and sites with the greatest human disturbance.
- Production, including metrics derived from measures of biomass such as chlorophyll, ash-free dry mass (AFDM), microalgal growth, and macroalgal growth.

Speaking to the last category above, a variety of primary producer abundance measures can be used to assess the relative levels of algal growth in streams (Fetscher et al. 2014), such as:

- Algal biomass measures:
    - Benthic chlorophyll-a
    - Benthic AFDM
- Algae/macrophytes cover measures:
    - Percent presence of attached macroalgae (defined as algal mats or filaments easily visible to the naked eye)
    - Percent presence of macroalgae (attached and/or unattached)
    - Percent presence of unattached macroalgae
    - Percent presence of thick microalgae (1 mm+)
    - Percent presence of thick microalgae (1 mm+), where microalgae present
    - Percent presence of microalgae
    - Percent presence of nuisance algae (macroalgae + thick microalgae (1 mm+))
    - Mean microalgae thickness (mm)
    - Mean microalgae thickness (mm,) where microalgae present
    - Percent presence of macrophytes

Eleven diatom metrics and one diatom IBI (“D18”) were computed per Fetscher et al. (2014) from the CCCWP data for Water Years 2012 and 2013 and presented in this report. The diatom IBI (“D18”) is computed from five of the eleven metrics, with scoring ranges and values provided by Dr. A. Elizabeth Fetscher (Marco Sigala, pers. comm.). After each metric was scored, values were summed and then converted to a 100-point scale. Only diatom data were included in this analysis, because the soft algae taxonomic data were not harmonized with the California Algae and Diatom Taxonomic Working Group’s Master Taxa List. The eleven diatom metrics are described in Table 3-4.

Table 3-4. Metrics used in evaluating algae taxonomy data

Metric Name	Description	Implications	Correlation w/Metric Score
Proportion low TN indicators	Proportion of diatoms that are indicators for low Total N (nitrogen) levels	Higher levels indicate lower levels of nutrient enrichment	Positive
Proportion low TP indicators *	Proportion of diatoms that are indicators for low Total P (phosphorous) levels	Higher levels indicate lower levels of nutrient enrichment	Positive
Proportion halobiontic *	Proportion of diatoms that are brackish-fresh + brackish (i.e., they have a tolerance of, or requirements for, dissolved salts)	Higher levels indicate higher salinity and conductivity, and possibly higher nutirent or sediment levels	Negative
Proportion requiring >50% DO saturation *	Proportion of diatoms that require at least 50% dissolved oxygen saturation	Higher levels indicate less well-oxygenated stream conditions	Positive
Proportion requiring nearly 100% DO saturation	Proportion of diatoms that require nearly 100% dissolved oxygen saturation	Higher levels indicate well-oxygenated stream conditions	Positive
Proportion N heterotrophs *	Proportion of diatoms that are heterotrophs (i.e., are capable of using energy sources other than photosynthesis; includes both obligate and facultative heterotrophs)	Higher levels indicate possible organic enrichment of the water	Negative
Proportion oligo- & beta-mesosaprobic	Proportion of diatoms that are oligosaprobous+beta-mesosaprobous (i.e., they have a low to moderate ability to use decomposing organic material for nutrition)	Higher levels indicate lower levels of organic contamination	Positive
Proportion poly- & eutrophic	Proportion of diatoms that are polytrophic+eutrophic (i.e., have a tolerance of, or requirements for, high nutrient levels)	Higher levels indicate higher levels of nutrients (N and P) in the water	Negative
Proportion sediment tolerant (highly motile) *	Proportion of diatoms (for which there is information for both the "motility" and "habit" classifications) that are highly motile (for "motility") OR planktonic (for "habit")	Higher levels may indicate the presence of excess silt and sediment	Negative
Proportion highly motile	Proportion of diatoms that are highly motile (i.e., have the ability to move through the water column or glide along surfaces)	Higher levels may indicate the presence of excess silt and sediment	Negative
Proportion *A. minutissimum*	Proportion of diatoms that are the species *Achnanthidium minutissimum*; Common diatoms that are known to be tolerant of a wide range of conditions	Higher levels tend to be associated with higher quality sites (Betty Fetscher, personal comm.)	Positive
* metric is used in calculating the "D18" algae IBI			

3.4.2 Physical Habitat Condition

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

3.4.3 Water and Sediment Chemistry and Toxicity

As part of the Stressor Assessment for this report, water and sediment chemistry and toxicity data generated during Water Years 2012 and 2013 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 (SF Bay Water Board, 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 MRP 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 water body 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 other common, "conventional" constituents.)
- **Water Toxicity**: if toxicity results are less than 50% of Laboratory Control results, resample and retest; 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 from and more than 20% less than results for Laboratory Control.
- **Sediment Chemistry**: three or more chemicals exceed Threshold Effect Concentrations (TECs), mean Probable Effects 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 effects 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

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

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 & Control

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

Data Quality Objectives (DQOs) 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 by the Programs responsible for collecting them, 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.

4.0 Results and Discussion

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 biological, physical, chemical and toxicity testing monitoring data are evaluated against the trigger criteria shown in MRP Table 8.1 and, for sediment triad data, Table H-1 (SF Bay Water Board, 2009) to provide a preliminary identification of potential stressors. The results of the initial stressor assessment evaluation (BASMAA, 2013) are currently being used in follow-up efforts to plan and implement stressor/source identification (SSID) projects.

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, 2012a), and monitoring was performed according to protocols specified in the RMC SOPs (BASMAA, 2012b), and in conformity with SWAMP protocols. QA/QC issues noted by the laboratories and/or RMC field crews are summarized below.

4.1.1 Bioassessment

During Water Year 2012, some biological assessment sites had to be sampled along a shortened reach (less than 150 m), and in some cases, stream characterization points may have been skipped along the reach due to physical limitations or obstructions. During the BMI taxonomic analysis, some minor counting discrepancies were noted between the original BioAssessment Services results and the QA recount conducted by the California Department of Fish and Wildlife (CDFW), Aquatic Bioassessment Laboratory–Chico, California State University, Chico. Collection of algae samples was difficult or impossible at several sites due to varying levels of algal growth, making it hard to collect a distinguishable clump for analysis. EcoAnalysts, the algae taxonomy laboratory, reported low sample counts for soft algae in some cases, leading to a projected increase in processing costs. A field audit performed by Jim Harrington of CDFG generally confirmed that bioassessment field protocols were properly employed by RMC field crews.

During Water Year 2013, there were relatively minor field data collection issues. One reach was shortened to 120 m due to physical barriers on both ends. A number of reaches had deep pools, dry patches, or silt/mud substrate, making algae collection difficult at some transects. One CCCWP BMI sample was shared with California Department of Fish and Wildlife, Aquatic Bioassessment Laboratory–Chico, California State University, Chico (ABL) for interlab QA/QC analysis. The ABL found three instances of “tagalong” organisms. These are defined as specimens accidentally included in a vial of organisms of another taxon and are marked as "Probable sorting error" in the attached Listing of Taxonomic Discrepancies file. These are considered to be minor sorting discrepancies. There were no other discrepancies encountered during the QC analysis.

4.1.2 Sediment Chemistry

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

- Low level contamination noted in Method Blanks
- Matrix Spike recoveries outside of control limits noted due to possible matrix interferences
- Many laboratory reporting limits (RLs) exceed 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.

4.1.3 Water Chemistry

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

- In both 2012 and 2013, RMC field crews noted numerous 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 elevated 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. Individual Programs' data were qualified as dictated by comparison with RMC MQOs (BASMAA, 2014a).

4.1.4 Sediment Toxicity

In Water Year 2012, for several sediment toxicity samples, during laboratory testing for chronic toxicity of ambient sediment to *Hyalella azteca*, the dissolved oxygen level dropped below 2.5 mg/L during testing; aeration was initiated following this observation per the EPA testing manual. It is possible that hypoxia could have had a role in the significantly reduced survival observation of *Hyalella azteca*.

4.1.5 Water Toxicity

In both Water Year 2012 and Water Year 2013, multiple aquatic toxicity samples were identified by the analytical laboratory as being affected during testing by pathogen-related mortality (PRM), a cause of interference in aquatic sample toxicity tests with ambient surface waters. In some cases in 2012, the affected samples were retested using a modified approach per Geis et al. (2003). In 2013, these retests used the standard EPA 20-replicate test (USEPA, 2000) to assess impacts of PRM.[14]

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[14] As part of contracting for WY 2014 creek status monitoring, RMC Programs have asked the laboratory to provide more comprehensive documentation supporting PRM identification, when applicable.

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?"*** The designated beneficial uses listed in the San Francisco Bay Region Basin Plan (SF Bay Water Board, 2013) for RMC creeks sampled from East Bay sites are shown in Table 4-1. Statistical properties of the aquatic life use indicators used for this condition assessment that were observed at the CCCWP sites sampled in Water Years 2012 and 2013 are reported in Sections 4.2.1 (benthic macroinvertebrates) and 4.2.2 (algae), and discussed in relation to aquatic life beneficial uses designated by the SF Bay Water Board (Table 4-1) in section 4.2.3. Due to the relatively small sample size available after the second year of implementing the RMC regional probabilistic monitoring design, results are presented only in terms of their comparative statistical ranges within urbanized portions of Contra Costa County. Future reports will provide additional analysis at the countywide program level, as well as comparisons between urban and non-urban land use sites.

Table 4-1. RMC creeks and associated designated beneficial uses listed in the San Francisco Bay Region Basin Plan (SF Bay Water Board, 2013)

← Human Consumptive Uses → ← Aquatic Life Uses → Wildlife Use Recreational Uses

Site ID	Water Body	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
ALAMEDA COUNTY																				
205R00110	Agua Caliente (Zone 6 Line F)															E	E	E	E	
204R00356	Arroyo de la Laguna				E					E			E		E	E	E	E	E	
204R00100	Arroyo Mocho				E					E			E		E	E	E	E	E	
204R00191	Arroyo del Valle		E		E					E			P	E	E	E	E	E	E	
204R00340	Big Canyon Creek, Line 7-J-1															E	E	E	E	
204R00047	Castro Valley Creek									E				E		E	E	E	E	
204R00303	Chabot Creek									E				E		E	E	E	E	
204R00068	Collier Canyon Creek													E		E	E	E	E	
204R00647	Dry Creek													E		E	E	E	E	
204R00084	Dublin Creek															E	E	E	E	
205R00430	Line 6D															E	E	E	E	
205R00535	Plummer Creek (Zone 5 Line F-1)										E			E			E	E	E	
204R00639	San Lorenzo Creek		E	E	E					E			E		E	E	E	E	E	
204R00319	Sausal Creek									E				E	E	E	E	E	E	
204R00383	Sulphur Creek															E	E	E	E	
204R00367	Ward Creek															E	E	E	E	
204R00455	Zeile Creek															E	E	E	E	
205R00686	Canada Del Aliso															E	E	E	E	
204R00967	Crandall Creek															E	E	E	E	
204R00852	Alamo Creek				E					P			E	E	E	E	E	E	E	
204R00334	Arroyo del Valle		E		E					E			P	E	E	E	E	E	E	
204R00590	Arroyo del Valle		E		E					E			P	E	E	E	E	E	E	

Site ID	Water Body	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
204R00473	Arroyo Mocho				E					E			E		E	E	E	E	E	
205R01134	Agua Caliente															E	E	E	E	
204R00724	Dublin Creek															E	E	E	E	
204R01316	Arroyo de la Laguna				E					E			E		E	E	E	E	E	
205R00174	Line 6-K															E	E	E	E	
204R00623	San Lorenzo Creek		E	E	E					E			E		E	E	E	E	E	
204R00063	Peralta Creek															E	E	E	E	
204R00751	Redwood Canyon Creek			E						E					E	E	E	E	E	
203R00983	Strawberry Creek															E	E	E	E	
204R01471	Arroyo Mocho				E					E			E		E	E	E	E	E	
205R01198	Zone 6 Line G															E	E	E	E	
205R01390	Zone 6 Line G															E	E	E	E	
CONTRA COSTA COUNTY																				
203R00039	Cerrito Creek															E	E	E	E	
543R00137	Deer Creek	E	E							E			E		E	E	E	E	E	
207R00011	Grayson Creek									E			E	E		E	E	E	E	
207R00139	Las Trampas Creek									E				E		E	E	E	E	
543R00219	Marsh Creek							E						E		E	E	P	P	
543R00245	Marsh Creek							E						E		E	E	P	P	
206R00155	San Pablo Creek			E						E			E	E	E	E	E	E*	E	
206R00215	San Pablo Creek			E						E			E	E	E	E	E	E*	E	
207R00247	Walnut Creek									E			E	E	E	E	E	E	E	
206R00727	Pinole Creek									E			E	E	E	E	E	E	E	
207R00375	Galindo Creek									E						E	E	E	E	
207R00395	Las Trampas Creek									E				E		E	E	E	E	
207R00503	Pine Creek									E			E	E	E	E	E	E	E	
207R00567	Walnut Creek									E			E	E	E	E	E	E	E	
207R00631	Grayson Creek									E			E	E		E	E	E	E	

Site ID	Water Body	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
207R00788	San Ramon Creek															E	E	E	E	
544R00281	Marsh Creek							E						E		E	E	P	P	
SOLANO – FSURMP																				
207R00236,	Laurel Creek			E						E			E		E	E	E	E	E	
207R01452	Laurel Creek			E						E			E		E	E	E	E	E	
207R00476	Ledgewood Creek			E						E			E		E	E	E	E	E	
SOLANO – Vallejo																				
207R00064	Blue Rock Springs Creek			E												E	E	E	E	
207R04080	Blue Rock Springs Creek			E												E	E	E	E	
207R05524	Blue Rock Springs Creek			E												E	E	E	E	
207R03504	Rindler Creek			E												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” (SF Bay Water Board, 2013).

Creeks not listed in Chapter 2 of the Basin Plan do not appear in this table.

4.2.1 Benthic Macroinvertebrate Metrics

From a regional perspective, BMI metrics for 60 sites sampled within the RMC area in the spring index period of Water Year 2012 exhibited a wide range of scores, as described in the 2012 Regional UCMR (BASMAA, 2013).

Key BMI taxonomic metrics are shown in Table 4-2 for the CCCWP creek status sites monitored in the spring index period of Water Years 2012 and 2013. BMI metrics for the 20 sites sampled within Contra Costa County monitored in Water Years 2012 and 2013 exhibited a wide range of scores, particularly for some important metrics such as taxonomic richness, EPT Index, and % tolerant organisms.

B-IBI scores are presented in Table 4-3 for the 20 Contra Costa County sites monitored in Water Years 2012 and 2013. As noted above, based upon an a comparison and analysis of the NorCal and SoCal B-IBIs, the SoCal B-IBI score was chosen for the biological condition assessment in the 2012 UCMR (BASMAA, 2013). For consistency with the 2012 UCMR and other RMC programs, the SoCal B-IBI score is the primary tool used for condition assessment in this report. The preliminary Contra Costa B-IBI also is reported for purposes of comparison with the extensive historical database of bioassessment data produced by CCCWP during 2001–2011.

4.2.2 Algae Metrics

Algae metrics for sites sampled within the RMC area in the spring index period of Water Year 2012 exhibited a wide range of scores. For RMC Water Year 2012 data, in the absence of an available algae IBI pertaining to this region, diatom sensitivity and tolerance to pollutants were presented in the 2012 Regional UCMR (BASMAA, 2013) in an exploratory data analytical mode. Pollutant tolerant dominant diatom taxa comprised a total of 33% of the RMC sample counts, while pollutant intolerant diatom taxa comprised 27% (Figure 4-1).

The diatom A-IBI scores and five associated algae metrics calculated for the 20 samples collected from sites in Contra Costa County during Water Years 2012 and 2013 are shown in Table 4-4. The results for the other six diatom metrics not included in the calculation of the “D18” A-IBI score are shown in Table 4-5. This analysis is also considered to be in a preliminary, exploratory mode, as the diatom A-IBI and other metrics have not been fully tested for application to SF Bay Area streams.

There was a substantial range in diatom A-IBI scores, from the highest scores at Stations 207R0011 (70) and 543R00219 (62), to the lowest scores at Stations 544R00025 (4) and 543R00137 (6). The average diatom A-IBI score across all sites was 37.8 (20 sites, Water Years 2012 and 2013 combined), on a scale of 100. Station 207R00011 had three of the highest scores and proportions for three of the five metrics in the IBI while Station 544R00025 had three of the lowest scores and proportions for three of the five metrics.

Overall, the scores were low for ‘Proportion of low TP indicators’, with 16 of the 20 stations receiving a score less than 3, suggesting that many of the sites had relatively high total phosphorous concentrations. This pattern appears to match with the ‘Proportion of low TN indicators’ values. Stations with higher proportions of diatoms requiring >50% dissolved oxygen saturation tended to have higher IBI scores. Fetscher et al. (2014) found the diatom IBI (“D18”) to be responsive to stream order, watershed area, and percent fines, so those watershed characteristics also could play a role in the observed A-IBI scores.

Table 4-2. Benthic macroinvertebrate metrics for CCCWP bioassessment samples collected in the 2012 and 2013 Water Years

				Metrics:	Richness								Composition					Tolerance					Functional Feeding Group								Estimated Abundance		
Creek Name	Sampling Year	Land Use	Flow Class	Station ID	Taxonomic	EPT	Ephemeroptera	Plecoptera	Trichoptera	Coleoptera	Predator	Diptera	EPT Index (%)	Sensitive EPT Index (%)	Shannon Diversity	Dominant Taxon (%)	Non-Insect Taxa (%)	Tolerance Value	Intolerant Organisms (%)	Intolerant Taxa (%)	Tolerant Organisms (%)	Tolerant Taxa (%)	Collector-Gatherers (%)	Collector-Filterers (%)	Collectors (%)	Scrapers (%)	Non-Gastropoda Scrapers (%)	Predators (%)	Shredders (%)	Other (%)	Composite Sample (11ft^2)	#/ft^2	#/m^2
Cerrito	2012	U	P	203R00039	19	4	1	1	2	0	4	8	12	3.5	1.7	52	32	5.2	3.5	16	1.8	16	88	5.4	93	0.8	0.0	2.3	3.5	0.0	5306	482	5151
San Pablo	2012	U	P	206R00155	20	3	2	1	0	1	6	10	18	1.9	2.1	25	25	5.4	1.9	5	1.3	30	81	11	92	0.3	0.0	5.2	1.9	0.5	2190	199	2126
San Pablo	2012	U	P	206R00215	19	2	1	0	1	1	6	8	5.5	0.0	1.7	41	32	5.7	0.3	5.3	1.9	32	93	2.0	95	0.2	0.0	4.6	0.0	0.3	1197	109	1162
Grayson	2012	U	P	207R00011	14	2	1	0	1	0	4	7	13	0.0	2.1	29	42	6	0.0	0.0	11	29	70	16	86	3.7	0.0	2.2	0.0	8.1	16747	1522	16259
Las Trampas	2012	U	P	207R00139	11	2	1	0	1	0	2	3	5.5	0.0	1.5	51	45	5.6	0.0	0.0	14	45	86	0.0	86	13	0.0	1.2	0.3	0.2	2420	220	2350
Walnut	2012	U	P	207R00247	17	5	2	0	3	0	4	6	27	0.2	2.2	19	29	5.6	0.0	0.0	3.1	29	82	4.1	86	0.3	0.0	2.8	0.0	10.7	9856	896	9569
Deer	2012	U	P	543R00137	8	0	0	0	0	0	1	4	0.0	0.0	1.5	40	50	6.8	0.0	0.0	43	38	89	5.4	94	1.7	0.0	4.2	0.0	0.0	6933	630	6731
Marsh	2012	NU	P	543R00219	39	14	7	0	7	3	10	8	19	406	2.8	23	31	5.9	3.7	10	26	31	68	13	81	2.3	0.2	12	0.5	4.1	10496	954	10190
Marsh	2012	NU	P	543R00245	35	10	8	0	2	4	12	8	8.4	5.6	2.5	38	33	6.7	2.8	5.6	55	25	23	0.8	24	46	0.0	23	0.0	6.8	2693	245	2615
Dry	2012	U	P	544R00025	12	0	0	0	0	0	2	6	0.0	0.0	1.8	35	42	6	0.0	0.0	25	42	93	4.1	97	1.6	0.0	1.1	0.0	0.2	4645	422	4510
Pinole	2013	U	P	206R00727	20	2	2	0	0	1	8	9	4.8	0.0	2.1	22	25	6	0.0	0.0	18	30	56	22	78	0.2	0.0	20	0.0	1.8	934	85	907
Sycamore	2013	U	P	207R00271	19	1	1	0	0	0	6	10	0.6	0.0	2.0	35	32	5.9	0.2	5.3	12	26	83	8.1	91.1	0.0	0.0	8.8	0.0	0.2	5923	538	5750
Galindo	2013	U	P	207R00375	17	2	0	0	2	0	5	5	0.3	0.2	1.7	47	53	6.3	0.0	0.0	26	41	84	0.0	84	7.1	0.0	8.5	0.0	0.5	2976	271	2889
Las Trampas	2013	U	P	207R00395	14	3	1	0	2	0	2	7	21	0.0	2.2	20	29	5.9	0.2	7.1	16	29	65	16	81	7.1	0.0	12	0.0	0.3	5306	482	5151
Pine	2013	U	P	207R00503	21	3	2	0	1	0	6	11	45	0.0	1.7	44	32	5.5	0.0	0.0	7.8	32	55	26	81	0.2	0.0	17	0.2	1.1	1514	138	1470
Sycamore	2013	U	P	207R00532	13	1	1	0	0	0	4	5	1.5	0.0	1.5	54	46	5.8	0.0	0.0	1.5	15	41	55	96	0.2	0.0	4.1	0.0	0.0	2684	244	2606
Walnut	2013	U	P	207R00567	11	1	1	0	0	0	3	5	1.5	0.0	1.9	22	36	5.5	0.0	0.0	3.7	36	86	10	96	0.0	0.0	3.2	0.0	0.7	1254	114	1217
Grayson	2013	U	P	207R00631	15	3	1	0	2	0	4	6	13	0.0	1.9	29	33	5.4	0.0	0.0	0.7	20	91	3.0	94	0.0	0.0	1.5	0.0	4.3	2158	196	2095
San Ramon	2013	U	P	207R00788	17	6	3	0	3	0	2	6	32	0.6	1.9	30	24	5.6	0.8	12	1.7	24	83	13	96	0.2	0.0	3.4	0.6	0.6	3864	351	3751
Marsh	2013	U	P	544R00281	19	3	1	0	2	0	4	5	2.7	0.2	1.8	44	47	6.4	0.0	5.3	31	32	75	2.7	77.7	15	0.0	4.1	0.0	3.0	5088	463	4940

Land Use: U = Urban; NU = Nonurban; Flow Class: P = Perennial

Table 4-3. B-IBI scores for CCCWP bioassessment sites sampled in Water Years 2012 and 2013 (n=20)

Year Sampled	Creek Names	Site IDs	Land Use	Flow Class	3-sided Concrete Channel	COLD	WARM	SoCal B-IBI Score	SoCal B-IBI Condition	NorCal B-IBI Score	NorCal B-IBI Condition	Contra Costa B-IBI Score	Contra Costa B-IBI Condition
2012	Cerrito	203R00039	Urban	P	no		x	23	Poor	24	Poor	28	Fair
2012	San Pablo	206R00155	Urban	P	no	x	x	24	Poor	30	Poor	30	Fair
2012	San Pablo	206R00215	Urban	U	no	x	x	19	Very Poor	23	Very Poor	27	Fair
2012	Grayson	207R00011	Urban	P	yes	x	x	13	Very Poor	15	Very Poor	27	Fair
2012	Las Trampas	207R00139	Urban	P	no	x	x	7	Very Poor	9	Very Poor	18	Marginal
2012	Walnut	207R00247	Urban	U	yes	x	x	21	Poor	21	Very Poor	32	Fair
2012	Deer	543R00137	Urban	U	no		x*	0	Very Poor	9	Very Poor	14	Marginal
2012	Marsh	543R00219	Nonurban	P	no		x*	43	Fair	41	Poor	45	Very Good
2012	Marsh	543R00245	Nonurban	U	no		x*	43	Fair	36	Poor	47	Very Good
2012	Dry	544R00025	Urban	P	no		x*	3	Very Poor	9	Very Poor	18	Marginal
2013	Pinole	206R00727	Urban	P	no	x	x	21	Poor	28	Poor	38	Good
2013	Sycamore	207R00271	Urban	P	no		x*	12	Very Poor	22	Poor	28	Fair
2013	Galindo	207R00375	Urban	P	no		x	7	Very Poor	13	Very Poor	25	Fair
2013	Las Trampas	207R00395	Urban	P	no	x	x	13	Very Poor	24	Poor	30	Fair
2013	Pine	207R0050	Urban	P	yes	x	x	14	Very	28	Poor	34	Fair

Year Sampled	Creek Names	Site IDs	Land Use	Flow Class	3-sided Concrete Channel	COLD	WARM	SoCal B-IBI Score	SoCal B-IBI Condition	NorCal B-IBI Score	NorCal B-IBI Condition	Contra Costa B-IBI Score	Contra Costa B-IBI Condition
		3							Poor				
2013	Sycamore	207R00532	Urban	P	no		x*	10	Very Poor	12	Very Poor	19	Marginal
2013	Walnut	207R00567	Urban	P	no	x	x	5	Very Poor	13	Very Poor	20	Marginal
2013	Grayson	207R00631	Urban	P	no	x	x	12	Very Poor	14	Very Poor	27	Fair
2013	San Ramon	207R00788	Urban	P	no		x	14	Very Poor	19	Very Poor	28	Fair
2013	Marsh	544R00281	Urban	P	no		x*	9	Very Poor	12	Very Poor	29	Fair

P = Perrenial; U= Unknown; N= non-perennial

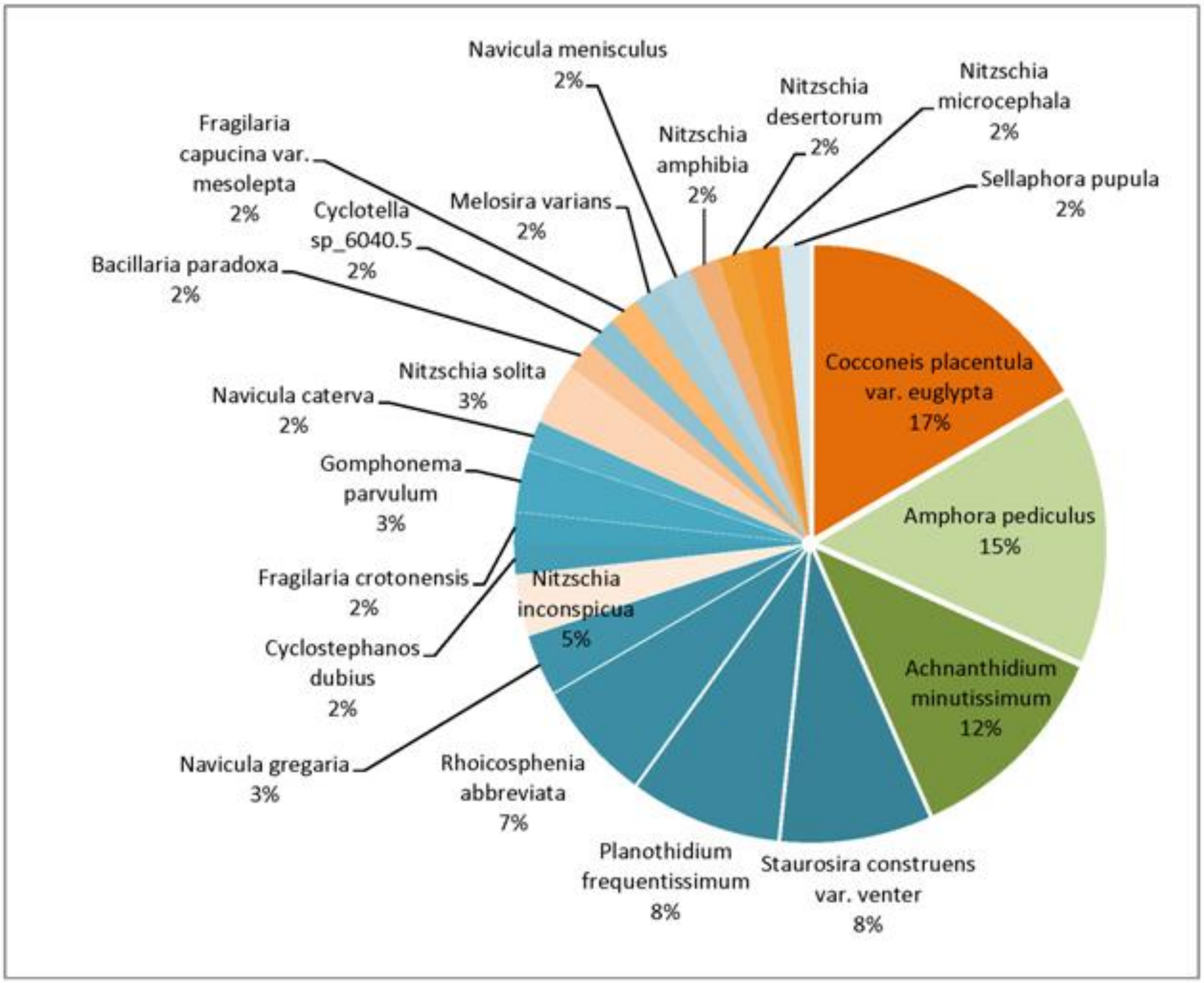

Figure 4-1. Dominant diatom taxa sampled at RMC sites in Water Year2012. Green-hued sections indicate sensitive species intolerant to pollutants; orange-hued sections indicate species more tolerant of pollutants, including fine sediment (Blinn and Herbst, 2003; Herbst and Blinn, 2008).

Table 4-4. A-IBI scores and associated metrics for CCCWP bioassessment sites sampled in Water Years 2012 and 2013 (n=20)

Station Code	Sample Date	A-IBI Score	Proportion low TP indicators	Proportion halobiontic	Proportion requiring >50% DO saturation	Proportion N heterotrophs	Proportion sediment tolerant (highly motile)
203R00039	5/14/2012	40	0.019 (1)	0.190 (6)	0.776 (4)	0.291 (4)	0.236 (5)
206R00155	5/16/2012	40	0 (0)	0.309 (4)	0.904 (7)	0.294 (4)	0.267 (5)
206R00215	5/23/2012	34	0.046 (1)	0.267 (5)	0.859 (6)	0.356 (3)	0.399 (2)
207R00011	5/22/2012	70	0.024 (1)	0.143 (7)	0.993 (9)	0.025 (9)	0.027 (9)
207R00139	5/17/2012	40	0.052 (1)	0.342 (4)	0.667 (1)	0.099 (8)	0.207 (6)
207R00247	5/22/2012	26	0.084 (1)	0.442 (2)	0.781 (4)	0.259 (5)	0.445 (1)
543R00137	5/15/2012	6	0 (0)	0.713 (0)	0.563 (0)	0.504 (1)	0.434 (2)
543R00219	5/21/2012	62	0.616 (8)	0.170 (7)	0.814 (5)	0.212 (6)	0.245 (5)
543R00245	5/21/2012	42	0.261 (4)	0.354 (4)	0.779 (4)	0.300 (4)	0.277 (5)
544R00025	5/15/2012	4	0 (0)	0.440 (2)	0.585 (0)	0.642 (0)	0.646 (0)
206R00727	5/13/2013	24	0.014 (1)	0.647 (0)	0.712 (2)	0.135 (7)	0.430 (2)
207R00271	4/29/2013	38	0.042 (1)	0.374 (3)	0.658 (1)	0.106 (8)	0.198 (6)
207R00375	5/1/2013	42	0.050 (1)	0.341 (4)	0.734 (3)	0.110 (7)	0.209 (6)
207R00395	5/14/2013	46	0.013 (1)	0.271 (5)	0.725 (3)	0.095 (8)	0.18 (6)
207R00503	5/2/2013	58	0.215 (3)	0.138 (7)	0.932 (8)	0.258 (5)	0.196 (6)
207R00532	4/29/2013	20	0.027 (1)	0.704 (0)	0.538 (0)	0.054 (8)	0.440 (1)
207R00567	4/30/2013	30	0.161 (2)	0.360 (3)	0.703 (2)	0.182 (6)	0.403 (2)
207R00631	5/16/2013	30	0.018 (1)	0.392 (3)	0.701 (2)	0.204 (6)	0.363 (3)
207R00788	5/15/2013	48	0.083 (1)	0.262 (5)	0.762 (4)	0.157 (7)	0.152 (7)
544R00281	5/14/2013	56	0.518 (7)	0.214 (6)	0.796 (5)	0.193 (6)	0.316 (4)
Metric scores are shown as raw metric value followed by (score)							
IBI Score is calculated by summing the five individual metric scores and multiplying the sum X 2							

Table 4-5. Additional algae metrics for CCCWP bioassessment sites sampled in Water Years 2012 and 2013 (n=20)

Station Code	Sample Date	Proportion low TN indicators	Proportion requiring ~100% DO saturation	Proportion oligo- & beta-mesosaprobic	Proportion poly- & eutrophic	Proportion highly motile	Proportion A. minutissimum
203R00039	5/14/2012	0.019	0.025	0.594	0.838	0.236	0.013
206R00155	5/16/2012	0	0	0.629	0.857	0.267	0
206R00215	5/23/2012	0.074	0.019	0.312	0.842	0.392	0
207R00011	5/22/2012	0.021	0.018	0.965	0.979	0.020	0.017
207R00139	5/17/2012	0.050	0.019	0.571	0.793	0.200	0.013
207R00247	5/22/2012	0.077	0.128	0.713	0.819	0.094	0.032
543R00137	5/15/2012	0	0.044	0.224	0.986	0.397	0
543R00219	5/21/2012	0.604	0.605	0.693	0.398	0.182	0.486
543R00245	5/21/2012	0.258	0.235	0.614	0.731	0.244	0.188
544R00025	5/15/2012	0.005	0.005	0.201	0.995	0.523	0
206R00727	5/13/2013	0.014	0.012	0.444	0.879	0.424	0
207R00271	4/29/2013	0.040	0.026	0.360	0.828	0.185	0
207R00375	5/1/2013	0.044	0.029	0.571	0.860	0.206	0.007
207R00395	5/14/2013	0.008	0.008	0.677	0.949	0.165	0.003
207R00503	5/2/2013	0.098	0.303	0.672	0.672	0.185	0.049
207R00532	4/29/2013	0.025	0.035	0.442	0.857	0.423	0.003
207R00567	4/30/2013	0.153	0.155	0.590	0.723	0.383	0.102
207R00631	5/16/2013	0.012	0.025	0.503	0.918	0.336	0.010
207R00788	5/15/2013	0.074	0.064	0.700	0.888	0.092	0.052
544R00281	5/14/2013	0.472	0.499	0.694	0.477	0.309	0.411

4.2.3 Analysis of Condition Indicators

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

Benthic Macroinvertebrate Metrics

There are marked differences among the condition categories indicated by the three different B-IBI scores, as shown in Table 4-3. In particular, the SoCal B-IBI condition categories differ markedly from the Contra Costa B-IBI categories, with the Contra Costa conditions often scoring two categories higher than the SoCal B-IBI categories. A comparison of the number of sites in the various condition categories is shown in Table 4-6 for SoCal B-IBI scores and Contra Costa B-IBI scores. In both cases, the two sites scoring in the highest condition category were the two non-urban sites monitored during Water Year 2012.

The discrepancy between the Southern California and Contra Costa condition categories should be further investigated. Based simply on the distribution of sites in the various categories, and on the prior CCMAP monitoring results (which revealed an even broader distribution of scores and categories), it appears that the Contra Costa B-IBI may more accurately represent benthic biological conditions in Contra Costa County streams. Looking at the scores and condition categories at the extremes (highest and lowest), the Contra Costa B-IBI generally appears to reasonably characterize the sites monitored under CCMAP and by CCCWP under the RMC for MRP compliance. However, the SoCal B-IBI was developed using a more rigorous and more recently-evolved protocol than the earlier provisional Contra Costa B-IBI, and the Contra Costa B-IBI should undergo additional investigation in accordance with more recent standards in procedural approach to B-IBI development (e.g., per Stoddard et al., 2008).

As indicated in Table 4-1, all 20 sites monitored by CCCWP for the RMC during Water Years 2012 and 2013 are presumed to have the WARM (warm water fishery) beneficial use, while only about half of those are designated as having the COLD (cold water fishery) beneficial use. To the extent that benthic conditions may reflect or influence the viability of the fisheries in these water bodies, it may be assumed that benthic conditions in the lower categories (poor or very poor for SoCal B-IBI, marginal or poor for Contra Costa B-IBI) may indicate some difficulty in supporting the designated aquatic life beneficial uses.

Using the SoCal B-IBI scores, all 18 of the non-urban sites (18 of 20 sites total) monitored by CCCWP would be considered potentially deficient regarding biological conditions necessary to support a viable fishery. Using the Contra Costa B-IBI scores, only 5 of the non-urban sites monitored by CCCWP would be considered potentially deficient regarding biological conditions necessary to support a viable fishery. In the absence of an available B-IBI developed for the San Francisco Bay Region, the SoCal B-IBI was used to assess the condition of BMI data sampled in the RMC area, and therefore these results should be considered provisional.

Table 4-6. Summary of biological condition categories based on SoCal B-IBI and Contra Costa B-IBI scores for CCCWP bioassessment sites sampled in Water Years 2012 and 2013 (n=20)

So. California B-IBI Condition		**Contra Costa B-IBI Condition**	
# Sites	**Category**	**# Sites**	**Category**
0	Very Good	2 *	Very Good
0	Good	1	Good
2 *	Fair	12	Fair
4	Poor	5	Marginal
14	Very Poor	0	Poor

* Two non-urban sites monitored in WY 2012

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, Table 8-1 is associated with a specification for "Results that Trigger a Monitoring Project in Provision C.8.d.i" (Stressor/Source Identification). The definitions of these "Results that Trigger…," as shown 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 RMC participants during Water Years 2012 and 2013 were compiled and evaluated, and analyzed against these trigger criteria. When the data analysis indicated that the associated trigger criteria were not met, those sites and results were identified as potentially warranting further investigation.

When interpreting analytical chemistry results, it is important to account for laboratory data reported as either below method detection limits (MDLs) or between detection and reporting limits (RLs). Dealing with data in this range of the analytical spectrum introduces some level of uncertainty, especially when attempting to generate summary statistics for a data set. In the 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 differs from the 2012 Regional UCMR (BASMAA, 2013), which substituted a value of one-half of the RL for NDs.[15] 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 Indicators

Physical Habitat Parameters

A wide range of physical habitat characteristics can influence the biological conditions of urban streams. Physical habitat condition was assessed on a preliminary basis using PHab scores (Table 4-7), computed for Contra Costa County sites from three physical habitat attributes (epifaunal substrate/cover, sediment deposition, and channel alteration) measured in the field during bioassessment monitoring in Water Years 2012 and 2013. The composite PHab score has a possible range from 0 to 60, with each of the contributing factors scored on a range of 0-20 points. Higher PHab scores reflect higher-quality habitat.

In an initial evaluation, the PHab scores do not correspond well with either the B-IBI scores or the A-IBI scores; therefore the PHab scores initially do not have substantial value as stressor indicators as reflected in composite biological condition scores.

Water Chemistry Parameters

Table 4-8 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).

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[15] Substitution of one-half of the MRL in several cases brought about a situation where analytical data reported as ND was, for statistical purposes, estimated at higher concentrations than similar data reported between the MDL and RL. Specific instances are discussed in subsequent sections.

Table 4-7. Physical habitat scores for CCCWP bioassessment sites sampled in Water Years 2012 and 2013 (n=20)

Site	Sample Date	Epifaunal Substrate	Sediment Deposition	Channel Alteration	Mini-PHab Score
203R00039	5/14/2012	12	18	12	42
206R00155	5/16/2012	18	14	14	46
206R00215	5/23/2012	12	8	17	37
207R00011	5/22/2012	2	17	0	19
207R00139	5/17/2012	12	13	14	39
207R00247	5/22/2012	1	19	0	20
543R00137	5/15/2012	3	16	19	38
543R00219	5/21/2012	13	12	17	42
543R00245	5/21/2012	15	15	15	45
544R00025	5/15/2012	3	8	7	18
206R00727	5/13/2013	14	9	15	38
207R00271	4/29/2013	14	16	18	48
207R00375	5/1/2013	17	13	13	43
207R00395	5/14/2013	15	13	14	42
207R00503	5/2/2013	2	18	1	21
207R00532	4/29/2013	18	9	18	45
207R00567	4/30/2013	5	6	5	16
207R00631	5/16/2013	9	11	12	32
207R00788	5/15/2013	10	11	9	30
544R00281	5/14/2013	9	8	9	26

Table 4-8 Descriptive statistics for water chemistry results collected at RMC sites during Water Years 2012 and 2013. Results include two years of monitoring for ACCWP and CCCWP and one year (2013) for FSURMP and Vallejo

"Nutrients"	N	N ≥ RL	Min	Max	Max Detected	Mean
Chloride	68	68	17	410	410	85
Chlorophyll-a	68	55	<5.14	414.14	414.14	106.50
Dissolved Organic Carbon	68	66	<0.3	14	14	4.0
Ammonia as N	68	22	<0.04	0.79	0.79	0.09
Nitrate as N	68	47	<0.01	7.50	7.50	0.69
Nitrite as N	68	4	<0.002	0.19	0.19	0.012
Nitrogen, Total Kjeldahl	68	68	0.11	2.10	2.10	0.55
OrthoPhosphate as P	68	60	<0.006	0.85	0.85	0.10
Phosphorus as P	68	65	<0.007	3.5	3.5	0.16
Suspended Sediment Concentration	68	47	<2	171	171	14
Silica as SiO2	68	68	5.9	43	43	22

In comparing the effect of using one-half the MDL in place of one-half the MRL to estimate values of NDs, the differences are relatively minor (Table 4-9). The greatest difference is observed in calculation of chlorophyll-a, while relatively minor differences are observed elsewhere.

Table 4-9. Calculation of mean concentration of water chemistry parameters using MDL- vs. MRL-based substitutions for non-detects

“Nutrients”	MDL-based	MRL-based
Chloride	85	85
Chlorophyll-a	106.50	114.61
Dissolved Organic Carbon	4.0	4.0
Ammonia as N	0.09	0.10
Nitrate as N	0.69	0.69
Nitrite as N	0.012	0.018
Nitrogen, Total Kjeldahl	0.55	0.55
OrthoPhosphate as P	0.10	0.10
Phosphorus as P	0.16	0.16
Suspended Sediment Concentration	14	14
Silica as SiO2	22	22

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 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.[16] 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 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
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

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[16] 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.”

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, ambient water samples were collected by the four collaborating Programs from five sites throughout the region during storm events in March 2012, and seven locations in March and April of 2013, 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). Testing in 2013 also included retests at those locations sampled in 2012 where samples met MRP-defined thresholds triggering follow-up monitoring. The following sections discuss the results of 2012 and 2013 monitoring in the context of MRP triggers.

In 2012, no samples were found to be toxic to either *C. dubia* or *S. capricornutum*. Three of five samples were identified as toxic to *H. azteca* (Table 4-10). Two of five samples generated a toxic response within *P. promelas*. Of those two, one was identified with significant toxicity relative to the chronic endpoint (growth), and one relative to the acute endpoint criterion (survival). Both of these test results were identified by the toxicity-testing laboratory as having been affected by interference due to pathogen-related mortality (PRM), an acknowledged source of laboratory interference in receiving water samples. The lab reports for these samples include the following statement relative to the PRM-affected samples: "observations of PRM are not associated with or indicative of stormwater toxicity." In those three cases, the samples were retested using a method developed to minimize PRM interference (Geis et al., 2003). In both cases, no toxic response was observed.

In 2013, ambient water samples were collected from a total of 10 sites during storm events in March and April 2013. Sampling was unable to be conducted synoptically due to the lack of storm events that met the mobilization criteria for sampling regionwide. Of the monitoring conducted, 7 sites were tested with the four MRP test species identified previously. In addition, samples were collected from three sites sampled in 2012, as discussed previously, that required retest per the MRP; these samples were analyzed only with the test species for which 2012 samples met MRP-defined triggers.

As shown in Table 4-10, none of the 2013 samples analyzed against the full suite of test species were found to be toxic to *S. capricornutum*. Two samples were identified as toxic to *C. dubia*, both for the chronic endpoint (growth). Two samples were reported as toxic to *H. azteca*.

In 2013, one sample was identified as toxic to *P. promelas*, with significant toxicity relative to the acute endpoint criterion (survival). As in 2012, this toxic result was identified by the laboratory as having been caused by interference due to PRM. Following up on the initial identification of PRM, the laboratory was requested to retest the sample media using the 20-replicate EPA (2000) protocol, which resulted in removal of the toxic response, supporting the initial identification of PRM as a contributor to mortality.

Table 4-10. Summary of WY 2012 and WY 2013 wet-season water toxicity results for four-species tests. Shaded cells indicate monitoring conducted in WY 2012

Wet-Season Water Samples			Date of Analysis	Toxicity Relative to the Lab Control Treatment?					
				S. capricornutum	*C. dubia*		*H. azteca*	*P. promelas*	
County/ Program	**Sample Station**	**Collection Date**		**Growth**	**Sur-vival**	**Repro-duction**	**Sur-vival**	**Sur-vival**	**Growth**
ACCWP	204R00047	3/14/12	3/15/12	No	No	No	**Yes**	No	**Yes**[1]
ACCWP	204R00084	3/14/12	3/15/12	No	No	No	No	No	No
ACCWP	204R00100	3/14/12	3/15/12	No	No	No	No	**Yes**[1]	No
ACCWP	204R00327	3/6/13	3/6/13	No	No	**Yes**	No	No	No
ACCWP	204R00447	3/6/13	3/6/13	No	No	No	**Yes**	No	No
ACCWP	205R00686	3/6/13	3/6/13	No	No	**Yes**	No	No	No
CCCWP	207R00011	3/14/12	3/15/12	No	No	No	**Yes**	No	No
CCCWP	544R00025	3/14/12	3/17/12	No	No	No	**Yes**	No	No
CCCWP	207R00271	3/6/13	3/6/13	No	No	No	No	**Yes**[2]	No
CCCWP	544R00281	4/4/13	4/5/13	No	No	No	**Yes**	No	No
FSURMP	207R00236	3/20/13	3/21/13	No	No	No	No	No	No
Vallejo	207R00064	3/20/13	3/21/13	No	No	No	No	No	No

Notes:

[1] PRM was identified by laboratory in multiple replicates for this stormwater sample; toxicity was not observed in retests using Geis technique.

[2] PRM was identified by laboratory in multiple replicates for this stormwater sample; toxicity was not observed in retests using EPA 20-replicate method (USEPA 2000).

Table 4-11 provides detailed results for RMC wet-weather receiving water samples in Water Years 2012 and 2013 tested against the four target species and found to be toxic relative to the laboratory control. Samples collected in 2012 at sites 204R00047, 207R00011, and 544R00025, and a sample collected in 2013 at site 544R00281 each exhibited *H. azteca* survival that was signicantly different from and less than 50% of the control.

Table 4-11. Comparison between laboratory control and receiving water sample toxicity results (*H. azteca* and *C. dubia*) for RMC samples collected in WY 2012 and WY 2013 wet season, in the context of MRP trigger criteria

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	3/15/12	*Hyalella azteca*	Lab Control	100	NA	NA
	3/15/12		204R00047	**48***		**<50% of Control**
CCCWP	3/15/12		Lab Control	100		NA
	3/15/12		207R00011	**32***		**<50% of Control**
	3/15/12		Lab Control	94		NA
	3/15/12		544R00025	**0***		**<50% of Control**
ACCWP	3/07/13	*H. azteca*	Lab Control	98		NA
	3/07/13		204R00447	**60***		Not <50% of control
	3/06/13	*C. dubia*	Lab Control	100	36.6	NA
	3/06/13		204R00327	100	**28.1***	Not <50% of control
	3/06/13		Lab Control	100	36.6	NA
	3/06/13		205R00686	80	**24.6***	Not <50% of control
CCCWP	4/4/13	*H. azteca*	Lab Control	100		NA
	4/4/13		544R00281	**0***		**<50% of control**

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

For the retests following up on 2012 triggers, three samples were retested with *H. azteca*, the species exhibiting toxic response, and two of these again showed an acute toxic response (Table 4-12). The two samples identified with significant toxicity, 207R00011 and 544R00025, both again met MRP triggers that would typically require follow-up retesting (Table 4-13). The single sample collected in 2013 that met triggers for retesting (544R00281) will be similarly incorporated into 2014 monitoring.

Table 4-12. Summary of WY 2013 wet-season water toxicity testing conducted as retests of 2012 results

Wet Season Water Samples			Date of Analysis	Toxicity Relative to the Lab Control Treatment?
County/ Program	**Sample Station**	**Collection Date**		***H. azteca***
				Survival
ACCWP	204R00047	3/5/2013	3/6/2013	No
CCCWP	207R00011	3/6/2013	3/6/2013	**Yes**
CCCWP	544R00025	4/4/2013	4/5/2013	**Yes**

Table 4-13. Comparison between laboratory control and receiving water sample toxicity results (*H. azteca)* for RMC samples retested in WY 2013 wet season, in the context of MRP trigger criteria

County/ Program	Test Initiation Date (Time)	Species Tested	Treatment/ Sample ID	10-Day Mean % Survival	Mean Reproduction (# neonates/ female)	Comparison to MRP Table 8.1 Trigger Criteria
CCCWP	3/6/13	*H. azteca*	Lab Control	100		NA
	3/6/13		207R00011	**4***		**< 50% of control**
	4/4/13		Lab Control	100		NA
	4/4/13		544R00025	**20***		**< 50% of control**

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

Table 4-14 provides detailed results for the *P. promelas* tests that were noted to have statistically different results from laboratory controls, as well as the results of retesting using a version of the Geis technique (for 2012 samples) or USEPA (2000) 20-replicate test (for 2013 samples). In three of the four cases, the original *P. promelas* tests were identified by the laboratory to be affected by PRM interference, based upon visual examination of test organisms. When retested using a technique designed to prevent PRM interference, toxicity was not observed in these samples, supporting the original determination of PRM interference in the initial tests.

As indicated in Table 4-14, while significantly less than the associated laboratory Control values in some cases, the affected results were in each case not less than the associated MRP threshold of less than 50% of the Control values for either survival or biomass growth.

Table 4-14. Comparison between laboratory control and receiving water sample toxicity results for *P. promelas* for RMC samples collected in the WY 2012 and WY 2013 wet seasons, in the context of MRP trigger criteria. Shaded cells indicate monitoring conducted in WY 2012

County/ Program	Test Initiation Date (Time)	Treatment/ Sample ID	Mean % Survival	Mean Biomass Value (mg)	Comparison to MRP Table 8.1 Trigger Criteria; Identification of PRM Effects and PRM Method Retests
ACCWP	3/15/12	Lab Control	100	0.52	NA
	3/15/12	204R00047	95 (a)	**0.42*** (a)	Not <50% of control; PRM noted
	3/15/12	204R00100	**72.5*** (a)	0.46	Not <50% of control; PRM noted
	3/23/12	Lab Control	100	0.27	PRM method retest (Geis et al., 2003)
	3/23/12	204R00047	90	0.29	PRM method retest (Geis et al., 2003)
	3/23/12	204R00100	100	0.34	PRM method retest (Geis et al., 2003)
CCCWP	3/6/13	Lab Control	97.5	0.73	NA
	3/6/13	207R00271	**50*** (a)	0.52	Not <50% of control; PRM noted and retested
	3/15/13	Lab Control	92.5	0.50	PRM method retest (20-replicate test)
	3/15/13	207R00271	90	0.55	PRM method retest (20-replicate test)

* The response at this test treatment was significantly less than the Lab Control at $p < 0.05$.
(a) PRM was observed in multiple replicates for this stormwater sample

Dry-Season Aquatic Toxicity

Water samples were collected during the summer 2012 and 2013 periods from the same sites where wet season sampling occurred (five sites in 2012 and seven sites in 2013), and were again tested for aquatic toxicity using the same four test species. The results are summarized in Table 4-15. In comparisons to the control samples, no samples collected in 2012 were found to be toxic to the test species.

There were multiple samples collected in 2013 where aquatic toxicity was observed by the laboratory. These included samples toxic to *C. dubia* (207R00064), *H. azteca* (204R00447 and 207R00271), and *P. promelas* (204R00327, 204R00447, 205R00686, 207R00271, and 544R00281).

Table 4-15. Summary of WY 2012 and WY 2013 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	204R00047	7/25/12	No	No	No	No	No	No
ACCWP	204R00084	7/25/12	No	No	No	No	No	No
ACCWP	204R00100	7/25/12	No	No	No	No	No	No
CCCWP	207R00011	7/25/12	No	No	No	No	No	No
CCCWP	544R00025	7/25/12	No	No	No	No	No	No
ACCWP	204R00327	7/9/13	No	No	No	No	No	**Yes**
ACCWP	204R00447	7/9/13	No	No	No	**Yes**	No	**Yes**
ACCWP	205R00686	7/9/13	No	No	No	No	No	**Yes**
CCCWP	207R00271	7/9/13	No	No	No	**Yes**	**Yes**	No
CCCWP	544R00281	7/9/13	No	No	No	No	No	**Yes**
FSURMP	207R00236	7/11/13	No	No	No	No	No	No
Vallejo	207R00064	7/11/13	No	No	**Yes**	No	No	Yes

For samples identified with significant toxicity, one of the two samples toxic to *H. azteca*, collected at site 207R00271, met the MRP criterion for triggering follow-on retesting (Table 4-16). The single sample identified as toxic to *C. dubia* did not meet the MRP trigger for follow-on testing.

Table 4-16. Comparison between laboratory control and receiving water sample toxicity results (*C. dubia* and *H. azteca)* for RMC samples collected in WY 2012 and WY 2013 dry seasons and reported as toxic, in the context of MRP trigger criteria

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	7/10/13	*H. azteca*	Lab Control	100		NA
	7/10/13		204R00447	**94***		Not <50% of control
CCCWP	7/10/13	*H. azteca*	Lab Control	96		NA
	7/10/13		207R00271	**2***		**<50% of control**
Vallejo	7/10/13	*C. dubia*	Lab Control	100	36.3	NA
	7/10/13		207R00064	100	**24.0***	Not <50% of control

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

Multiple dry-season *P. promelas* tests were noted to have statistically different results from laboratory control, each associated with monitoring in Water Year2013. As shown in Table 4-17, only one of the samples reported as significantly toxic to *P. promelas* fell below the MRP threshold of being <50% of the control (207R00271). This sample was identified as affected by PRM, and retested using the standard EPA 20-replicate method (USEPA, 2000). Toxicity was not observed in the retest, again supporting the original determination of PRM interference in the initial test.

Table 4-17. Comparison between laboratory control and receiving water sample toxicity results for *P. promelas* for RMC samples identified as toxic collected in the WY 2012 and WY 2013 dry seasons, in the context of MRP trigger criteria

County/ Program	Test Initiation Date	Treatment/ Sample ID	Mean % Survival	Mean Biomass Value (mg)	Comparison to MRP Table 8.1 Trigger Criteria; Identification of PRM effects and PRM Method Retests
ACCWP	7/10/13	Lab Control	95	0.80	NA
	7/10/13	204R00327	92.5	**0.68***	Not <50% of control
	7/10/13	Lab Control	95	0.80	NA
	7/10/13	204R00447	97.5	**0.70* (a)**	Not <50% of control
	7/10/13	Lab Control	95	0.80	NA
	7/10/13	205R00686	77.5 (a)	**0.66***	Not <50% of control
CCCWP	7/10/13	Lab Control	95	0.80	NA
	7/10/13	207R00271	**27.5* (a)**	0.36	**< 50% of Control**
	7/18/13	Lab Control	97.5	0.56	PRM retest using 20 replicate method
	7/18/13	207R00271	97.5	0.53	PRM retest using 20 replicate method
	7/10/13	Lab Control	95	0.80	NA
	7/10/13	544R00281	97.5	**0.67***	Not <50% of control
Vallejo	7/11/13	Lab Control	98.8	0.21	NA
	7/11/13	207R00064	97.5	**0.16***	Not <50% of control

* The response at this test treatment was significantly less than the Lab Control at $p < 0.05$.
(a) PRM was observed in multiple replicates for this stormwater sample

Dry Season Sediment Toxicity

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

The results of the sediment toxicity testing in Water Years 2012 and 2013 are summarized in Table 4-18. Three of the five samples collected in Water Year 2012 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 4-18. Summary of WY 2012 and WY 2013 dry-season sediment toxicity results. Shaded cells indicate monitoring conducted in WY 2012

Dry-Season Sediment Samples				Toxicity relative to the Lab Control treatment?	
				H. azteca	
County/ Program	**Sample Station**	**Collection Date**	**Date of Analysis**	**Survival**	**Growth**
ACCWP	204R00047	7/25/12	7/28/12	**Yes**	N/A*
ACCWP	204R00084	7/25/12	7/28/12	No	No
ACCWP	204R00100	7/25/12	7/28/12	No	No
ACCWP	204R00327	7/9/13	7/14/13	No	No
ACCWP	204R00447	7/9/13	7/14/13	No	**Yes**
ACCWP	205R00686	7/9/13	7/14/13	No	**Yes**
CCCWP	207R00011	7/25/12	7/28/12	**Yes**	N/A*
CCCWP	544R00025	7/25/12	7/28/12	**Yes**	N/A*
CCCWP	207R00271	7/9/13	7/14/13	**Yes**	N/A*
CCCWP	544R00281	7/9/13	7/14/13	**Yes**	N/A*
FSURMP	207R00236	7/11/13	7/14/13	**Yes**	N/A*
Vallejo	207R05524	7/18/13	7/26/13	No	**Yes**

* Per EPA guidance, samples with a significant reduction in survival are not evaluated for chronic endpoints (i.e., growth).

Detailed results of dry-season sediment samples identified as having toxic effects in Water Years 2012 and 2013 are shown in Table 4-19, along with comparisons to the relevant trigger criteria from MRP Tables 8.1 and H-1. Over the first two years of monitoring, 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 (204R00047). For the remaining five samples for which significant toxicity was identified, the magnitude of the acute endpoint results met MRP thresholds potentially triggering follow-on activity.

Table 4-19. Detailed sediment toxicity results for dry-season samples exhibiting significant toxicity to *H. azteca.* Shaded cells indicate sampling conducted in WY 2012

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	7/28/12	Lab Control	96.3	0.23	NA
	7/28/12	204R00047	**88.8***	0.24	Not more than 20% < Control
ACCWP	7/14/13	Lab Control	91.3	0.28	NA
	7/14/13	204R00447	78.8	**0.15***	No MRP comparison for growth endpoint
	7/14/13	Lab Control	91.3	0.28	NA
	7/14/13	205R00686	87.5	**0.24***	No MRP comparison for growth endpoint
CCCWP	7/28/12	Lab Control	96.3	0.23	NA
	7/28/12	207R00011	**43.8***	0.09	**More than 20% < Control**
	7/28/12	Lab Control	96.3	0.23	NA
	7/28/12	544R00025	**60***	0.23	**More than 20% < Control**
CCCWP	7/14/13	Lab Control	91.3	0.281	NA
	7/14/13	207R00271	**0***	-	**More than 20% < Control**
	7/14/13	Lab Control	91.3	0.281	NA
	7/14/13	544R00281	**53.8***	0.109	**More than 20% < Control**
FSURMP	7/14/13	Lab Control	98.8	0.23	NA
	7/14/13	207R00236	**71.2***	0.09	**More than 20% < Control**
Vallejo	7/26/13	Lab Control	98.8	0.21	NA
	7/26/13	207R05524	97.5	**0.16***	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 Water Years 2012 and 2013 are provided in Table 4-20. 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 six 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 24 PAH compounds reported by the laboratory, including biphenyl. Biphenyl is often not considered to be a member of the PAH class, but as a compound with two benzene rings it can be considered a closely related compound. Biphenyl was not detected in the 10 RMC sediment samples analyzed in Water Year 2012, and was not counted in the list of 23 PAH compounds summed for the “Total PAHs” parameter in the 2013 Urban Creeks Monitoring Report.

Table 4-20. Descriptive statistics for WY 2012 and WY 2013 sediment chemistry results[1]

Analyte	N	N ≥ MDL	Min	Max	Max Detected	Mean
Acenaphthene	12	2	<3.1	48	48	16
Acenaphthylene	12	1	<3.1	7.1	7.1	12
Anthracene	12	1	<3.1	220	220	30
Arsenic	12	12	2.1	26	26	7
Benz(a)anthracene	12	3	<3.1	700	700	72
Benzo(a)pyrene	12	2	<3.1	230	230	34
Benzo(b)fluoranthene	12	4	<3.1	430	430	61
Benzo(e)pyrene	12	2	<3.1	170	170	33
Benzo(g,h,i)perylene	12	3	<3.1	230	230	38
Benzo(k)fluoranthene	12	1	<3.1	170	170	26
Bifenthrin	12	12	<0.19	58	58	15
Biphenyl	12	1	<3.4	<610	11	66
Cadmium	12	12	<0.066	0.72	0.72	0.3
chlordane, cis-	12	0	<1.3	<21	NA	2
chlordane, trans-	12	0	<1.3	<21	NA	2
Chromium	12	12	<8.5	58	58	29
Chrysene	12	4	<3.1	870	870	92
Copper	12	12	8.6	92	92	33
Cyfluthrin, total	12	10	<0.31	15	15	5
Cyhalothrin, lambda, total	12	3	<0.076	4.2	4.2	1
Cypermethrin, total	12	5	<0.13	3.6	3.6	1
DDD(o,p')	12	0	<0.58	<43	NA	4
DDD(p,p')	12	3	<1.2	17	17	4
DDE(o,p')	12	0	<0.52	<43	NA	4
DDE(p,p')	12	4	<1.3	240	240	24
DDT(o,p')	12	1	<0.6	4.7	4.7	5
DDT(p,p')	12	1	<0.8	9.2	9.2	2
Deltamethrin/Tralomethrin	12	6	<0.15	23	23	3
Dibenz(a,h)anthracene	12	0	<3.1	<92	NA	12
Dibenzothiophene	12	1	<3.4	44	44	70
Dieldrin	12	0	<1.4	<92	NA	3
Dimethylnaphthalene, 2,6-	12	8	<3.1	360	360	84
Endrin	12	0	<0.78	<11	NA	2
Esfenvalerate/Fenvalerate, total	12	1	<0.16	1.2	1.2	0.4
Fluoranthene	12	8	<3.1	2100	2100	243
Fluorene	12	1	<3.1	67	67	17
HCH, gamma-	12	0	<0.66	<15	NA	2
Heptachlor epoxide	12	0	<0.63	<17	NA	2
Indeno(1,2,3-c,d)pyrene	12	1	<3.1	220	220	30
Lead	12	12	4.9	51	51	16
Mercury	12	12	<0.025	0.29	0.29	0.1
Methylnaphthalene, 1-	12	0	<3.1	<92	NA	12
Methylnaphthalene, 2-	12	0	<3.1	<92	NA	12
Methylphenanthrene, 1-	12	0	<3.1	<92	NA	12
Naphthalene	12	2	<3.1	14	14	13
Nickel	12	12	9.8	96	96	40
Permethrin, cis-	12	7	<0.14	9.3	9.3	3
Permethrin, trans-	12	3	<0.14	2.4	2.4	1
Perylene	12	1	<3.1	54	54	16
Phenanthrene	12	5	<3.1	1100	1100	117
Pyrene	12	9	<3.1	1900	1900	233
Total Organic Carbon	12	12	<0.38	9.2	9.2	3
Zinc	12	12	<9.8	740	740	187

[1] “N” = number of samples; “N > MDL” = number of samples detected above the laboratory method detection limit

4.3.2 Stressor Analysis

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"; SF Bay Water Board, 2013), the California Toxics Rule (CTR) (USEPA, 2000a), and various USEPA sources. Of the 11 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 4-21.

For ammonia, the standard provided in the 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,[17] 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 Criterion Continuous Concentration (CCC) of 230 mg/L (USEPA Water Quality Criteria)[18] for the protection of aquatic life were used for comparison purposes.[19]

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.

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

[18] 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.

[19] 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 4-21. Water quality thresholds available for comparison to Water Year 2012 and 2013 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 4-21 are shown in Table 4-22. The results for these three constituents are plotted against the prevailing thresholds on Figures 4-2 through 4-4. Of the 68 sites monitored, the water quality standard was exceeded at one site for chloride (204R00068 in 2012).[20] Two results (sites 205R00686 and 207R03504, both sampled in 2013) exceeded the un-ionized ammonia standard.[21] No samples exceeded the nitrate + nitrite standard. The MRP Table 8.1 trigger criterion for “Nutrients” (20% of results in one water body exceed one or more water quality standards or applicable thresholds) was therefore considered to be exceeded at only 3 of the 68 sites.

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[20] 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.

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

Table 4-22. Comparison of water quality (nutrient) data to associated water quality thresholds for WY 2012 and WY 2013 water chemistry results. (NDs estimated as ½ MDL). Shaded cells indicates monitoring conducted in WY 2012

				Parameter and Threshold				
County/ Program	Site Code	Alameda Creek Above Niles	MUN	Un-ionized Ammonia (as N)	Chloride	Nitrate + Nitrite (as N)	# of Parameters >Threshold/ Water Body	% of Parameters >Threshold/ Water Body
				25 µg/L	230/250 mg/L [1]	10 mg/L [2]		
ACCWP	204R00047			25.0	97	NA	0	0%
ACCWP	204R00068	X		10.1	**410**	NA	1	**50%**
ACCWP	204R00084	X		0.14	64	NA	0	0%
ACCWP	204R00100	X		2.27	87	NA	0	0%
ACCWP	204R00191	X	X	1.26	57	0.26	0	0%
ACCWP	204R00303			2.48	46	NA	0	0%
ACCWP	204R00319			4.36	24	NA	0	0%
ACCWP	204R00340	X		1.47	160	NA	0	0%
ACCWP	204R00356	X		3.10	110	NA	0	0%
ACCWP	204R00367			1.59	54	NA	0	0%
ACCWP	204R00383			1.46	54	NA	0	0%
ACCWP	204R00391			1.47	93	NA	0	0%
ACCWP	204R00455			1.20	36	NA	0	0%
ACCWP	204R00583			5.67	51	NA	0	0%
ACCWP	204R00596	X		0.67	240	NA	0	0%
ACCWP	204R00639		X	8.99	64	0.06	0	0%
ACCWP	204R00647			0.67	39	NA	0	0%
ACCWP	205R00110			1.16	32	NA	0	0%
ACCWP	205R00430			4.61	80	NA	0	0%
ACCWP	205R00535			0.87	110	NA	0	0%
ACCWP	203R00983			0.47	17	NA	0	0%
ACCWP	204R00063			2.53	29	NA	0	0%
ACCWP	204R00327			0.72	39	NA	0	0%
ACCWP	204R00334	x	x	0.32	63	0.07	0	0%
ACCWP	204R0044	x		6.04	230	NA	0	0%

County/ Program	Site Code	Alameda Creek Above Niles	MUN	Parameter and Threshold			# of Parameters >Threshold/ Water Body	% of Parameters >Threshold/ Water Body
				Un-ionized Ammonia (as N)	Chloride	Nitrate + Nitrite (as N)		
				25 µg/L	230/250 mg/L [1]	10 mg/L [2]		
	7							
ACCWP	204R00473	x		1.45	42	NA	0	0%
ACCWP	204R00590	x	x	2.63	50	0.01	0	0%
ACCWP	204R00623			2.34	47	NA	0	0%
ACCWP	204R00724	x		0.49	79	NA	0	0%
ACCWP	204R00751			0.28	29	NA	0	0%
ACCWP	204R00852	x		0.79	130	NA	0	0%
ACCWP	204R00967			2.81	110	NA	0	0%
ACCWP	204R01316	x		2.16	120	NA	0	0%
ACCWP	204R01471	x		1.92	190	NA	0	0%
ACCWP	205R00174			3.98	150	NA	0	0%
ACCWP	205R00686			**46.55**	140	NA	1	**50%**
ACCWP	205R00878			6.75	68	NA	0	0%
ACCWP	205R01134			0.00	30	NA	0	0%
ACCWP	205R01198			0.00	94	NA	0	0%
ACCWP	205R01390			0.49	90	NA	0	0%
CCCWP	203R00039			1.41	38	NA	0	0%
CCCWP	206R00155			2.57	23	NA	0	0%
CCCWP	206R00215			0.51	97	NA	0	0%
CCCWP	207R00011			5.23	80	NA	0	0%
CCCWP	207R00139			1.40	40	NA	0	0%
CCCWP	207R00247			4.05	46	NA	0	0%
CCCWP	543R00137			9.49	210	NA	0	0%
CCCWP	543R00219			3.57	140	NA	0	0%
CCCWP	543R00245			0.19	180	NA	0	0%
CCCWP	544R00025			2.30	160	NA	0	0%
CCCWP	206R00727			3.19	39	NA	0	0%

County/ Program	Site Code	Alameda Creek Above Niles	MUN	Parameter and Threshold			# of Parameters >Threshold/ Water Body	% of Parameters >Threshold/ Water Body
				Un-ionized Ammonia (as N)	**Chloride**	**Nitrate + Nitrite (as N)**		
				25 µg/L	**230/250 mg/L [1]**	**10 mg/L [2]**		
CCCWP	207R00271			0.00	23	NA	0	0%
CCCWP	207R00375			1.05	160	NA	0	0%
CCCWP	207R00395			3.15	43	NA	0	0%
CCCWP	207R00503			6.11	110	NA	0	0%
CCCWP	207R00532			13.74	62	NA	0	0%
CCCWP	207R00567			0.69	110	NA	0	0%
CCCWP	207R00631			3.42	83	NA	0	0%
CCCWP	207R00788			2.84	35	NA	0	0%
CCCWP	544R00281			7.75	130	NA	0	0%
FSURMP	207R00428			1.13	48	NA	0	0%
FSURMP	207R00476			0.04	17	NA	0	0%
FSURMP	207R00556			0.90	61	NA	0	0%
FSURMP	207R01452			1.69	46	NA	0	0%
Vallejo	207R03504			**112.69**	34	NA	1	**50%**
Vallejo	207R04080			10.28	44	NA	0	0%
Vallejo	207R00688			13.50	35	NA	0	0%
Vallejo	207R00064			3.61	38	NA	0	0%
# Values >Threshold:				2	1	0		
% Values >Threshold:				3%	1%	0%		
Overall Number and % of Sites Meeting Trigger Criterion [3]:							**3**	**4%**

[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.

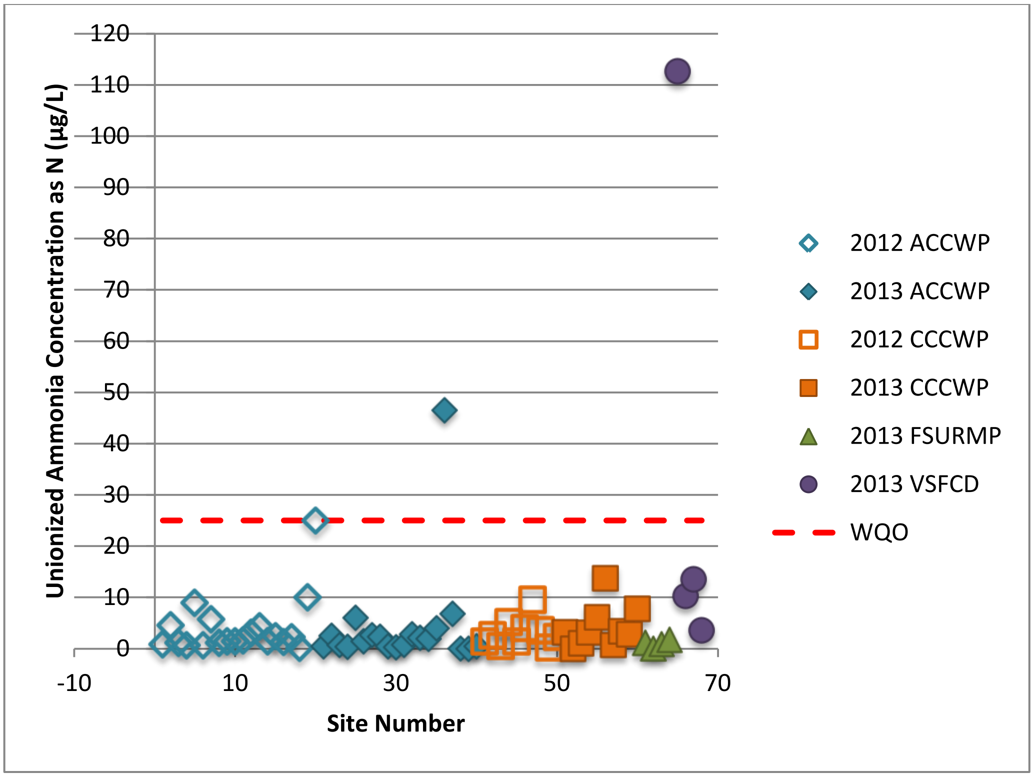

Figure 4-2. Plot of unionized ammonia (calculated from total ammonia, pH, temperature, and electrical conductivity) with threshold indicated, WY 2012 and WY 2013 data.

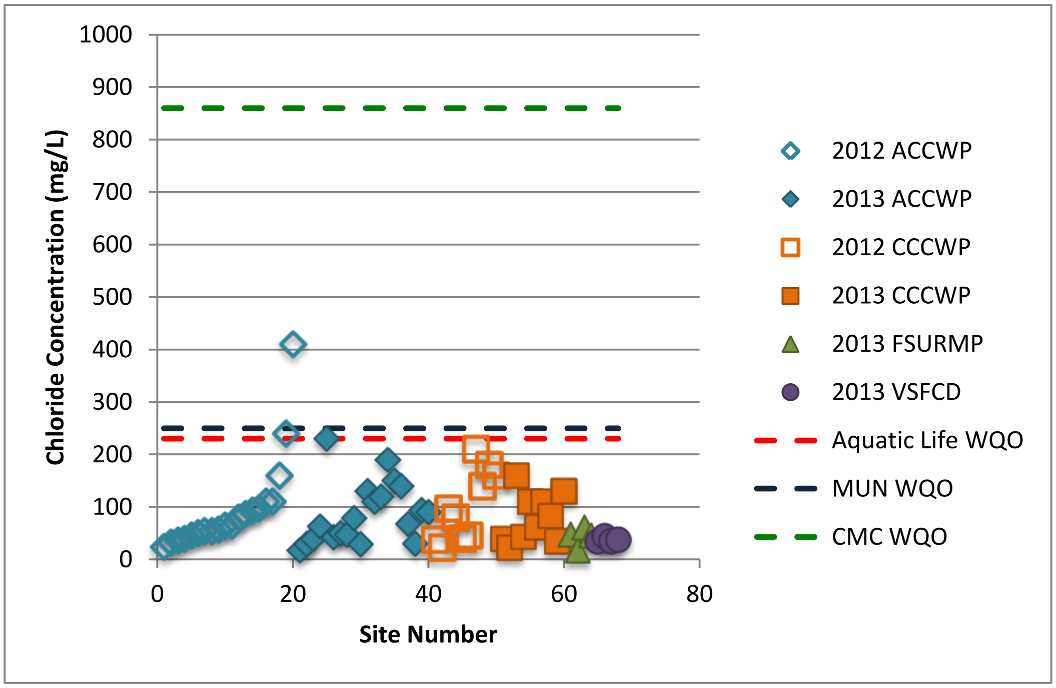

Figure 4-3. Plot of chloride with Aquatic Life and MUN thresholds indicated, WY 2012 and WY 2013 data

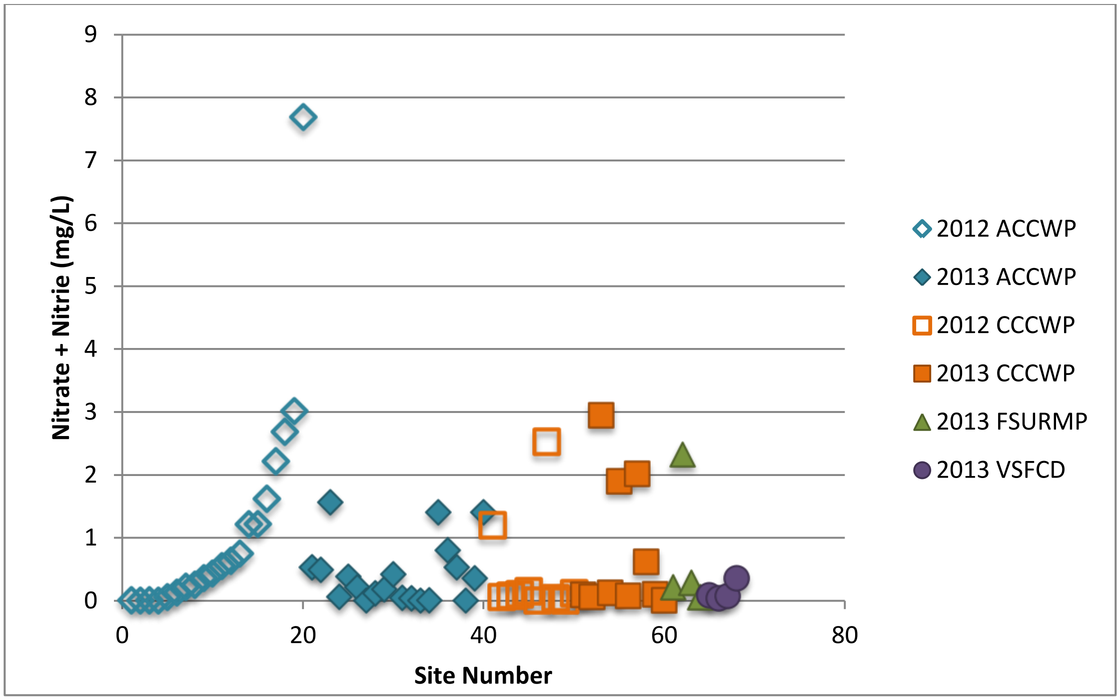

Figure 4-4. Plot of nitrate and nitrite as N, WY 2012 and WY 2013 data (threshold not shown = 10 mg/L for MUN only).

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 4-23. The MRP trigger criterion for chlorine states, "After immediate resampling, concentrations remain >0.08 mg/L."

There were 35 site measurements for free and total chlorine in 2012 collected by ACCWP and CCCWP, 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 total. Overall, the percentage of samples meeting the trigger threshold for free and/or total chlorine was 19%.

Table 4-23. Summary of chlorine testing results (mg/L) for samples collected in WY 2012 and WY 2013 in comparison to Municipal Regional Permit trigger criteria. Shaded cells represent data collected in WY 2012

County/ Program	Site Code	Sample Date	Chlorine, Free	Chlorine, Total	Meets Trigger Threshold?
ACCWP	204R00047	6/6/12	**0.12**	0.08	**Yes**
ACCWP	204R00047	7/25/12	<0.04	0.04	No
ACCWP	204R00068	5/31/12	<0.04	0.04	No
ACCWP	204R00084	5/24/12	<0.04	**0.10**	**Yes**
ACCWP	204R00084	7/25/12	<0.04	<0.04	No
ACCWP	204R00100	5/30/12	**0.12**	0.04	**Yes**
ACCWP	204R00100	7/25/12	**0.12**	0.08	**Yes**
ACCWP	204R00191	5/29/12	**0.10**	<0.04	**Yes**
ACCWP	204R00303	6/14/12	<0.04	<0.04	No
ACCWP	204R00319	6/7/12	<0.04	<0.04	No
ACCWP	204R00340	6/11/12	0.08	0.08	No
ACCWP	204R00356	6/4/12	0.04	0.04	No
ACCWP	204R00367	6/12/12	<0.04	<0.04	No
ACCWP	204R00383	6/11/12	**0.12**	**0.12**	**Yes**
ACCWP	204R00391	6/6/12	<0.04	<0.04	No
ACCWP	204R00455	6/13/12	**0.10**	<0.04	**Yes**
ACCWP	204R00583	6/13/12	**0.12**	**0.16**	**Yes**
ACCWP	204R00596	5/31/12	**0.12**	**0.12**	**Yes**
ACCWP	204R00639	6/19/12	0.04	0.04	No
ACCWP	204R00647	6/18/12	<0.04	<0.04	No
ACCWP	205R00110	6/18/12	<0.04	<0.04	No
ACCWP	205R00430	6/5/12	0.04	<0.04	No
ACCWP	205R00535	6/20/12	<0.04	<0.04	No
ACCWP	203R00983	6/6/13	<0.04	<0.04	No
ACCWP	204R00063	6/4/13	<0.04	<0.04	No
ACCWP	204R00327	5/7/13	<0.04	<0.04	No
ACCWP	204R00334	5/8/13	<0.04	<0.04	No
ACCWP	204R00447	4/22/13	0.06	<0.04	No
ACCWP	204R00473	5/9/13	<0.04	<0.04	No
ACCWP	204R00590	5/8/13	<0.04	<0.04	No
ACCWP	204R00623	6/3/13	<0.04	<0.04	No
ACCWP	204R00724	5/21/13	0.04	**0.2**	**Yes**
ACCWP	204R00751	6/5/13	<0.04	<0.04	No
ACCWP	204R00852	5/6/13	<0.04	<0.04	No
ACCWP	204R00967	4/25/13	<0.04	<0.04	No
ACCWP	204R01316	5/22/13	0.04	<0.04	No
ACCWP	204R01471	5/22/13	**0.12**	**0.16**	**Yes**
ACCWP	205R00174	4/23/13	<0.04	<0.04	No
ACCWP	205R00686	4/24/13	<0.04	<0.04	No
ACCWP	205R00878	4/24/13	<0.04	<0.04	No
ACCWP	205R01134	5/20/13	<0.04	<0.04	No
ACCWP	205R01198	5/20/13	<0.04	<0.04	No

County/ Program	Site Code	Sample Date	Chlorine, Free	Chlorine, Total	Meets Trigger Threshold?
ACCWP	205R01390	5/23/13	<0.04	<0.04	No
ACCWP	204R00327	7/9/13	<0.04	<0.04	No
ACCWP	204R00447	7/9/13	<0.04	<0.04	No
ACCWP	205R00686	7/9/13	<0.04	<0.04	No
CCCWP	203R00039	5/14/12	<0.04	<0.04	No
CCCWP	206R00155	5/16/12	<0.04	<0.04	No
CCCWP	206R00215	5/23/12	<0.04	<0.04	No
CCCWP	207R00011	5/22/12	<0.04	<0.04	No
CCCWP	207R00011	7/25/12	0.04	<0.04	No
CCCWP	207R00139	5/17/12	**0.12**	0.04	**Yes**
CCCWP	207R00247	5/22/12	0.03	0.04	No
CCCWP	543R00137	5/15/12	<0.04	<0.04	No
CCCWP	543R00219	5/21/12	0.04	0.06	No
CCCWP	543R00245	5/21/12	0.04	<0.04	No
CCCWP	544R00025	5/15/12	<0.04	<0.04	No
CCCWP	544R00025	7/25/12	<0.04	**0.12**	**Yes**
CCCWP	206R00727	5/13/13	0.04	0.05	No
CCCWP	207R00271	4/29/13	<0.04	<0.04	No
CCCWP	207R00375	5/1/13	<0.04	<0.04	No
CCCWP	207R00395	5/14/13	0.04	0.04	No
CCCWP	207R00503	5/2/13	<0.04	<0.04	No
CCCWP	207R00532	4/29/13	<0.04	<0.04	No
CCCWP	207R00567	4/30/13	<0.04	<0.04	No
CCCWP	207R00631	5/16/13	<0.04	<0.04	No
CCCWP	207R00788	5/15/13	<0.04	<0.04	No
CCCWP	544R00281	5/15/13	<0.04	<0.04	No
CCCWP	207R00271	7/9/13	<0.04	<0.04	No
CCCWP	544R00281	7/9/13	<0.04	<0.04	No
FSURMP	207R00428	5/21/13	0.06	0.04	No
FSURMP	207R00476	5/23/13	**0.2**	**0.12**	**Yes**
FSURMP	207R00556	5/15/13	NR	**0.2**	**Yes**
FSURMP	207R01452	5/28/13	**0.16**	**0.1**	**Yes**
FSURMP	207R00236	8/14/13	0.07	0.05	No
Vallejo	207R03504	5/29/13	<0.04	<0.04	No
Vallejo	207R04080	5/30/13	<0.04	<0.04	No
Vallejo	207R00688	5/29/13	<0.04	<0.04	No
Vallejo	207R00064	5/28/13	<0.04	<0.04	No
Number of samples exceeding 0.08 mg/L:			12	10	16
Percentage of samples exceeding 0.08 mg/L:			16%	14%	22%

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 4-24 for those Water Year 2012 samples that initially exceeded thresholds.

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.." Therefore the three 2012 water samples indicated in Table 4-24 as having results "< 50% of Control" were retested in 2013.

Three sites were retested in wet season 2013 for the test species that triggered the retest. While the ACCWP retest (site 204R00047) did not exhibit toxicity in the retest, the two CCCWP sites again exhibited significant toxicity to *H. azteca*, with survival less than the MRP trigger of 50% of the Control. Results of these retests are summarized in Table 4-25.

Table 4-24. Overall summary of 2012 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	3/15/12	*H. azteca*	Acute (survival)	204R00047	**<50% of control**
CCCWP	3/15/12	*H. azteca*	Acute (survival)	207R00011	**<50% of control**
CCCWP	3/15/12	*H. azteca*	Acute (survival)	544R00025	**<50% of control**
Sediment					
CCCWP	7/28/12	*H. azteca*	Acute (survival)	207R00011	**More than 20% < control**
CCCWP	7/28/12	*H. azteca*	Acute (survival)	544R00025	**More than 20% < control**

Table 4-25. Overall summary of WY 2013 aquatic toxicity retests triggered by WY 2012 MRP toxicity trigger criteria

County/ Program	Test Initiation Date	Species Tested	Treatment/ Sample ID	10-Day Mean % Survival	Comparison to MRP Table 8.1 Trigger Criteria
ACCWP	3/7/13	*H. azteca*	Lab Control	98	NA
	3/7/13		204R00047	98	No signficant difference
CCCWP	3/7/13	*H. azteca*	Lab Control	98	NA
	3/7/13		207R00011	**4***	**<50% of control**
CCCWP	4/5/13	*H. azteca*	Lab Control	100	NA
	4/5/13		544R00025	**20***	**<50% of control**

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

The analysis of toxicity testing results and comparisons to MRP trigger thresholds are summarized in Table 4-26 for those Water Year 2013 samples that initially exceeded thresholds. In addition to the results identified, there was one additional toxicity test, for *P. promelas* collected at site 207R00271 in July 2013, for which signficiant toxicity was identified in the initial analysis, but the laboratory reported interference from pathogen-related mortality. In the 20-replicate reanalysis (USEPA, 2000) to address PRM identified by the laboratory the toxic response was removed.[22]

Table 4-26. Overall summary of 2013 toxicity results 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					
CCCWP	4/5/13	*H. azteca*	Acute (survival)	544R00281	**< 50% of control**
CCCWP	7/10/13	*H. azteca*	Acute (survival)	207R00271	**< 50% of control**
Sediment					
CCCWP	7/14/13	*H. azteca*	Acute (survival)	544R00281	**More than 20% < control**
CCCWP	7/14/13	*H. azteca*	Acute (survival)	207R00271	**More than 20% < control**
FSURMP	7/14/13	*H. azteca*	Acute (survival)	207R00236	**More than 20% < control**

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.[23]
- 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.
- 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 4-27 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 0 to a high of 13, out of 27 constituents included in the constituent list in MacDonald et al. (2000). Ten of 12 sites sampled met the relevant trigger criterion from MRP Table H-1, which is

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[22] See discussion in Section 4.3.1, Dry Season Aquatic Toxicity, and Table 4-14.

[23] 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.”

interpreted to stipulate three or more constituents with TEC quotients greater than or equal to 1.0.

Table 4-28 provides PEC quotients for all non-pyrethroid sediment chemistry constituents, and calculated mean values of the PEC quotients for each site, with the mean PEC quotient highlighted for sites where mean PEC quotient greater than or equal to 0.5. One site (544R00025) met the MRP Table H-1 action criteria with a mean PEC greater than 0.5. The mean PEC quotients are shown graphically by site on Figure 4-5.

Table 4-29 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. Eight of the 12 sites meet the MRP Table H-1 action criterion with at least one TU quotient greater than or equal to 1.0. These results are shown graphically on Figure 4-6. In most cases, the greatest contributor to the TU sum is bifenthrin (greater than 1.0 TU in 6 of the 12 samples). Both deltamethrin and cyfluthrin exceeded 1.0 TUs in 1 of the 12 samples.

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.

In assessing the effect of using one-half of the MDL in place of one-half of the MRL to estimate ND results for statistical purposes, relatively large differences were observed in some cases for the 2012 assessments reported in the UCMR (BASMAA, 2013), which have been recalculated for this report. For example, assessments for trace metals remain unchanged, as there were no NDs reported for any of the metals analyzed. In comparison, calculated TEC quotients for individual and total PAHs are lower across-the-board using the MDL due to the relatively large proportion of NDs and the difference between MDLs and MRLs reported. For example, for site 204R00047, the number of TEC quotients above the 1.0 threshold dropped from six to one. Similar to the case for PAHs, the TEC quotients for OC pesticides dropped associated with the change in estimation technique. However, there remain multiple cases where the TEC quotient is greater than 1.0; it should be noted that 2012 analyses are predominantly non-detects, and therefore that the TEC quotients calculated are driven by the MDL rather than quantified laboratory results. TEC quotients for OC pesticides calculated for this report are approximately one-half of UCMR reported values.

Table 4-27. Threshold Effect Concentration (TEC) quotients for 2012 and 2013 sediment chemistry constituents

Stormwater Program, Site ID	**ACCWP 204R00047 (2012)**	**ACCWP 204R00084 (2012)**	**ACCWP 204R00100 (2012)**	**ACCWP 204R00327 (2013)**	**ACCWP 204R00447 (2013)**	**ACCWP 205R00686 (2013)**	**CCCWP 207R00011 (2012)**	**CCCWP 544R00025 (2012)**
Metals (mg/kg DW)								
Arsenic	0.32	0.55	0.51	0.26	0.84	0.25	0.21	0.46
Cadmium	0.23	0.63	0.08	0.55	0.73	0.17	0.07	0.16
Chromium	0.20	0.76	**1.34**	0.55	**1.24**	0.21	0.20	0.65
Copper	0.70	0.70	0.85	0.76	**2.91**	0.92	0.27	0.89
Lead	0.36	0.59	0.25	**1.42**	0.59	0.17	0.18	0.36
Mercury	0.28	0.21	**1.61**	0.67	0.83	0.22	0.83	0.14
Nickel	0.57	**1.32**	**4.23**	**1.15**	**3.30**	0.57	0.43	**1.15**
Zinc	**1.40**	0.79	0.44	**1.32**	**6.12**	**3.14**	0.38	0.74
PAHs (µg/kg DW)								
Anthracene	0.45	0.19	0.04	**3.85**	0.09	0.07	0.53	0.80
Fluorene	0.33	0.14	0.03	0.87	0.06	0.05	0.39	0.59
Naphthalene	0.14	0.06	0.01	0.08	0.07	0.02	0.17	0.26
Phenanthrene	0.69	0.05	0.01	**5.39**	0.14	0.12	0.15	0.23
Benz(a)anthracene	0.24	0.10	0.02	**6.48**	0.12	0.20	0.28	0.43
Benzo(a)pyrene	0.41	0.07	0.02	**1.53**	0.03	0.03	0.20	0.31
Chrysene	0.15	0.07	0.01	**5.24**	0.31	0.29	0.18	0.28
Fluoranthene	0.90	0.15	0.01	**4.96**	0.10	0.12	0.50	0.11
Pyrene	**2.15**	0.36	0.01	**9.74**	0.23	0.38	**1.03**	0.24
Total PAHs	**1.31**	0.34	0.05	**5.38**	0.20	0.40	**1.04**	**1.01**
Pesticides (µg/kg DW)								
Chlordane	**6.48**	0.90	0.49	0.40	0.65	0.52	**2.59**	**4.01**
Dieldrin	**6.84**	0.92	0.50	0.37	0.61	0.50	**2.63**	**3.95**
Endrin	**2.48**	0.34	0.18	0.34	0.54	0.45	0.95	**1.44**
Heptachlor Epoxide	**3.44**	0.47	0.24	0.13	0.40	0.17	**1.36**	**2.02**
Lindane (gamma-BHC)	**3.16**	0.42	0.23	0.14	0.44	0.18	**1.24**	**1.88**
Sum DDD	**6.15**	**4.08**	0.44	0.76	0.35	0.28	**2.43**	**5.43**
Sum DDE	**10.92**	**1.47**	0.79	0.94	**2.12**	0.38	**4.27**	**79.91**
Sum DDT	**6.73**	**2.91**	0.48	**1.23**	0.27	0.23	**2.64**	**3.92**
Total DDTs	**17.52**	**6.94**	**1.26**	**2.23**	**1.81**	0.66	**6.88**	**55.93**
Number of constituents with TEC quotient ≥ 1.0	**12**	**5**	**4**	**13**	**6**	**1**	**10**	**11**

Note: Bolded values indicate TEC quotient ≥ 1.0.

Stormwater Program, Site ID	CCCWP 207R00271 (2013)	CCCWP 544R00281 (2013)	FSURMP 207R00236 (2013)	Vallejo 207R05524 (2013)
Metals (mg/kg DW)				
Arsenic	0.25	0.72	**1.12**	**2.66**
Cadmium	0.08	0.20	0.15	0.23
Chromium	0.28	0.92	0.99	0.81
Copper	0.31	**1.08**	**1.68**	**1.55**
Lead	0.14	0.27	0.53	0.39
Mercury	0.23	0.46	0.23	**1.00**
Nickel	0.57	**3.22**	**2.42**	**2.03**
Zinc	0.46	0.99	**1.32**	**1.40**
PAHs (µg/kg DW)				
Anthracene	0.03	0.06	0.10	0.09
Fluorene	0.02	0.04	0.07	0.06
Naphthalene	0.01	0.02	0.03	0.03
Phenanthrene	0.01	0.02	0.03	0.05
Benz(a)anthracene	0.01	0.03	0.05	0.05
Benzo(a)pyrene	0.01	0.02	0.04	0.03
Chrysene	0.01	0.04	0.03	0.03
Fluoranthene	0.00	0.02	0.01	0.03
Pyrene	0.01	0.04	0.08	0.10
Total PAHs	0.02	0.10	0.10	0.13
Pesticides (µg/kg DW)				
Chlordane	0.40	0.43	0.69	0.65
Dieldrin	0.37	0.39	0.63	0.61
Endrin	0.34	0.36	0.59	0.54
Heptachlor Epoxide	0.13	0.14	0.22	0.20
Lindane (gamma-BHC)	0.14	0.15	0.23	0.23
Sum DDD	0.21	0.23	0.37	0.35
Sum DDE	0.29	**4.20**	0.47	0.45
Sum DDT	0.17	0.18	0.29	0.27
Total DDTs	0.50	**2.86**	0.85	0.80
Number of constituents with TEC quotient $\geq$ 1.0	**0**	**4**	**4**	**5**

Table 4-28. Probable Effect Concentration (PEC) quotients for WY 2012 and WY 2013 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	ACCWP 204R00047 (2012)	ACCWP 204R00084 (2012)	ACCWP 204R00100 (2012)	ACCWP 204R00327 (2013)	ACCWP 204R00447 (2013)	ACCWP 205R00686 (2013)	CCCWP 207R00011 (2012)	CCCWP 544R00025 (2012)
Metals (mg/kg DW)								
Arsenic	0.09	0.16	0.15	0.08	0.25	0.07	0.06	0.14
Cadmium	0.05	0.12	0.02	0.11	0.14	0.03	0.01	0.03
Chromium	0.08	0.30	0.52	0.22	0.49	0.08	0.08	0.25
Copper	0.15	0.15	0.18	0.16	0.62	0.19	0.06	0.19
Lead	0.10	0.16	0.07	0.40	0.16	0.05	0.05	0.10
Mercury	0.05	0.03	0.27	0.11	0.14	0.04	0.14	0.02
Nickel	0.27	0.62	**1.98**	0.53	**1.54**	0.27	0.20	0.53
Zinc	0.37	0.21	0.12	0.35	**1.61**	0.83	0.10	0.19
PAHs (µg/kg DW)								
Anthracene	0.03	0.01	0.00	0.26	0.01	0.00	0.04	0.05
Fluorene	0.05	0.02	0.00	0.13	0.01	0.01	0.06	0.09
Naphthalene	0.05	0.02	0.00	0.02	0.02	0.01	0.05	0.08
Phenanthrene	0.12	0.01	0.00	0.94	0.02	0.02	0.03	0.04
Benz(a)anthracene	0.02	0.01	0.00	0.67	0.01	0.02	0.03	0.04
Benzo(a)pyrene	0.04	0.01	0.00	0.16	0.00	0.00	0.02	0.03
Chrysene	0.02	0.01	0.00	0.67	0.04	0.04	0.02	0.04
Fluoranthene	0.17	0.03	0.00	0.94	0.02	0.02	0.09	0.02
Pyrene	0.28	0.05	0.00	**1.25**	0.03	0.05	0.13	0.03
Total PAHs	0.09	0.02	0.00	0.38	0.01	0.03	0.07	0.07
Pesticides (µg/kg DW)								
Chlordane	**1.19**	0.16	0.09	0.07	0.12	0.10	0.48	0.74
Dieldrin	0.21	0.03	0.02	0.01	0.02	0.02	0.08	0.12
Endrin	0.03	0.00	0.00	0.00	0.01	0.00	0.01	0.02
Heptachlor Epoxide	0.53	0.07	0.04	0.02	0.06	0.03	0.21	0.31
Lindane (gamma-BHC)	**1.50**	0.20	0.11	0.07	0.21	0.09	0.59	0.89
Sum DDD	**1.07**	0.71	0.08	0.13	0.06	0.05	0.42	0.95
Sum DDE	**1.10**	0.15	0.08	0.09	0.21	0.04	0.43	**8.07**
Sum DDT	0.45	0.19	0.03	0.08	0.02	0.01	0.17	0.26
Total DDTs	0.16	0.06	0.01	0.02	0.02	0.01	0.06	0.52
Mean PEC Quotient	0.31	0.13	0.14	0.29	0.22	0.08	0.14	**0.51**

Stormwater Program, Site ID	CCCWP 207R00271 (2013)	CCCWP 544R00281 (2013)	FSURMP 207R00236 (2013)	Vallejo 207R05524 (2013)
Metals (mg/kg DW)				
Arsenic	0.07	0.21	0.33	0.79
Cadmium	0.02	0.04	0.03	0.05
Chromium	0.11	0.36	0.39	0.32
Copper	0.07	0.23	0.36	0.33
Lead	0.04	0.08	0.15	0.11
Mercury	0.04	0.08	0.04	0.17
Nickel	0.27	**1.50**	**1.13**	0.95
Zinc	0.12	0.26	0.35	0.37
PAHs (µg/kg DW)				
Anthracene	0.00	0.00	0.01	0.01
Fluorene	0.00	0.01	0.01	0.01
Naphthalene	0.00	0.01	0.01	0.01
Phenanthrene	0.00	0.00	0.00	0.01
Benz(a)anthracene	0.00	0.00	0.01	0.00
Benzo(a)pyrene	0.00	0.00	0.00	0.00
Chrysene	0.00	0.01	0.00	0.00
Fluoranthene	0.00	0.00	0.00	0.01
Pyrene	0.00	0.00	0.01	0.01
Total PAHs	0.00	0.01	0.01	0.01
Chlordane	0.07	0.08	0.13	0.12
Dieldrin	0.01	0.01	0.02	0.02
Endrin	0.00	0.00	0.01	0.01
Heptachlor Epoxide	0.02	0.02	0.03	0.03
Lindane (gamma-BHC)	0.07	0.07	0.11	0.11
Sum DDD	0.04	0.04	0.06	0.06
Sum DDE	0.03	0.42	0.05	0.05
Sum DDT	0.01	0.01	0.02	0.02
Total DDTs	0.00	0.03	0.01	0.01
Mean PEC Quotient	0.04	0.13	0.12	0.13

Table 4-29. Calculated pyrethroid toxic unit equivalents, 2012 and 2013 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 (ng/g dw)	ACCWP 204R00047 (2012)	ACCWP 204R00084 (2012)	ACCWP 204R00100 (2012)	ACCWP 204R00327 (2013)	ACCWP 204R00447 (2013)	ACCWP 205R00686 (2013)	CCCWP 207R00011 (2012)	CCCWP 544R00025 (2012)
Bifenthrin	0.52	**1.756**	0.370	0.096	0.14	**1.21**	0.14	**1.469**	**3.302**
Cyfluthrin	1.08	0.201	0.028	**2.680**	0.02	0.05	0.19	0.302	0.043
Cypermethrin	0.38	0.137	0.072	0.045	0.04	0.02	0.01	0.163	0.112
Deltamethrin	0.79	0.083	0.041	0.025	0.01	0.06	0.05	0.092	0.064
Esfenvalerate	1.54	0.016	0.023	0.014	0.00	0.00	0.00	0.051	0.036
Lambda-Cyhalothrin	0.45	0.025	0.036	0.022	0.02	0.01	0.01	0.081	0.056
Permethrin	10.83	0.028	0.006	0.003	0.02	0.01	0.00	0.012	0.009
Sum of Toxic Unit Equivalents per Site		**2.245**	0.575	**2.886**	0.26	**1.37**	0.41	**2.17**	**3.62**

Pyrethroid	LC50 (ng/g dw)	CCCWP 207R00271 (2013)	CCCWP 544R00281 (2013)	FSURMP 207R00236 (2013)	Vallejo 207R05524 (2013)
Bifenthrin	0.52	**4.58**	0.96	**3.17**	0.12
Cyfluthrin	1.08	0.96	0.04	0.76	0.04
Cypermethrin	0.38	0.10	0.01	0.56	0.01
Deltamethrin	0.79	**4.62**	0.01	0.11	0.00
Esfenvalerate	1.54	0.01	0.00	0.05	0.00
Lambda-Cyhalothrin	0.45	0.13	0.01	0.55	0.01
Permethrin	10.83	0.08	0.00	0.06	0.00
Sum of Toxic Unit Equivalents per Site		**10.48**	**1.03**	**5.26**	0.19

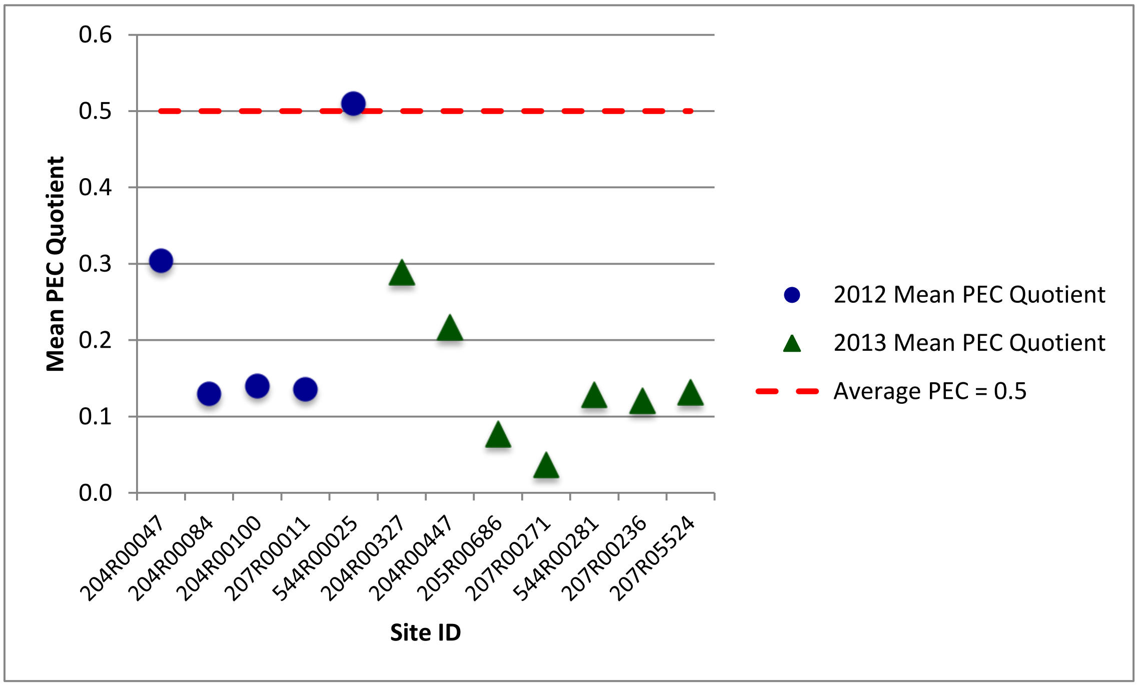

Figure 4-5. Plot of mean PEC quotient per site, WY 2012 and WY 2013 data

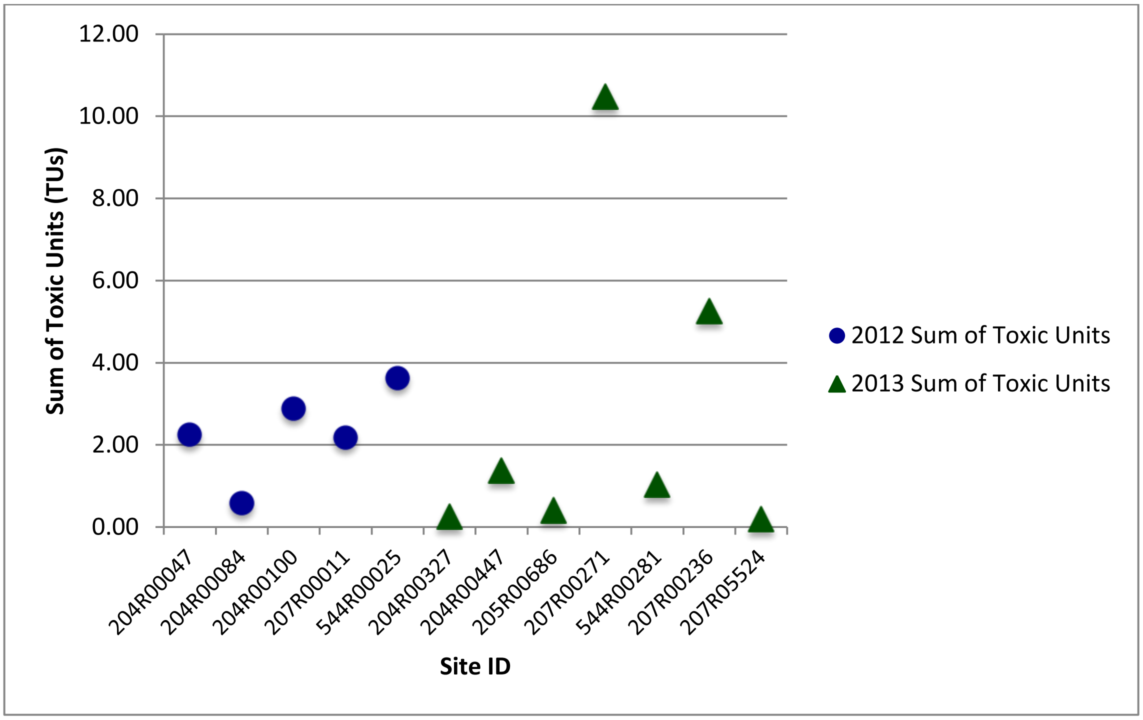

Figure 4-6. Plot of the sum of pyrethroid toxic unit equivalents per site, WY 2012 and WY 2013 data

Sediment Triad Analysis

Table 4-30 summarizes stressor evaluation results for those sites with data collected for sediment chemistry, sediment toxicity, and bioassessment parameters. Biological condition assessments are shown using a provisional regional consensus approach based on the SoCal B-IBI.

Table 4-30. Summary of sediment quality triad evaluation results, WY 2012 (shaded cells) and WY 2013 data. Yellow highlighted cells indicate results above MRP trigger threshold

Agency / Program	Water Body	Site ID	B-IBI Condition Category	Sediment Toxicity	# TEC Quotients ≥ 1.0:	Mean PEC Quotient	Sum of TU Equiv.	Next Step per MRP Table H-1
CCCWP	Grayson Creek	207R00011	Very Poor	Yes	10	0.14	2.17	C
CCCWP	Dry Creek	544R00025	Very Poor	Yes	11	0.51	3.62	C
CCCWP	Sycamore Creek	207R00271	Very Poor	Yes	0	0.04	10.48	C
CCCWP	Marsh Creek	544R00281	Very Poor	Yes	4	0.13	1.03	C

Key to Next Steps:

Action Code	Exceeds Bioassessment/ Toxicity/ Chemistry Threshold	Next Step per MRP Table H-1
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 dentify cause and spatial extent. (3) Where impacts are under Permittee's control, take management actions to minimize upstream sources.

While MacDonald (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 PAHs (anthracene, fluorine, and fluoranthene) and OC pesticides (dieldrin, DDDs, DDTs, endrin, heptachlor epoxide, and lindane).

Additionally, MacDonald (2000) TECs and PECs were generated with the assumption that the predictive ability of the thresholds would be acceptable if the prediction were correct 75% of the time. For the 12 samples collected by the four contributing programs, a single sample exceeded the mean PEC criterion of 0.5; significant toxicity was reported associated with this sample (Table 4-27). For the one sample in which more than three analytes exceeded associated PECs, statistically significant toxicity was not reported.

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). Half of the 12 samples analyzed by the four collaborating programs in Water Years 2012 and 2013 fell within this range (Table 4-29). This uncertainty can potentially be seen in the RMC results where a sample with a pyrethroid TU of 1.0 was associated with a toxic sample, and one with a TU of 2.9 was not (Table 4-29).

5.0 Conclusions and Next Steps

During water years 2012 and 2013, 68 sites were monitored by the four Programs contributing to this report under the RMC regional probabilistic design for bioassessment, physical habitat, and related water chemistry parameters. Twelve 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 conjuction 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 water body names, and latitutdes and longitudes); sample ID, collection date (and time where relevant), and 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 Water Year 2013 may continue to be evaluated by the individual stormwater programs for potential sampling in Water Year 2014.

5.1 Summary of Stressor Analyses

The stressor analysis revealed the following potential stressors, based on an analysis of the first two years of data collection activities collected by the four Programs under the RMC umbrella:

- **Water Quality –** Of 11 parameters[24] 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 68 sites monitored by the four collaborating programs reporting herein for those three parameters, only two un-ionized ammonia concentrations and one chloride concentration exceeded the applicable water quality standard or threshold; each of these occurred at different sites. The MRP Table 8.1 trigger thresholds for “Nutrients”

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[24] Algal mass (ash-free dry weight), chlorophyll-a, dissolved organic carbon, ammonia, nitrate, total nitrogen, dissolved orthophosphate, phosphorus, suspended sediment concentration, silica, and chloride.

(i.e., 20% of results in one water body exceed one or more water quality standards or applicable thresholds) was therefore exceeded at only three of the 68 sites.

- **Water Toxicity –** A total of 96 toxicity endpoints were derived through testing of four species at 24 sites regionwide during two wet-season and two dry-season events. Of these endpoints, samples from five sites exhibited significant toxicity to at least one test species with survival and/or growth “<50% of Control,” indicating retesting per MRP Table 8.1. Three of these were the result of monitoring in Water Year 2012, and they were retested in Water Year 2013. Of these three retests, two exhibited a toxic response at levels meeting MRP thresholds.
- **Sediment Toxicity –** Of the bedded sediment collected from 12 sites, a toxic response in test species *H. azteca* was observed at 9 sites. Results were more than 20% less than the control at 5 of these sites, exceeding the Table H-1 sediment toxicity threshold.
- **Sediment Chemistry –** Results produced evidence of potential stressors in three ways, based on the criteria from MRP Table H-1: **(**1) at 10 of 12 sites, 3 or more constituents exhibited TEC quotients greater than 1.0,[25] (2) at 1 of 12 sites, the mean PEC quotient was > 0.5, and (3) at 8 of 12 sites, the sum of TU equivalents for all measured pyrethroids was greater than or equal to 1.0.
- **Sediment Triad Analyses (partial) –** 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 discussed in Appendix A.1.

5.2 Next Steps

The preceding analysis has identified a number of potential sites that may deserve further evaluation and/or investigation to provide better understanding of the sources/stressors that may be contributing to reduced water quality and lower biological condition at these sites. During Water Year 2013, the RMC collaboratively reviewed trigger results from Water Year 2012 and selected a total of 10 sites in four counties for implementation of SSID projects based on prioritization of the type, extent, and geographic spread of the triggers. A summary of CCCWP’s SSID projects is included in IMR Part A section A.4, regarding projects which are to be initiated by the second Fiscal Year following the year in which the potential stressor was identified.

RMC participants will continue to implement the regional probabilistic monitoring design in Water Year 2014. Site evaluation and sampling are planned at new sites for this Water Year, as well as resampling and retesting as required to complete the evaluaton of trigger thresholds per MRP Table 8.1.

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[25] For nearly all 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.

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CONTRA COSTA
CLEAN WATER
PROGRAM

CREEK STATUS MONITORING REPORT – LOCAL/TARGETED PARAMETERS

Integrated Monitoring Report, Part A – Appendix A.2

Water Years 2012 and 2013
(October 1, 2011 – September 30, 2013)

Submitted to the San Francisco Bay and
Central Valley Regional Water Quality Control Boards
in Compliance with Provision C.8.g.v

NPDES Permit Nos. CAS612008 and CAS083313

March 12, 2014

A Program of Incorporated Cities/Towns and
the Contra Costa Flood & Water Conservation District

This report is submitted by the participating agencies of the

CONTRA COSTA
CLEAN WATER
PROGRAM

Program Participants:

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

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Preface

In early 2010, several members of the Bay Area Stormwater Agencies Association (BASMAA) jointly formed the Regional Monitoring Coalition (RMC) to coordinate and oversee water quality monitoring required by the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (MRP).[1] The RMC includes the following participants:

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

This Local/Targeted Creek Status Integrated Monitoring Report complies with MRP Reporting Provision C.8.g.v for Status Monitoring data collected in Water Years 2012 and 2013 (October 1, 2011, through September 30, 2013). Data presented in this report were produced under the direction of the CCCWP using a targeted (non-probabilistic) monitoring design as described herein.

Local/targeted monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Program Plan (QAPP) and BASMAA RMC Standard Operating Procedures. Where applicable, monitoring data were derived using methods comparable with methods specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP.[2] Data presented in this report were also submitted in electronic SWAMP-comparable formats by SCVURPPP to the San Francisco Bay Regional Water Quality Control Board on behalf of CCCWP's Co-Permittees and pursuant to MRP Provision C.8.g.ii.

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

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

List of Abbreviations

ACCWP	Alameda Countywide Clean Water Program
ADH	ADH Environmental
BASMAA	Bay Area Stormwater Management Agencies Association
CCCCDP	Contra Costa County Community Development Department
CCCWP	Contra Costa Clean Water Program
CDFG	California Department of Fish and Game
Central ValleyWater Board	Central Valley Regional Water Quality Control Board
cfu	colony forming units
CRAM	California Rapid Assessment Method
DO	dissolved oxygen
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FC District	Contra Costa Flood Control and Water Conservation District
FSURMP	Fairfield Suisun Urban Runoff Management Program
IBI	Index of Biotic Integrity
MPC	Monitoring and Pollutants of Concern Committee
MPN	most probable number
MRP	Municipal Regional Permit
MWAT	Maximum Weekly Average Temperature
NPDES	National Pollutant Discharge Elimination System
POC	pollutants of concern
QAPP	Quality Assurance Project Plan
Region 2	San Francisco Regional Water Quality Control Board
Region 5	Central Valley Regional Water Quality Control Board
RWQC	Recreational Water Quality Criteria
RMC	Regional Monitoring Coalition
RMP	Regional Monitoring Program
RWQCB	Regional Water Quality Control Board
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SF Bay Water Board	San Francisco Bay Regional Water Quality Control Board
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program\
SSID	stressor/source identification
STV	statistical threshold value
SOP	Standard Operating Procedure
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
USA	Unified Stream Assessment
Vallejo	City of Vallejo and Vallejo Sanitation and Flood Control District
WQO	water quality objective
WY	Water Year

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Executive Summary

This appendix to the Integrated Monitoring Report (IMR), Part A documents the results of targeted monitoring performed by the Contra Costa Clean Water Program (CCCWP) during Water Years 2012 and 2013 (WY 2012 and WY 2013).Together with the regional creek status monitoring data reported for probabilistic sites in Appendix A.1 of IMR Part A, this submittal fulfills reporting requirements for Table 8.1 monitoring specified in Provision C.8.c of both the Municipal Regional Permit (MRP) for Urban Stormwater issued by the San Francisco Bay Regional Water Quality Control Board (SF Bay Water Board; MRP, Order No. R2-2011-0083) and the East Contra Costa County Municipal NPDES Permit issued by the Central Valley Regional Water Quality Control Board (Central Valley Water Board; Central Valley Permit, Order No. R5-2010-0102). Reporting requirements for Table 8.1 constituents are established in Provision C.8.g.iii of both permits.

CCCWP conducted targeted monitoring in WY 2012 and WY 2013 for water temperature, general water quality (field-measured parameters), pathogen indicators, and riparian assessments. The other parameters required in Table 8.1 of the MRP and Central Valley Permit were monitored using a probabilistic design; those results are reported in Appendix A.1.

WY 2012

During WY 2012, from April through September, hourly water temperature measurements were recorded using HOBO® data loggers deployed at Alhambra Creek, Wildcat Creek, and Marsh Creek 2012, and at Walnut Creek. General water quality monitoring (temperature, dissolved oxygen, pH, and specific conductivity) was conducted using YSI continuous water quality equipment (Sondes) in Walnut Creek during spring (May 23–June 4) and summer (August 1–13), and in Marsh Creek during spring (May 8–18) and summer (August 1–13). Walnut Creek was prioritized for this type of water quality monitoring because it lies in part within an urbanized area and it supports a coldwater biological community; in addition, the SF Bay Water Board is interested in the data and can use it to further develop and/or implement watershed management plans.

The Contra Costa Flood Control and Water Conservation District (“FC District”) performed a pilot study in June 2012, to compare the effectiveness of grazing with goats and sheep versus the traditional use of herbicides for vegetation management, and to assess potential impacts to water quality from each maintenance practice. Water quality samples were collected by FC District staff at eight sites along a transect from upstream to downstream along the reach where the livestock were grazing, and analyzed for fecal coliform during each day of the 12-day grazing period, from June 12–23. To augment this pilot study, and to meet MRP and Central Valley Permit Provision C.8.c. requirements, pathogen indicator samples were collected at five sites along the same reach of Walnut Creek by ADH Environmental staff on July 12, 2012, and analyzed for fecal coliform and *Escherichia coli* (*E. coli*).

In lieu of performing a stream assessment using either the California Rapid Assessment Method (CRAM) or the Unified Stream Assessment (USA) method, for WY 2012, CCCWP completed an assessment of Wildcat Creek that was funded in part by CCCWP and provides comparable information.[3] The MRP allows recent stream surveys and studies to be submitted in lieu of the required 6 miles of stream survey specified in Table 8.1.

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[3] The most recent use of this information (www.urbancreeks.org/WildcatWRAP.html) was published as the Wildcat Creek Restoration Action Plan (WRAP) by the Wildcat–San Pablo Watershed Council (Watershed Council). Participants of the Watershed Council include Permittees City of Richmond and City of San Pablo. Funding for the original studies supporting the WRAP (see http://legacy.sfei.org/watersheds/wildcatreport/cover-V.pdf) was provided by CCCWP as well.

WY 2013

During WY 2013, hourly water temperature measurements were recorded using HOBO® data loggers deployed on April 17, 2013, at one site on San Pablo Creek and three sites on Pinole Creek. The HOBOs were retrieved on September 30, 2013. General water quality monitoring (temperature, dissolved oxygen, pH, and conductivity) was conducted using YSI continuous water quality recording equipment (Sondes), also at San Pablo and Pinole Creeks in Contra Costa County, during two time periods at each creek, once during spring (April 30–May 10), and once during summer (August 1–12). Twelve miles of creek also were surveyed in Region 2 under the purview of the SF Bay Regional Water Board, and 3 miles were surveyed in Region 5 under the purview of the Central Valley Water Board,[4] using a modified version of the *Unified Stream Assessment: A User's Manual* (Center for Watershed Protection, 2005).

During fall 2013, Stream Surveys were conducted on Wildcat, San Pablo, and Pinole Creeks for a total of 12.1 miles assessed in Region 2 (submitted for WY 2012 and WY 2013) and 3 miles assessed on East Antioch Creek in Region 5. All sampling conformed to protocols identified in the RMC Standard Operating Procedures. This report presents findings associated with implementation of those surveys.

Comparisons to Trigger Thresholds

The targeted monitoring data were evaluated to determine whether MRP trigger thresholds were met, using numeric Water Quality Objectives (WQOs) or other applicable criteria, as described in Table 8.1 in the MRP and Central Valley Permit. The results are summarized below:

- **Temperature:** A maximum weekly average temperature (MWAT) of 20.5°C was used as the applicable criterion to evaluate temperature data. For WY 2012, two of the four lower watershed sites (Walnut Creek and Marsh Creek) exceeded this MWAT value more than 20% of the monitoring period, exceeding the relevant trigger criterion from MRP Table 8.1. For WY 2013, at the four stations with continuously recorded temperature from April until August, one station had results that exceeded the MWAT threshold. At either of the sites in the spring or summer index periods, no results were above the MWAT threshold.
- **Dissolved Oxygen (DO):** Basin Plan WQOs for DO in nontidal waters are applied as follows: 7.0 mg/L minimum for waters designated as cold-water fisheries habitat (COLD) and 5.0 mg/L minimum for waters designated as warm water habitat (WARM). In WY 2012, over 20% of the DO measurements were below the COLD threshold in Walnut Creek during the two week summer deployment only, exceeding the relevant trigger criterion from MRP Table 8.1. The trigger criterion was not exceeded in Walnut Creek during the spring deployment nor in Marsh Creek during either period. In WY 2013, DO concentrations measured substantially below the COLD threshold at Pinole Creek during the August deployment. At San Pablo Creek during both deployments, and at Pinole Creek during the April deployment, there were negligible results that measured lower than the WARM threshold. As field observations indicate that both creeks should be classified only as WARM, neither creek is determined to exhibit serious DO WQO issues.

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[4] Creeks in the eastern portion of Contra Costa County drain to Region 5 of the State Water Resources Control Board (i.e., the Central Valley Regional Water Quality Control Board); creeks in the rest of the county drain to Region 2 (i.e., the San Francisco Bay Regional Water Quality Control Board).

- **pH:** The applicable Basin Plan WQO range of 6.5–8.5 was used to define the upper and lower limits of the pH threshold. In WY 2012, the pH WQO range was exceeded more than 20% of the time in Walnut Creek during the spring deployment and in Marsh Creek during each two week deployment (spring and summer). In WY 2013, pH levels measured at Pinole and San Pablo Creeks were within WQOs.

- **Pathogen Indicator Bacteria:** The Basin Plan 90th percentile WQO of 400 MPN/100 mL for fecal coliform and the U.S. Environmental Protection Agency (EPA) recommended statistical threshold value of 410 cfu/100 mL for *E. coli* were used as Water Contact Recreation (REC1) evaluation criteria. For Non-water Contact Recreation (REC2), the Basin Plan 90th percentile WQO of 4,000 MPN/100 mL for fecal coliform was used in the evaluation. In WY 2012, only one of the five samples collected exceeded the fecal coliform WQO and the *E. coli* EPA-recommended level. In WY 2013, samples for fecal coliform and *E.coli* at one of five Walnut Creek stations exceeded the maximum single sample concentration.

- **Stream Surveys:** The reach assessment scores for individual reaches ranged from 55 to 113 on the four creeks surveyed, with a score value combined from both urban and non-urban landscape types (out of a possible range of 0-160). The natural and relatively undisturbed landscape in Wildcat Creek had the highest average score of 109, reflective of being located in a regional park in spite of the lower scores in Alvarado Park. San Pablo Creek has the second highest average score of 102, with a range of 89-111, which also combines protected park area and urbanized environments. Pinole Creek's overall average score is 85, with an overall range from 55 in the channelized portion to 104 in the meadows. The rural upper watershed reaches score higher, while the downstream two areas received lower scores as the floodplain became more impacted by human disturbance. East Antioch Creek has been highly channelized and has a range of scores between 65 and 89, with an overall reach score of 70. The majority of impacts on the creeks surveyed in Contra Costa were either channelization or bank hardening, or in the rural areas, stream bank erosion – with neither of these results unexpected. There was one remarkable trash deposit, and one leaking irrigation pipe that resulted in notifying authorities for attention, both occurring in East Antioch Creek.

CCCWP has been working with the RMC to plan and implement appropriate stressor/source identification (SSID) projects that follow up on WY 2012 and WY 2013 creek status monitoring data, in accordance with the requirements of Provision C.8.d.i of the MRP and Central Valley Permit.

Pursuant to Provision C.11.l of Order No. R5-2010-0102 (the Central Valley Permit), CCCWP is implementing a Work Plan to characterize concentrations of methylmercury in urban runoff discharges in eastern Contra Costa County and evaluate attainment of the numeric target of 0.06 nanograms per liter methylmercury established by the Total Maximum Daily Load for methylmercury for the Sacramento–San Joaquin River Delta.

CCCWP will consider using the California Rapid Assessment Method (CRAM) for 2014 stream assessments at the same locations (and reach lengths) that will be monitored for the RMC probabilistic design. The purpose of using CRAM would be to determine whether CRAM data can be useful for explaining aquatic biological condition in a more appropriate way than the USA method, which was designed for a different climate. In addition, the CRAM assessments could supplement biological and physical habitat data collected at RMC bioassessment sites to investigate potential stressors to aquatic health.

1.0 Introduction

Contra Costa County lies within both the Region 2 and Region 5 jurisdictions of the State Water Resources Control Board (SWRCB). This *Local/Targeted Creek Status Integrated Monitoring Report* documents the results of targeted (non-probabilistic) monitoring performed by CCCWP and is intended for submittal in fulfillment of the requirements of both Municipal NPDES permits (Permits) from the respective water boards.[5,6]. This report, along with the companion Creek Status Monitoring Report for regional parameters (Appendix A.1 to the IMR, Part A) complies specifically with reporting Provision C.8.g.v for creek status monitoring data collected in Water Year (WY) 2012 and WY 2013 (two years from October 1, 2011, through September 30, 2013).

The Bay Area Stormwater Management Agencies Association (BASMAA) formed the Regional Monitoring Coalition (RMC) to implement monitoring provisions found in Provision C.8 of the MRP. The BASMAA RMC was formed in early 2010 as a collaborative effort among a number of BASMAA members and MRP Permittees (Table 1.1) to develop and implement a regionally coordinated water quality monitoring program to address water quality monitoring required by the MRP. Implementation of the RMC's creek status and long-term trends monitoring plan allows permittees and the water board to 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).

The goals of the RMC are listed as follows:

1. Assist permittees in complying with requirements in MRP Provision C.8 (Water Quality Monitoring).
2. Develop and implement regionally consistent creek monitoring approaches and designs in the Bay Area, through improved coordination among RMC participants and other agencies (e.g., SWRCB) that share common goals.
3. Stabilize the costs of creek monitoring by reducing duplication of efforts and streamlining reporting.

The BASMAA RMC has developed monitoring protocols, sampling and analysis plans, data quality objectives (DQOs), standard operating procedures (SOPs), data management tools, and reporting templates and guidelines. Costs for these activities are shared among RMC members on a population-weighted basis by direct contributions and provision of in-kind services by RMC members to complete required tasks. The RMC protocols for creek status and pollutants of concern (POC) monitoring were developed to include CCCWP's monitoring requirements established by the Region 2 Permit; analysis and reporting of results required in the Region 2 Permit is the sole responsibility of CCCWP. The RMC addresses the scope of sub-provisions specified in MRP Provision C.8 as shown in Table 1.2.

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[5] The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) issued the five-year Municipal Regional Permit for Urban Stormwater (MRP, Order No. R2-2011-0083) 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.

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

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)	City of Antioch, City of Brentwood, City of Clayton, City of Concord, Town of Danville, City of El Cerrito, City of Hercules, City of Lafayette, City of Martinez, Town of Moraga, City of Oakley, City or Orinda, City of Pinole, City of Pittsburg, City of Pleasant Hill, City of Richmond, City of San Pablo, City of San Ramon, City of Walnut Creek, Contra Costa County Flood Control and Water Conservation District and Contra Costa County Watershed Program
San Mateo 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

Table 1.2 Municipal Regional Permit Provisions addressed by the Regional Monitoring Coalition

Sub-Provision	Sub-Provision Title	Reporting Document
C.8.a	Compliance Options	• Regional Monitoring Coalition Creek Status & Long-Term Trends Monitoring Plan (BASMAA, 2011)
C.8.b	San Francisco Bay Estuary Monitoring	• Regional Monitoring Program Annual Monitoring Results (www.sfei/rmp.org)
C.8.c	Creek Status Monitoring	• Regional Urban Creeks Status Monitoring Reports • Local Urban Creeks Status Monitoring Reports
C.8.d	Monitoring Projects: • Stressor/Source Identification (SSID) • BMP Effectiveness Investigation • Geomorphic Project	• SSID Reports • BMP Effectiveness Reports • Integrated Monitoring Report
C.8.e	Pollutants of Concern (Loads) and Long-Term Trends Monitoring	• Small Tributaries Loading Strategy Multi-Year Monitoring Plan (Version 2013A) • Pollutants of concern (POC) loads monitoring data progress report (WY 2012)
C.8.f	Citizen Monitoring and Participation	• Urban Creeks Monitoring Report (Main Body)
C.8.g	Data Analysis and Reporting	• Urban Creeks Monitoring Report (Main Body) • Individual Monitoring Reports

This report focuses on the creek status and long-term trends monitoring activities that were conducted to comply with Provision C.8.c using a targeted (non-probabilistic) monitoring design, as listed in Table 1.3. Stream surveys, designated by the RMC as a targeted monitoring parameter, are addressed in this report, but the surveys were conducted at probabilistic sites to coincide with WY 2013 bioassessment monitoring, and simultaneously satisfy stream survey monitoring requirements per MRP Table 8.1.

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

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/ Probabilistic	Local Targeted	Regional	Local
Bioassessment & Physical Habitat Assessment	X		X (2012)	X (2013)
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

2.0 Study Area and Design

2.1 Regional Monitoring Coalition Area

The RMC area encompasses 3,407 square miles of land in the San Francisco Bay Area. This includes the portions of the five participating counties that fall within the jurisdiction of the sf Bay Water Board (Figure 2.1). As shown on Figure 2.2, the eastern portion of Contra Costa County drains to the Central Valley region (Region 5), while the rest of the county drains in to the San Francisco Bay region (Region 2). Status and trends monitoring is conducted in flowing water bodies (i.e., creeks and rivers), including perennial and non-perennial streams that run through both urban and non-urban areas.

2.2 Contra Costa County Targeted Monitoring Areas and Siting Rationale

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

During WY 2012, the local/targeted creek status monitoring focused on the Marsh Creek and Walnut Creek watersheds, the County's two largest watersheds. During WY 2013, the majority of CCCWP's targeted monitoring was focused on the San Pablo Creek and Pinole Creek watersheds. In addition, stream surveys were conducted on Wildcat Creek and East Antioch Creek. Walnut Creek also was sampled for pathogen indicators in WY 2013 to augment an independent ongoing study conducted by the Contra Costa Flood Control District. Further details and discussion about the targeted sampling areas can be found in the Methods and Results sections of this report, Sections 3 and 4, respectively. When identifying the targeted monitoring locations, CCCWP considered water bodies designated as impaired by the State of California pursuant to Clean Water Act Section 303(d) listings in the decision-making process.]

2.2.1 Pinole Creek Watershed (Region 2)

Pinole Creek is located in the northwest portion of Contra Costa County and flows roughly northwest to San Pablo Bay. With headwaters in the Briones Hills, Pinole Creek drains 9,705 acres. The central reaches of Pinole creek and its tributaries run approximately 6 miles through a broad open valley with a relatively intact floodplain up to about the Pinole City line.

After it flows beyond an overpass on Interstate 80, Pinole Creek changes drastically after it leaves the confines of the East Bay Hills. Downstream (i.e., west) of I-80, Pinole creek is confined to a flood control channel, with parts of the stream channel consisting of vegetated riprap while other lengths are completely concrete lined. This downstream section of the creek cannot overflow into any surrounding floodplain, and it provides no buffers for the protection of the local riparian ecological community. This part of the stream is relatively wide and flat so that the water in it is typically one inch deep or less, which is too shallow to allow steelhead passage. If flow in the stream is increased from sources such as storm runoff, the velocities in the stream are too high for steelhead to ascend it. The condition in which stream flow is just right to allow fish passage rarely occurs. Thus, Pinole Creek downstream from the I-80 overpass is a barrier to upstream steelhead migration.

Contra Costa Resource Conservation District is coordinating a fish passage improvement project under I-80 for development in 2014. The plan is to install a series of baffles for the high velocity problem and to direct low flows to one side of each of the two culverts to concentrate low flows and attain water depths to facilitate steelhead passage. The targeted monitoring conducted by CCCWP in 2013 will provide a baseline of water quality and habitat data to compare pre- and post-project environment and parameters for evaluating the success of the improvement (Cressey, 2014).

2.2.2 San Pablo Watershed (Region 2)

San Pablo Watershed is also located in western Contra Costa County. Almost three times larger than Pinole Watershed, San Pablo Creek drains 27,640 acres and flows almost 20 miles before it enters San Francisco Bay. Originating in Orinda, the creek runs through urbanized areas, a water treatment facility, and natural areas surrounding San Pablo Reservoir and Dam that are owned by East Bay Municipal Utility District. San Pablo’s lower reaches are urbanized and the creek discharges south of Point Pinole into the bay.

In 2012, CCCWP sampled a reach in Orinda as part of the RMC probabilistic study and permit fulfillment. The bioassessment monitoring at Site 155, San Pablo Creek returned unexpectedly low Index of Biotic Integrity (IBI) scores. In an attempt to eliminate causes of the low IBI scores, CCCWP chose to monitor this reach in 2014 with continuous monitoring devices to collect both summer-long continuous temperature data, as well as two-week intervals in spring and late summer for general water quality parameters (temperature, dissolved oxygen, pH, and specific conductivity). In addition, 0.4 mile of stream assessment were conducted along and upstream of the bioassessment site to collect an array of data that could help determine the reason for low IBI scores in this location.

Stream assessment of San Pablo Creek was conducted upstream of San Pablo Reservoir to increase the data collection along this creek and observe the effects of the water treatment facility on the in-stream habitat.

2.2.3 Wildcat Creek (Region 2)

Wildcat Creek is located in western Contra Costa County, south of San Pablo and Pinole watersheds, respectively. The Wildcat Creek watershed drains nearly 7,000 acres before it discharges into San Francisco Bay, roughly one mile south of San Pablo Creek. The upper watershed is contained in Wildcat Canyon and surrounded by East Bay Regional Parks land until it reaches Alvarado Park. At that point it enters a highly urbanized watershed and the creek flows through the cities of Richmond and San Pablo before reaching the bay.

In 2012, CCCWP monitored Wildcat Creek below Alvarado Park for continuous temperature from April through September. Creek surveys in 2014 were conducted to augment temperature data collected in 2013. Two RMC probabilistic sites were planned for bioassessment monitoring in Wildcat Canyon in 2014, but permits were received after the index period had concluded for the year. At least one of those sites is expected to be sampled in 2014, which will supplement the information gathered on Wildcat Creek to direct management activities in the future.

2.2.4 Walnut Creek (Region 2)

Walnut Creek is in central Contra Costa and is one of the largest watersheds in the county, draining a total of almost 94,000 acres. In June 2012, the Contra Costa Flood Control and Water Conservation District ("FC District") performed a pilot study to compare the effectiveness and potential impacts to water quality of grazing with goats and sheep versus the traditional use of herbicides for vegetation management in the Walnut Creek channel. The study was continued during the summer of 2013, and another set of pathogen indicator samples were collected at the same five sites along the same reach of Walnut Creek as in 2012, and were analyzed for fecal coliform and *Escherichia coli* (*E. coli*) to see if pathogen indicator organism concentrations indicate potential impacts to recreational beneficial uses on this creek and to fulfill the Region 2 Permit requirement.

2.2.5 East Antioch Creek (Region 5)

East Antioch Creek is located in the northeastern part of Contra Costa County and discharges into the Sacramento–San Joaquin River Delta within the jurisdiction of the Central Valley Water Board (Region 5). East and West Antioch Creeks together drain about 8 acres of watershed. Channelized in its lower half, East Antioch Creek is slightly buffered from dense commercial and urban landscapes, as it runs through drop structures and culverts and a grassy power and transportation corridor. Some of the channel and tributaries run underground, where it is crossed by Highway 4 to provide flood protection in the developed area. Lake Alhambra is a small man-made lake upstream of the terminus at the river delta.

This creek is of interest to CCCWP as one of the foci of a methylmercury control study due to commence in 2014 pursuant to Provision C.11.l of Order No. R5-2010-0102 (the Central Valley Permit), as well as fulfillment for the stream survey parameter in Table 8.1.of the Region 5 Permit.

2.2.6 Marsh Creek (Region 5)

Marsh Creek is the major watershed located in the northeastern part of Contra Costa County and discharges into the Sacramento–San Joaquin River Delta within the jurisdiction of the CVRWQCB. The Friends of Marsh Creek watershed group is interested in the data for the associated fish ladder project.

Figure 2.1 Map of BASMAA RMC area, county boundaries, and major creeks

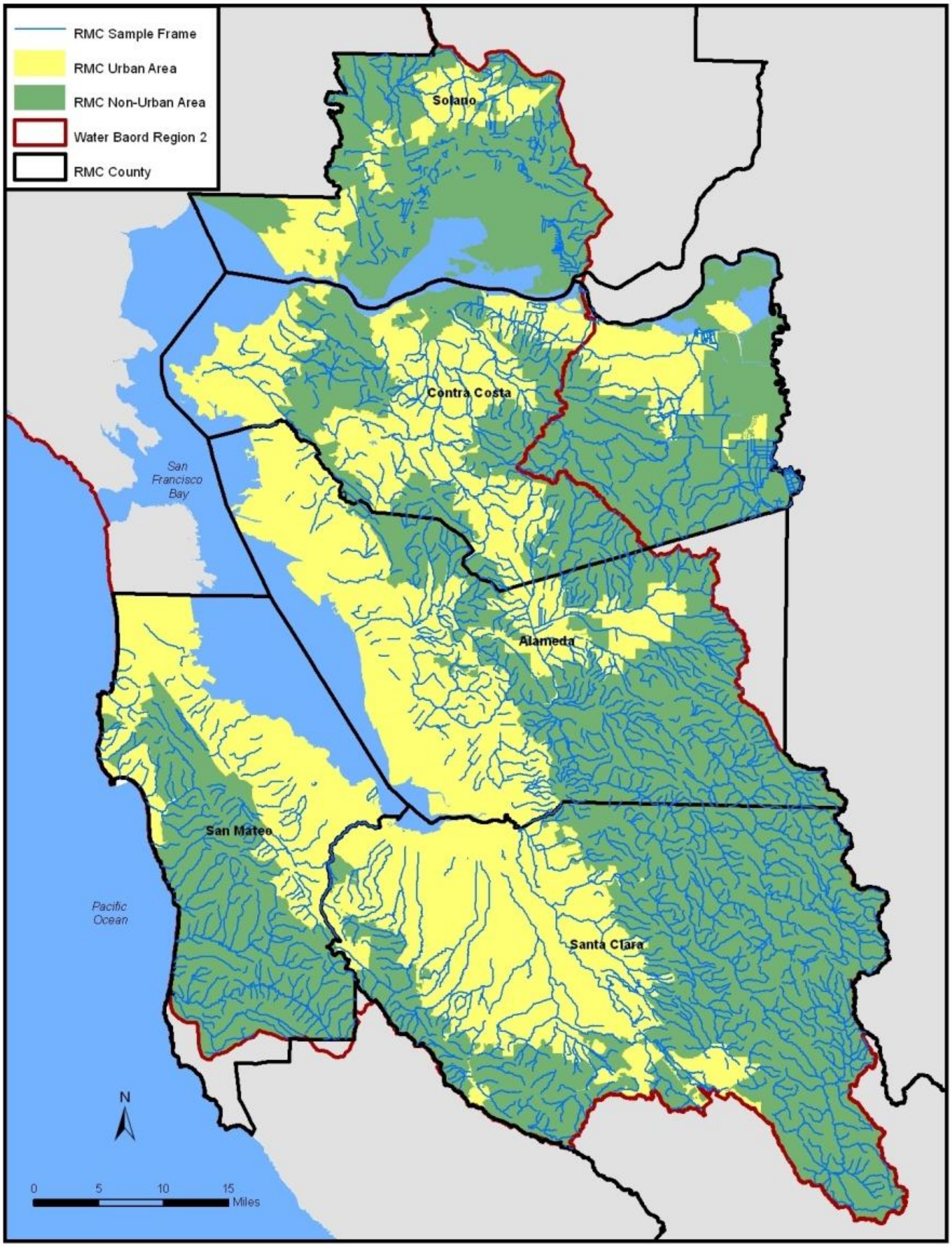
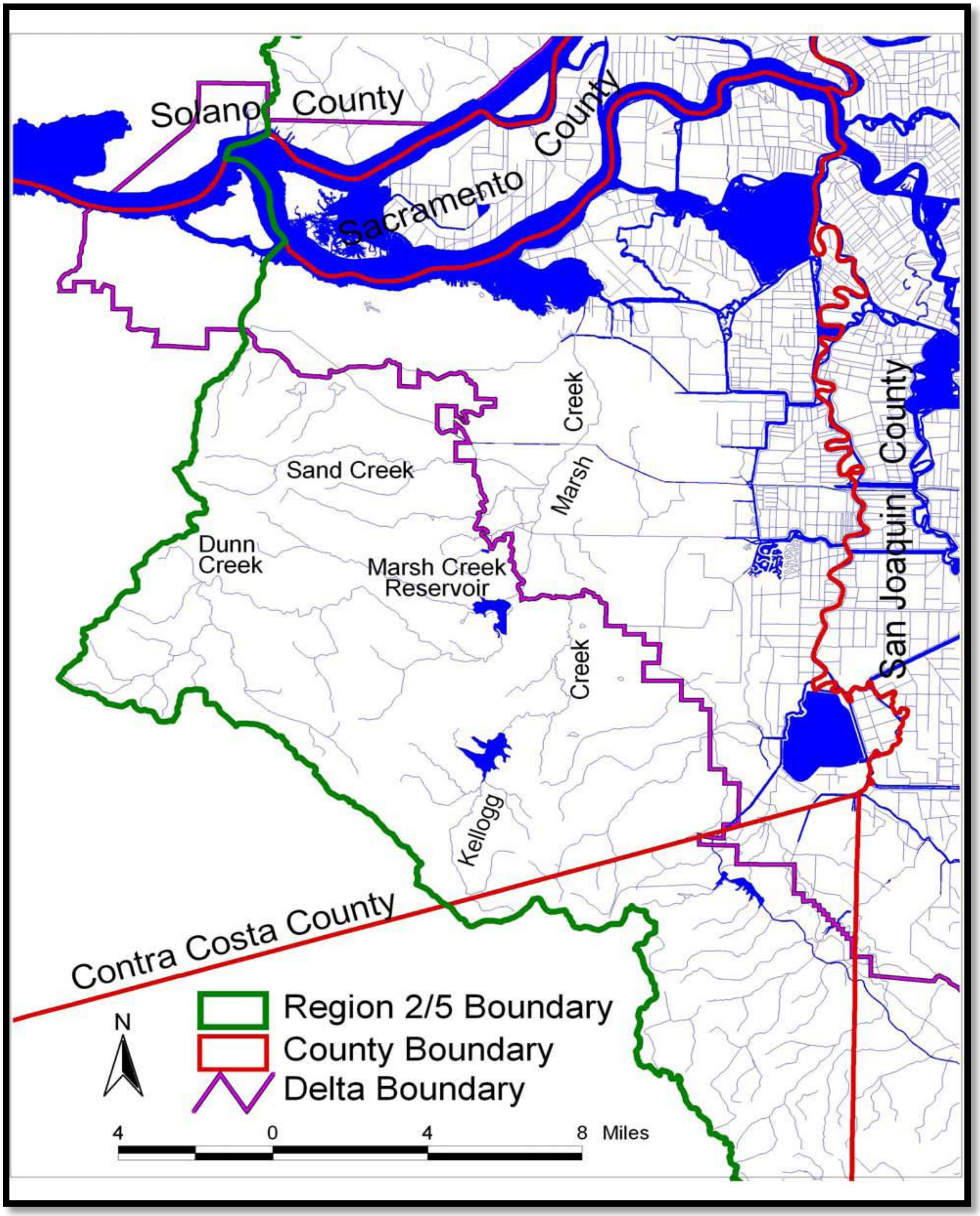


Figure 2.2 SWRCB Region 2 and 5 Boundaries (Source Map: CVRWQB, 2010)



2.3 Contra Costa Targeted Monitoring Design

During WY 2012 and WY 2013, water temperature, general water quality, pathogen indicators, and stream surveys were monitored at the targeted locations listed in Tables 2.1 and 2.2 and shown on Figures 2.3 and 2.4.

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

1. What is the range of 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?

Within Contra Costa County, targeted monitoring conducted during WY 2012 and WY 2013 included the following locations:

- Four automated, continuous water temperature monitoring locations
- Two automated, continuous general water quality monitoring locations
- Five pathogen indicator monitoring locations
- Twelve miles of creek were surveyed in Region 2 (SF Bay Water Board) and 3 miles of creek were surveyed in Region 5 (Central Valley Water Board,). The twelve miles surveyed in Region 2 fulfilled requirements for annual surveys for both WY 2012 and WY 2013.

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

Table 2.1 Sites and local reporting parameters monitored in WY 2012 in Contra Costa County

Map ID	Site Code	Creek Name	Latitude	Longitude	Bioassessment	Continuous Temperature	Water Quality	Pathogen Indicators
11	207R00011	Grayson	37.95427	-122.07869	X			
25	544R00025	NA	37.92297	-121.71890	X			
39	203R00039	Cerrito	37.89830	-122.30085	X			
55	206R00055[1]	Bear	37.92998	-122.14887	X			
75	207R00075[1]	Las Trampas	37.82957	-122.07430	X			
137	543R00137	Deer	37.92211	-121.74002	X			
139	207R00139	Las Trampas	37.88658	-122.08098	X			
155	206R00155	San Pablo	37.87286	-122.17865	X			
215	206R00215	San Pablo	37.95807	-122.27814	X			
219	543R00219[1]	Marsh	37.88850	-121.84499	X			
245	543R00245[1]	Marsh	37.86669	-121.74377	X			
247	207R00247	Walnut	37.92925	-122.04751	X			
60	206WIL060	Wildcat	37.95321	-122.33835		X		
100	207ALH100	Alhambra	38.00383	-122.12969		X		
160	207WAL160	Walnut	37.90495	-122.05793		X	X	

400	544MRC400	Marsh	37.96278	-121.68639		X	X	
W-01	207WAL W-01	Walnut	37.96900	-122.05413				X
W-02	207WAL W-02	Walnut	37.96560	-122.05441				X
W-03	207WAL W-03	Walnut	37.96241	-122.05262				X
W-04	207WAL W-04	Walnut	37.95838	-122.05117				X
W-05	207WAL W-05	Walnut	37.95323	-122.05318				X

1 – Non-urban probabilistic site

Table 2.2 Sites and local reporting parameters monitored in WY 2013 in Contra Costa County

Map ID	Site Code	Creek Name	Latitude	Longitude	Bio-assessment	Continuous Temperature	Water Quality	Pathogen Indicators
271	207R00271	Sycamore	37.8267	-121.9184	X			
281	544R00281	Marsh	37.9523	-121.6964	X			
375	207R00375	Galindo	37.9624	-122.0143	X			
395	207R00395	Las Trampas	37.8918	-122.1034	X			
503	207R00503	Pine	37.9528	-122.0284	X			
532	207R00532	Sycamore	37.8147	-121.9665	X			
567	207R00567	Tributary of Walnut	37.9953	-122.0376	X			
631	207R00631	East Branch of Grayson	37.9454	-122.0658	X			
727	206R00727	Pinole	37.9793	-122.2666	X			
788	207R00788	San Ramon	37.8085	-121.9807	X			
13	206PNL013	Pinole	38.0055	-122.2890		X		
29	206PNL029	Pinole	37.9929	-122.2850		X	X	
44	206PNL044	Pinole	37.9793	-122.2646		X		
239	206SPA239	San Pablo	37.8726	-122.1787		X	X	
243	206SPA242	San Pablo	37.8727	-122.1788			X	
WAL035	207WAL035	Walnut	37.9690	-122.0541				X
WAL040	207WAL040	Walnut	37.9656	-122.0544				X
WAL045	207WAL045	Walnut	37.9624	-122.0526				X
WAL055	207WAL055	Walnut	37.9584	-122.0512				X
WAL070	207WAL070	Walnut	37.9532	-122.0532				X
n/a[1]	206R00471		37.97275	-122.22828	X		X	
n/a[1]	206R00487		37.96288	-122.20152	X		X	
n/a[1]	204R00495		37.80472	-122.11276	X		X	

Explanation

[1] Sites sampled by the SWAMP bioassessment monitoring team in 2013. These sites were chosen from the probabilistic sample frame design (RMC probabilistic CC_R2_Nonurb). Data is not yet available. No data. Sites are not reflected on maps.

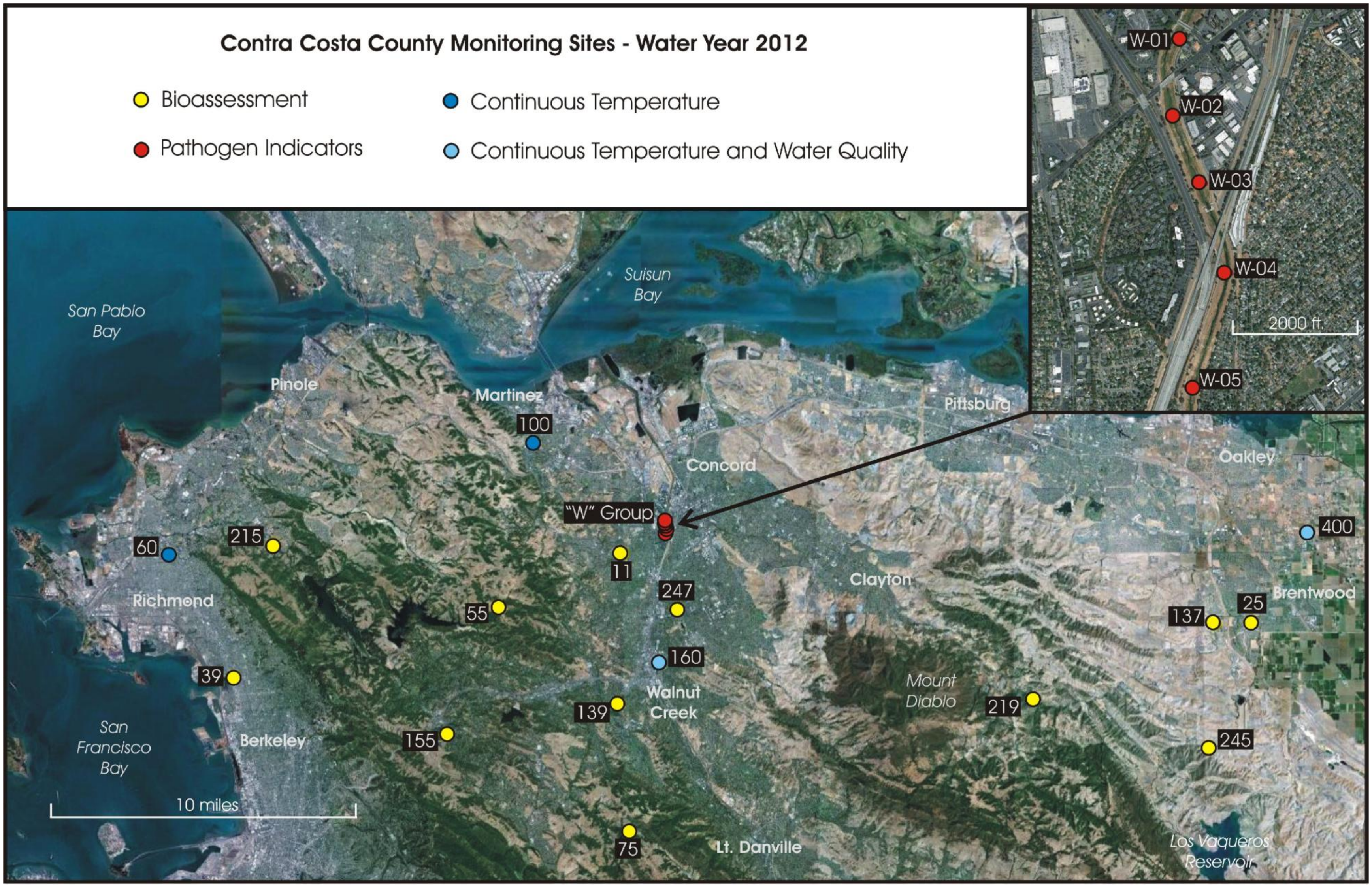

Figure 2.3 Probabilistic and targeted sites monitored by CCCWP in 2012

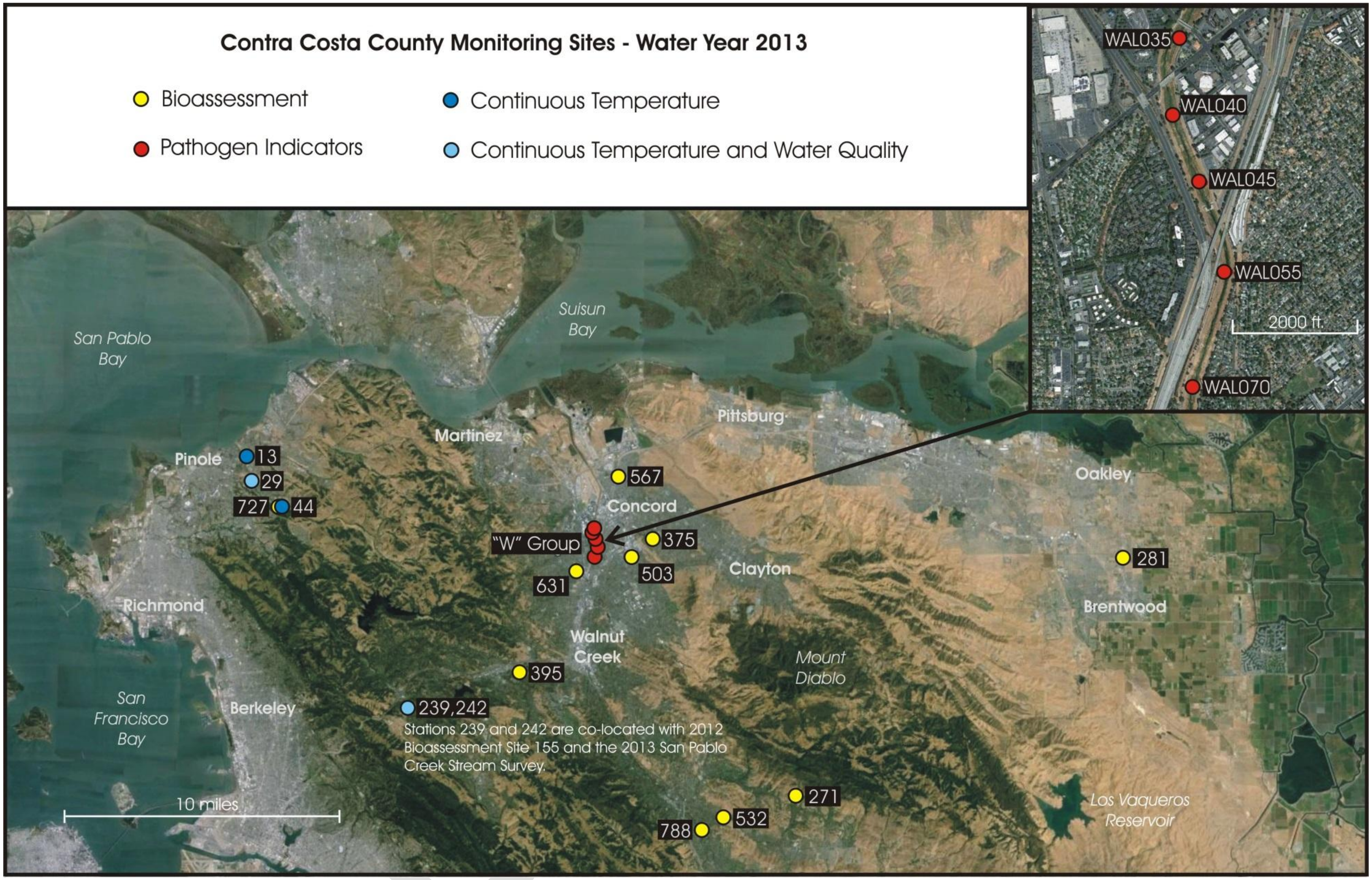

Figure 2.4 Probabilistic and targeted sites monitored by CCCWP in 2013

3.0 Monitoring Methods

3.1 Data Collection Methods

Targeted monitoring data were collected in accordance with the BASMAA RMC Quality Assurance Program Plan (QAPP; BASMAA, 2014a) and BASMAA RMC Standard Operating Procedures (SOPs; BASMAA, 2014b). Where applicable, monitoring data were collected using methods comparable to those specified by the California Surface Water Ambient Monitoring Program (SWAMP) QAPP[8], and were submitted in SWAMP-compatible format by CCCWP to the SFBRWQCB and the CVRWQCB on behalf of Contra Costa County permittees The SOPs were developed using a standard format that describes health and safety precautions and considerations, relevant training, site selection, and sampling methods/procedures, including pre-fieldwork mobilization activities to prepare equipment, sample collection, and demobilization activities to preserve and transport samples.

3.1.1 General Water Quality Measurements

Water quality monitoring equipment (YSI 6600 data Sondes) was deployed at one site each in San Pablo Creek and Pinole Creek. General water quality parameters (DO, specific conductivity, pH, and temperature) were recorded at 15-minute intervals for approximately two week intervals. The equipment was deployed for two time periods at each creek as follows:

WY 2012:

- Walnut Creek – during spring (May 23–June 4) and during summer (August 1–13).
- Marsh Creek – during spring (May 8–May 18) and during summer (August 1–13).

WY 2013:

- San Pablo Creek: Once during spring (April 30–May 10) and once during summer (August 1–12)
- Pinole Creek: Once during spring (April 30–May 10) and once during summer (August 1–12)

Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-4 (BASMAA, 2014b).

3.1.2 Continuous Temperature Monitoring

Digital temperature loggers (Onset HOBO® Water Temp Pro V2) were deployed at each site for automated, continuous temperature measurement.

In WY 2012, the CCCWP monitored water temperature and other water quality parameters at one location on each of the following creeks: Marsh Creek between Brentwood and Knightsen; Walnut Creek in the City of Walnut Creek; Alhambra Creek in Martinez; and Wildcat Creek in San Pablo. Hourly temperature measurements were recorded at each respective site as follows;

- Walnut Creek – during summer into early fall (June 20–September 30).

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

- Alhambra Creek – from mid-spring through early fall (April 17–September 30).
- Wildcat Creek – from mid-spring through mid-summer (April 17– July 31).
- Marsh Creek – during mid-spring through early fall (April 25– September 18).

In WY 2013, the CCCWP monitored water temperature at one location on San Pablo Creek in the Town of Orinda and at 3 locations on Pinole Creek in the City of Pinole. Hourly temperature measurements were recorded at each respective site during the same time period:

- San Pablo Creek: April 17–September 30, 2013
- Pinole Creek: April 17–September 30, 2013

Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-5 (BASMAA, 2014b).

3.1.3 Pathogen Indicators

The FC District performed a pilot study in June 2012 to compare the effectiveness of grazing with goats and sheep versus the traditional use of herbicides for vegetation management and assess potential impacts to water quality from each maintenance practice. Water quality samples were collected by FC District staff at eight sites along the reach (upstream to downstream) where the livestock were grazing and were analyzed for fecal coliform during each day of the 12-day grazing period from June 12 to June 23. To augment this pilot study, and to meet MRP Permit requirements, another set of pathogen indicator samples were collected by ADH Environmental (ADH) staff on July 12, 2012, and again on July 15, 2013, at the same five sites along the same reach of Walnut Creek, and were analyzed for fecal coliform and *E. coli*.

Sampling techniques by the County and ADH included direct filling of containers and immediate transfer of samples on ice to analytical laboratories within specified holding time requirements. Procedures used for sampling and transporting samples by ADH are described in RMC SOP FS-2 (BASMAA, 2014b).

3.1.4 Stream Survey Assessment

MRP Table 8.1 requires conduct of stream surveys using a modified Unified Stream Assessment (USA) protocol or comparable technique, such as CRAM. During WY 2013, CCCWP surveyed 12 stream miles in Region 2 (SF Bay Water Board) and 3 stream miles in Region 5 (Centreal Valley Water Board) areas of Contra Costa County. During fall 2013, ADH conducted these surveys at predetermined reaches within the Pinole, San Pablo, Wildcat, and East Antioch Creek watersheds. This report presents findings of associated with implementation of those surveys.

ADH assessed instream habitat and riparian corridor conditions using a modified version of the USA protocol (CWP, 2005). The USA protocol 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.

To increase survey efficiency, 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. In this study, reaches were identified and delineated in the office. Reaches began and ended at major crossings or changes in creek environment or condition. 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
- 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 data sheets were completed to identify within each reach locations and general characteristics of seven potential creek impacts:

- Erosion
- Channel modification
- Outfalls
- Creek crossings
- Trash/debris
- Utilities
- Miscellaneous features (blockages, structures, other)

Table 3.1 Summary of stream mileage surveyed for each Contra Costa County creek and Regional Water Quality Control Board Region

Creek Name	Mileage	RWQCB Region	Total miles/region
Wildcat	4.2	2	12.1
San Pablo Creek	1.5	2	
Pinole	6.4	2	
East Antioch Creek	3.1	5	3.1

All survey work was completed between August 26 and September 6, 2013.

3.2 Quality Assurance/Quality Control

Data quality assessment and quality control procedures are described in detail in the BASMAA RMC QAPP (BASMAA, 2014a). 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 an in-situ field audit were conducted by California Department of Fish and Game (CDFG).

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.

3.2.1 Documentation/QA Methods for Stream Surveys

Impact assessments were documented on USA impact forms and point/segment inventory lists, modified from the USA survey. The modified forms are a list containing the information contained on the USA impact forms. The impacts have been entered into an excel workbook containing tabs with tables for each impact's documentation details. Photographs have been taken of the impacts and were downloaded and stored after each field day. Maps were created illustrating the recorded reaches surveyed.

Coordinates were collected with GPS units that had varying degrees of accuracy depending on the signal in the field. Coordinates were confirmed and adjusted as needed to accurately plot on the maps in office. All sampling conformed to protocols identified in the RMC Standard Operating Procedures (BASMAA, 2014b).

3.3 Data Quality Assessment Procedures

Following completion of the field and laboratory work, the field data sheets and laboratory reports were reviewed by the local Quality Assurance Officer and compared against the methods and protocols specified in the SOPs and QAPP. The findings and results were then evaluated against the relevant DQOs to provide the basis for an assessment of programmatic data quality. A summary of data quality steps associated with water quality measurements is shown in Table 3.2. The data quality assessment consisted of 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.
- Temperature data were checked for accuracy by comparing measurements taken by HOBOs with NIST thermometer readings in room temperature water and ice water.
- General water quality data were checked for accuracy by comparing measurements taken before and after deployment with measurements taken in standard solutions to evaluate potential drift in readings.

- Quality assessment laboratory procedures for accuracy and precision (i.e., lab duplicates, lab blanks) were not implemented for pathogen samples collected in WY 2012, but were implemented in WY 2013. A duplicate sample was provided.

- Impact assessments were documented on USA impact forms and point/segment inventory lists, modified from the USA survey. The modified forms are a list containing the information contained on the USA impact forms. The impacts have been entered into an excel workbook containing tabs with tables for each impact's documentation details. Photographs have been taken of the impacts and were downloaded and stored after each field day. Maps were created illustrating the recorded reaches surveyed.

- The impact site IDs are still associated with the location/coordinates on the map. Coordinates were collected with GPS units that had varying degrees of accuracy depending on the signal in the field. Coordinates were confirmed and adjusted as needed to accurately plot on the maps in office. All sampling conformed to protocols identified in the RMC SOPs (BASMAA, 2014b).

Table 3.2 Data quality steps implemented for temperature and general water quality monitoring

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

3.4 Data Analysis and Interpretation

Continuous temperature and general water quality data were plotted as box and whisker plots for each site during each deployment. The middle line of the box represents the median value (50th percentile), and top and bottom edge of the box indicate the 75th and 25th percentile, respectively. The upper whisker represents the 90th percentile, while the bottom whisker represents the 10th percentile. All data that do not fall between the 10th and 90th percentile are plotted as points outside of the whiskers.

The hourly water temperature measurements were used to calculate daily maxima over a 24-hour period from midnight to 11:00 pm. Seven-day "rolling" average daily maximum stream temperatures ("maximum weekly average temperature" ("MWAT"), per Sullivan et al., 2000) were calculated by averaging each daily maximum temperature with the previous six daily maximum temperatures.

Targeted monitoring data were evaluated against WQOs or other applicable thresholds, as described in Table 8.1 in the MRP. Table 3.3 defines thresholds used for selected targeted monitoring parameters. For the general water quality and temperature measurements, the MRP Table 8.1 trigger is met when 20% or more of the results exceed the applicable threshold.

The subsections below provide additional details on thresholds selected and the underlying rationale.

Table 3.3 Description of water quality thresholds for Municipal Regional Permit and Region 5 Permit Provision C.8.c parameters monitored using a targeted design

Monitoring Parameter	Threshold Description
Temperature	20% of results for the deployment period at each monitoring site exceed one or more of the following applicable temperature thresholds: • For a water body designated as COLD and/or supports steelhead trout population (SF Bay Water Board, 2011): ○ 7-day Mean Maximum Temperature should not exceed 20.5°C • For a water body designated as COLD or WARM (SF Bay Water Board, 2011): ○ The temperature shall not be increased by more than 2.8°C above natural receiving water temperature.
General Water Quality	20% of results for the deployment period at each monitoring site exceed one or more water quality standards or established thresholds: • Water temperature: see above • Dissolved oxygen: for WARM <5.0 mg/L and for COLD <7.0 mg/L (SF Bay Water Board, 2011) • pH: >6.5 and <8.5 (SF Bay Water Board, 2011) • Conductivity: NA
Pathogen Indicators	Single sample result meets one or more of the following criteria: • Fecal coliform: ≥400 MPN/100 mL (based on SF Bay Water Board, 2011) • *E. coli*: ≥410 MPN/100 mL (based on U.S. EPA, 2012, infrequently used area)

3.4.1 Dissolved Oxygen

The Basin Plan (SF Bay Water Board, 2011) lists WQOs for DO in nontidal waters as follows: 5.0 mg/L minimum for waters designated as warm water habitat (WARM) and 7.0 mg/L minimum for waters designated as COLD. Although these WQOs are suitable criteria for an initial evaluation of water quality impacts, further evaluation may be needed to determine the overall extent and degree that COLD and/or WARM beneficial uses are supported at a site. For example, further analyses may be necessary at sites in lower reaches of a water body that may not support salmonid spawning or rearing habitat, but may be important for upstream or downstream fish migration. In these cases, DO data will be evaluated for the salmonid life stage and/or fish community that is expected to be present during the monitoring period. Such evaluations of both historical and current ecological conditions will be made, where possible, when evaluating water quality information.

3.4.2 pH

WQOs for pH in surface waters are stated in the Basin Plan (SF Bay Water Board, 2011) as follows: the pH shall not be depressed below 6.5 nor raised above 8.5. This range was used in this report to evaluate the pH data collected from creeks.

3.4.3 Pathogen Indicators

The Basin Plan (SF Bay Water Board, 2011) includes Water Contact Recreation WQOs of fecal coliform concentrations less than 200 MPN/100 mL (geometric mean of data) and less than 400 MPN/100 mL (90th percentile of data). For Non-contact Water Recreation, the Basin Plan includes WQOs of fecal coliform concentrations less than 2,000 MPN/100 mL (geometric mean of data) and less than 4,000 MPN/100 mL (90th percentile of data).

In 2012, The EPA released its 2012 Recreational Water Quality Criteria (RWQC) recommendations for protecting human health in all coastal and non-coastal waters designated for primary contact recreation use. The EPA RWQC provide two sets of recommended criteria as shown in Table 3.4. Primary contact recreation is protected if either set of criteria recommendations are adopted into state water quality standards. However, these recommendations are intended as guidance to states, territories, and authorized tribes in developing water quality standards to protect swimmers from exposure to water that contains organisms that indicate the presence of fecal contamination. They are not regulations themselves (U.S. EPA, 2012).

Table 3.4 EPA 2012 Recommended Recreational Water Quality Criteria

Criteria Elements	**Recommendation 1 Estimated Illness Rate 36/1000**		**Recommendation 2 Estimated Illness Rate 32/1,000**	
Indicator	**GM (cfu/100 mL)**	**STV (cfu/100 mL)**	**GM (cfu/100 mL)**	**STV (cfu/100 mL)**
Enterococci	35	130	30	110
E. coli (fresh)	126	410	100	320

The Basin Plan objectives are based on a sampling protocol where a minimum of five consecutive samples are collected equally spaced over a 30-day period. The RMC monitoring design for pathogen indicators was to collect single water samples at individual water bodies, which is not consistent with this sampling protocol. Furthermore, as discussed in Section 3.1.3, CCCWP participated in a goat and sheep grazing pilot study with the County of Contra Costa during June 2012 and June 2013, to compare the effectiveness of grazing with goats and sheep versus the traditional use of herbicides for vegetation management. To augment the pilot study, and to meet MRP and Region 5 Permit Provision C.8.g requirements, another set of pathogen indicator samples were collected by CCCWP during summer 2012 and summer 2013 at five sites along the same reach of Walnut Creek, and were analyzed for fecal coliform and *E. coli* to see whether pathogen indicator organism concentrations indicate potential impacts to recreational beneficial uses on this reach of the creek.

For the purposes of this evaluation, fecal coliform maximum (single sample) concentrations of 400 MPN/100 mL and 4,000 MPN/100 mL were used as Water Contact Recreation and Non-water Contact Recreation evaluation criteria, respectively. While the Basin Plan does not include WQOs for *E. coli,* the EPA has established a statistical threshold value (STV) criterion of

410 CFU/100 mL that can be used to evaluate maximum or single sample concentrations of *E. coli* for Water Contact Recreation. The U.S. EPA STV criterion for a single sample maximum was used as the basis for analyzing *E. coli* data to determine which might "trigger" a monitoring project under MRP and Region 5 Permit Provision C.8.d.i. In regard to EPA 2012 RWQC standard threshold values, since the time-based geometric mean cannot be determined from the data collected, the only applicable recommended exceedance is the *E. coli* Standard Threshold Values of 410 colony forming units (CFU) per 100 mL and 320 CFU/mL, for Recommendation 1 and 2, respectively. For interpretive purpose CFU and MPN are considered equivalent.

3.4.4 Temperature

Temperature is one indicator of the ability of a water body to support either warm water fisheries habitat (WARM) or cold water fisheries habitat (COLD). In California, the beneficial use of COLD is generally associated with suitable spawning habitat and passage for anadromous fish (e.g., salmon and steelhead). In MRP Table 8.1 the temperature trigger threshold specification is footnoted as follows:

> "31 If temperatures exceed applicable threshold (e.g., Maximum Weekly Average Temperature, Sullivan K., Martin, D.J., Cardwell, R.D., Toll, J.E., Duke, S. 2000. *An Analysis of the Effects of Temperature on Salmonids of the Pacific Northwest with Implications for Selecting Temperature Criteria, Sustainable Ecosystem Institute*) or spike with no obvious natural explanation observed."

The *Local Urban Creeks Monitoring Report, Water Year 2012* (ADH, 2013) provided an extensive review and discussion of water temperature criteria for steelhead and various other salmonids as they might apply to Contra Costa County streams. Ultimately, the Sullivan et al. (2000) recommendation of an upper temperature threshold of 20.5 degrees Celsius (°C; average of a 7-day maximum temperature) for rearing juvenile steelhead was determined to be the most useful benchmark for evaluating Contra Costa County streams with a COLD beneficial use designation. Therefore the 20.5°C MWAT is used again in this year's evaluation as the water temperature criterion for cold water streams supporting salmonids in Contra Costa County . This same temperature criterion is also used for the resident rainbow trout population of San Pablo Creek upstream of San Pablo Reservoir in Orinda as discussed in the following subsections.

As noted above, a 7-day "rolling" average daily maximum stream temperature ("MWAT," per Sullivan et al., 2000) was calculated by averaging each daily maximum temperature with the previous six daily maximum temperatures.

3.4.1.1 Pinole Creek

Pinole Creek has historically sustained a population of steelhead, and several adult steelheads have been observed in the creek during the past decade. The 2007 report by the Center for Ecosystem Management and Restoration states that 5.8 miles of Pinole Creek are suitable and available habitat for steelhead. The largest concern is the culvert at the I-80 crossing of Pinole Creek, about 1.5 miles east of the mouth of the creek where it enters San Pablo Bay. Unless flows are unusually high from winter storm runoff, adult steelhead cannot migrate upstream through this culvert. Between this culvert and San Pablo Bay, Pinole Creek has little spawning and rearing habitat as it is channelized, and its extensive exposure to solar radiation heats up the stream flow in this reach during the summer months. The *San Francisco Estuary Watersheds Evaluation* report (2007) states that East Bay Municipal Utility District (EBMUD) biologists consider suitable steelhead rearing habitat to exist in Pinole Creek from Ramona

Street (0.47 mile east of I-80) or the lower end of Simas Avenue (0.93 mile east of I-80) to a natural barrier in the upper watershed (Burt Mulchaey, EBMUD, personal communication).

3.4.1.2 San Pablo Creek

The *Local Urban Creeks Monitoring Report, Water Year 2012* (ADH, 2013) contains water quality monitoring data from a site on San Pablo Creek in Orinda. It is important to understand that while this reach of San Pablo Creek supported a run of steelhead prior to the construction of the San Pablo dam and reservoir, adult steelhead can presently migrate upstream only as far as the base of San Pablo Dam. Additionally, it should be noted that rainbow trout from San Pablo Reservoir can only migrate a short distance (0.5 mile) up San Pablo Creek to a high drop structure near the EBMUD Orinda water treatment facility. The water temperature monitoring site on San Pablo Creek in Orinda is approximately 2 miles upstream of this drop structure. Therefore, the creek at this location contains resident rainbow trout, not steelhead or migratory trout from San Pablo Reservoir.

Assessment monitoring results presented in Section 4 of Pinole Creek and the monitored reach of San Pablo Creek were provided in a memorandum by Scott Cressey, Fisheries Biologist, who has several years' experience conducting benthic macroinvertebrate monitoring on these two creeks for the CCCWP over the past decade (Cressey, 2014). In addition, his evaluation included review of the following reports on the Pinole Creek watershed: *Pinole Creek Watershed Announcements* (CCRCD undated); *Pinole Creek Watershed Vision Plan* (Urban Creeks Council of California, 2004); and *San Francisco Estuary Watershed Evaluation* (Center for Ecosystem Management and Restoration, 2007). The *San Francisco Bay Water Quality Control Plan* (SF Bay Water Board, 2011) was reviewed for Beneficial Use designations for Pinole Creek and San Pablo Creek.

4.0 Results

4.1 Statement of Data Quality

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

WY 2012

- Temperature data (from HOBOs) were collected from four sites. 73% of the expected data were collected for the following reasons:
    - HOBOs were deployed on April 27, 2012, at Alhambra Creek and Wildcat Creek, Marsh Creek on May 2, 2012, and at Walnut Creek on May 11, 2012, and not by April 1, 2012.
    - Retrieval of the HOBOs at Marsh Creek on September 18, 2012, Alhambra Creek on September 24, 2012, and Walnut Creek on September 25, 2012, and not through September 30, 2012.
    - Additionally, when the HOBO was deployed at Walnut Creek on May 11, 2012, the measurement interval was inadvertently set to 30 seconds instead of hourly. As a result the memory reached capacity on May 26, 2012, and the HOBO discontinued collecting measurements. This issue was corrected during a site visit on June 19, 2012.
    - Upon retrieval, Wildcat Creek was observed to be dry where the HOBO was installed and is believed to be reason that temperature measurements discontinued on August 11, 2012.
- Continuous water quality data (temperature, pH, DO, specific conductivity) were collected during spring and summer season resulting in collection of 100% of the expected data.
- Continuous water quality data generally met measurement quality objectives (accuracy) for all parameters with the exception of DO at one site during Event 1 (Table 4.1). Data were flagged but used in the analysis.

Quality assurance laboratory procedures were inadvertently not implemented for pathogen indicator analyses this year; thus, data quality could not be evaluated.

Table 4.1 Accuracy measurements taken for dissolved oxygen, pH, and specific conductivity in WY 2012

Parameter	Measurement Quality Objectives	Site 207WAL160		Site 544MRC400	
		Event 1	Event 2	Event 1	Event 2
Dissolved oxygen (mg/L)	± 0.2 mg/L	**0.22**	0.05	-0.06	**0.27**
pH 7.0	± 0.2	0.12	-0.04	0.08	-0.05

pH 10.0	± 0.2	0.13	0.19	-0.19	0.22
Conductivity (µS/cm)	± 2 µS/cm	-0.01	0.02	-0.09	0.06

Notes: Accuracy of the water quality measurements was determined by calculating the difference between the YSI Sonde readings using a calibration standard and the actual concentration of the calibration standard. The results displayed are those taken following measurements taken within the stream, defined as "post-calibration" as opposed to the "pre-calibration values," where all the YSI Sonde probes were offset to match the calibration standard prior to deployment. Bold values exceed the Measurement Quality Objectives.

WY 2013

- Temperature data from HOBOs were collected from four stations. 91% of the expected data were collected for the following reasons:
  - HOBOs were deployed on April 17, 2013, at Pinole Creek (3 locations) and San Pablo Creek, not beginning on April 1, 2013.
  - Retrieval of the HOBOs at Pinole and San Pablo Creeks occurred on September 30, 2013.
  - All data recorded during the deployment period were stored without error.
- Continuous water quality data (temperature, pH, DO, specific conductivity) were collected during the spring and summer seasons, resulting in collection of 100% of the expected data.
- Continuous water quality data generally met measurement quality objectives (accuracy) for almost all parameters. See Table 4.2 for the results.
- Quality assurance laboratory procedures were implemented for pathogen indicator analyses this year. Samples were collected at five stations on Walnut Creek on August 15, 2013.There were four instances of quality assurance samples failing to meet DQOs:
  - Laboratory control samples for both fecal coliform and for *E. coli* had percent recoveries of 63.6%. This is outside of the DQO range of 80%–120%.
  - At station 207WAL45, laboratory duplicate samples for both fecal coliform and for *E. coli* had relative percent differences of 116% from the native sample values. This is above the DQO maximum of 25%.
  - At station 207WAL70, field blind duplicate samples for both fecal coliform and for *E. coli* had relative percent differences of 126% from the native sample values. This is above the DQO maximum of 25%.

  RMC participants will review and discuss these results with the laboratory, and develop follow-up actions as appropriate prior to the WY 2014 creek status monitoring.

Table 4.2 Accuracy measurements taken for dissolved oxygen, pH, and specific conductivity in WY 2013

Parameter	Measurement Quality Objectives	Site 206PNL029		Site 206SPA243	
		Event 1	Event 2	Event 1	Event 2
Dissolved Oxygen (mg/L)	± 0.2 mg/L	**-0.32**	0.02	0.08	**-0.27**
pH 7.0	± 0.2	0.02	0.07	0.01	0.09
pH 10.0	± 0.2	0.05	0.06	0.04	-0.06
Conductivity (µS/cm)	± 2 µS/cm	0.00	0.00	0.01	0.00

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

4.2 Water Quality Monitoring Results

4.2.1 Water Temperature

WY 2012

Summary statistics for water temperature data collected at the four sampled creeks between April and September 2012 are shown in Table 4.3. Hourly temperature data were collected for approximately 106 consecutive days at Wildcat Creek, 148 days at Marsh Creek, 161 days at Alhambra Creek, and 117 days at Walnut Creek, in two periods: May 2012 (17 days) and June–September 2012 (100 days). Water temperatures measured at each site, along with the upper temperature threshold of 20.5°C (7-day maximum) for juvenile salmonid rearing, are illustrated on Figures 4.1 through 4.3.

Table 4.3 Descriptive statistics for continuous water temperature measured at four sites in Contra Costa County, April 19–September 25 (Alhambra Creek and Walnut Creek), April 19–August 1 (Wildcat Creek), and April 25–September 18 (Marsh Creek), 2012

Site	206WIL060	207ALH100	207WAL160	544MRC400
Temperature	Wildcat Creek	Alhambra Creek	Walnut Creek	Marsh Creek
Minimum	11.10	13.23	16.11	11.93
Median	14.52	17.23	19.39	21.82
Mean	14.74	17.31	20.49	23.71
Maximum	24.48	22.08	24.34	32.07
Max 7-day mean	18.65	19.98	23.81	27.56
# Measurements	2494	3813	2718	3502

The minimum and maximum temperature for all sites was 11.10°C and 32.07°C, respectively. The median temperature range for all four sites was 14.52°C to 21.82°C, and the maximum weekly average temperature (MWAT) range was 18.65°C to 27.56°C.

Figure 4.1 Water temperature data collected using HOBOs at four sites in Marsh, Walnut, Alhambra, and Wildcat Creeks, from April through September 2012

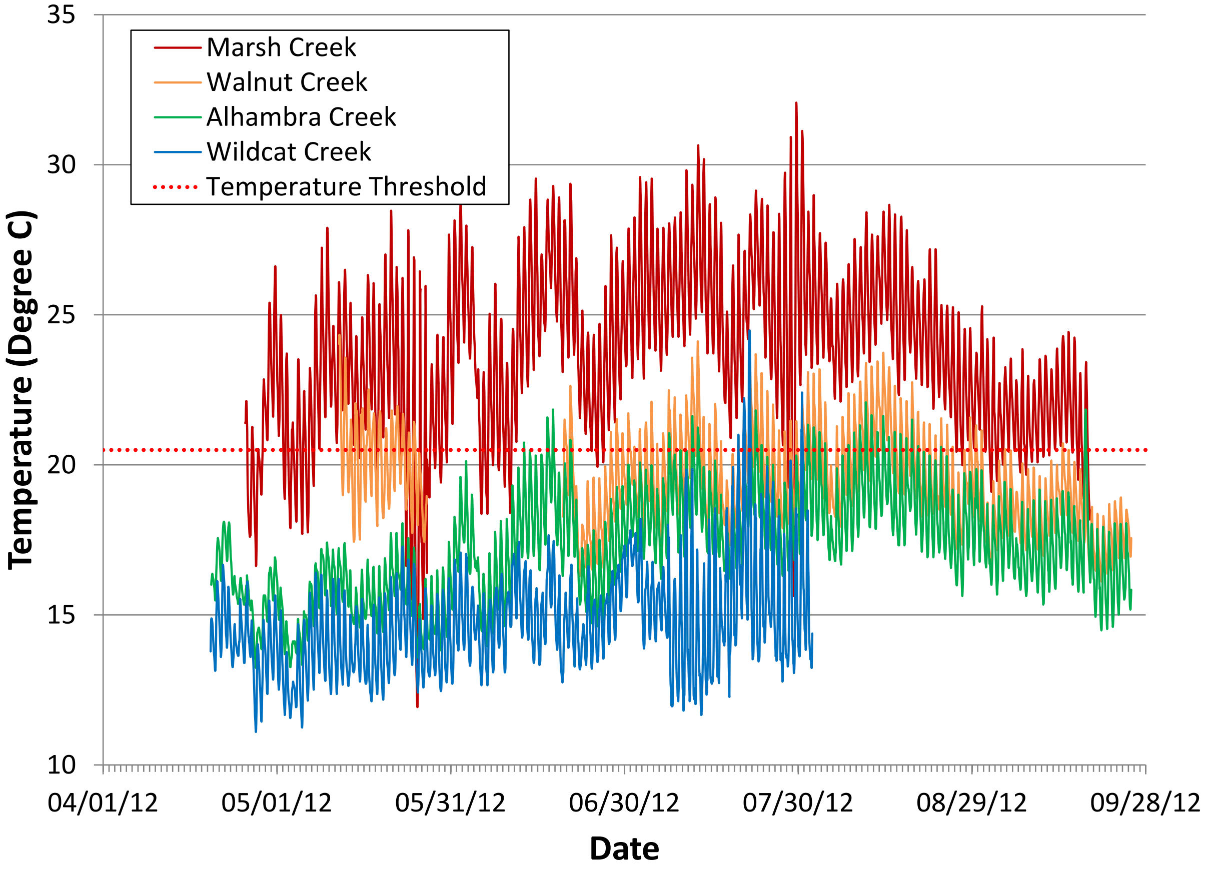


Figure 4.2 Seven-day average maximum daily water temperature (MWAT) data collected using HOBOs at four sites in Marsh, Walnut, Alhambra, and Wildcat Creeks, from April through September

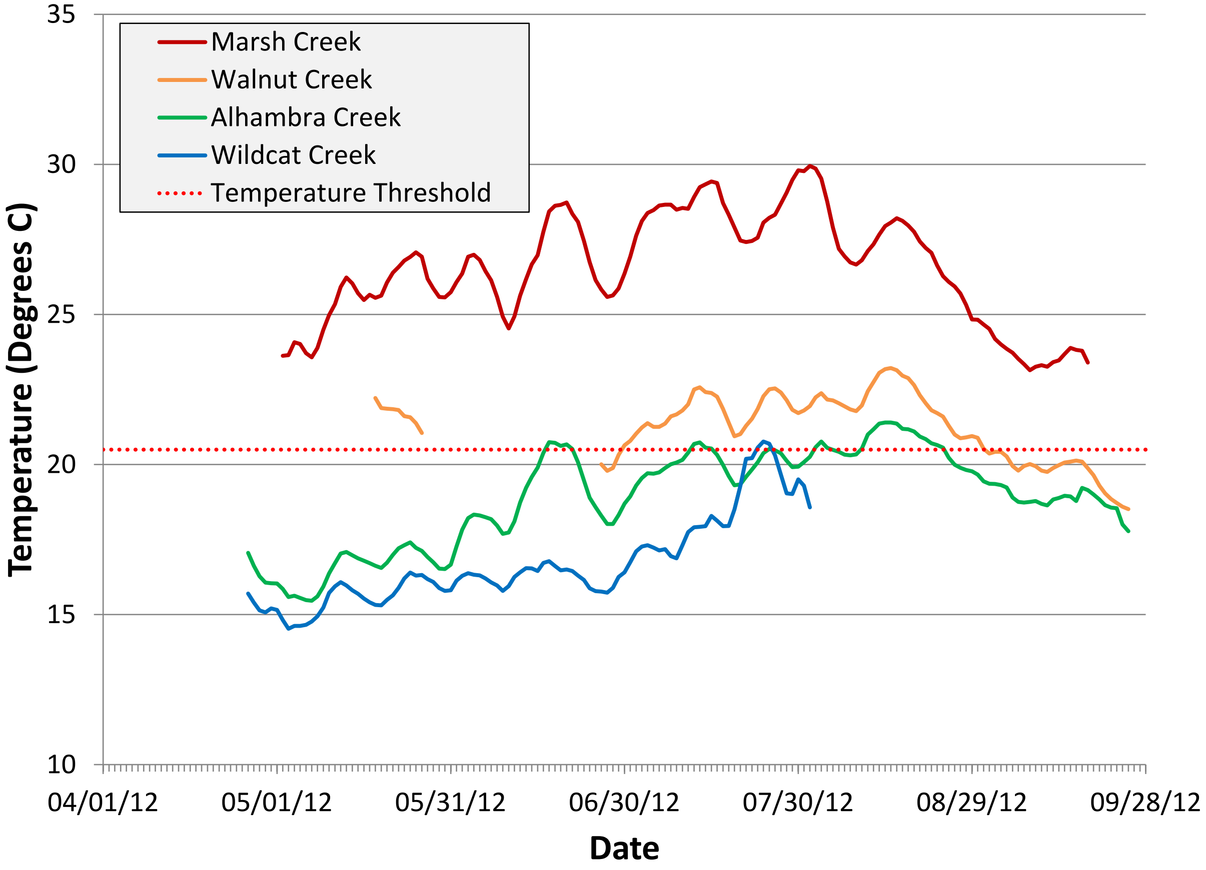
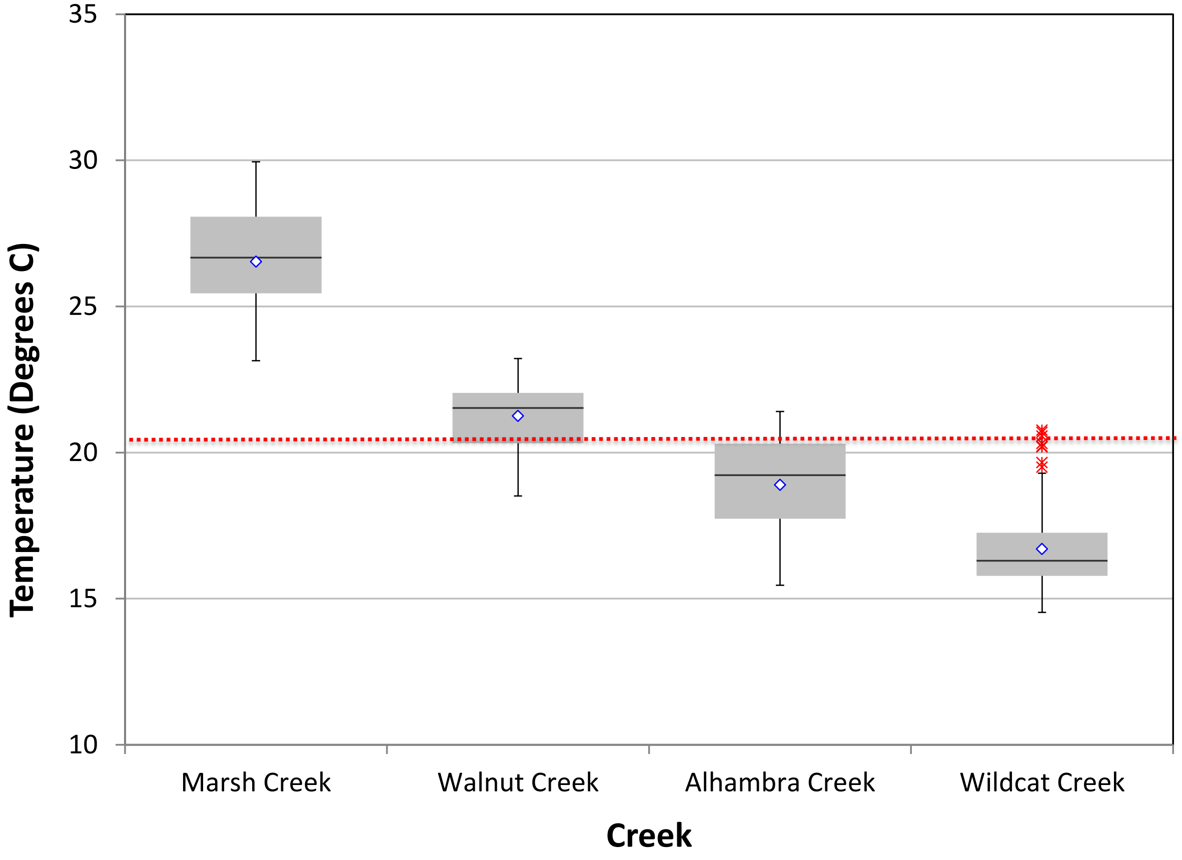


Figure 4.3 Box plots of 7-day average maximum daily water temperature (MWAT) at four sites in Marsh, Walnut, Alhambra, and Wildcat Creeks, from April through September 2012 (The red "X" points are outliers of the Wildcat Creek distribution. These outliers were the result of a rapid temperature rise at Wildcat Creek at the end of the deployment of the station HOBO device. Outliers are defined here as any value outside of the range Q1 – 1.5 (Q3 – Q1) and Q3 + 1.5 (Q3 – Q1), were Q3 = 75th quartile point and Q1 = 25th quartile point for each distribution.)



The distributions of 7-day average maximum daily water temperatures measured at the Alhambra Creek and Wildcat Creek stations both exceeded the annual maximum temperature threshold for salmonids (20.5° C) for less than 20% of the time during the sampling period (Table 4.4). The distributions at Marsh Creek and Walnut Creek show 100% and 68% exceedance, respectively (Table 4.4). Although the data set from Walnut Creek is missing the relatively cooler period from May 27 through June 18, 2012, the missing data do not appreciably alter the results. These water temperature monitoring results indicate the need for possible follow-up actions at Marsh Creek and Walnut Creek.

Table 4.4 Percent of water temperature data measured at four sites that exceed water quality criteria

Site ID	Creek Name	Monitoring period	*Temp Percent Results MWAT >20.5°C*
206WIL060	Wildcat	April 19–August 1, 2012	3%
207ALH100	Alhambra	April 19–September 25, 2012	18%
207WAL160	Walnut	April 19–September 25, 2012	68%
544MRC400	Marsh	April 25–September 18, 2012	100%

WY 2013

Summary statistics for water temperature data collected at the four sampling locations from April to September 2013 are shown in Table 4.5. Hourly temperature data were collected for approximately 166 consecutive days at each of four stations on Pinole and San Pablo Creeks. Water temperatures measured at each station, along with the upper temperature threshold of 20.5°C (7-day maximum) for juvenile salmonid rearing, is illustrated on Figures 4.4 through 4.6.

Table 4.5 Descriptive statistics for continuous water temperature measured at four sites in Contra Costa County, April 17–September 30, 2013.

Site Temperature	206PNL029	206PNL013	206PNL044	206SPA239
	Pinole Library	Pinole Creek West	Pinole Creek Park	San Pablo Creek
Minimum	11.35	11.22	10.59	9.51
Median	16.70	19.46	15.67	15.61
Mean	16.77	19.48	15.69	15.60
Maximum	20.96	25.70	18.89	21.08
Max 7-day Mean[1]	19.61	22.55	18.22	18.84
# Measurements	3980	3978	3982	3979

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

The minimum and maximum temperature for all stations was 9.51°C and 25.7°C, respectively. The median temperature range for all four stations was 15.61°C to 19.46°C, and the maximum weekly average temperature (MWAT) range was 18.22°C to 22.55°C.

Figure 4.4 Water temperature data collected using HOBOs at four sites in Pinole and San Pablo Creeks, from April through September 2013

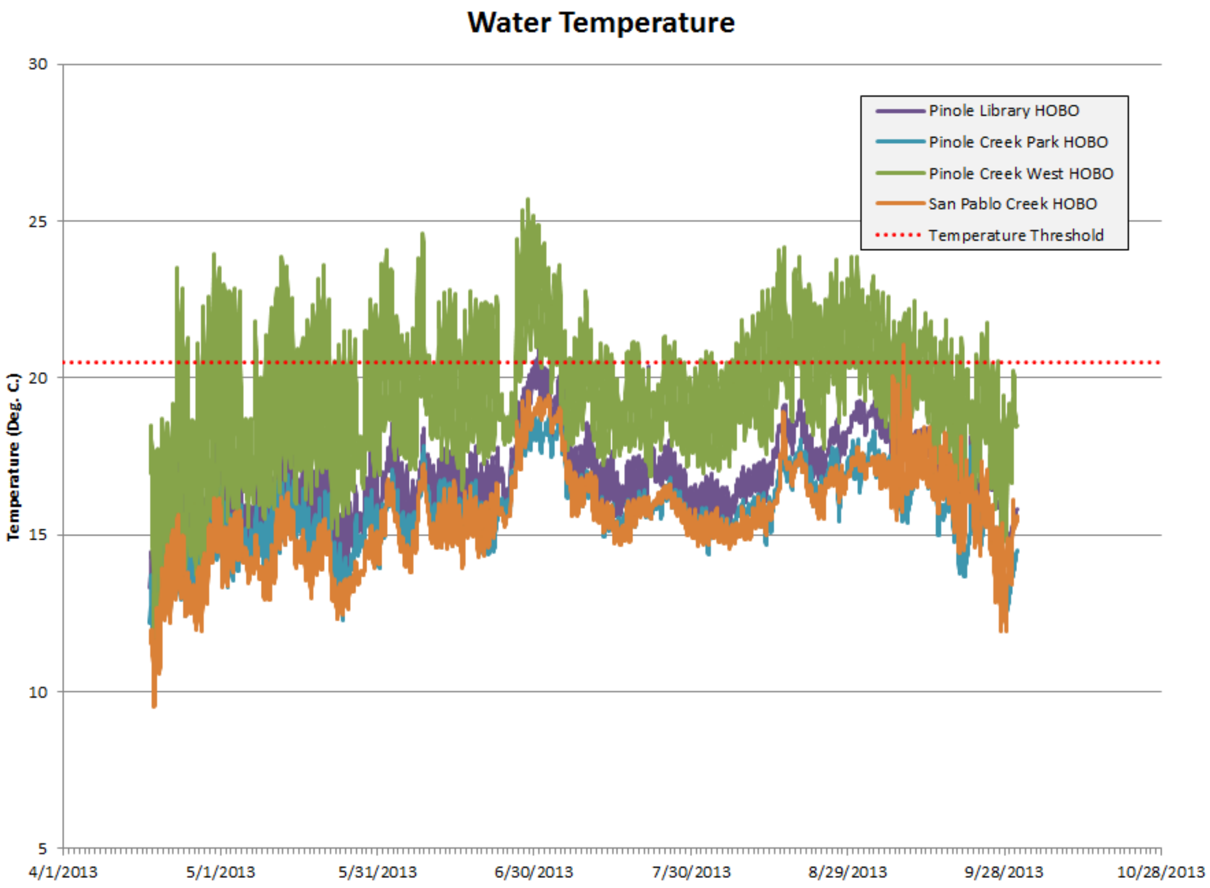


Figure 4.5 Seven-day average maximum daily water temperature (MWAT) data collected using HOBOs at four sites in Pinole and San Pablo Creeks, from April through September

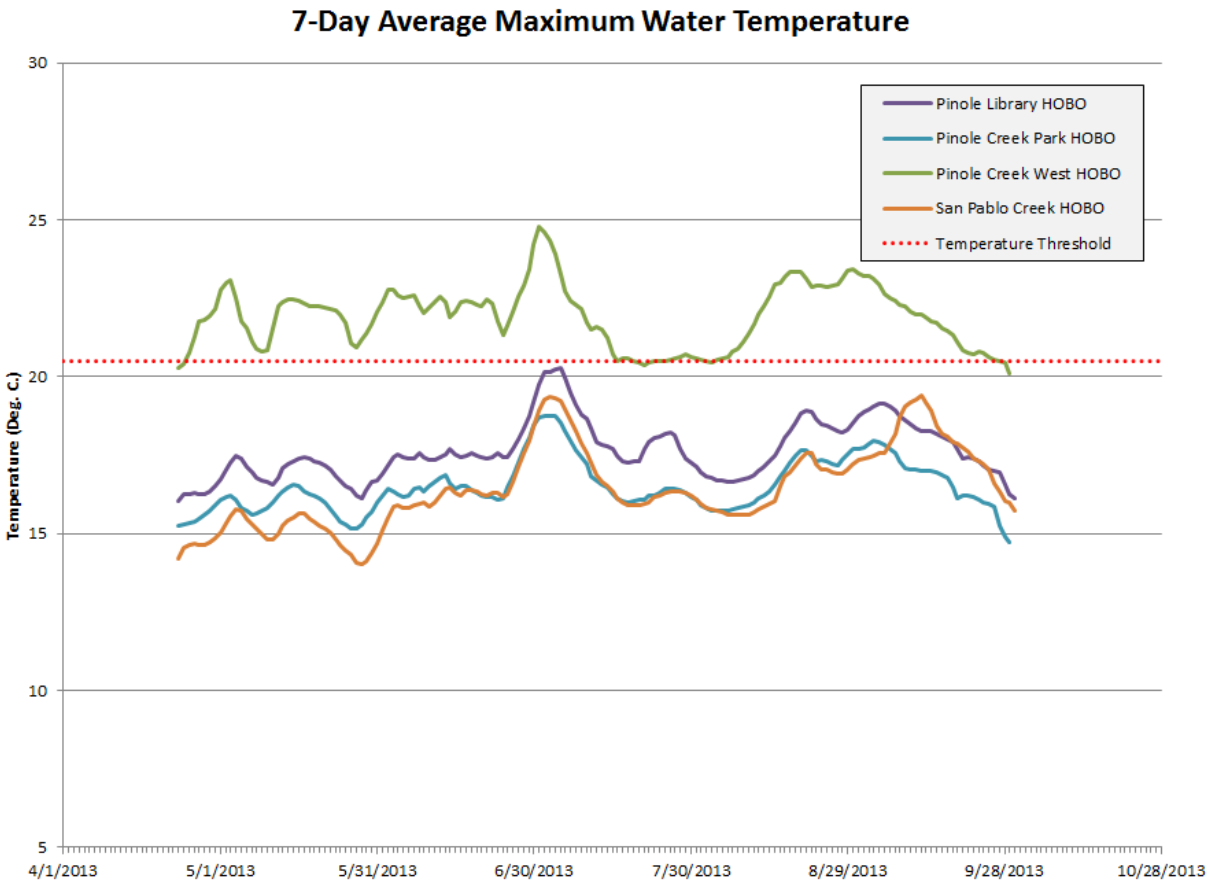
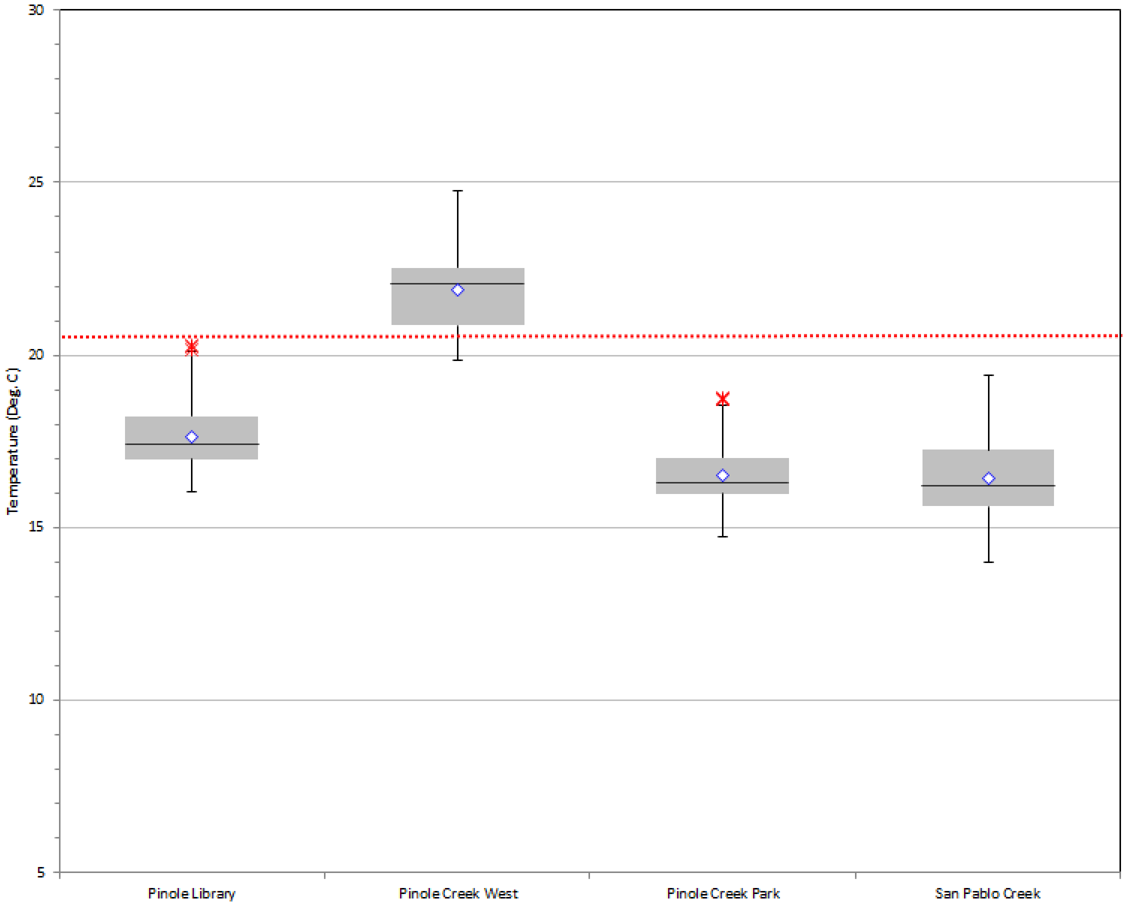


Figure 4.6 Box plots of 7-day average maximum daily water temperature (MWAT) at four sites in Pinole and San Pablo Creeks, from April through September 2013



(The red “X” points are outliers of the distributions. Outliers are defined here as any value outside of the range Q1 – 1.5 (Q3 – Q1) and Q3 + 1.5 (Q3 – Q1), were Q3 = 75th quartile point and Q1 = 25th quartile point for each distribution.)

The distribution of 7-day average maximum daily water temperatures measured at the Pinole Library, the Pinole Creek Park, and the San Pablo Creek stations were all less than the annual maximum temperature threshold for salmonids (20.5°C) for the entire duration of the sampling period (Table 4.6). The distribution at the Pinole Creek West station was above 20.5°C for 96% of the sampling period.

Table 4.6 Percent of water temperature data measured at four sites that exceed water quality criteria

Site ID	Creek Name	Monitoring period	*Temp Percent Results MWAT >20.5°C*
206PNL029	Pinole Library	April 17–September 30, 2013	0%
206PNL013	Pinole Creek West	April 17–September 30, 2013	96%
206PNL044	Pinole Creek Park	April 17–September 30, 2013	0%
206SPA239	San Pablo Creek	April 17–September 30, 2013	0%

4.2.2 General Water Quality

WY 2012

Summary statistics for general water quality measurements collected at two sites in Marsh Creek and Walnut Creek during two periods (May-June and August 2012) are shown in Table 4.7. Data collected during both periods along with the required thresholds are plotted on Figures 4.7 and 4.8. The measurements taken during the May-June 2012 period do not co-occur because only one YSI Sonde device was available for deployment at these stations. For that reason, the general water quality measurements for Marsh Creek were taken between May 8 and May 18, 2012, and those for Walnut Creek were taken between May 23 and June 3, 2012.

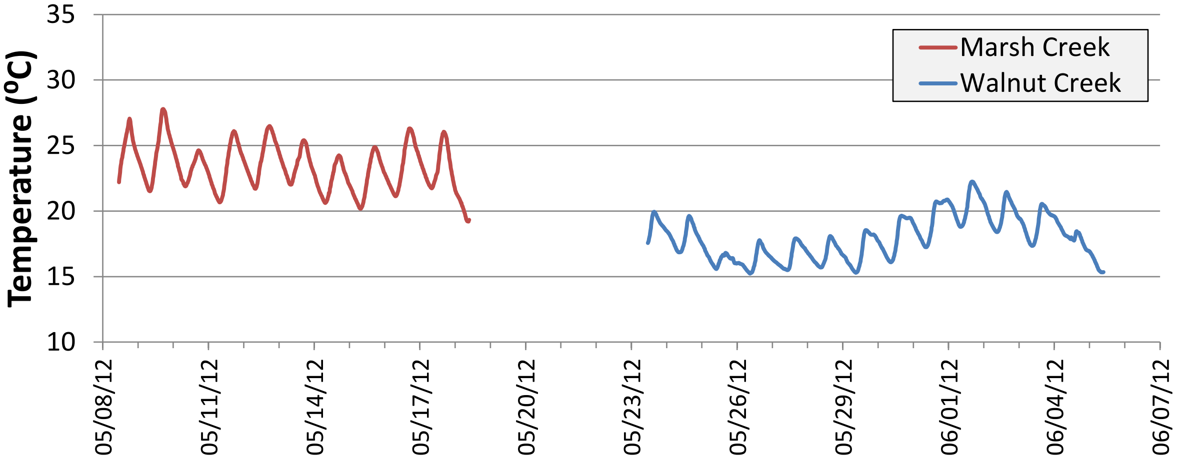
The lowest measured dissolved oxygen (DO) concentrations occurred during August 2012 at both Marsh Creek (4.09 mg/L) and Walnut Creek (6.35 mg/L).

The minimum and maximum pH measurements for Marsh Creek during both periods were 7.69 and 9.29, respectively. The minimum and maximum pH measurements for Walnut Creek during both periods were 8.20 and 8.55, respectively.

Table 4.7 Descriptive statistics for daily and monthly continuous water temperature, dissolved oxygen, conductivity, and pH measured at two sites in Contra Costa County, May 23–June 5 (Walnut Creek), May 8–18 (Marsh Creek), and August 1–13 (Event 2 both sites), 2012

Parameter		**Walnut Creek Site 207WAL160**		**Marsh Creek Site 544MRC400**	
		May	**August**	**May**	**August**
Temperature (°C)	Min	15.22	17.82	19.2	22.11
	Median	17.82	20.45	23.3	25.05
	Mean	17.96	20.50	23.37	23.71
	Max	22.25	23.53	27.79	28.98
	Max 7-day mean	20.53	21.59	25.06	27.47
Dissolved Oxygen (mg/L)	Min	7.17	6.35	5.03	4.09
	Median	8.72	7.34	10.56	8.96
	Mean	8.84	7.88	10.79	9.15
	Max	10.79	10.71	17.22	14.92
pH	Min	8.2	8.25	7.99	7.69
	Median	8.47	8.37	8.67	8.38
	Mean	8.46	8.38	8.68	8.37
	Max	8.55	8.53	9.28	9.29
Specific Conductivity (µS/cm)	Min	780	757	964	935
	Median	944	853	1347	1180
	Mean	933	847	1352	1189
	Max	980	889	1754	1480

Figure 4.7a Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) collected at Marsh and Walnut Creeks, May 8–June 5, 2012



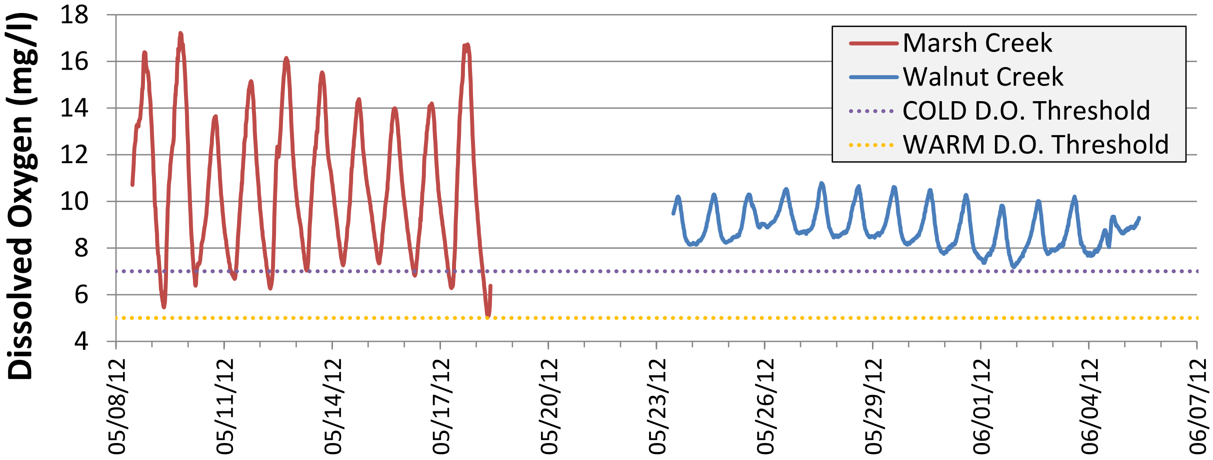
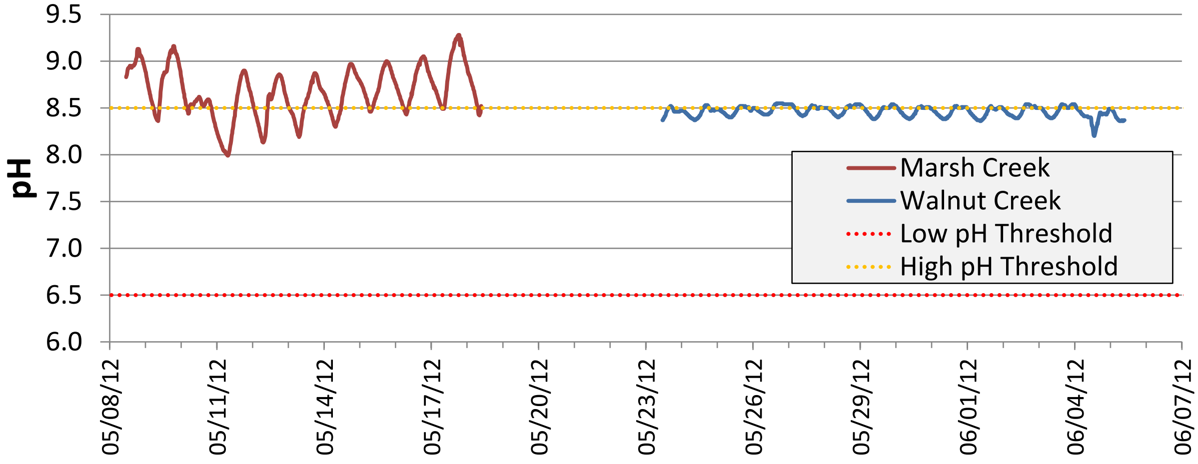


Figure 4.7b Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) collected at Marsh and Walnut Creeks, May 8–June 5, 2012 (Continued)



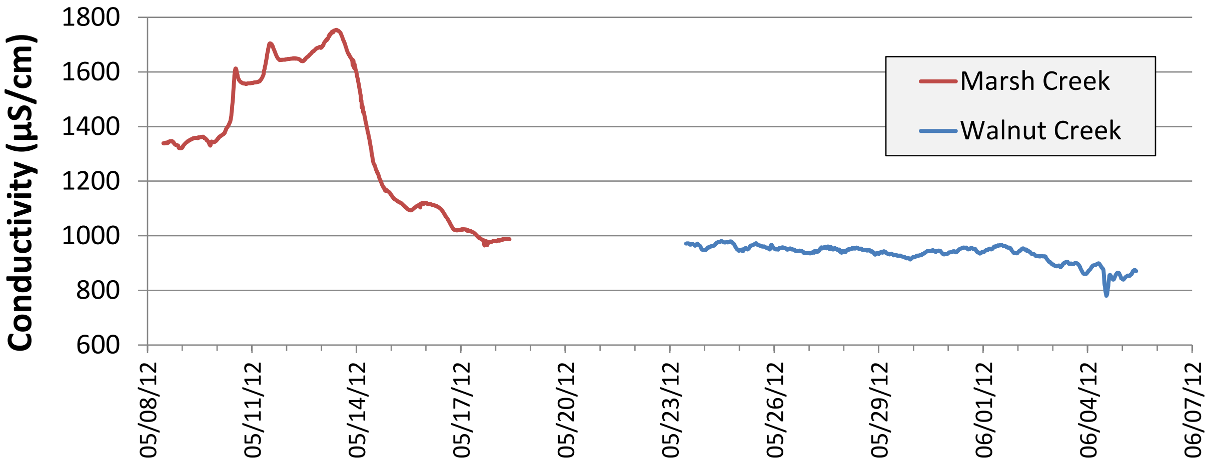


Figure 4.8a Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) for Marsh and Walnut Creeks, August 8–13, 2012

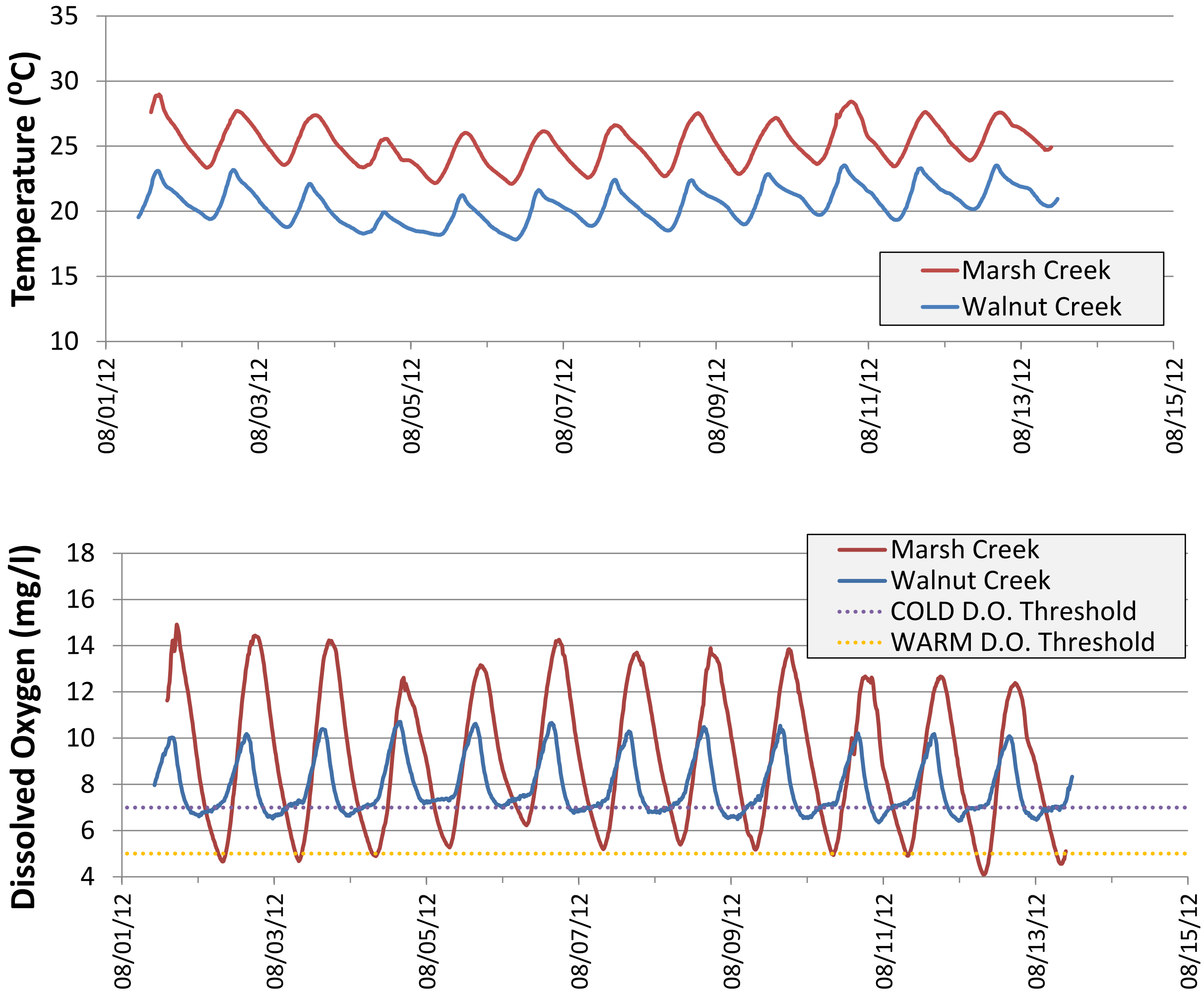
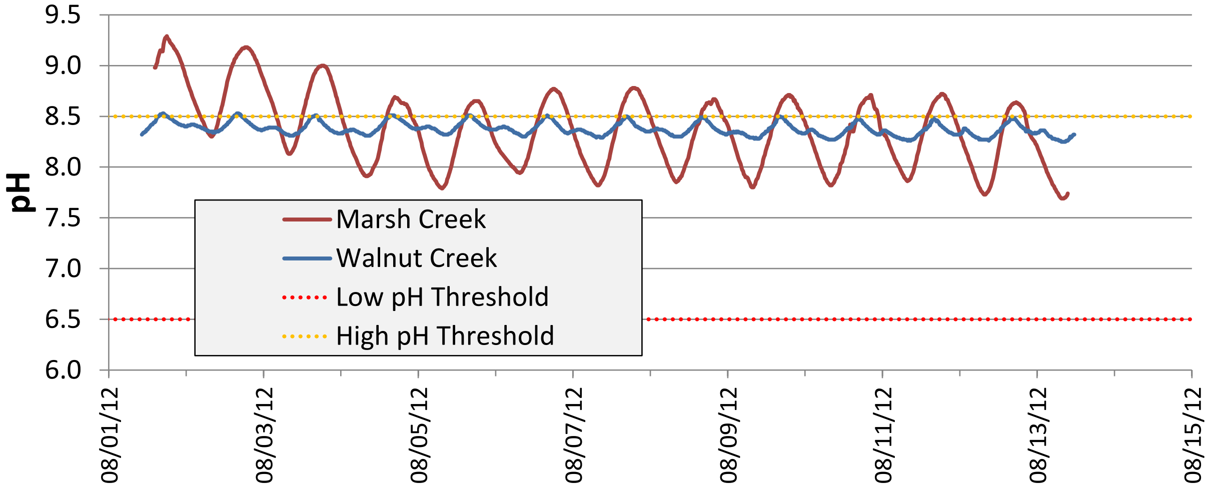


Figure 4.8b Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) for Marsh and Walnut Creeks, August 8-13, 2012 (Continued)



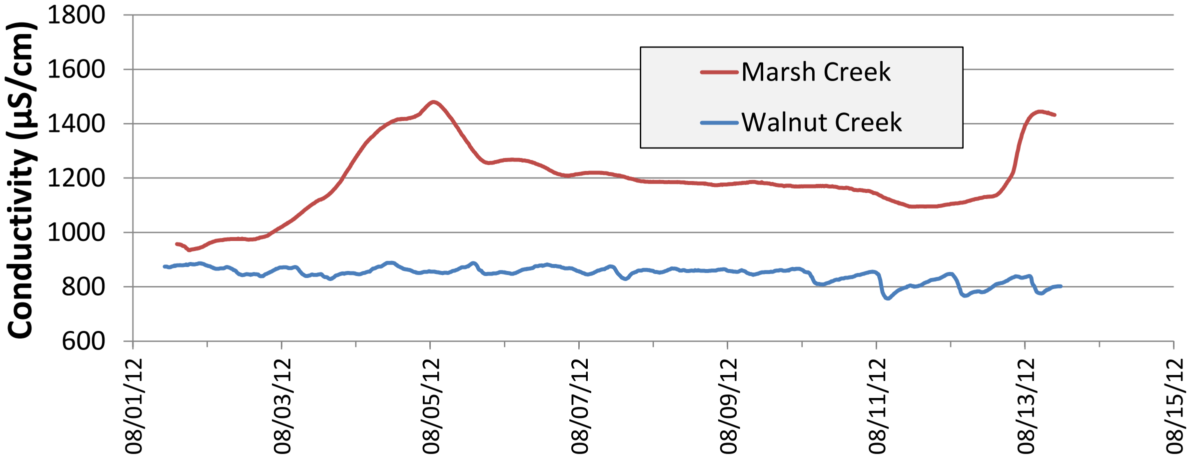


Figure 4.9 compares distributions of 7-day average maximum daily water temperature (MWAT) to the annual maximum temperature threshold for salmonids (20.5°C) at the Marsh Creek and Walnut Creek sites as recorded by the YSI Sonde devices during May-June and August 2012. The results show that only during the May-June deployment was Walnut Creek below the threshold. These results are consistent with those for the longer HOBO-based temperature series at these two stations.

Figure 4.9 Box plots of 7-day average maximum daily water temperature (MWAT) at Marsh and Walnut Creeks, during May-June 2012 and August 2012

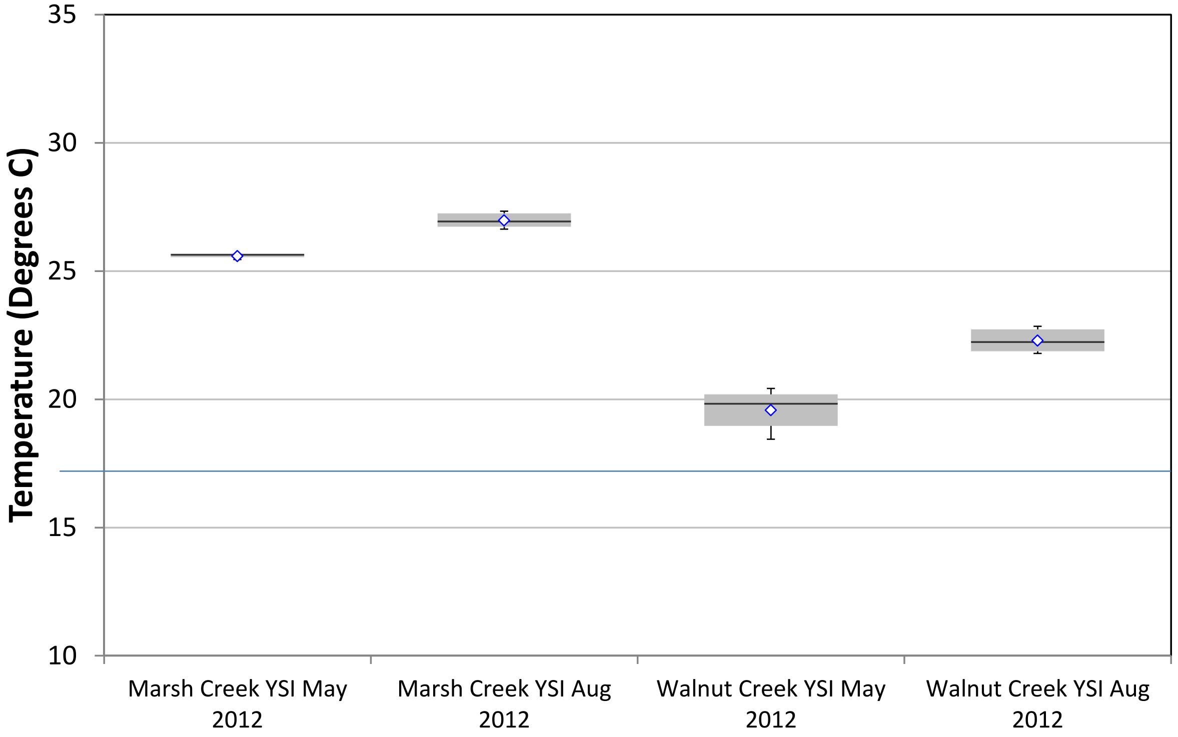


Table 4.8 presents the distribution of continuous water quality data for temperature, dissolved oxygen, and pH measured at Marsh Creek and Walnut Creek during both monitoring periods compared to water quality evaluation criteria specified in Table 8.1 of the MRP and Region 5 Permit (as summarized in this report, Table 3.3). The following summarizes any exceedances that occurred at either creek as follows:

- Walnut Creek:

    a. During the May-June 2012 deployment, water temperature exceeded the MWAT threshold 100% of the time.
    b. During the August 2012 deployment, DO fell below the COLD threshold 26% of the time.
    c. During the May 2012 deployment, pH exceeded the 8.5 threshold 26% of the time.
    d. During the August 2012 deployment, pH exceeded the 8.5 threshold 3% of the time.

- Marsh Creek:
  a. During the May and August 2012 deployments, water temperature exceeded the MWAT threshold 100% of the time.
  b. During the August 2012 deployment, DO fell below the WARM threshold 5% of the time.
  c. During the May 2012 deployment, pH exceeded the 8.5 threshold 75% of the time.
  d. During the August 2012 deployment, pH exceeded the 8.5 threshold 39% of the time.

These monitoring results indicate the need for possible follow-up actions at Marsh Creek and Walnut Creek.

Table 4.8 Percent of dissolved oxygen, water temperature, and pH data measured at two sites for both events that exceed water quality evaluation criteria identified in Table 3.3.

Site ID	Creek Name	Monitoring Period	*Temp Percent Results MWAT >20.5°C*	*DO Percent Results <5.0 mg/L (WARM)*	*DO Percent Results <7.0 mg/L (COLD)*	*pH Percent Results <6.5 or >8.5*
207WAL160	Walnut Creek	May 23–June 5, 2012	0%	-	0%	26%
		August 1–13, 2012	100%	-	28%	3%
544MRC400	Marsh Creek	May 8–18, 2012	100%	0%	-	75%
		August 1–13, 2012	100%	5%	-	39%

WY 2013

Summary statistics for general water quality measurements collected at stations on Pinole (near the Pinole Library) and San Pablo Creeks during two periods in April-May and August 2013 are shown in Table 4.7. Data collected during both periods along with the required thresholds are plotted on Figures 4.7 and 4.8.

Table 4.9 Descriptive statistics for continuous water temperature, dissolved oxygen, conductivity, and pH measured at two sites in Contra Costa County, Pinole Library (206PNL029) and San Pablo Creek (206SPA243), between April 30 and May 10 (Event 1), and between August 1 and August 12 (Event 2), 2013

Parameter		Pinole Creek (Library) Site 206PNL029		San Pablo Creek Site 206SPA243	
		Event 1	Event 2	Event 1	Event 2
Temperature (°C)	Min	14.28	15.09	12.64	14.31
	Median	15.66	16.35	14.20	14.80
	Mean	15.82	16.36	14.32	14.82
	Max	17.86	17.54	16.62	15.65

Parameter		Pinole Creek (Library) Site 206PNL029		San Pablo Creek Site 206SPA243	
		Event 1	Event 2	Event 1	Event 2
	Max 7-day mean[1]	16.14	16.49	14.72	14.89
Dissolved Oxygen (mg/L)	Min	5.18	3.83	7.86	6.67
	Median	6.95	5.76	9.14	8.16
	Mean	6.95	5.70	9.14	8.28
	Max	8.28	7.70	10.05	8.89
pH	Min	7.72	7.63	8.02	7.99
	Median	7.88	7.77	8.12	8.10
	Mean	7.89	7.78	8.12	8.10
	Max	7.97	7.91	8.23	8.20
Specific Conductivity (µS/cm)	Min	1343	1583	664	606
	Median	1366	1604	686	620
	Mean	1365	1609	685	621
	Max	1403	1657	717	633

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

Figure 4.10a Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) collected at Pinole Library and San Pablo Creeks, April 30-May 10, 2013

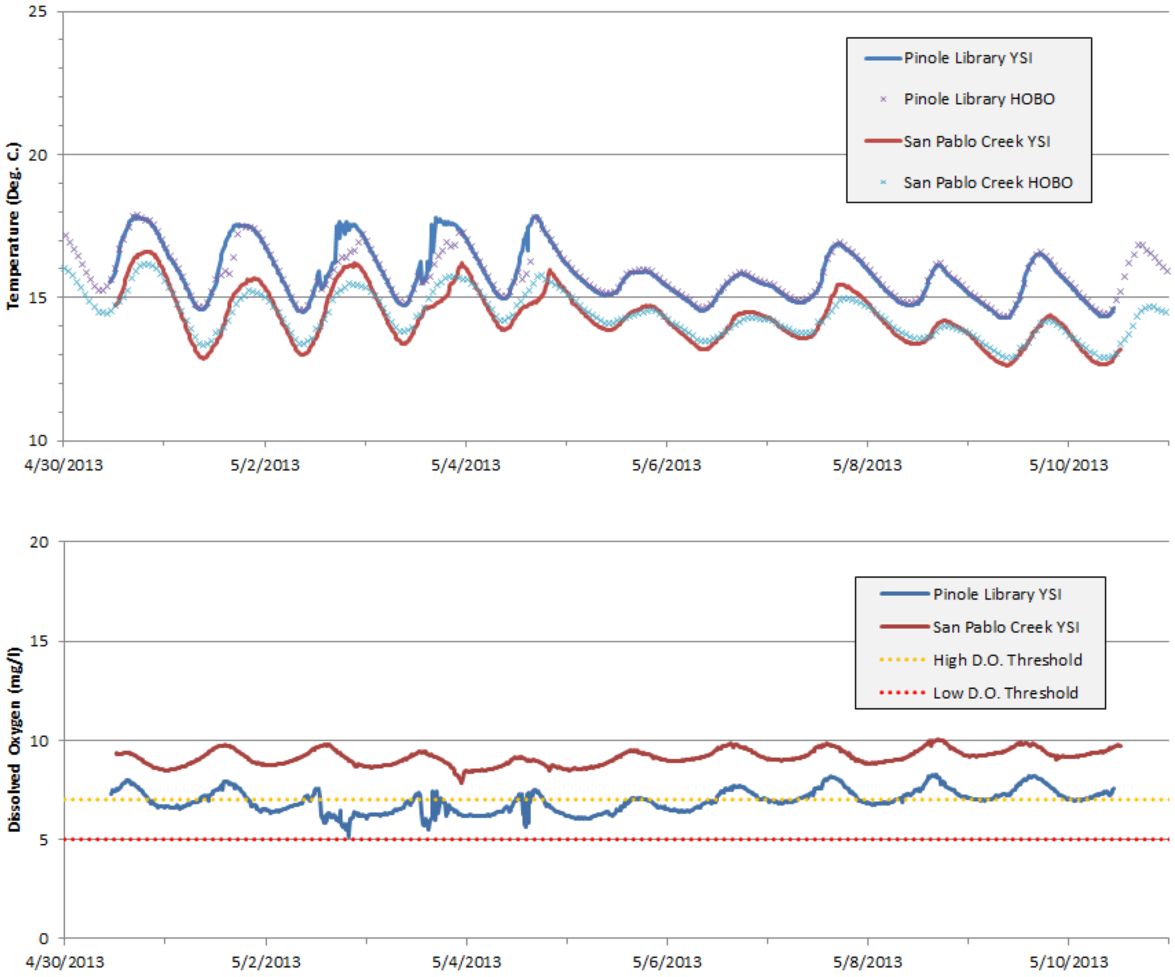
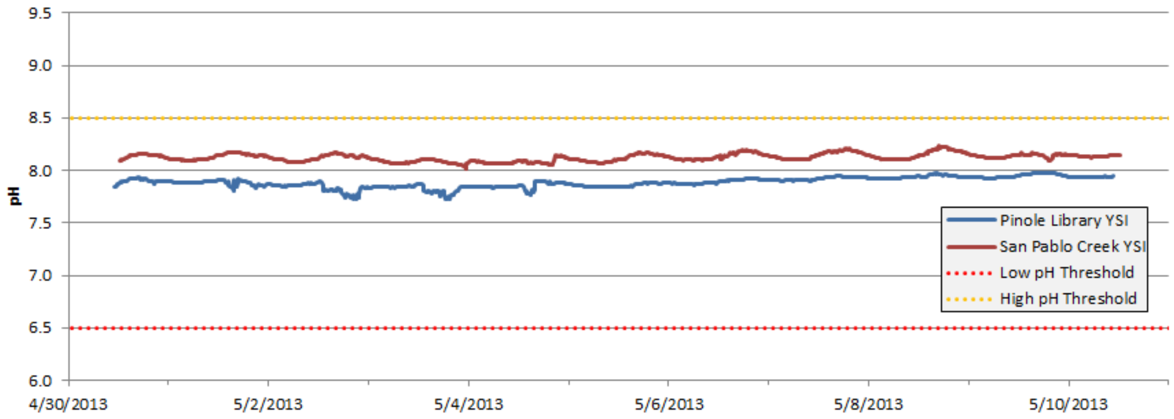


Figure 4.10b Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) collected at Pinole Library and San Pablo Creeks, April 30-May 10, 2013 (continued)



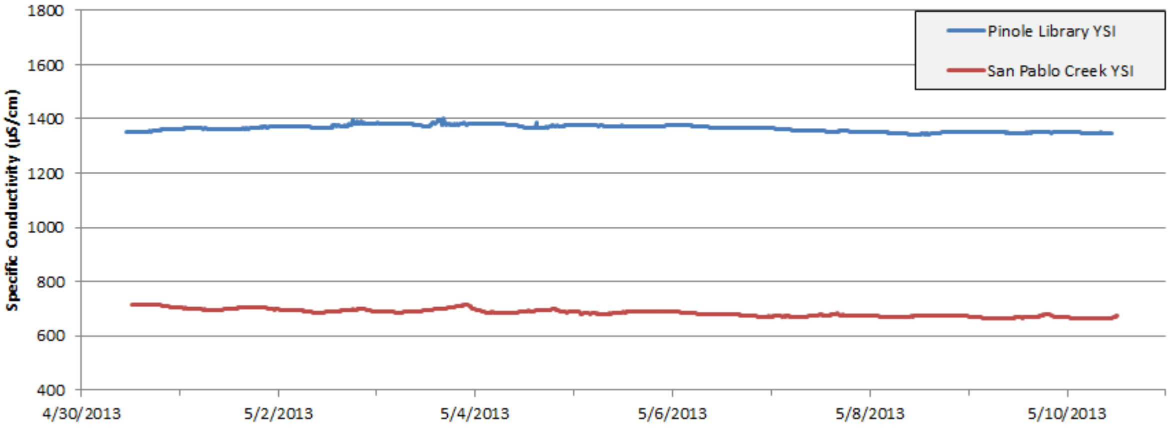
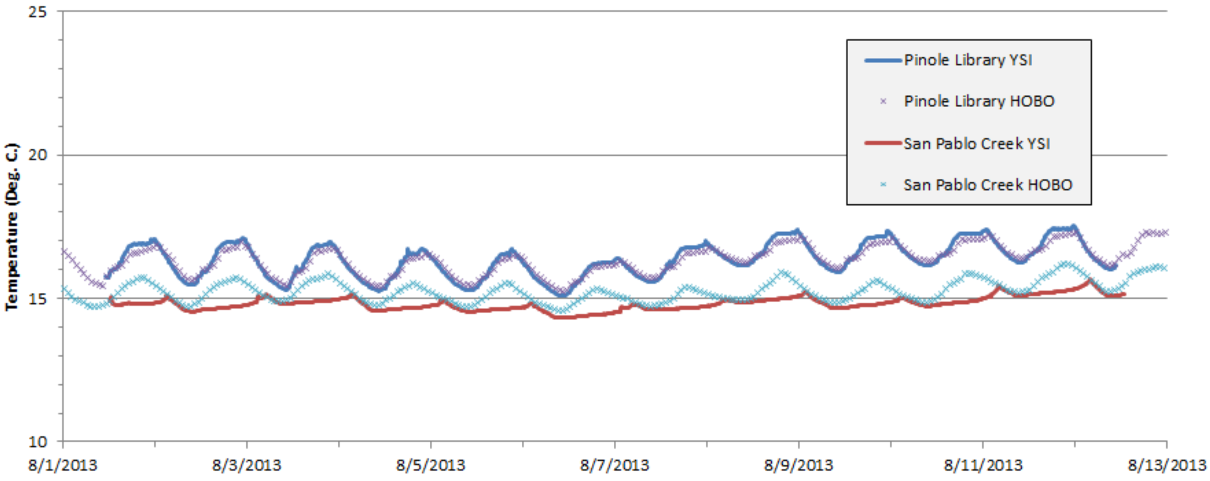


Figure 4.11a Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) collected at Pinole Library and San Pablo Creeks, August 1-12, 2013



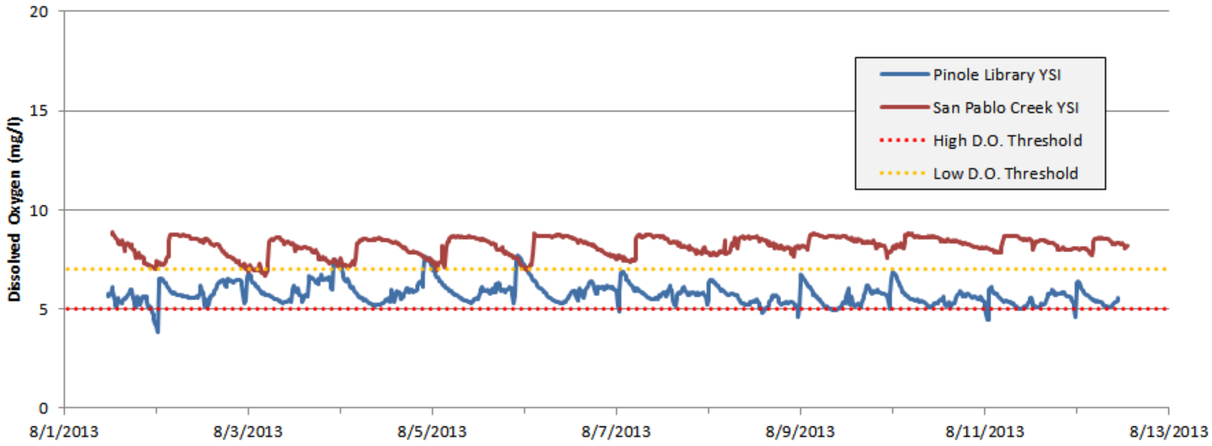
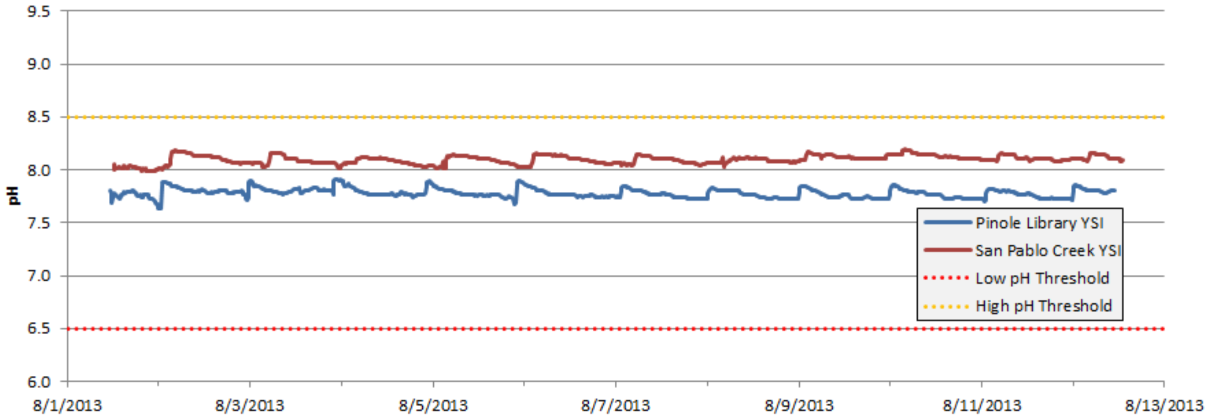
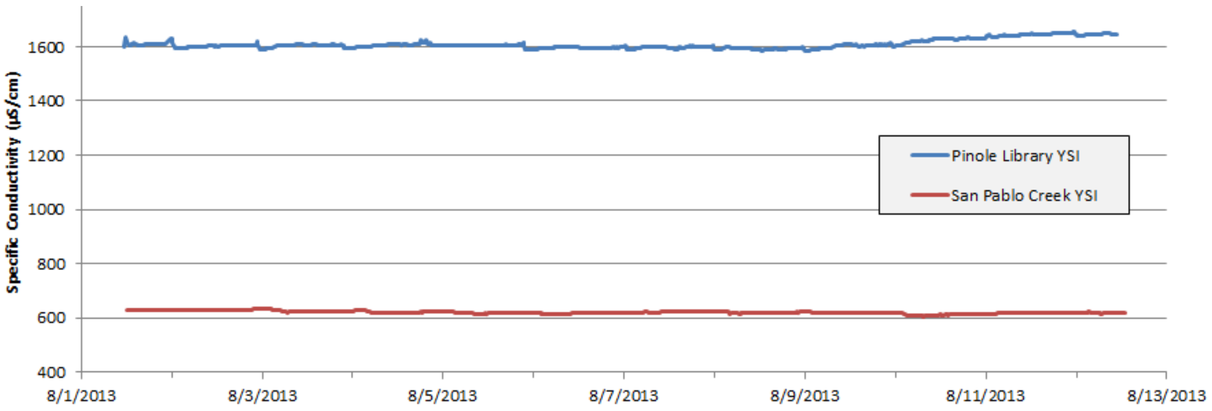


Figure 4.11b Continuous water quality data (temperature, dissolved oxygen, pH, and specific conductivity) collected at Pinole Library and San Pablo Creeks, August 1-12, 2013 (Continued)





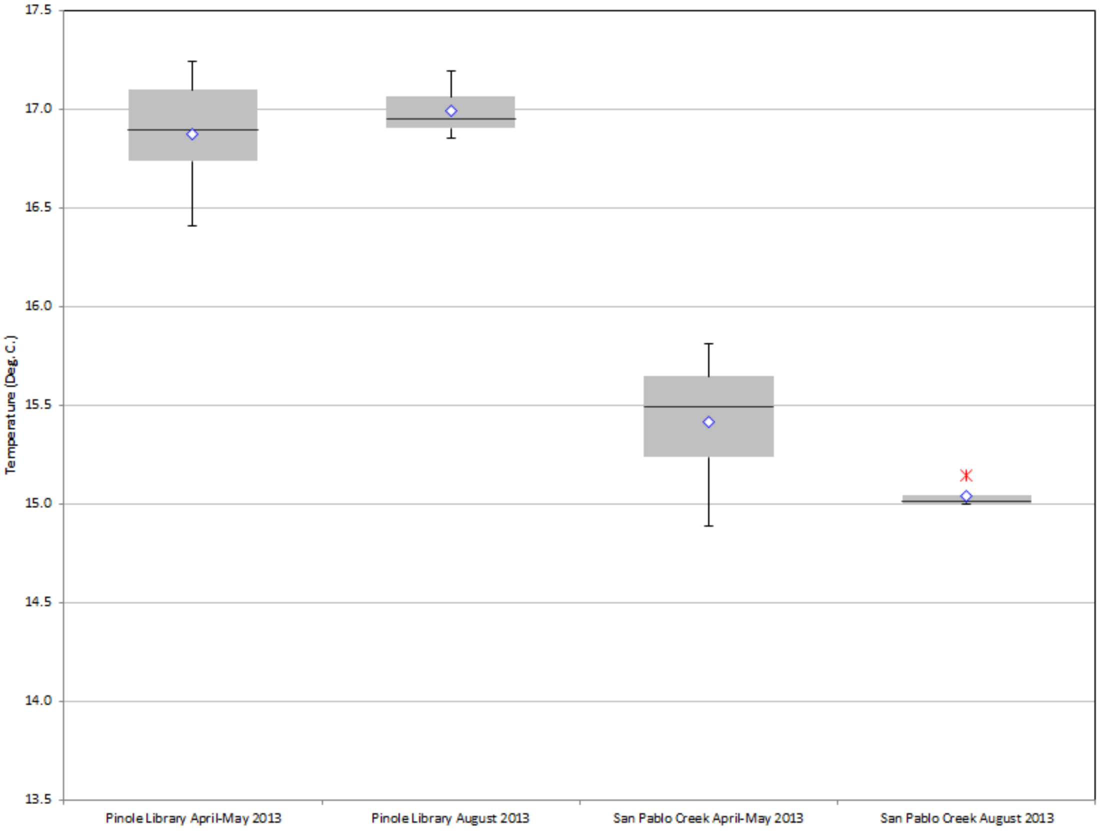
The lowest dissolved oxygen (DO) concentration (3.83 mg/L) at the Pinole Library station occurred during August 2013. The lowest DO concentration (6.67 mg/L) at the San Pablo Creek station also occurred during August 2013. The minimum and maximum pH measurements for the Pinole Library station during both periods were 7.63 and 7.97, respectively. The minimum and maximum pH measurements at the San Pablo Creek station during both periods were 7.99 and 8.23, respectively.

During the second deployment at San Pablo Creek (August 1-12, 2013) of the YSI Sonde, the device was located in a different location from that used in the first deployment (April 30 through May 10, 2013). This was done as there was not enough water at the first deployment location for the device to be completely submerged. A suitable location was found about 80 feet downstream from the April–May sampling spot. As a result, temperature data recorded by this device does not match the same parameter recorded by the HOBO device as it normally would. This result can be seen in the first time series graph on Figure 4.5. The device was located in deeper water than the HOBO device, so, in general, the water temperatures measured by it are lower than the YSI Sonde.

Figure 4.12 compares distributions of 7-day average maximum daily water temperature (MWAT) to the selected maximum temperature threshold for salmonids (20.5°C) at the Pinole Library and

San Pablo Creek stations as recorded by YSI Sonde devices in April and May 2013 and August 2013. The results show that the MWATs at these stations were always below the temperature threshold. These results are consistent with those for the longer HOBO temperature series at these two stations.

Figure 4.12 Box plots of 7-day average maximum daily water temperature (MWAT) at Pinole Library and San Pablo Creeks, during April and May 2013 and August 2013



(The red “X” points are outliers of the distributions. Outliers are defined here as any value outside of the range Q1 – 1.5 (Q3 – Q1) and Q3 + 1.5 (Q3 – Q1), were Q3 = 75th quartile point and Q1 = 25th quartile point for each distribution.)

Table 4.10 presents the distribution of continuous water quality data for temperature, dissolved oxygen, and pH measured at the Pinole Library and San Pablo Creek stations during both monitoring periods compared to water quality evaluation criteria specified in Table 8.1 of the MRP and Region 5 Permit (as summarized in this report, Table 3.3). The following summarizes water quality evaluation criteria exceedances that occurred at either creek:

- Pinole Library:
  - During the April–May 2013 deployment, DO fell below the COLD threshold 53% of the time.
  - During the August 2013 deployment, DO fell below the COLD threshold 2% of the time and the WARM threshold 97% of the time.

- San Pablo Creek:
    - During the August 2013 deployment, DO fell below the COLD threshold 1% of the time.

Table 4.10 Percent of water temperature, dissolved oxygen, and pH data measured at two sites for both events that exceed water quality evaluation criteria identified in Table 3.3.

Site ID	Creek Name	Monitoring Period	Temp Percent Results MWAT >20.5°C	DO Percent Results <5.0 mg/L (WARM)	DO Percent Results <7.0 mg/L (COLD)	pH Percent Results <6.5 or >8.5
206PNL029	Pinole Library	April 30–May 10, 2013	0%	0%	53%	0%
		August 1–12, 2013	0%	2%	97%	0%
206SPA243	San Pablo Creek	April 30–May 10, 2013	0%	0%	0%	0%
		August 1–12, 2013	0%	0%	1%	0%

4.2.3 Water Quality Data Evaluation for Steelhead Suitability

4.2.3.1 Water Year 2012: Alhambra, Marsh, Walnut and Wildcat Creeks

In 2012, the Contra Costa County Clean Water Program and its consultants monitored water temperature and other water quality parameters at one location on each of the following creeks: lower Marsh Creek between Brentwood and Knightsen; Walnut Creek in the City of Walnut Creek; Alhambra Creek in Martinez; and Wildcat Creek in San Pablo. Water temperature monitoring occurred from April or May through September of that year. This water temperature data showed the two waterways of greatest concern regarding temperatures to support salmonids were Marsh Creek and Walnut Creek, with Marsh Creek temperatures being particularly high throughout the period monitored. The water temperatures in Alhambra Creek and Wildcat Creek appeared sufficiently cool for juvenile steelhead rearing. Therefore, only Marsh Creek and Walnut Creek are addressed below.

Previous observation of Marsh Creek and Walnut Creek have shown that slow currents, warm water temperatures, and a high degree of channel exposure to solar radiation result in extensive growth of filamentous algae in the wetted creek channel. When this large amount of algae biomass is living, it begins to produce dissolved oxygen by photosynthesis once the sun rises, particularly as it shines on the water. If there is minimal current and wind rippling the stream channel waters, super saturation of dissolved oxygen is common. During the night, the algae revert to respiration and consume dissolved oxygen, dropping the stream's dissolved oxygen level to its minimum by dawn. Carbon dioxide produced by the algae during the evening's respiration is the major natural factor holding down the pH of the water. When excessive dissolved oxygen is produced in the stream water because of a large volume of living algae or aquatic plant biomass responding to the sunlight, the carbon dioxide in the water is greatly reduced and pH rises. So even long before decomposition of the dying filamentous algae in the fall increases the stream's Biochemical Oxygen Demand (BOD) and lowers levels of dissolved oxygen, the natural cycle of algae photosynthesis during the day and respiration during the night causes large shifts in dissolved oxygen and pH on a diurnal basis.

As these algae-filled lower ends of Marsh Creek and Walnut Creek are not providing summer rearing habitat for juvenile salmonids (too warm, too much fluctuation of dissolved oxygen, not enough shelter), the observed spring and summer exceedances of dissolved oxygen and pH standards are not impacting any salmonid fisheries which may occur upstream in cooler waters. Relative to salmonids, the October-November levels of dissolved oxygen and pH are a greater concern as Chinook salmon adults attempt to ascend the stream at this time of year, and the lower portions of these two creeks provide migratory passage habitat for these spawning adults. In addition to monitoring temperature, dissolved oxygen, and pH in the lower ends of these creeks during adult Chinook salmon migration in the fall, it might also be worthwhile to monitor the water quality at these locations during the March-April outmigration of steelhead smolts and salmon young-of-the-year. One year's set of water quality monitoring data during these periods and locations may be all that is needed to dismiss concerns for water quality suitability for salmonid passage through the lower portions of these two creeks.

4.2.3.2 Water Year 2013: Pinole and San Pablo Creeks

In 2013, the Contra Costa County Clean Water Program and its consultants monitored water temperature and other water quality parameters at three locations on Pinole Creek (Pinole Creek West, Pinole Library, and Pinole Creek Park), and one on San Pablo Creek in Orinda.

Pinole Creek

Water Temperature: Using 20.5°C as the water temperature upper threshold for juvenile steelhead rearing, only Pinole Creek West had MWATs recorded by the HOBO devices in excess of this criteria (Table 4.2). This is to be expected as this monitoring station lies midway in the 1.5 mile long channelized reach below I-80. For much of the year, Pinole Creek flows slowly through these shallow channels with little shade. Just 0.3 mile upstream of the channelized reach and I-80, the Pinole Library monitoring station showed a maximum MWAT temperature recorded by the YSI Sonde of 19.61°C, well within the criteria, with a maximum of 18.22°C at Pinole Creek Park further upstream. This channelized lower end of Pinole Creek is passage habitat for adult steelhead and smolts during high flows and is never rearing habitat for juveniles. The 5.8 miles of juvenile steelhead rearing habitat begins approximately 0.2 mile east of the Pinole Library and proceeds upstream until a natural barrier waterfall is encountered (Mulchaey, personal communication).

Dissolved Oxygen: The Basin Plan's objective for waters designated as COLD water habitat is to have dissolved oxygen concentrations at 7.0 mg/L or greater, and WARM water habitat at 5.0 mg/L dissolved oxygen or greater. Pinole Creek is listed in the Basin Plan as having both WARM and COLD water habitat. It is logical that the WARM designation would apply to the lower creek while the COLD would apply to the upper creek, but the location of this line of demarcation is unknown. The single dissolved oxygen monitoring site on Pinole Creek was at the Pinole Library monitoring station, which is only 0.3 mile upstream of the channelized portion and at the lower end of the 5.8-mile stream reach with water temperatures suitable for rearing steelhead. The measured dissolved oxygen concentrations values met the WARM water criteria of 5.0 mg/L dissolved oxygen except for 2% of the time during the August 2013 deployment. Generally, they failed to meet the COLD water criteria of 7.0 mg/L.

When questioned as to the location of the demarcation line for WARM versus COLD water designation in Pinole Creek, Dr. Mulchaey, fisheries biologist at EBMUD's San Pablo Reservoir office, said he was unaware of any official line of demarcation. He said that based on his electrofishing and water quality monitoring of Pinole Creek, he would put the demarcation line at either Ramona Street or lower Simas Avenue in Pinole. He reported that gradient, water temperature, and riparian cover west of these locations are suitable for juvenile steelhead rearing and that he has captured juvenile steelhead/resident rainbow trout at these locations, but not at the Pinole Library site which is closer to I-80 (Mulchaey, personal communication). Therefore, unless told otherwise by the RWQCB, the Pinole Library monitoring site will be considered to be in the WARM water habitat designation. Using the WARM water criteria of a minimum of 5.0 mg/L dissolved oxygen for evaluation of the Pinole Library dissolved oxygen data, this site met the Basin Plan criteria.

pH: The Basin Plan states that pH shall not be depressed below 6.5 or raised above 8.5. All pH readings met these criteria.

Specific Conductivity: There is no Basin Plan criterion for specific conductivity. The increase in conductivity seen in the median value of 1366 µS/cm in May versus the median value of 1604 µS/cm in August is likely because streams in the East Bay are reliant on a higher percent of their flow being groundwater as the summer progresses. Many of these streams have groundwater that leaches through old marine formations. The groundwater picks up salts that make the stream flow have higher conductivity as the summer progress until the rainy season begins. Although relatively high in conductivity, Pinole Creek conductivity values are common in the San Francisco Bay area.

San Pablo Creek

Temperature: The 2013 water quality data from San Pablo Creek is from a location in Orinda, well upstream of San Pablo Reservoir. Although steelheads have not entered these waters since San Pablo Dam was completed in 1919, resident rainbow trout do occur in this reach. Using the same temperature criteria used for juvenile steelhead (20.5°C) for the resident rainbow trout habitat, and as the maximum MWAT for this site was 18.84°C, this San Pablo Creek station met the upper threshold temperature criteria for resident rainbow trout.

Dissolved Oxygen: San Pablo Creek is also listed in the Basin Plan as being both WARM and COLD water habitat as Beneficial Uses. It is assumed that this upper watershed stream reach in Orinda would be designated as COLD water habitat and would have a Basin Plan objective for dissolved oxygen of 7.0 mg/L or greater. The monitored dissolved oxygen values met the criteria for waters designated COLD water habitat.

pH: All pH readings met the Basin Plan criteria.

Specific Conductivity: The May median reading was 686 µS/cm conductivity, and the August median reading was 620 µS/cm. All August readings of conductivity were lower than the May reading. These are very normal values of conductivity in freshwater streams in the San Francisco Bay area.

4.2.3.3 Summary Water Quality Data Evaluation for Steelhead Suitability

The 2012 water temperature data from the lower ends of the Contra Costa Creeks are valuable for determining which creeks need close attention when assessing stream temperature conditions. Wildcat Creek and Alhambra Creek appear suitable regarding summer water temperatures for anadromous salmonids, in relation to the upper threshold water temperature criteria of 20.5°C for rearing juvenile steelhead. Due to numerous temperature threshold exceedances in their lower reaches, both Walnut Creek and Marsh Creek need further investigation. The upper end of Marsh Creek above Curry Creek contains resident rainbow trout and has instream habitat and riparian shading very suitable for salmonids. However, whether or not anadromous salmonids can access the upper waters because of physical or thermal barriers will require further study and temperature monitoring. Marsh Creek is in the Central Valley Basin Plan and is not designated as cold water habitat, so it is assumed to have a warm water designation. If further monitoring of water temperature along its length shows that temperatures allow anadromous salmonid passage through the lower portion of March Creek in October through December, and summer water temperatures upstream are suitable for steelhead rearing, then it may be necessary to have separate water temperature criteria for the upper and lower portions of the creek.

Based on the 2013 temperature data, only the lowermost 1.5 miles of Pinole Creek west of I-80 had MWAT values that were generally in excess of the 20.5°C criterion. Pinole Creek West is located in the middle of a reach of channelized stream channel with minimal shade. An estimated 5.8 miles of Pinole Creek with summer temperatures suitable for rearing juvenile steelhead exists east of I-80.

At the lower end of the 5.8 miles of suitable rearing habitat, monitoring station Pinole Library is 0.3 mile from I-80. Water temperature readings met the temperature criteria, but may or may not meet the dissolved oxygen criteria. Pinole Creek is designated in the Basin Plan as being both WARM and COLD water habitat, but the line of demarcation is unknown. Burt Mulchaey, fisheries biologist for EBMUD, believes the appropriate location for this line of demarcation is in Pinole at either Ramona Street (0.17 mile upstream of the Pinole Library) or the lower end of Simas Avenue (0.63 mile upstream of the Pinole Library). Dr. Mulchaey's assessment is based on stream gradient, water temperature, riparian cover, and electrofishing results. This placement puts the Pinole Library monitoring station in the WARM water habitat designation where the dissolved oxygen objective is 5.0 mg/L dissolved oxygen or higher. The dissolved oxygen levels recorded for this site met this criterion.

The water temperature, dissolved oxygen, and pH values for San Pablo Creek at Orinda all met the Basin Plan criteria.

4.3 Pathogen Indicators

WY 2012

The FC District performed a pilot study in June 2012, to compare the effectiveness of grazing with goats and sheep versus the traditional use of herbicides for vegetation management and assess potential impacts to water quality from each maintenance practice. Water quality samples were collected by FC District staff at eight sites along the reach (upstream to downstream) where the livestock were grazing and were analyzed for fecal coliform during each day of the 12-day grazing period from June 12 through June 23. To augment this pilot study, and to meet MRP and Region 5 Permit Provision C.8.g. requirements, another set of pathogen indicator samples were collected by ADH staff on July 12, 2012, at five sites along the same reach of Walnut Creek and were analyzed for fecal coliform and *E. coli*. Table 4.11 summarizes the results of analyses of the samples collected on July 12, 2012.

Table 4.11 Fecal coliform and *E. coli* levels measured from water samples collected on July 12, 2012, at five locations in Walnut Creek

Site ID	*Fecal Coliform (MPN/100 mL)*	*E. Coli (MPN/100 mL)*
207WALW01	**450**[1]	450[2]
207WALW02	300	300
207WALW03	240	130
207WALW04	130	34
207WALW05	130	130

1 – Exceeded Basin Plan WQO of 400 MPN/100 mL fecal coliform.
2 – Exceeded EPA criterion of 410 cfu/100 mL *E. coli*

As described previously (Section 3.4.3), single sample maximum concentrations of 400 MPN/100 mL fecal coliform (SF Bay Water Board, 2011) and 410 CFU/100 mL *E. coli* (U.S. EPA, 2012) were used as Water Contact Recreation evaluation criteria for the purposes of this evaluation. Also, a fecal coliform single sample maximum concentration of 4,000 MPN/100 mL was used as a Non-water Contact Recreation evaluation criterion. In addition, the 2012 Recreational Water Quality Criteria (RWQC) STV Recommendations 1 and 2 for protecting human health in all coastal and non-coastal waters designated for primary contact recreation use were applied.

Total coliform concentrations ranged from 130 to 450 MPN/100 mL; *E. coli* concentrations ranged from 34 to 450 MPN/100 mL. Only one sample collected exceeded any applicable criteria: the sample collected at (upstream) site 207WALW01 exceeded the Basin Plan WQO of 400 MPN/100 mL for fecal coliform and the 2012 RWQC STV for Recommendations 1 and 2 for *E. coli* of 410 and 320, respectively at a value of 450 MPN/mL.

The WY 2012 fecal coliform data from the County pilot study and pathogen samples collected by ADH staff along the reach on Walnut Creek demonstrated two noteworthy features:

- Pathogen indicator data for fecal coliform and *E. coli* were generally relatively low.
- There is no spatial trend of pathogen indicator bacteria increasing in concentration upstream to downstream along the pilot study reach.

This may indicate that there are negligible water quality impacts related to indicator bacteria due to goat grazing along the pilot study reach. In any case, there is no legal access to this area of the creek for contact recreation.

WY 2013

The FC District performed a follow-up pilot study in June 2013, similar to the study of June 2012, to compare the effectiveness of grazing with goats and sheep versus the traditional use of herbicides for vegetation management and to assess potential impacts to water quality from each maintenance practice. Water quality samples were collected by FC District staff at eight stations along the reach (upstream to downstream) where the livestock were grazing and were analyzed for fecal coliform. To augment this pilot study, and to meet MRP and Region 5 Permit Provision C.8.g. requirements, another set of pathogen indicator samples were collected by ADH staff on August 15, 2013, at five stations along the same reach of Walnut Creek and were analyzed for fecal coliform and *E. coli*. Table 4.12 summarizes the results of analyses of the samples collected.

Table 4.12 Fecal coliform and *E. coli* levels measured from water samples collected on August 15, 2013, at five locations creeks in Walnut Creek

Site ID	***Fecal Coliform*** **(MPN/100 mL)**	***E. coli*** **(MPN/100 mL)**
207WAL035	**500**[1]	**500**[2]
207WAL040	110	110
207WAL045	300[3]	300[3]
207WAL055	23	23
207WAL070	220[4]	220[4]

1 – Exceeded EPA fecal coliform single sample maximum concentrations of 400 MPN/100 mL.
2 **–** Exceeded *E. coli* EPA RWQC Recommendations 1 and 2 STVs of 410 and 320 MPN/100 mL, respectively.
3 **–** Relative percent difference from a laboratory duplicate sample of 116% exceeded the MQO of 25%.
4**–** Relative percent difference from a blind field duplicate sample of 126% exceeded the MQO of 25%.

As described previously (Section 3.4.3), single sample maximum concentrations of 400 MPN/100 mL fecal coliform (SF Bay Water Board, 2011) and 410 CFU/100 mL *E. coli* (U.S. EPA, 2012) were used as Water Contact Recreation evaluation criteria for the purposes of this evaluation. Also, a fecal coliform single sample maximum concentration of 4,000 MPN/100 mL was used as a Non-water Contact Recreation evaluation criterion. In addition, 2012 RWQC STV Recommendations 1 and 2 for protecting human health in all coastal and non-coastal waters designated for primary contact recreation use were applied.

Fecal coliform concentrations ranged from 23 to 500 MPN/100 mL; *E. coli* concentrations also ranged from 23 to 500 MPN/100 mL. Only one sample collected exceeded any applicable EPA criteria: the sample collected at station 207WAL035 exceeded EPA single sample maximum concentrations of 400 MPN/100 mL for fecal coliform and the 2012 RWQC STV Recommendations 1 and 2 for *E. coli* of 410 and 320, respectively at a value of 500 MPN/mL.

The WY 2013 fecal coliform data from the County pilot study and pathogen samples collected by ADH staff along the reach on Walnut Creek again demonstrated two noteworthy features:

- Pathogen indicator data for fecal coliform and *E. coli* were generally relatively low.
- There is no spatial trend of pathogen indicator bacteria increasing in concentration upstream to downstream along the pilot study reach.

This may indicate that there are negligible water quality impacts related to indicator bacteria due to goat grazing along the pilot study reach. In any case, there is no legal access to this area of the creek for contact recreation.

QA/QC problems were noted with laboratory control, laboratory duplicate, and blind field duplicate sample results for both fecal coliform and *E. coli*. In particular, the laboratory control sample had a percent recovery of about 64%, which is out of the QAPP MQO range of 80 to 120%. This result affects all of the indicator pathogen sample results from August 15, 2013. Indicator pathogen sample results do have a tendency to have high variability, which may partially explain the quality problems of these data. RMC participants will review and discuss these results with the laboratory, and develop follow-up actions as appropriate prior to the WY 2014 creek status monitoring.

4.4 Stream Survey Results

The following section provides a summary of the stream surveys using a modified version of the Unified Stream Assessment Protocol (Center for Watershed Protection, 2005) as fulfillment of the compliance monitoring for both R2 and R5 regional permits. The result summaries for the surveyed reaches in all creeks can be found in the attached work sheets, Appendix 1. The coordinates and general characteristics in Reach Details tab, Impact Assessment Summaries are in the Pinole Impact Summary and Other Impact Summaries tabs, and Reach Scores for all creeks in the Reach Scores tab.

4.4.1 Pinole Creek

The stream survey assessment in Pinole Creek was conducted between August 26 and September 3, 2013, with a total assessed reach of 6.4 miles (Figure 4.7). The coordinates, general characteristics, and result summaries for the surveyed reaches of Pinole Creek can be found in Appendix 1.

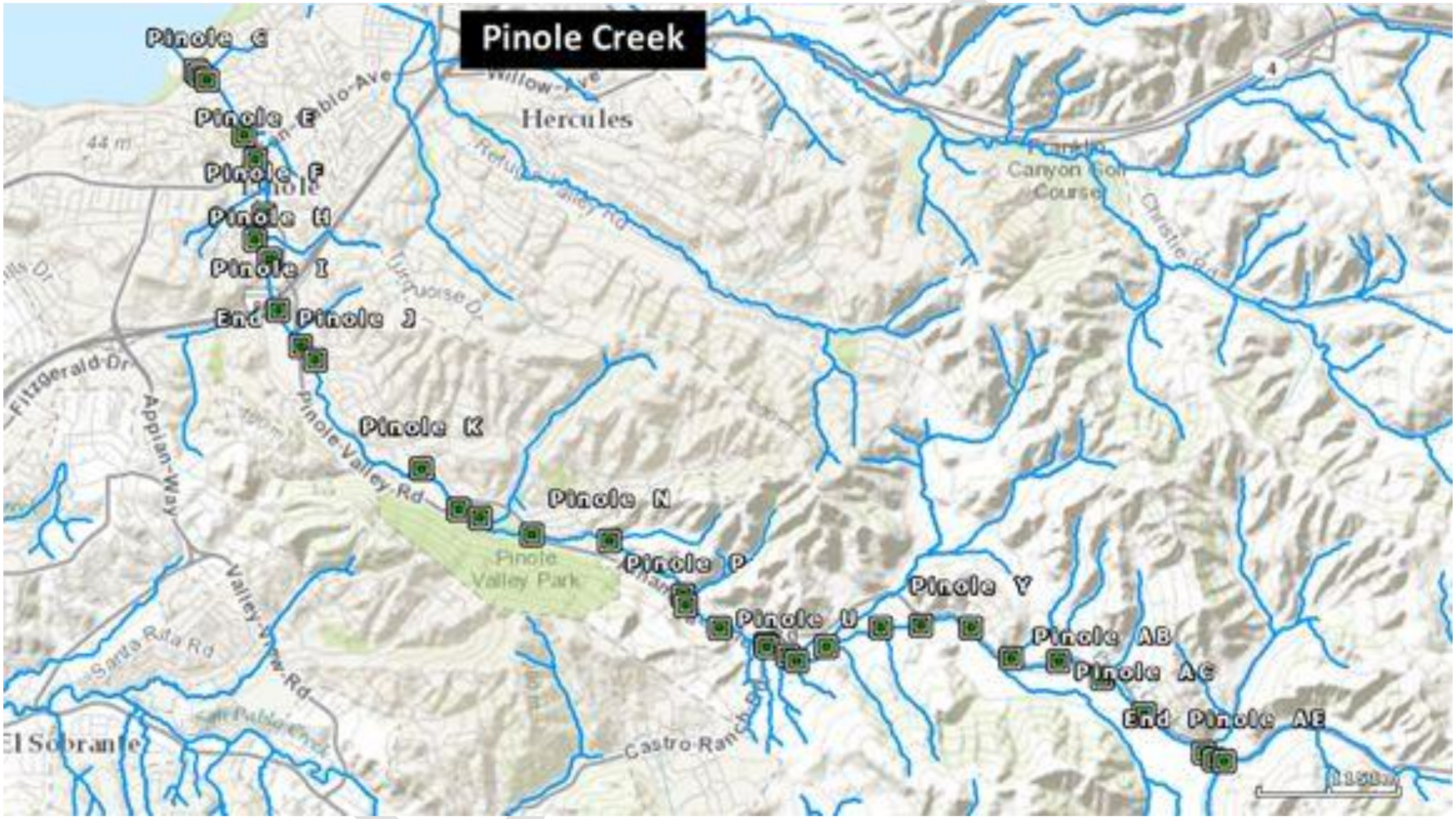
For the purposes of interpreting impact summaries and Reach Assessment Scores for the Stream Survey on Pinole Creek, the creek could be divided and into three distinct grouped conditions/locations. The downstream portion of the creek from the San Pablo Bay, working upstream to the I-80 overpass creek is channelized; some areas constructed with vegetated rip-rap and other lengths completely hardened with concrete. This stretch of creek runs through residential/commercial area. This section of Pinole Creek has no access to any “natural” floodplain, and does not have native buffers for shading or protection of the riparian ecological community. These reaches had the highest urban impacts reflected by the lowest of the Pinole Reach Assessment scores. These scores ranged from 55 to 62, with an average of 57, mainly due to low scoring floodplain and buffer condition. The hardened channel scored high due to lack of erosion.

From I-80 to Pinole Valley Park could be considered a second separate area with different reach conditions from the downstream channelized mileage or the upstream non-urban reaches. This central section of the creek was necessarily discontinuous due to inability to secure permission to access some properties. In general, the creek channel from the freeway to Pinole Valley Park is less densely urbanized than West of the freeway and has vegetated buffers surrounding a natural channel. The scores in this area range from 83 to 100, with an average score of 89. The lower reaches near the library are impacted by bank armoring and erosion, while upstream in the Pinole Valley Park area is somewhat incised and have some urban impacts such as outfalls and road crossings.

The farther reaches of Pinole creek and its tributaries run through a broad open valley with a relatively intact floodplain from about the Pinole City line to Pereira Rd. This third condition is non-urban and mainly impacted by lack of connection to the floodplain except in very high flows.

The assessment scores here range from 93 to 104, with an average score of 97. The creek channel in this area is surrounded by grazing lands and erosion is of natural stream processes with steep banks that slough in high flows, sometimes causing trees to fall and even to create log jams. Most of the log jams were high enough to allow high flows through, though there was one location at reach AB where the channel was nearing Pinole Valley Rd. due to bank failure and erosion. Authorities are aware of this, and the road is reduced to one lane at that point.

Figure 4.7 Pinole Creek 2013 Stream Survey Reaches



4.4.2 San Pablo Creek

The Stream Assessment on San Pablo Creek was conducted on September 4, 2013, in two areas: 1.1 miles starting just upstream of the San Pablo Reservoir (Figure 4.8) and a reach of 0.4 mile, including and upstream of 2012 RMC bioassessment Site #155. The coordinates, general characteristics, and result summaries for the surveyed reaches of San Pablo Creek can be found in Appendix 1.

The two reaches along Site #155 have a Total Reach Assessment Score of 105. The impacts in this creek were mainly bank armoring, road crossings, and sediment deposition. This area has steep banks and no connection to a floodplain, but there is a generous vegetative buffer that provides beneficial habitat characteristics in spite of the urban-impacted surroundings.

Figure 4.8 San Pablo Site #155 Stream Survey Reaches

The reaches upstream of the San Pablo Reservoir (Figure 4.9) run mainly through natural forested landscape. The Total Reach Assessment Scores in this area span from 97-111, with an average score of 102. Low scores in this area reflect the East Bay Municipal Utility District Drop structure and the road crossing at Bear Creek Rd., as well as bank armoring at various locations. This reach has regular releases from the water treatment facility that send high flows through the channel, scouring the cobble with very “clean” water. This reach seems to serve as a conveyance from the treatment facility to the reservoir, more than a habitat for fish, as it has barriers upstream and downstream for any passage of the native trout population. A bioassessment survey could verify this further, but it seems low priority due to its land use.

Figure 4.9 San Pablo Reservoir 2013 Stream Survey Reaches

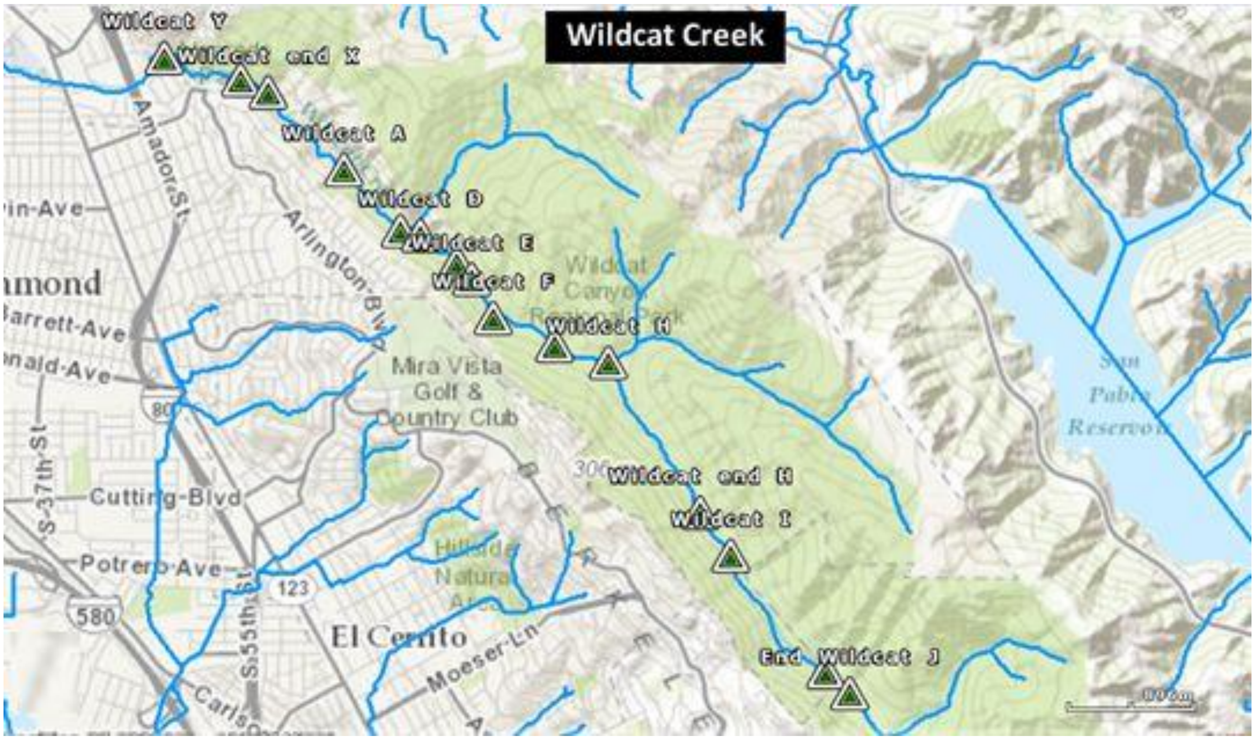
4.4.3 Wildcat Creek

The Stream Assessment on Wildcat Creek is broken into two distinct areas; in Wildcat Canyon, a largely undisturbed natural park, and in Alvarado Park, an urban park where the creek enters the alluvial floodplain and the urban environment (Figure 4.10). The coordinates, general characteristics, and result summaries for the surveyed reaches of Wildcat Creek can be found In Appendix 1.

Roughly 4 miles of creek in Wildcat Canyon were assessed on September 5 and 6, 2013. Total Reach Assessment Scores in this area ranged from 101 to 113, with an average of 109. The impacts in this area are from various erosive processes that appear to be from large flow events and do not threaten infrastructure in their respective immediate vicinities since they are surrounded by East Bay Regional Parks land.

Approximately 0.5 mile of Wildcat Creek was assessed on September 10, 2013. Due to the urban environment of Alvarado Park, the Total Reach Assessment Scores in this area was 77, due to many outfalls and bank armoring.

Figure 4.10 Wildcat Creek 2013 Stream Survey Reaches

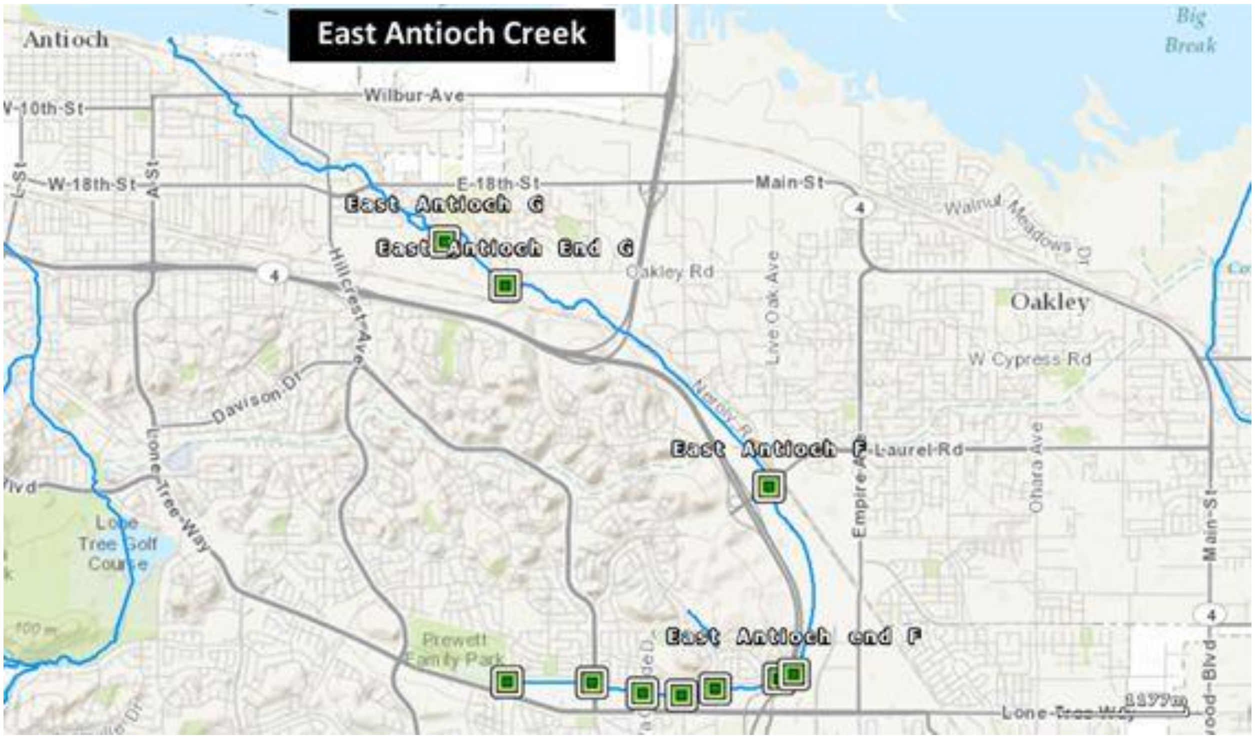


4.4.4 East Antioch Creek

East Antioch Creek is a highly modified channel which flows through many detention basins, culverts and underground channels for flood control purposes. The Stream Assessment was conducted on 3 miles of channel on September 11, 2013 (Figure 4.11). The coordinates, general characteristics, and result summaries for the surveyed reaches of East Antioch Creek can be found in Appendix 1.

Total Stream Assessment Scores ranged from 65 to 85, with an average of 70. Two main impacts that needed attention was a large pile of illegally dumped trash and a leaking irrigation pipe, both which were reported to local authorities.

Figure 4.11 East Antioch Stream Survey Reaches



The Unified Stream Assessment method scoring was not entirely appropriate for Contra Costa creeks compared to the Maryland streams they were developed in, therefore the scores chosen are relative only to those riparian environments. Maryland gets rain year-round and has different geology and other characteristics from Contra Costa's, such as isolated wetlands in the floodplain, which are not found in Contra Costa. USA scoring forms have some metrics that do not correlate to the creek corridors that were assessed for this permit. For instance, in the Floodplain Encroachment category, flood control channels by design are disconnected and have no floodplain. The incised channel in the "non-urban" landscape in Pinole, for instance, has no floodplain access unless there are extremely high flows, and they score low even though they are being compared to flood control channels.

In the Floodplain Habitat category, the *"Either all or mix of floodplain and non-floodplain habitat, evidence (or no evidence) of standing/ponded water*" is not reflective of the landscape surveyed, therefore scores are low and add to a low score overall. Pinole and Wildcat creeks had isolated pools in the creek. This is not the same as the standing/ponded water in the floodplain that you might find in Maryland, but could be scored as the same thing by reading the description. In addition, the descriptions in the Floodplain Connection category optimal and suboptimal are the same description: "High flows…able to enter floodplain, stream not deeply entrenched." These are examples where the scoring can be skewed by choosing one or another of the same description ranging from 0 to 10.

The above differences stood out for these particular creeks surveyed, and it could be more valuable for the CCCWP to use the USA protocol when restoration potential is being sought, as it is intended.

CCCWP is researching the potential of using the Level 2 CRAM framework as an assessment method when paired with the probabilistic site surveys used by the RMC, as other programs have done. A more comprehensive habitat health data set could be built when collected at the specific sites where bioassessment and water quality monitoring (similar to Level 3 CRAM framework) is already happening, especially when other targeted parameters are being monitored there as well.

5.0 Next Steps

Pursuant to Provision C.11.l of Order No. R5-2010-0102 (the Central Valley Permit). CCCWP is implementing a work plan (CCCWP, 2012) to characterize concentrations of methylmercury in urban runoff discharges with eastern Contra Costa County and evaluate attainment of the numeric target of 0.06 nanograms per liter methylmercury established by the Total Maximum Daily Load for methylmercury for the Sacramento–San Joaquin River Delta.

CCCWP has identified stressor/source identification (SSID) projects to follow up on WY 2012 and WY 2013 creek status toxicity monitoring data, per the respective requirements of MRP and Central Valley Permit Provision C.8.d.i. (see IMR Part A, section A.4).

During WY 2014, CCCWP will continue conducting monitoring for general water quality parameters according to the requirements of Provision C.8 in the MRP and the Region 5 Permit. CCCWP will perform a Stream Survey on a total of 6 miles on a yet-to-be-determined water body or water bodies within Contra Costa County using CRAM rather than the USA modified method to provide additional data that can be used in the assessment of aquatic life condition in Contra Costa County creeks.

CCCWP will consider using CRAM for 2014 Stream Assessments at the same locations (and reach lengths) that will be monitored for the RMC probabilistic designas CRAM data may be more useful for explaining aquatic biological conditions than the USA method, which was designed for a much wetter climate. In addition, the CRAM assessments could supplement biological and physical habitat data collected at RMC bioassessment sites to investigate potential stressors to aquatic health.

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Appendix 1: Stream Survey Results

Reach Details **Wildcat Creek (4 miles)**

Reach	Date surveyed	Reach Length (ft)	Starting Coordinates (DS)		Ending Coordinates (US)		Description
			Decimal Degrees		Decimal Degrees		
			Latitude	Longitude	Latitude	Longitude	
X	9/10/13	771	37.95171	-122.31861	37.95094	-122.31637	natural channel in Alvarado Park
Y	9/10/13	2001	37.95312	-122.32472	37.95216	-122.31929	natural channel in Alvarado Park
A	9/5/13	467	37.94618	-122.31032	37.94234	-122.30516	natural channel
B	9/5/13	3083	37.94240	-122.30519	37.94018	-122.30126	natural channel
D	9/5/13	2026	37.94180	-122.30452	37.93916	-122.29997	natural channel
E	9/5/13	1183	37.93916	-122.29997	37.93678	-122.29830	natural channel
F	9/5/13	1945	37.93678	-122.29830	37.93502	-122.29343	natural channel
G	9/5/13	1556	37.93502	-122.29343	37.93391	-122.28886	natural channel
H	9/6/13	4542	37.93389	-122.28887	37.92442	-122.28190	natural channel (dry)
I	9/6/13	3635	37.92180	-122.27938	37.91479	-122.27110	natural channel
J	9/6/13	790	37.91481	-122.27113	37.91328	-122.26990	natural channel

Reach Details **San Pablo Creek (1.5 miles)**

Reach	Date surveyed	Reach Length (ft)	Starting Coordinates (DS)		Ending Coordinates (US)		Description
			Decimal Degrees		Decimal Degrees		
			Latitude	Longitude	Latitude	Longitude	
SITE 155 A	9/4/13	1432	37.87551	-122.17962	37.87222	-122.17831	bedrock channel
SITE 155 A	9/4/13	444	37.87222	-122.17831	37.87144	-122.17783	bedrock channel
A	9/4/13	480	37.90289	-122.21283	37.90133	-122.20848	trib/weir/armoring
B	9/4/13	1858	37.90133	-122.20848	37.90157	-122.20699	DS of Bear Creek Rd
C	9/4/13	144	37.90162	-122.20707	37.90153	-122.20660	natural channel to drop structure
D	9/4/13	775	37.90153	-122.20660	37.89972	-122.20527	drop structure into natural channel
E	9/4/13	318	37.89972	-122.20527	37.89915	-122.20525	natural channel
F	9/4/13	2282	37.89914	-122.20523	37.89415	-122.20193	natural channel

Attempted 1231 more ft. (.25mi.) US of Manzanita Rd. Unable to complete due to construction.

Reach Details

Pinole Creek (6 miles)

Reach	Date surveyed	Reach Length (ft)	Starting Coordinates (DS)		Ending Coordinates (US)		Description
			Decimal Degrees		Decimal Degrees		
			Latitude	Longitude	Latitude	Longitude	
A	8/26/13	157	38.01253	-122.29484	38.01242	-122.29534	constructed channel veg'd rip-rap
B	8/26/13	261	38.01242	-122.29534	38.01205	-122.29366	constructed channel veg'd rip-rap
C	8/26/13	1759	38.01204	-122.29364	38.00799	-122.29044	constructed channel veg'd rip-rap
D	8/26/13	795	38.00799	-122.29044	38.00620	-122.28941	constructed channel veg'd rip-rap
E	8/26/13	1606	38.00620	-122.28941	38.00239	-122.28847	concrete channel
F	8/26/13	988	38.00269	-122.28872	38.00035	-122.28960	concrete channel
G	8/26/13	660	38.00035	-122.28960	37.99912	-122.28821	constructed channel veg'd rip-rap
H	8/26/13	1537	37.99912	-122.28821	37.99528	-122.28758	natural channel
I	8/26/13	1256	37.99528	-122.28758	37.99284	-122.28527	natural channel
J	8/26/13	700	37.99928	-122.28527	37.99175	-122.28389	natural channel
K	8/27/13	1616	37.98403	-122.27416	37.98103	-122.27075	natural channel
L	8/27/13	663	37.98103	-122.27075	37.98038	-122.26910	natural channel
M	8/27/13	1607	37.98038	-122.26910	37.97929	-122.26395	natural channel
N	9/3/13	2779	37.97871	-122.25694	37.97482	-122.25000	natural channel
O	9/3/13	315	37.97460	-122.25000	37.97403	-122.25013	natural channel
P	9/3/13	1370	37.97403	-122.25013	37.97246	-122.24677	natural channel
Q	9/3/13	1340	37.97246	-122.24677	37.97116	-122.24265	natural channel
R	8/29/13	66	37.97116	-122.24262	37.97110	-122.24263	natural channel
S	8/29/13	607	37.97110	-122.24263	37.97038	-122.24079	natural channel
T	8/29/13	341	37.97038	-122.24079	37.96991	-122.23991	natural channel
U	8/29/13	994	37.96991	-122.23991	37.97117	-122.23695	natural channel
V	8/29/13	1591	37.97117	-122.23695	37.97246	-122.23217	natural channel
W	8/29/13	1090	37.97246	-122.23217	37.97262	-122.22836	natural channel
X	8/28/13	1491	37.97265	-122.22838	37.97258	-122.22377	natural channel
Y	8/28/13	1556	37.97258	-122.22377	37.97029	-122.21999	natural channel
Z	8/28/13	1419	37.97029	-122.21999	37.96999	-122.21582	natural channel
AA	8/28/13	1335	37.96998	-122.21584	37.96877	-122.21202	natural channel
AB	8/28/13	1517	37.96877	-122.21202	37.96631	-122.20797	natural channel
AC	8/28/13	1936	37.96631	-122.20797	37.96320	-122.20242	natural channel
AD	8/28/13	332	37.96388	-122.20242	37.96287	-122.20148	natural channel
AE	8/28/13	279	37.96287	-122.20148	37.96286	-122.20068	natural channel

Reach Details **East Antioch Creek (3 miles)**

Reach	Date surveyed	Reach Length (ft)	Starting Coordinates (DS)		Ending Coordinates (US)		Description
			Decimal Degrees		Decimal Degrees		
			Latitude	Longitude	Latitude	Longitude	
A	9/11/13	2533	37.96420	-121.76913	37.96422	-121.76038	flood control channel
B	9/11/13	1585	37.96920	-121.76038	37.96333	-121.75504	flood control channel
C	9/11/13	1158	37.96333	-121.75504	37.96317	-121.75102	flood control channel
D	9/11/13	971	37.96317	-121.75102	37.96367	-121.74772	flood control channel
E	9/11/13	1614	37.96367	-121.74772	37.96419	-121.74205	flood control channel
F	9/11/13	5605	37.97945	-121.74200	37.96492	-121.73932	flood control channel
G	9/11/13	2950	38.00029	-121.77561	37.99670	-121.76932	flood control channel

Reach Scores																															**Pinole Creek**
Reach Number	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**	**AA**	**AB**	**AC**	**AD**	**AE**
Overall Stream Condition																															
Instream Habitat	9	9	9	10	11	13	13	13	9	13	17	15	17	13	16	16	16	13	13	16	16	18	18	17	17	17	13	13	12	12	12
Vegetative Protection (LB)	8	8	8	8	5	5	5	5	8	8	8	7	8	6	8	8	8	9	9	8	8	9	9	7	7	7	6	7	6	6	6
Vegetative Protection (RB)	8	8	8	8	5	5	5	7	8	8	7	7	8	5	8	8	8	8	8	8	8	9	9	7	7	7	6	7	6	6	6
Bank Erosion (LB)	9	9	9	9	9	9	9	9	7	7	7	7	5	8	7	7	7	9	9	8	8	4	4	5	5	5	7	3	7	7	7
Bank Erosion (RB)	9	9	9	9	9	9	9	9	7	7	7	7	5	5	8	8	8	9	9	8	8	4	4	5	5	5	7	2	7	7	7
Floodplain Connection	2	2	2	3	9	3	3	3	9	9	5	10	4	7	9	9	8	10	10	8	8	6	6	9	9	9	12	9	12	12	12
Instream Habitat Total Score	45	45	45	47	48	44	44	46	48	52	51	53	47	44	56	56	55	58	58	56	56	50	50	50	50	50	51	41	50	50	50
Overall Buffer and Floodplain Condition																															
Vegetative Buffer Width (LB)	1	1	1	1	2	1	1	1	4	7	7	5	7	8	8	8	8	8	8	7	7	8	8	7	7	7	8	7	8	8	8
Vegetative Buffer Width (RB)	1	1	1	1	2	1	1	1	3	7	7	5	7	9	9	9	9	7	7	7	7	8	8	7	7	7	8	7	8	8	8
Floodplain Vegetation	6	6	6	6	6	6	6	6	13	14	13	12	13	8	14	14	14	10	10	10	10	14	14	15	15	15	12	13	12	12	12
Floodplain Habitat	1	1	1	1	2	2	2	6	13	12	5	4	5	4	4	4	4	5	5	5	5	3	3	3	3	3	5	5	5	5	5
Floodplain Encroachment	1	1	1	1	2	2	2	2	14	8	5	6	5	10	13	13	13	14	14	14	14	11	11	17	17	17	10	12	10	10	10
Floodplain and Buffer Total Score	10	10	10	10	14	12	12	16	47	48	37	32	37	39	48	48	48	44	44	43	43	44	44	49	49	49	43	44	43	43	43
Reach Assessment Total Score	**55**	**55**	**55**	**57**	**62**	**56**	**56**	**62**	**95**	**100**	**88**	**85**	**84**	**83**	**104**	**104**	**103**	**102**	**102**	**99**	**99**	**94**	**94**	**99**	**99**	**99**	**94**	**85**	**93**	**93**	**93**

Reach Scores											**Wildcat Creek**
Reach Number	**X**	**Y**	**A**	**B**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Overall Stream Condition											
Instream Habitat	13	13	14	14	18	18	18	18	18	15	15
Vegetative Protection (LB)	7	7	9	9	6	6	6	6	6	7	7
Vegetative Protection (RB)	7	7	9	9	7	7	7	7	7	7	7
Bank Erosion (LB)	7	7	8	8	7	7	7	7	7	9	9
Bank Erosion (RB)	7	7	8	8	8	8	8	8	8	9	9
Floodplain Connection	7	7	8	8	11	11	11	11	11	7	7
Instream Habitat Total Score	48	48	56	56	57	57	57	57	57	54	54
Overall Buffer and Floodplain Condition											
Vegetative Buffer Width (LB)	3	3	8	8	9	9	9	9	9	9	9
Vegetative Buffer Width (RB)	3	3	7	7	9	9	9	9	9	6	6
Floodplain Vegetation	13	13	13	13	18	18	18	18	18	18	18
Floodplain Habitat	5	5	4	4	2	2	2	2	2	3	3
Floodplain Encroachment	5	5	13	13	18	18	18	18	18	15	15
Floodplain and Buffer Total Score	29	29	45	45	56	56	56	56	56	51	51
Reach Assessment Total Score	**77**	**77**	**101**	**101**	**113**	**113**	**113**	**113**	**113**	**105**	**105**

Reaches X and Y are in Alvarado Park (urban). Reaches A-J are in Wildcat Park (non-urban). No Reach C

Reach Scores				**East Antioch Creek**			
Reach Number	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Overall Stream Condition							
Instream Habitat	8	8	8	8	8	9	8
Vegetative Protection (LB)	5	5	5	5	5	2	2
Vegetative Protection (RB)	3	3	3	3	3	3	2
Bank Erosion (LB)	9	9	9	9	9	9	9
Bank Erosion (RB)	9	9	9	9	9	9	9
Floodplain Connection	8	8	8	8	8	16	15
Instream Habitat Total Score	42	42	42	42	42	48	45
Overall Buffer and Floodplain Condition							
Vegetative Buffer Width (LB)	4	4	4	4	4	9	8
Vegetative Buffer Width (RB)	4	4	4	4	4	9	8
Floodplain Vegetation	8	8	8	8	8	1	1
Floodplain Habitat	4	4	4	4	4	1	1
Floodplain Encroachment	3	3	3	3	3	17	16
Floodplain and Buffer Total Score	23	23	23	23	23	37	34
Reach Assessment Total Score	**65**	**65**	**65**	**65**	**65**	**85**	**79**

Stream Survey Impact Summary Pinole Creek

Reach Number	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	total miles
Reach Length (ft)	157	261	1759	795	1606	988	660	1537	1256	700	1616	663	1607	2779	315	1370	1340	66	607	341	994	1591	1090	1491	1556	1419	1335	1517	1936	332	279	6.4
Outfalls																																
Storm drain outfalls		1	9	7	11	3	2	3	5	0	1	0	2				3								1							
Total outfalls	0	1	9	10	19	3	3	3	5	1	1	0	0				3								1							
Total outfalls with dry weather flow		1	5	5	5	0	1	1	3	0	0	0	2				0								0							
Channel Modification																																
Channelization	X	X	X	X	X	X	X	X	X	X																						
Bank armoring						X			X	X			X																X			
Drop structure																																
Other																																
Total Length Modified (ft.)	This is flood control channel; some concrete, some veg'd rip-rap. See CM tab.								50	157			25																250			
Erosion																																
Downcutting																																
Widening																																
Headcutting										X																						
Aggrading																																
Bank erosion																					X		X					X	X	X		
Bank failure													X	X							X			X	X			X				
Bank scour																					X								X			
Slope failure																																
Total length										2			635	962							383		365	275	70			200	125	50		
Stream Crossings																																
Total crossings	1		1	2	2		1	1	2	1			1				1									1					1	
Total length crossing	8		12	104	30		63	360	9	84			58				104									58					47	
Trash																																
Total trash sites																																
Source: L-Litter; ID-Illegal Dumping; A-Accumulation																																
Utilities																																
Various utilities				X							X	X					X										X					
Miscellaneous																																
Pump and PVC in creek												X																				

Log/debris jam													X									X	X				X	X			
Lumber waste																										X					

Stream Survey Impact Summary San Pablo Creek

Reach Number	**SP 155 A**	**SP 155 B**	**A**	**B**	**C**	**D**	**E**	**F**	total miles
Reach Length (ft)	1432	444	480	1858	144	775	318	2282	1.5
Outfalls									
Storm drain outfalls (8-24 inch dia)	2	0	0	1	0	0	0	2	
Total outfalls with dry weather flow	0	0	0	0	0	0	0	2	
Channel Modification									
Channelization								X	
Bank armoring	X	X	X	X					
Drop structure						X		X	
Other								X	
Total length modified (ft.)	255	640	50	45	0	130	0	145	
Erosion									
Downcutting									
Widening									
Headcutting									
Aggrading									
Bed scour	X								
Bank failure	X		X			X		X	
Bank scour						X			
Slope failure									
Total length	93	0	200	0	0	208	0	80	
Stream Crossings									
Total crossings	1	1	1	2	0	0	0	X	
Total length crossing	50	70	6	40	0	0	0	65	
Trash									
Total trash sites	0	0	0	0	0	0	0	0	
Utilities									
Various utilities	X								
Miscellaneous									
Runoff trickle	X								

Stream Survey Impact Summary

Wildcat Creek

Reach Number	**X**	**Y**	**A**	**B**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	total miles
Reach Length (ft)	771	2001	467	3083	2026	1183	1945	1556	4542	3635	790	4.2
Outfalls												
Storm drain outfalls (8-24 inch dia)	1	4		1				2				
Total outfalls	1	4	0	1	0	0	0	2	0	0	0	
Total outfalls with dry weather flow	0	1	0	0	0	0	0	1	0	0	0	
Channel Modification												
Channelization												
Bank armoring	X	X										
Drop structure												
Other												
Total length modified (ft.)	60	985	0	0	0	0	0	0	0	0	0	
Erosion												
Downcutting												
Widening												
Headcutting												
Aggrading												
Bank erosion							X		X			
Bank failure		X	X	X	X	X			X			
Bank scour		X		X	X	X	X		X			
Bed scour		X							X			
Slope failure												
Total length	0	85	34	387	105	99	145	0	341	0	0	
Stream Crossings												
Total crossings	1	0	0	0	0	0	0	0	0	0	0	
Total length crossing	18											
Trash												
Total trash sites	0	0	0	0	0	0	0	0	0	0	0	
Utilities												
Various utilities	X							X		X		
Miscellaneous												
Stairs for recreation access	X											
Drainage ditch				X								
Log jam							X					

Stream Survey Impact Summary — East Antioch Creek

Reach Number	A	B	C	D	E	F	G	total miles
Reach Length (ft)	2533	1585	1158	971	1614	5605	2950	3.1
Outfalls								
Storm drain outfalls (8-24 inch dia)	5	1	1	1	1	5	0	
Total outfalls with dry weather flow	4	0	1	1	1	0	0	
Channel Modification								
Channelization						X	X	
Bank armoring								
Drop structure								
Other	X							
Total length modified	61	0	0	0	0	280	200	
Erosion								
Downcutting								
Widening								
Headcutting	X			X	X			
Aggrading								
Bed scour	X							
Bank failure								
Bank scour					X			
Slope failure								
Total length	5	0	0	2	5	0	0	
Stream Crossings								
Total crossings	0	1	1	1	1	3	1	
Total length of crossings	0	295	110	110	124	280	280	
Trash								
Total trash sites	0	0	0	0	0	1	0	
Source: L-Litter; ID-Illegal Dumping; A-Accumulation	NA	NA	NA	NA	NA	L	NA	
Utilities								
Various utilities								
Miscellaneous								

Broken sprinkler pipe				X	X		

CONTRA COSTA CLEAN WATER PROGRAM
STRESSOR / SOURCE ID STUDY CONCEPT PLAN

Submitted to:
Contra Costa Clean Water Program
255 Glacier Drive
Martinez, California 94553

Submitted by:

AMEC Environment & Infrastructure, Inc.
San Diego, California

And

Armand Ruby Consulting

May 2013

AMEC Project No. 5025133001

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ACRONYMS AND ABBREVIATIONS

BASMAA	Bay Area Stormwater Management Agencies Association
BMI	Benthic Macroinvertebrate Index
BMP	Best Management Practice
CASQA	California Association of Stormwater Quality Agencies
CCCWP	Contra Costa Clean Water Program
Central Valley Permit	California Regional Water Quality Control Board Central Valley Region, East Contra Costa County Municipal NPDES Permit Waste Discharge Requirements, Order No. R5-2010-0102.
CVRWQCB	California Regional Water Quality Control Board, Central Valley Region
DPR	California Department of Pesticide Regulation
FY	Fiscal Year
IPM	Integrated Pesticide Management
LID	Low Impact Development
MRP	California Regional Water Quality Control Board San Francisco Bay Region Municipal Regional Stormwater NPDES Permit, Order No. R2-2009-0074, adopted October 14, 2009, revised November 28, 2011
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PEC	Probable Effects Concentration
RMC	Regional Monitoring Coalition
RWQCB	Regional Water Quality Control Board
SFBRWQCB	Regional Water Quality Control Board, San Francisco Bay Region
SSID	Source/Stressor Identification
TEC	Threshold Effect Concentration
TIEs	Toxicity Identification Evaluations
TU	Toxicity Unit
USEPA	United States Environmental Protection Agency

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1.0 PROBLEM STATEMENT

Provision C.8.d.i of the Municipal Regional Permit (MRP), and a parallel provision in the Central Valley Permit, require that when Creek Status Monitoring conducted through Provision C.8.c produces measurements that exceed triggers defined in the respective permits, follow-up actions are required. The follow-up actions may include Stressor / Source ID (SSID) Studies. The MRP establishes a cap on the number of SSID studies, when the monitoring is performed under a regional collaborative, no more than two SSID Studies need to be initiated by CCCWP during the permit term. The Central Valley Permit also caps the SSID studies required of East County permittees (Antioch, Brentwood, Oakley, Unicorporated County, and the Flood Control District) to one such study during the permit term. Both permits allow for and encourage Creek Status Monitoring and SSID studies to be conducted regionally.

CCCWP has participated in a regional collaborative with Bay Area Stormwater Management Agencies (BASMAA) members, known as the Regional Monitoring Coalition (RMC), to design the Creek Status monitoring approach and to select SSID Studies. CCCWP also worked with staff of both the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) and the Central Valley Regional Water Quality Control Board (CVRWQCB) during permit negotiations to implement coordinated monitoring requirements. As a result, the Creek Status Monitoring conducted through the BASMAA program includes monitoring locations in East County jurisdictions. SSID studies at the two selected sites will fulfill CCCWP's requirement to conduct SSID studies for both permits for the permit term expiring in 2014 (MRP) and 2015 (Central Valley Permit).

The two selected SSID Studies in Contra Costa County are investigations of water and sediment toxicity to the indicator organism *Hyalella azteca* in samples collected from Dry Creek and Grayson Creek. Dry Creek is a tributary to Marsh Creek in eastern Contra Costa County; Grayson Creek is a tributary to Walnut Creek in central Contra Costa County. The evidence for toxicity and other monitoring results that triggered a SSID study is summarized in Table 1. During wet weather, toxicity to *Hyalella azteca* was observed in both Grayson Creek and Dry Creek. Significant toxicity to other test organisms (water fleas, green algae, and fathead minnows) was not observed. During dry weather, significant water column toxicity to *Hyalella Azteca* was not observed, but sediment toxicity was. In lower Marsh Creek, downstream of Dry Creek, wet weather toxicity to *Hyalella azteca* was observed for the two storms monitored during the 2012 monitoring year.

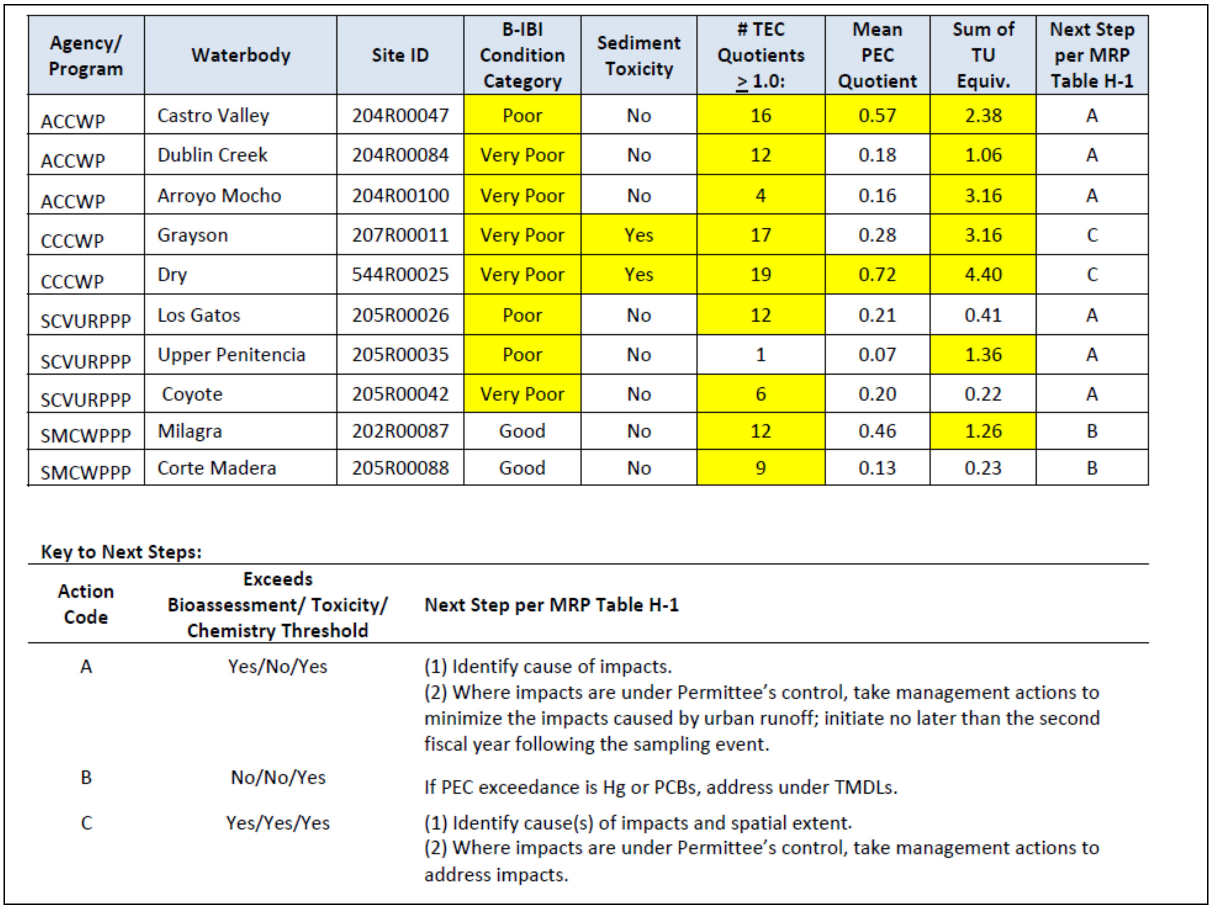
In addition to toxicity, sediment chemistry results and benthic macroinvertebrate index (BMI) scores from the 2012 RMC monitoring make the selected locations favorable locations for the RMC to consider as places to conduct toxicity-related SSID studies. The two locations have the highest concentrations of pollutant chemicals in sediments relative to thresholds of concern compared to all other Bay Area Creek Status locations sampled thus far (Figure 1). Detailed analysis of the data indicates that pyrethroid pesticides are likely, but not confirmed, causes of observed toxicity.

The goals of this SSID study is to determine what are causes of observed toxicity, identify potential sources, propose abatement measures, and evaluate the effectiveness of the abatement measures.

Table 1.

Details of Creek Status Monitoring Results Triggering Toxicity SSID Studies

Location	Date	Event / Media	Negative Observations	Benign Observations
Grayson Creek	March 2012	Wet Weather / Water Toxicity	Significant reductions in survival of *Hyalella azteca*	No significant toxicity to other test organisms observed
	July 2012	Dry Weather / Water Toxicity		No significant toxicity to *Hyallell azteca* or any other test organism observed
		Dry Weather / Water Toxicity		Ammonia, nitrate, chloride triggers not exceeded
		Dry Weather / Sediment Toxicity	Significant reductions in survival of *Hyalella azteca*	
		Dry Weather / Sediment Chemistry	Second highest concentration of sediment contaminants of all Creek Status stations in the Region	
	Spring 2012	BMI	Very Poor	
Dry Creek	March 2012	Wet Weather / Water Toxicity	Significant reductions in survival of *Hyalella azteca*	No toxicity to other test organisms observed
	July 2012	Dry Weather / Water Toxicity		No significant toxicity to *Hyallell azteca* or any other test organism observed
		Dry Weather / Water Toxicity		Ammonia, nitrate, chloride triggers not exceeded
		Dry Weather / Sediment Toxicity	Significant reductions in survival of *Hyalella azteca*	
		Dry Weather / Sediment Chemistry	Highest concentration of sediment contaminants of all Creek Status stations in the Region	
	Spring 2012	BMI	Very Poor	
Lower Marsh Creek (below Dry Creek)	January 2012 and February 2012	Wet Weather / Water Toxicity	Significant reductions in survival of *Hyalella azteca*	No significant toxicity to other test organisms observed



Agency/ Program	Waterbody	Site ID	B-IBI Condition Category	Sediment Toxicity	# TEC Quotients ≥ 1.0:	Mean PEC Quotient	Sum of TU Equiv.	Next Step per MRP Table H-1
ACCWP	Castro Valley	204R00047	Poor	No	16	0.57	2.38	A
ACCWP	Dublin Creek	204R00084	Very Poor	No	12	0.18	1.06	A
ACCWP	Arroyo Mocho	204R00100	Very Poor	No	4	0.16	3.16	A
CCCWP	Grayson	207R00011	Very Poor	Yes	17	0.28	3.16	C
CCCWP	Dry	544R00025	Very Poor	Yes	19	0.72	4.40	C
SCVURPPP	Los Gatos	205R00026	Poor	No	12	0.21	0.41	A
SCVURPPP	Upper Penitencia	205R00035	Poor	No	1	0.07	1.36	A
SCVURPPP	Coyote	205R00042	Very Poor	No	6	0.20	0.22	A
SMCWPPP	Milagra	202R00087	Good	No	12	0.46	1.26	B
SMCWPPP	Corte Madera	205R00088	Good	No	9	0.13	0.23	B

Key to Next Steps:

Action Code	Exceeds Bioassessment/ Toxicity/ Chemistry Threshold	Next Step per MRP Table H-1
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.

Figure 1. Summary of Sediment Quality Triad Analysis Results, Monitoring Year 2012 Regional Monitoring Coalition Data.

Notes: Yellow Highlights Indicate Trigger Exeedances. Figure from BASMAA (2013).

- **Additional notes**: The terms TEC Quotient (Threshold Effect Quotient), PEC Quotient (Probable Effects Quotient) are defined in an established and accepted sediment quality guidelines publication (Macdonald, 2000) as follows:
- **Threshold Effect Concentration (TEC)**: Represents the concentration below which adverse effects are expected to occur only rarely.
- **TEC Quotient**: ratio of measured concentration to TEC; a TEC Quotient > 1 indicates potential for effects, albeit infrequently. The sixth column in Figure 1 above indicates the number of different pollutants in sediments that have measured TEC quotients exceeding 1.
- **Probable Effects Concentration (PEC)**: Represents the concentration above which adverse effects are expected to occur frequently.
- **PEC Quotient**: ratio of measured concentration to PEC; a higher PEC Quotients indicate greater potential for effects. The mean PEC quotients help evaluate the additive effect of multiple toxicants.
- **The Pyrethroid Toxicity Unit Equivalent (TU Equiv.)** The seventh column indicates the concentration relative to the lethal concentration that causes fifty percent mortality, based on literature data.

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2.0 STUDY LOCATIONS

A map of Grayson Creek is presented in Figure 2. The area in Grayson Creek where toxicity to *Hyalella* was observed is provided in Figure 3. A map of Dry Creek is presented in Figure 4. The area in Dry Creek where toxicity was observed is provided in Figure 5. Toxicity to *Hyalella* was also observed in Marsh Creek, downstream of the Dry Creek confluence. Land uses common to both watersheds include suburban residential, agricultural, golf courses, and additional impervious and pervious areas including light commercial and public facilities such as schools and athletic fields.

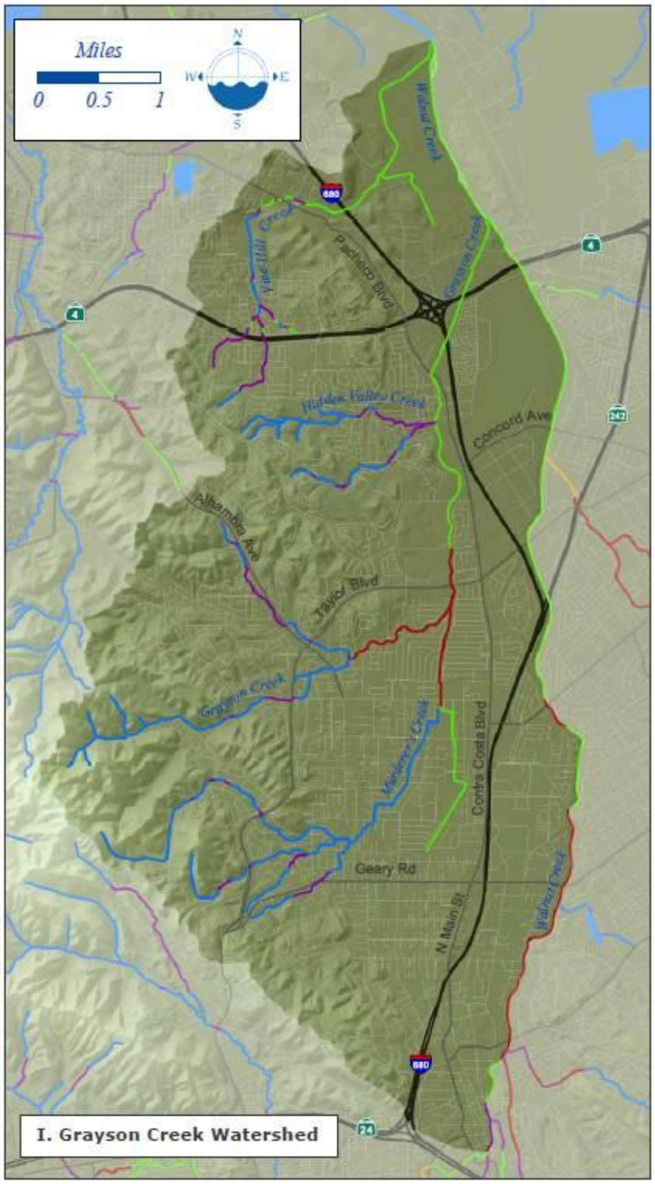

Figure 2. Locator Map of the Grayson Creek Watershed

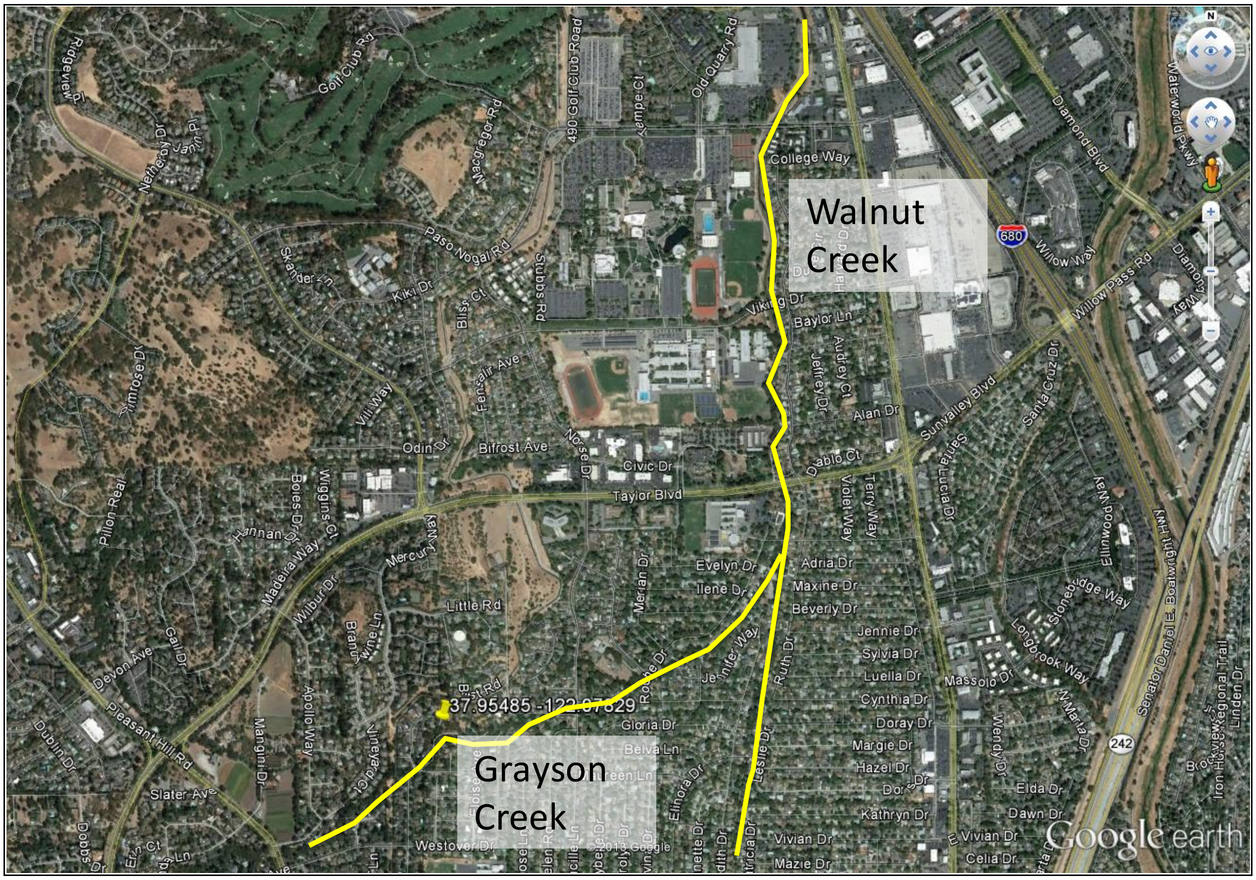

Figure 3. Google Earth View of Lower Grayson Creek in Vicinity of Detected Toxicity

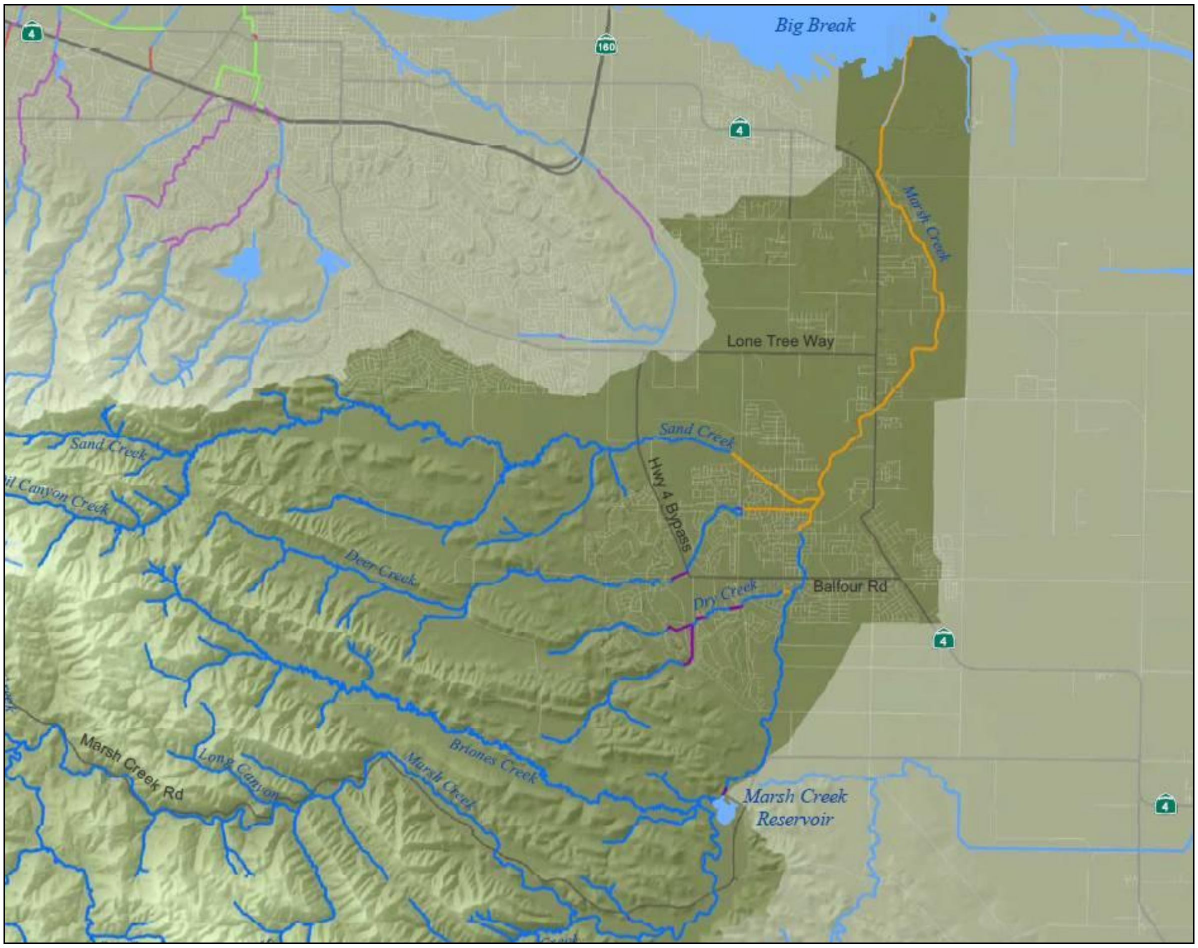

Figure 4. Locator Map of the Dry Creek Watershed

Figure 5. Google Earth View of Lower Grayson Creek in Vicinity of Detected Toxicity

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3.0 APPROACH OUTLINE

MRP Provision C.8.d.i requires four steps for SSID projects; the four parts of the study approach outlined below encompass those four required steps

Part A:

Toxicity studies first require positive identification of the stressor(s). It is presumed in these cases that the stressors are pesticides; however, additional water and sediment chemistry and toxicity testing are necessary to confirm this. In particular, determination of which pesticides are causing toxicity, and whether there are spatial patterns that may pinpoint more specific source areas or land uses. This work would involve data review, initial watershed assessments, reconnaissance using Google Earth, and site visits prior to the chemistry and toxicity testing. The work performed during the site visits would be conducted as part of the required Stream Surveys for labor efficiency. Monitoring would involve instream toxicity testing as well as toxicity identification evaluations(TIEs), as needed. This work is anticipated for Fiscal Year (FY) 2013 – 2014.

Part B:

After confirming the stressors, sources need to be identified.. Presuming that pesticide applications are determined to be the source(s) for the pesticides identified as stressors in Part A, the assessment would attempt to characterize the relative magnitudes of sources attributable to the following: Contra Costa County professional Pest Control Operators vs. homeowners, spatial and temporal characteristics of pesticide applications, the role of impervious surfaces, and any potential contribution from different land uses such as agriculture or golf courses. These activities are anticipated for FY 2014 - 2015.

Part C:

The next step is to identify controls to address the sources of the stressors identified in Parts A and B. CCCWP would coordinate with California Association of Stormwater Quality Agencies (CASQA) efforts to lobby the. California Department of Pesticide Regulation (DPR), as well as federal (United States Environmental Protection Agency (USEPA)) efforts to control pesticide use. CCCWP would also support public education and municipal adoption of Integrated Pesticide Management (IPM) methods and related programs such as Our Water Our World. If specific source areas are identified, public education and outreach may be targeted at those source areas. These activities are anticipated for FY 2015 - 2016.

Part D:

Step 4 would include testing and analyzing effectiveness of controls. This would involve additional sample collection to determine whether conditions have improved following implementation of control measures. In order to give the program a few years to work, it is anticipated that follow-up assessments would begin in FY 2018 – 2019.

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4.0 REFERENCES

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Contra Costa Clean Water Program

IMP Monitoring Report

IMP Model Calibration and Validation Project

Municipal Regional Permit Attachment C

Submitted to the

California Regional Water Quality Control Board

San Francisco Bay Region

September 15, 2013

Acknowledgements

Dan Cloak, of Dan Cloak Environmental Consulting, prepared the project plan, oversaw implementation of the model calibration and verification project, and prepared this report.

Tony Dubin, of Dubin Environmental Consulting, was involved in developing the model documented in CCCWP's 2005 HMP. He conducted the modeling runs, calibrated and verified the model, and prepared the tables, figures, and text in Chapter 6 of this report.

Scott McQuarrie, of the Contra Costa Flood Control and Water Conservation District, designed and implemented the instrumentation, monitored the IMPs, and compiled the data used in the model calibration and verification.

Tom Dalziel, of the Contra Costa Clean Water Program, has provided project management and coordination since the advent of this effort in 2003.

Jolan Longway, of the City of Pittsburg, provided project coordination and troubleshooting during design and construction of the facilities at the Pittsburg Fire Protection Bureau Building.

Carlton Thompson, Michael Hawthorne, and Scott Wikstrom, of the City of Walnut Creek, provided project coordination and troubleshooting during and following design and construction of the facilities at Walden Parks Commons.

Tom Mumley, Dale Bowyer, and Jan O'Hara, of the San Francisco Bay Regional Water Quality Control Board, were involved in developing and negotiating requirements for implementation of HM measures and for the IMP calibration and verification project.

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0 · Executive Summary

The Contra Costa Clean Water Program (CCCWP) comprises Contra Costa County and the 19 cities and towns within the County, all of which are Permittees under an NPDES permit issued by the San Francisco Bay Regional Water Quality Control Board (Water Board).

Pursuant to permit provision C.3.g., the Permittees require Hydromodification Management (HM) measures to be implemented on development projects. HM measures are intended to control runoff flows so that they do not exceed pre-project flow rates and durations for a specified range of flows. The requirements apply to projects that create or replace an acre or more of impervious area and increase the total amount of impervious area on the project site.

Criteria for HM measures—including factors for sizing HM facilities, called Integrated Management Practices or IMPs—are incorporated in CCCWP's *Stormwater C.3 Guidebook*. The IMPs include bioretention and variations consisting of bioretention combined with upstream or downstream storage.

The sizing factors were developed using a continuous-simulation computer model. The model uses 30 or more years of hourly local rainfall data and generates corresponding estimates of hourly runoff. Model output is used to compare estimated runoff in the site's pre-development condition to runoff post-development, including incorporation of HM measures. Sizing factors represent the minimum IMP areas and volumes required to fully control runoff flows to match the pre-development condition.

The permit requires CCCWP to implement a model calibration and verification project, which is the subject of this report. The purpose of the project is to determine the flow-control effectiveness of the IMPs. The permit specifies that IMPs at a minimum of five locations be monitored for a minimum of two years and that the observed flows be compared to flows that would be estimated by the model.

Three IMPs (bioretention facilities) at an office building in Pittsburg, and two IMPs (bioretention + downstream vault facilities) at a townhouse development in Walnut Creek, were monitored during the 2011-2012 and 2012-2013 water years. Rainfall data was collected at each location. For the IMPs at the Pittsburg site, the water level in the subsurface storage layer was also continuously monitored.

Results of the comparison show that the IMPs provide considerably greater flow-control effectiveness than predicted by the model. The primary reason is that model inputs underestimated the amount of runoff that would be infiltrated by the IMPs. In addition, it was found that runoff percolated through the IMPs soil/compost planting mix more readily than the model predicted. Following changes to input parameters, including the infiltration rate of underlying soils, the model outputs closely matched observed IMP flows and storage.

Local long-term rainfall records were then input to the calibrated model to analyze how IMPs would perform in comparison to current and potential future permit requirements. The simulation indicates that the IMPs fully control runoff flows between the thresholds specified in the current permit (two-tenths of the 2-year pre-project peak flow, or 0.2Q2, and the 10-year pre-project peak flow, or Q10). The Pittsburg bioretention IMPs also control runoff flows within a range extended to the potential future threshold of one-tenth of the 2-year pre-project peak flow, or 0.1Q2. The Walnut Creek bioretention + vault facilities could control flows within the extended range with minor modifications.

In next steps, CCCWP will work with other Bay Area Permittees, through the Bay Area Stormwater Management Agencies Association (BASMAA), to propose appropriate flow-control criteria and sizing factors to be used during the term of a reissued Regional Municipal Stormwater NPDES permit. Lessons learned with regard to facility design details have already been incorporated into the current 6th edition of the *Stormwater C.3 Guidebook.*

1 · Background: Hydrograph Modification Management

1.1 Permit Definitions and Requirements

Provision C.3.g. in the San Francisco Bay Regional Water Quality Control Board's Municipal Regional Stormwater Permit (MRP), titled "Hydromodification Management" (HM), defines HM projects as those creating or replacing an acre or more of impervious area, subject to various exclusions. Provision C.3.g. requires that:

> The stormwater discharges from HM Projects shall not cause an increase in the erosion potential of the receiving stream over the pre-project (existing) condition. Increases in runoff flow and volume shall be managed so that post-project runoff shall not exceed estimated pre-project rates and durations, where such increased flow and/or volume is likely to cause increased potential for erosion of creek beds and banks, silt pollutant generation, or other adverse impacts on beneficial uses due to increased erosive force.

Specific requirements for design of HM controls are:

> For Alameda, Contra Costa, San Mateo, and Santa Clara Permittees, HM controls shall be designed such that post-project stormwater discharge rates and durations match pre-project discharge rates and durations from 10 % of the pre-project 2-year peak flow up to the pre-project 10-year peak flow. For Fairfield-Suisun Permittees, HM controls shall be designed such that post-project stormwater discharge rates and durations shall match from 20 percent of the 2-year peak flow up to the pre-project 10-year peak flow. Contra Costa Permittees, when using pre-sized and pre-designed Integrated Management Practices (IMPs) per Attachment C of this Order, are not required to meet the low-flow criterion of 10% of the 2-year peak flow. These IMPs are designed to control 20% of the 2-year peak flow. After the Contra Costa Permittees conduct the required monitoring specified in Attachment C, the design of these IMPs will be reviewed.

Nearly identical requirements for new development projects appear in the 2010 East Contra Costa County Municipal NPDES Permit issued by the California Regional Water Quality Control Board for the Central Valley Region.

In the MRP, the referenced Attachment C specifies:

> The Program shall monitor flow from Hydrograph Modification Integrated Management Practices (IMPs) to determine the accuracy of its model inputs and assumptions. Monitoring shall be conducted with the aim of evaluating flow control effectiveness of the IMPs. The Program shall implement monitoring where feasible at future new development projects to gain insight into actual versus predicted rates and durations of flow from IMP overflows and underdrains.
>
> At a minimum, Permittees shall monitor five locations for a minimum of two rainy seasons. If two rainy seasons are not sufficient to collect enough data to determine the accuracy of model inputs and assumptions, monitoring shall continue until such time as adequate data are collected.
>
> Permittees shall conduct the IMP monitoring as described in the IMP Model Calibration and Validation Plan in Section 5 of this Attachment. Monitoring results shall be submitted to the Executive Officer by June 15 of each year following collection of monitoring data. If the first year's data indicate IMPs are not effectively controlling flows as modeled in the HMP, the Executive Officer may require the Program to make adjustments to the IMP sizing factors or design, or otherwise take appropriate corrective action. The Permittees shall submit an IMP Monitoring Report by August 30 of the second year of monitoring. The IMP Monitoring Report shall contain, at a minimum, all the data, graphic output from model runs, and a listing of all model outputs to be adjusted, with full explanation for each. Board staff will review the IMP Monitoring Report and require the Program to make any appropriate changes to the model within a 3-month time frame.

Section 4 of MRP Attachment C states in part:

> Monitoring shall be conducted with the aim of evaluating flow control effectiveness of the IMPs. The IMPs were redesigned in 2008 to meet a low flow criterion of 0.2Q2, not 0.1Q2, which is current HMP standard for Contra Costa County. The Program shall implement monitoring at future new development projects at a minimum of five locations and for a minimum of two rainy seasons to gain insight into actual versus predicted rates and durations of flow from IMP overflows and underdrains. If two rainy seasons are not sufficient to collect enough data to

> determine the accuracy of model inputs and assumptions, monitoring shall continue until such time as adequate data are collected….
>
> ….The principal use of the monitoring data shall be a comparison of predicted to actual flows. The Dischargers shall ensure that the HSPF model is set up as it was to prepare the curves in Attachment 2 of the HMP, with appropriate adjustments for the drainage area of the IMP to be monitored and for the actual sizing and configuration of the IMP. Hourly rainfall data from observed storms shall be input to the model, and the resulting hourly predicted output recorded. Where sub-hourly rainfall data are available, the model shall be run with, and output recorded for, 15-minute time steps.
>
> The Dischargers shall compare predicted hourly outflows to the actual hourly outflows. As more data are gathered, the Dischargers may examine aggregated data to characterize deviations from predicted performance at various storm intensities and durations.
>
> Because high-intensity storms are rare, it will take many years to obtain a suitable number of events to evaluate IMP performance under overflow conditions. Underdrain flows will occur more frequently, but possibly only a few times a year, depending on rainfall and IMP characteristics (e.g., extent to which the IMP is oversized, and actual, rather than predicted, permeability of native soils). However, evaluating a range of rainfall events that do not produce underflow will help demonstrate the effectiveness of the IMP.

Similar, but less detailed, requirements were incorporated into RWQCB Order R2-2006-0050, whereby the San Francisco Bay Regional Water Quality Control Board (Water Board) adopted Contra Costa's HMP in 2006. That Order was superseded by the MRP.

1.2 Hydromodification, Control Methods, and Measurements

1.2.1 Hydromodification and Stream Erosion

The following brief summary of factors affecting stream erosion was included in the HMP Work Plan submitted in November 2004. Subsequent research has upheld these points.

> Contra Costa streams are subject to a myriad of influences, and it is typically difficult, if not impossible,

to generalize regarding causes and effects across the entire County. Further, it is often difficult to attribute any particular observed condition in a specific stream to only one proximate cause. In general, it is necessary to consider many potential causes and to consider their relative significance. For example, Riley (2002) attributes the incision of stream channels in the Bay Area over the past 100 years primarily to climate changes and earth movement, while noting that incision may be induced accelerated by land use change as well.

As an illustration of the interaction of these influences, consider the stream equilibrium equation identified by Lane (1955).

(Sediment load × sediment size) α (slope × discharge)

A change in any one of these four factors may contribute to disequilibrium (net erosion or deposition stream sediments) and consequent changes in channel width and depth.

- Sediment load may increased by earth movement (e.g., geologic uplift and mass wasting), land disturbance (e.g., agriculture, road construction), or loss of vegetation, or may be decreased by land development (e.g., paving, terracing), by dams, or by dredging.
- Sediment size may be affected by changed balance among different sediment loads (and the erosion of different geologic strata), by dams, or by in-stream mining.
- Stream slopes are often increased by straightening (removal of meanders), or may be increased or decreased by the placement of downstream culverts or grade controls.
- Finally, stream discharge, and particularly rainfall/runoff relationships, may be increased by deforestation, agriculture, and other land use changes, prior to and including urbanization, or may be decreased by dams and diversions.

The above considerations address only system-wide instabilities, those that are in effect over a long reach or series of reaches. Bank erosion at specific sites may be related to the presence or absence of vegetation and to localized channel conditions (e.g., placement or removal of woody debris or riprap upstream or downstream).

1.2.2 Criteria for Control of Runoff Flows from Development Projects

Notwithstanding the complexity of factors affecting stream erosion, and the watershed scale at which those factors interact, California's nine Regional Water Quality Control Boards (Water Boards) have focused on controlling increased flows and durations from individual development sites.

The nine Water Boards have adopted a variety of criteria, using a mix of methodologies and engineering methods, to regulate land development.

Some Water Boards use the estimated peak flow or volume resulting from a specific storm event ("design storm") as a criterion. Examples of "design-storm" based criteria follow:

- No increase in the predevelopment 2-year peak flow (Orange County and the statewide Phase II permit for small municipalities)
- No increase in runoff volume resulting from the 85th percentile storm or 95th percentile storm, depending on development project location (Central Coast Region)
- No increase in 2-year peak flow or peak duration or increase in runoff volume from the 85th percentile storm (North Coast Region)

Criteria required by other Water Boards involve an analysis of rainfall and runoff over 30 years or more. This continuous simulation approach is discussed in Section 2 below. To determine whether the criteria are met, an hourly rainfall record of 30 years or more is used. Hourly runoff volumes are estimated using a continuous-simulation model applicable to the development site. Runoff is simulated in the pre-project condition and in the post-project condition with proposed IMPs or other flow-control facilities.

The pre-project and post-project runoff statistics are compiled to compare the duration of simulated flow at each flow rate, from rare high flows to more frequent low flows.

The post-project flow durations must be equal to or less than the pre-project flow durations for flows within a specified range.

The Water Boards have required different ranges to be used. The basis for setting different ranges is, ostensibly, that different streams have different thresholds of flow at which their beds or banks may be eroded and the resulting sediment transported downstream. However, in fact, the ranges are often applied to all the stream segments on all the streams in a whole city or even an entire county.

The lower limit of the range is more critical to facility design. The lower limit is commonly expressed as a fraction of the 2-year pre-project peak runoff flow (Q2). Here are some low-flow thresholds currently mandated by the various Water Boards:

- Sacramento-area municipalities: 0.25Q2 or 0.45Q2
- San Diego County municipalities: 0.1Q2, 0.3Q2, or 0.5Q2, depending on receiving channel material and dimensions.
- Cities of Fairfield and Suisun City: 0.2Q2
- Santa Clara, Alameda, and San Mateo Counties: 0.1Q2
- Contra Costa County: 0.2Q2 when applied to specified IMPs.

1.3 LID and HM

The California Ocean Protection Council describes Low Impact Development (LID) as a

> … stormwater management strategy aimed at maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements; LID employs a variety of natural and built features that reduce the rate of runoff, filter pollutants out of runoff, and facilitate the infiltration of water into the ground…
>
> …LID design detains, treats and infiltrates runoff by minimizing impervious area, using pervious pavements and green roofs, dispersing runoff to landscaped areas, and routing runoff to rain gardens, cisterns, swales, and other small-scale facilities distributed throughout a site.

LID was first developed as a comprehensive stormwater management strategy by Prince Georges County (1999). The hydrologic approach is described as follows:

> The LID approach attempts to match the predevelopment condition by compensating for losses of rainfall abstraction through maintenance of infiltration potential, evapotranspiration, and surface storage, as well as increased travel time to reduce rapid concentration of excess runoff.

In essence, LID seeks to address potential hydrologic impacts of land development by maintaining and restoring site characteristics and conditions at the smallest scale possible. Priority is placed on reducing runoff by limiting impervious surfaces, then on dispersing runoff to landscape within a site, and finally by directing runoff to small-scale facilities integrated into the landscape.

In contrast, HM attempts to address hydrologic impacts of land development at a watershed scale. Flow criteria are developed for streams draining the watershed, and those criteria are then translated to criteria for development of sites draining to the watershed. (In the case of the San Francisco Bay Water Board's approach, criteria developed for flows within selected reaches of three streams in Santa Clara County were applied to all Bay Area development sites directly and without further analysis.)

LID promotes a multiplicity of approaches and promotes "green" urban development, while HM specifies that runoff discharges adhere to a specified hydraulic regime.

The HM criteria adopted by the San Francisco Bay Water Board specify the use of flow duration control basins, and require "HM controls shall be designed such that post-project stormwater rates and durations match pre-project discharge rates and durations…." In flow duration control basins, this "match" is achieved through the sizing and placement of orifices draining a basin. Cost-effectiveness and operational considerations favor larger basins (the opposite of LID's small-scale approach). Indeed, the MRP allows compliance through the use of regional-scale flow-duration control basins.

1.4 CCCWP Approach to HM

CCCWP committed to implementing LID beginning in 2003, and published the first edition of the *Stormwater C.3 Guidebook (Guidebook),* emphasizing LID design, in 2004. Faced with the San Francisco Bay Water Board's subsequent emphasis on HM, as opposed to LID, CCCWP sought a way for local developers to meet the HM criteria by using LID. This was accomplished by creating designs for LID IMPs that can also demonstrably meet HM criteria.

CCCWP guidance for HM compliance is incorporated in the *Guidebook.* The *Guidebook* is referenced in stormwater ordinances adopted by each Contra Costa municipality.

The *Guidebook* provides applicants for HM projects the following options for HM compliance. The options also appear in MRP Attachment C:

1. Demonstrate there is no increase in impervious area.
2. Use the HM IMPs in the Guidebook.
3. Use a continuous simulation model and a rainfall record of at least 30 years to show estimated post-project runoff durations and peak flows do not exceed pre-project durations and peak flows.
4. Show that there is a low risk of downstream erosion because all downstream channels are pipes, hardened channels, subject to tidal action, or aggrading, or that a channel restoration project will be constructed that takes the post-project flows into account.

For Option 2, the *Guidebook* incorporates sizing factors that land development engineers may use to determine the minimum required dimensions of a variety of IMPs. The land development engineer divides the development site into discrete Drainage Management Areas (DMAs), determines the amount of equivalent impervious area within each DMA, and uses the *Guidebook* sizing factors to calculate minimum values for the following parameters for an IMP serving that DMA:

- area, **A**
- surface storage volume, **V_1**
- subsurface storage volume **V_2**

See Figure 1-1. The land development engineer then shows how, for each DMA, the IMP meets or exceeds minimum values for each parameter.

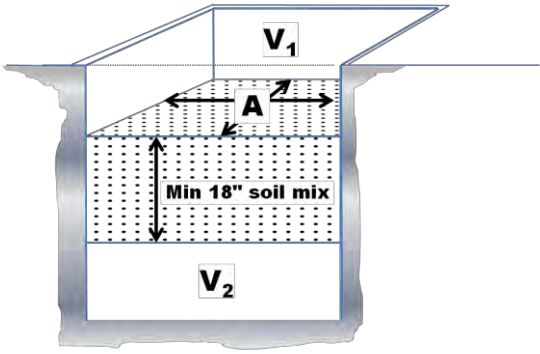


Figure 1-1. A, V_1, and V_2. Note V_2 is the free volume; gravel volume is multiplied by porosity

1.4.1 Bioretention HM Facilities

Bioretention facilities are the most commonly used IMPs on Contra Costa development projects. They are typically constructed for runoff treatment and to maximize retention of runoff via evapotranspiration and infiltration, but the design is adapted to also provide HM. Bioretention facilities work as follows:

Runoff enters the bioretention facility via sheet flow or pipes and is detained in a shallow surface reservoir. The reservoir also serves to spread runoff evenly across the facility surface. Runoff then percolates through an engineered soil (sand/compost mix). Some runoff is retained in soil pores and plant roots and is subsequently evapotranspirated. Runoff that exceeds the moisture-holding capacity of the soil percolates through the soil layer and enters a subsurface storage layer (typically gravel). The treated runoff subsequently then infiltrates into the soils below the facility. If runoff enters the gravel layer more rapidly than it infiltrates, the saturation level in the gravel layer rises until it reaches the discharge elevation for a perforated pipe underdrain. When this occurs, runoff will also discharge through the perforated pipe underdrain to a discharge point (typically connected to the municipal storm drain system). In general, this discharge will occur rarely—a few times per year, or even once in many years.

In facilities constructed for HM, this perforated pipe underdrain is equipped with a flow-limiting orifice. This allows the bioretention facility to act like a flow duration control basin during the infrequent occasions when the storage layer fills, and as a LID facility at other times.

The surface reservoir is also equipped with an overflow that will become active under either of two scenarios: (1) runoff enters the surface reservoir more rapidly than it percolates through the engineered sand/compost mix, and the surface reservoir fills to its maximum volume or (2) runoff enters the facility more rapidly than it leaves via *both* infiltration to the soils below the facility *and* discharge via the underdrain, and this continues until the gravel and soil layers become fully saturated, and the surface reservoir fills to its maximum volume.

In summary, a bioretention facility receives runoff from a specific delineated area, retains that runoff via infiltration and evapotranspiration, and discharges excess runoff via an underdrain and an overflow.

1.4.2 Variations of Bioretention Facilities for HM

The *Guidebook* includes criteria and sizing factors for three design variations:

1. The Flow-through Planter, which can be built above ground or other locations where infiltration to native soils cannot be allowed.

2. Bioretention + Vault, which includes surface storage and engineered soil, but provides for subsurface storage $\mathbf{V_2}$ in a separate structure rather than a subsurface gravel layer.
3. Cistern + Bioretention, which allows for upstream runoff storage $\mathbf{V_1}$ in a tank or basin; runoff is then metered through an orifice to be treated in a bioretention facility.

As described in Section 4, this model calibration and validation project included monitoring of Bioretention + Vault facilities as well as bioretention facilities.

The *Guidebook* also includes design criteria and sizing factors for “direct infiltration” facilities, that is, facilities designed to infiltrate runoff directly, without first routing it through a soil layer to remove pollutants. These design criteria and sizing factors for “direct infiltration” can be used to design infiltration basins, infiltration trenches, and dry wells. This model calibration and validation project did not include “direct infiltration” facilities.

2 · Model Representation of Hydrologic Performance

A project team comprising hydrologists and engineers from Philip Williams & Associates and Brown & Caldwell developed the continuous simulation model that is the subject of this model verification and calibration project. The work was done during 2004-2005. The modeling results formed the basis for the designs and sizing factors proposed in the CCCWP’s Hydrograph Modification Management Plan (HMP), submitted to the Water Board in May 2005 and approved by the Water Board, with minor changes, in July 2006.

In 2009, Brown and Caldwell used the same continuous simulation model—with the same input parameters and assumptions—to create sizing factors for new IMP designs. The new IMP designs and sizing factors were incorporated into an addendum to the 4th Edition of the *Stormwater C.3 Guidebook,* and subsequently carried forward through the 5th and 6th (most recent) *Guidebook* edition.

The model was created in HSPF (Hydrologic Simulation Program – Fortran). HSPF has a history going back to the 1960s, has been used and endorsed by USEPA, and has been embraced in many parts of the US for evaluation and design of the hydrologic impacts of new developments. The Western Washington Hydrologic Model (WWHM) consists of an HSPF-based simulation and a user interface, as does the Bay Area Hydrology Model

(BAHM) currently used in Alameda, Santa Clara, and San Mateo Counties. Because HSPF is widely used, there is a significant body of literature and a community of practitioners to support use of the model in HSPF applications.

In HSPF, the various hydrologic processes are represented as flows and storages. Each flow is an outflow from a storage, which, at each time step, is typically a function of the storage volume at that time step and the physical characteristics of the storage. For undeveloped watersheds, HSPF models the movement of water along three paths: overland flow, interflow, and groundwater flow. A variety of storage zones are used to represent storage that occurs on the land surface and in the soil horizons.

The continuous-simulation model was developed and used to demonstrate that, with the inclusion of appropriately sized IMPs in a development project, increases in runoff flow and volume are managed so that post-project runoff does not exceed estimated pre-project rates and durations.

This requires that the model generate representation of pre-project flows at each time step over a long period, as well as post-project flows at each time step during that same period. It is then possible to make statistical cumulative comparisons of the two sets of generated data.

To develop the model, the consultant team:

- Characterized pre-project runoff peaks and durations for a range of soil groups, vegetation, and rainfall patterns characteristic of Contra Costa County development sites.
- Modeled outflow peaks and durations from several IMP designs (based on a unit area of new impervious surface draining to the IMP).
- Compared modeled pre-project flows to modeled post-project-with-IMP flows, using conservative assumptions.
- Developed calculations for sizing factors for each IMP associated with each pre-project condition.

To model the IMPs, the project team constructed representations of each IMP in HSPF. For example, a bioretention facility is represented in HSPF by length, cross-section geometry, layers of soil and underdrain material, and transmissivity of underlying soils.

3 · Model Verification and Calibration Project Design

This project compared model-predicted hydrologic performance to actual hydrologic performance for five facilities at two test sites.

3.1 Steps for Model Verification and Calibration

The experimental design of this project can be summarized as follows:

1. Create a customized version of the HSPF model for each test facility and its corresponding tributary area to continuously simulate inflow, infiltration, evapotranspiration, and underdrain discharge for that test facility. The customized versions use the same values as the 2004-2005 model for soil permeability and bioretention planting soil characteristics, and facility-specific values for the tributary drainage area size and runoff factors and for facility dimensions.
2. Measure rainfall at each test site at each time increment.
3. Input site rainfall data, and use the model to predict, for each time increment, the rates and volumes of inflow, infiltration, evapotranspiration and underdrain discharge for each test facility, as well as storage within each component of the facility.
4. Directly measure the underdrain discharge for each facility at each time increment. (Also, for three of the test facilities, the saturation level in the gravel layer was measured at each time increment.)
5. Compare predicted to measured flows and storage.
6. Adjust the previously assumed model parameter values so that predicted flows and storage more closely approximate measured flows and storage at each time increment (that is, calibrate the model).

3.2 Evaluation of Sizing Factors

The procedure for calculating sizing factors, previously implemented in 2004-2005 and again in 2009, was used with the now-calibrated model to evaluate whether the current sizing factors for bioretention and bioretention + vault facilities are adequate.

Long-term hourly rainfall records from two of the same rain gauges previously used for calculating the sizing factors were input into one of the calibrated site-specific models to examine whether the facility met regulatory criteria.

This procedure was completed for two regulatory scenarios:

1. For a low-flow criterion of 0.2Q2, as specified under the MRP adopted in 2009.
2. For a low-flow criterion of 0.1Q2.

Results are in Section 6.

4 · Project Test Facility Characteristics and Parameters

The CCCWP sought to identify development projects with the following characteristics (Cloak, 2009):

- One or more facilities (bioretention, flow-through planter, bioretention + vault, or cistern + bioretention).
- Facilities must include an underdrain (as required on sites where native soils are in Hydrologic Soil Groups "C" or "D").
- Clearly defined and accurately sized Drainage Management Areas.
- Facilities designed according to the criteria in the Guidebook 4th Edition, including documentation and calculations of minimum and provided bioretention surface area, surface storage volume, diameter of circular orifice, and subsurface storage volume.
- Arrangements/permissions to work with the project contractor and inspector to document and verify construction of the facilities.
- 24-hour access and permission from site owner to access facilities to maintain monitoring equipment.
- Above-ground location to mount a datalogger, rain gauge, and telemetry.

There were five test facilities at two test sites. Three bioretention facilities were monitored at the Pittsburg Fire Prevention Bureau Building, and two bioretention + vault facilities were monitored at Walden Park Commons, a 65-unit townhouse development in Walnut Creek.

4.1 Pittsburg Fire Protection Bureau Building

4.1.1 Site Description

The Pittsburg Fire Protection Bureau Building is located at 2329 Loveridge Road in Pittsburg. Total project site area is 1.09 acres. The site is nearly flat. A single-story building of about 19,000 square feet houses offices of the Contra Costa Fire Protection District. There is an accompanying parking lot with 35 spaces and a trash enclosure. The site includes landscaping around the building, around the perimeter of the site adjacent to Loveridge Road and Loveridge Circle, and in parking medians. The project was constructed during 2011.

As originally designed, the project included a paved overflow parking area. With this area, the total new impervious surface exceeded one acre. The City of Pittsburg required HM compliance for the project. In later revisions to the project scope, the overflow parking area was left graveled rather than paved and the total new impervious area was reduced to 26,457 square feet.

Figure 4-1.
Pittsburg site pre-project

4.1.2 Pre-Project Condition and Site Soils

Figure 4-1 shows the site in its pre-project condition. As can be seen in the photo, the site was previously undeveloped; however, it had been used for parking and perhaps as a construction staging area.

Figure 4-2. Excavation of IMP #2 at Pittsburg Site.

Borings on the site were taken in 2004. According to the report by Kleinfelder (2004), subsurface soils “consisted predominantly of stiff to hard, moderately to highly plastic silty clays, extending to depths ranging from about 4 to 14 feet below existing site grade.” This covers the range of depths at the bottom of the bioretention facilities. Surface soils were found to have high shear strength and be highly plastic, as indicated by Atterberg Limits: a Liquid Limit of 59% and a corresponding Plasticity Index of 37. This indicates high expansion potential. The shear strength of the soils is apparent in Figure 4-2.

Boring depths extended as deep as 31 feet, and groundwater was not encountered.

4.1.3 Drainage Management Areas

The Pittsburg Fire Protection Bureau Building design for treatment and HM compliance incorporates eight DMAs.

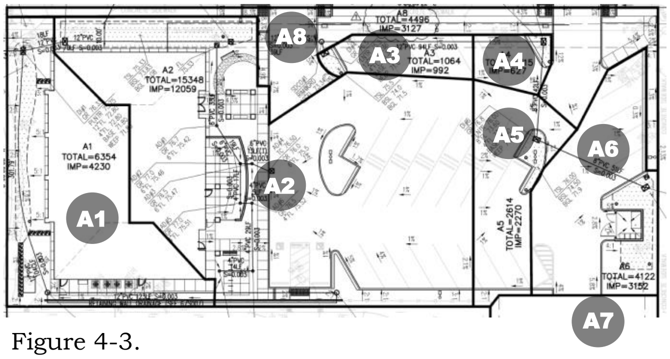


Figure 4-3.
Pittsburg site Drainage Management Areas.

For the model verification project, the completed site was inspected to verify that DMA delineation corresponded to site drainage as built. This included visual verification of the location of rain gutters and downspouts. In addition, the parking lot and grounds were inspected to verify that grade breaks correspond to the DMA boundaries shown in the project plans.

See Figure 4-3 and Table 4-1.

DMA 7 is a self-treating pervious graveled area. DMA 8 consists of driveway and sidewalk areas that could not be made to drain to treatment facilities. The remaining six DMAs each drain to a bioretention facility. Three of these six bioretention facilities were selected to be monitored as part of this project; these are designated as A2, A4, and A6 in Table 4-1.

Table 4-1. Pittsburg Fire Protection Bureau Building Facility Dimensions.

	Tributary Area		**Bioretention Facility Dimensions**						
	Landscaped (SF)	Impervious (SF)	A (SF)	A* (gravel layer)	V_1 (CF)	Surface Depth (in.)	V_2 (CF)	Gravel Depth (in.)	Orifice diameter (In.)
A1	1582	4230	558	558	316	7	379	21	0.51
A2	2415	12059	886	886	874	12	961	33	0.81
A3	0	992	60	72	72	12	72	30	0.21
A4	0	627	67.5	82.5	44	6	44	15	0.17
A5	180	2270	170	195	130	9.5	170	31	0.32
A6	562	3152	340	340	204	6	258	19	0.41

*The gravel layer on some facilities extended beyond the surface dimension due to installation of a curb that extended only to top of the gravel layer.

4.1.4 Design of Bioretention Facilities

Each of the three test bioretention facilities was constructed using the cross section and key features specified in the 4th Edition of the *Guidebook*. Some specifications that were new for the 5th ("MRP") Edition were incorporated. All three facilities have:

- Surface reservoir depth as required for V_1
- 18-inch depth sand/compost mix
- Subsurface reservoir of Class 2 permeable (Caltrans Specification 68-1.025), as required for V_2
- Underdrain of PVC SDR 35 perforated pipe
- Underdrain discharge orifice
- Curb inlets; these are constructed somewhat differently from the standard 12-inch-wide curb cut and consisted of pipe sections in the curb face.
- Outlet structures consisting of 24" × 36" precast catch basins; this larger size was to ensure the instrument technician would be able to enter and access the tipping buckets located where the underdrain discharges to the outlet structure.
- Monitoring wells, composed of a section of 6-inch PVC pipe extending vertically through the soil and gravel layers.

Bioretention facilities A2 and A4 were designed with perimeter walls. Bioretention facility A6 was designed without perimeter walls.

A discharge orifice design was developed for this project; the design was subsequently included in the 5th Edition of the *Guidebook*. The design incorporates a solid PVC pipe extending through the wall of the outlet structure; the pipe is fitted with a threaded cap. The orifice is drilled into the cap. This allows the cap to be removed so that the orifice and pipe can be cleaned if necessary; it also allows the cap to be

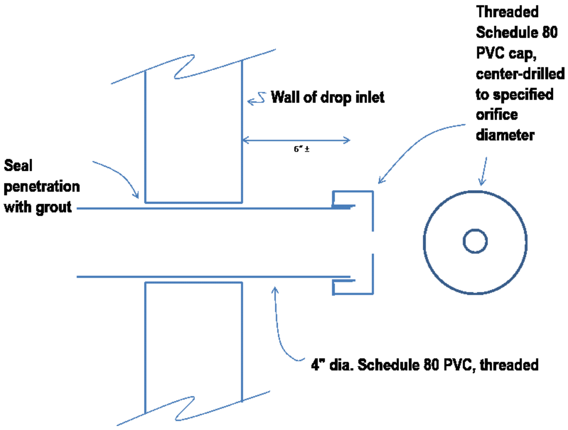


Figure 4-4. Underdrain Orifice Detail.

replaced if the orifice size needs to be adjusted. See Figure 4-4.

As is typical on development sites, the area for some of the IMPs substantially exceeds the minimum. See Table 4-1. This is done for constructability. It is often easier and more cost-effective to build a facility with dimensions that coincide with the available space (such as a parking median) than to build the additional walls and other structure necessary to minimize the size of the IMP.

4.1.5 Construction of Bioretention Facilities

The bioretention facilities were constructed consequent with the construction of the Fire Protection Bureau Building during 2011.

The facilities were constructed generally as designed. The following issues were encountered during construction:

The outfall structures had to be constructed deep enough to fit tipping buckets beneath the underdrain discharge elevation. Because the site is flat, and because the municipal storm drain in Loveridge Road is shallow, there was concern that during storm events flow from the municipal storm drain would back up into the site storm drains and flood the tipping buckets. To address this concern, the most downstream on-site drainage structure (not a bioretention outfall) was fitted with a weir wall and a pump placed on the upstream side with discharge to the downstream (municipal storm drain) side. The pump operated successfully to maintain drainage over the weir wall.

The addition of curbs and widening of curbs for structural stability resulted in reductions to the surface area of each test facility. The reduced areas were noted in updated drawings (and in Table 1) and incorporated into the customized model for each facility.

Following excavation, the native clay soils at the bottom of each bioretention facility were “ripped” using the toothed bucket of the excavator.

4.1.6 Instrumentation

A rain gauge was located on the roof of the trash enclosure.

Each of the three bioretention facilities was equipped with the following measuring devices:

- A tipping bucket, Model TB1L made by Hydrological Services Ltd., located in the facility overflow structure to measure flows discharged through the underdrain orifice

- A piezometer, located in a monitoring well

The instruments were connected to a datalogger on the site via wired connections. Some of the wired connections were strung through the site storm drains—a notable convenience. The datalogger was connected via telemetry to the County Flood Control District's data system.

4.2 Walden Park Commons

Walden Park Commons is a 65-unit multi-family development on a 4.59-acre site fronting Oak Road in Walnut Creek. The site is flat, sloping less than 0.5% away from Oak Road.

4.2.1 Pre-Project Conditions and Site Soils

The site was previously occupied by ten single-family homes with pools, sheds, and associated driveways. These accounted for 74,000 square feet (1.7 acres) of pre-project impervious area.

A geotechnical study of the site (Korbmacher Engineering, 2006) found site soils were native to the site (that is, not fill), and that soils "consisted of a medium stiff to very stiff silty clay and sandy clay." The near-surface soils have moderate expansion potential.

The Korbmacher report indicates groundwater was encountered in borings at a range of 7 to 11 feet below existing grade.

4.2.2 Drainage Management Areas

The applicant was required to ensure all site impervious surfaces drain to LID treatment. The applicant was allowed to size and design bioretention facilities for "treatment only" for new impervious areas equivalent to the pre-project impervious area. For the remainder of the site (corresponding to the increase in impervious area as a result of the project), the applicant was required to provide both treatment and HM control. See the CCCWP's "Guidance on Flow Control for Development Projects on Sites that are Already Partially Developed," (March 2009).

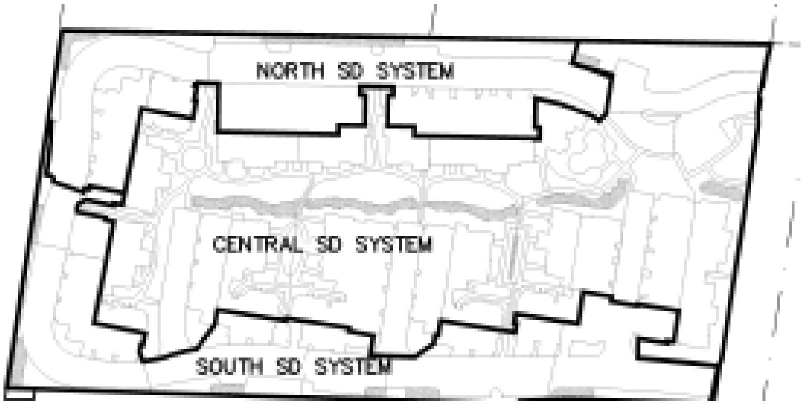


Figure 4-5.
Walden Park Commons Storm Drainage Areas

The site was divided into North, Central, and South areas, with the Central area being routed to treatment-only bioretention facilities. See Figure 4-5. The Central area DMAs and treatment facilities are not considered further in this report.

The North Area is divided into eight DMAs. There are six impervious DMAs totaling 33,301 square feet of impervious roof and driveway, and two landscaped DMAs with 5,948 square feet of pervious area.

The South Area is divided into 19 DMAs. There are 14 impervious DMAs with 36,257 square feet of impervious area, and five landscaped DMAs with 7,495 square feet of pervious area.

All DMAs in the North and South Areas were drained to bioretention facilities. Landscaped DMAs were assigned a runoff factor of 0.7 as specified in the 2005 HMP; that is, landscaped areas were assumed to be 70% impervious. Roofs and paved areas were assumed to be 100% impervious.

4.2.3 Design of Bioretention Facilities

A sizing factor of 0.04 was applied to the resulting equivalent impervious area. Bioretention facilities were sized to exceed this minimum.

Key characteristics of the bioretention facilities are:

- 18 inches of sand/compost mix
- Class 2 permeable drainage layer
- Overflow constructed of vertical ADS pipe, cut to design height
- 6-inch perforated pipe underdrain
- Overflow and underdrain connected to large-diameter storage pipe

The bioretention facilities are located between the site's loop road and the site perimeter fence and are generally configured as linear swales. According to construction drawings, the bottom of the excavation was sloped toward a central line running the length of the swale. The gravel (Class 2 permeable) layer is likewise sloped. The upstream sections do not have underdrains; the most downstream section of the bioretention facilities (near the rear of the development) includes a perforated pipe underdrain See Figure 4-6.

This configuration allows runoff to infiltrate over much of the bioretention facility area; however, runoff pooling in the gravel layer of the most downstream section will tend to enter the underdrain pipe rather than infiltrate.

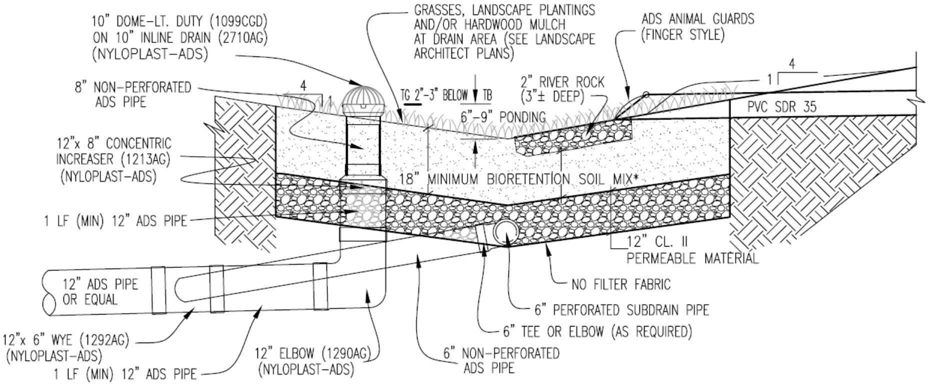


Figure 4-6. Configuration of Walden Park Commons Bioretention Facilities

4.2.4 Design of Downstream Storage

The underdrain/overflow from the bioretention facilities is routed to common storage facilities—one for the North Area and one for the South Area. The storage consists of reinforced concrete pipe of 30" and 42" diameter set at a slope of 0.005. This information was used to establish stage-storage relationships within the model (See Section 6.)

The concrete pipe storage facility is sealed, preventing exfiltration to the Class A/B backfill material around the pipes and eliminating the opportunity for subsequent infiltration to the native soils around and beneath the storage pipe. This is a significant variance from the design intent for Bioretention + Vault facilities. The *Guidebook* design detail for Bioretention + Vault shows a chamber with an open bottom.

The storage pipes for the North Area and South Area each discharge into concrete vaults at the rear of the development. Each vault is equipped with a weir wall. A pipe through each weir wall conveys metered flows. Each of these pipes is equipped with a PVC pipe and threaded cap. An orifice drilled into the cap meters flows.

Should either of the storage pipes become full, flows would overtop the corresponding weir wall. Downstream of the weir walls, the vaults discharge to the City of Walnut Creek storm drain system.

4.2.5 Construction of Facilities

Drainage facilities were constructed, along with most of the townhouses, during 2011. The following were noted following construction:

Because the bioretention facilities were designed without a hard delineation of their perimeter (that is, they slope seamlessly to surrounding landscaping), it is difficult to visually discern their areal extent. The facilities were surveyed post-construction to confirm the floodable area (that is, the area that lies below the overflow height) corresponded to the areas shown in the descriptions and calculations submitted by the applicant.

Data from the initial storm showed vault outflows began soon after the beginning of a rain event, the facilities were inspected for construction errors that might cause short-circuiting. It was found that the overflow pipe risers had been constructed with perforated pipe, which could have allowed ponded runoff to enter the overflow rather than percolating through the soil/compost mix layer. This was corrected on March 6, 2012.

4.2.6 Instrumentation

Because the bioretention areas were routed to common detention vaults, the total area tributary to the vault is relatively large, and the allowable discharge rate is correspondingly large. To illustrate, the 0.1Q2 discharge from the North and South Areas at Walden Park Commons is 0.07 and 0.08 cfs, respectively, compared with 0.02 cfs for the largest of the bioretention facilities (Facility A2) at the Pittsburg Fire Protection Bureau Building. The larger flow rates allowed the use of electromagnetic flow meters (“magmeters”) rather than tipping buckets. Model #EX 81P-40 by Seametrics was selected. The correspondingly larger orifice sizes (over an inch) also helped alleviate concerns about potential orifice clogging.

The magmeters were installed in 1.5" diameter sections of pipe extending upstream of the orifice discharge and through the weir.

The selected magmeter sensors generate a frequency range from 0 – 550Hz over a velocity range of 0.28 – 20 feet per second respectively. This frequency was sampled by the data logger every 15 minutes and velocity was calculated from frequency.

A rain gauge was located in the central courtyard of the development.

The data was transmitted every half hour to a County mountain top repeater and to the office base station where the entire data base is maintained.

5 · Data Collection and Review

Instrumentation and telemetry were established in September 2011 and maintained through May 2013. The instrumentation was operating for all storms during this period. Following is a list of occurrences that affected data collection.

5.1 Exceptions Affecting Data Collection—Pittsburg

5.1.1 Tips When Piezometer Levels Show No Outflow

During each sizable storm, tipping buckets recorded a single tip although piezometer levels indicated the saturation level in the gravel layer had not reached the height of the underdrain. These tips could have been caused by small amounts of runoff entering the underdrain rather than percolating through the unsaturated gravel layer, or by rain falling directly into the tipping bucket.

5.1.2 Data Loss on October 22, 2012

Data for a storm on this date showed very high flows entering the tipping bucket for IMP #2. On examination of the data, it was determined that the recorded flows were outside the range of the tipping buckets ability to record. On further investigation, it was determined that moisture had caused wired connections between the tipping buckets and the datalogger to short-circuit. The wired connections were insulated with silicone rubber sealer. The erroneous data was taken out of the data base at that time.

5.2 Exceptions Affecting Data Collection—Walden Park

5.2.1 Construction Error on Overflow Risers

As noted above, a construction error may have allowed short-circuiting of flows during storms prior to March 6, 2012.

5.2.2 Cut-out at High Flows

It was noted that data for some events showed flows rising following the onset of rain, suddenly dropping to zero, and then resuming with a falling limb as the storage pipe drained. On investigation it was determined the most likely cause was turbulent flow within the discharge pipe.

As a backup method of measuring flows, on January 17, 2013 level sensors were installed in the discharge vault. Also at this time two feet of linear pipe was installed upstream of the magmeters. It was planned to correlate the water levels and measured flows to establish a rating curve and to use the rating curve to estimate flows during intervals when the flow sensor was not registering. However, there were not enough subsequent storms to establish the rating curve, and no subsequent flows were high enough to cause recurrence of the problem.

5.3 Data Review and Consistency Check

Data were reviewed for internal consistency and consistency with expectations and visual observations. The following were noted:

- Rainfall data was consistent with observed events and other rain gauge data collected by the District.
- Saturation levels in the Pittsburg bioretention facilities rose to relative levels consistent with rainfall depths and with facility sizing.
- Discharge measured at the Walden Park facilities was recorded at relative flows consistent with rainfall intensity and depths.

In summary, the data collected covered most but not all storm events during the monitoring period. In addition, the 2-year monitoring period corresponded to a time of relatively few rainfall events, and smaller rainfall events, compared with long-term averages. There were no events intense enough to cause overflow of bioretention facility surface reservoirs at either site, or with enough intensity and volume to cause underdrain discharge at the Pittsburg facilities.

However, the data collected are sufficient for comparison of facility performance with the performance predicted by the model. See Section 6.

6 · Analysis and Results

This section describes the modeling and data analysis methods that were used together to characterize the performance of the Pittsburg and Walden Park Commons IMPs. This section contains the following details:

- Evaluation of rain gauge data for the monitoring period and a comparison of monitored storm events to long-term rainfall statistics for the area.
- Evaluation of IMP monitoring data and the potential implications of the hydraulic characteristics on long-term IMP performance.
- Comparison of HMP model results and IMP monitoring data.
- Description of model parameter adjustments to produce closer agreement between the model outputs and IMP monitoring data.
- Discussion of the current IMP sizing factors and their adequacy for meeting the NPDES permit's flow duration control standard.

Additional modeling and analysis details are contained in Appendix A.

6.1 Comparison of Simulated and Recorded Data

6.1.1 Storm Characteristics

Rainfall accumulations for the 2011-12 and 2012-13 monitoring periods were examined to determine how the monitoring period compares to long-term trends in the Pittsburg and Walnut Creek areas. The purpose of this analysis was to assess whether the monitored storms are representative for the area and whether the storms produced enough rain to adequately characterize the long-term performance of the IMPs at the Fire Prevention Bureau Building in Pittsburg and Walden Park Commons in Walnut Creek.

For the Pittsburg site, the closest rain gauge with a long-term record is Los Medanos, which is located between Pittsburg and Antioch. For Walnut Creek, the closest representative rainfall gauge with a long-term record is the FCD11 gauge located in Martinez.

Table 6-1 shows the seasonal rainfall totals at each project rain gauge and the long-term seasonal averages at the Los Medanos and Martinez gauges. At Pittsburg, the total rainfall was 13 percent below average for the first monitoring season and about average for the second season. At Walden Park Commons, the rainfall was 5 percent below average for the first monitoring season and 24 percent below average for the second season.

Table 6-1. Seasonal Rainfall Totals

Pittsburg Fire Prevention Bureau				
Season	Dates	Project Site Rainfall (in)	Los Medanos Avg. Rainfall (in)	Difference
1	Oct-2011 – Apr-2012	6.84	7.85	-13%
2	Sept-2012 – May-2013	8.14	8.20	-1%
Walden Park Commons				
Season	Dates	Project Site Rainfall (in)	Martinez Avg. Rainfall (in)	Difference
1	Nov-2011 – Apr-2012	17.19	18.05	-5%
2	Sept-2012 – May-2013	14.69	19.31	-24%

Even though the total rainfall was less than average over the monitoring period, there were several significant events during each season. Table 6-2 and Table 6-3 list the 10 and 13 largest rainfall events that were recorded during the monitoring period at the Fire Prevention Bureau and Walden Park Commons, respectively. The Walden Park Commons list was expanded to capture three events for which both outflow rates and storage pipe levels were recorded. The “recurrence” column in the two tables refers to how often a storm of similar magnitude would be expected to occur, based on the long-term rainfall data. Depth-duration-frequency curves were developed for the Los Medanos and Martinez sites for this analysis.

Table 6-2. Pittsburg Fire Prevention Bureau Site Storm Events			
Start Date	Duration (hours)	Total (in)	Recurrence (12-hr)
1/19/2012	90	1.45	3-month
3/15/2012	49	0.66	3-month
3/24/2012	13	0.65	3-month
4/12/2012	40	1.20	3-month
10/22/2012	26	0.51	<3-month
11/21/2012	9	0.45	<3-month
11/28/2012	56	1.64	2-year
12/1/2012	17	1.12	1-year
12/21/2012	46	1.00	3-month
12/25/2012	14	0.50	3-month

Table 6-3. Walden Park Commons Site Storm Events			
Start Date	Duration (hours)	Total (in)	Recurrence (12-hr)
1/19/2012	95	3.51	1-year
2/29/2012	36	1.01	<3-month
3/13/2012	109	2.59	3-month
3/24/2012	17	1.03	3-month
3/27/2012	16	0.89	<3-month
4/10/2012	79	2.81	3-month
11/20/2012	11	0.92	3-month
11/29/2012	69	4.64	2-year
12/21/2012	69	2.32	3-month
12/25/2012	24	0.79	<3-month
2/19/2013	9	0.34	<3-month
3/30/2013	36	0.76	<3-month
4/4/2013	8	0.29	<3-month

The number of significant storm events during the monitoring period is very consistent with the long-term local rainfall record. For example, there were 8 events that exceeded the 3-month recurrence (for 12-hour rainfall accumulations) at the Fire Prevention Bureau site and 7 events surpassing this threshold at the Walden Park Commons site. This is important, because 3-month storm events would be expected to produce flow rates that approach the lower control threshold flow rate in the County's current NPDES permit (two-tenths of the two-year flow rate, or 0.2Q2). Additionally, the Fire Prevention Bureau and Walden Park Commons sites both experienced 2 rainfall events that were larger than the 1-year (12-hour) storm. In conclusion, the monitoring period included enough storms across a range of intensities and total accumulations to adequately demonstrate how the IMPs perform.

6.1.2 Observed IMP Performance Characteristics

For each significant storm event, IMP monitoring data were examined to better understand the following soil hydraulics and performance characteristics:

1. Percolation of stormwater from the ponding layer through the bioretention soils into the storage layer
2. Infiltration of treated stormwater from the storage layer to the surrounding soils (note: this applies only to the Fire Prevention Bureau bioretention IMPs)
3. Performance of storage layer and frequency of underdrain discharges
4. Any evidence of performance problems

Percolation Characteristics

At the Fire Prevention Bureau site, a slotted-standpipe monitoring well was installed within the gravel storage layer of each monitored IMP. At the Walden Park Commons site, water levels were monitored in the vaults at the downstream end of the storage pipes. The IMP percolation characteristics were examined by comparing the timing and volume of rainfall to the appearance of water within the storage layer at each IMP.

The monitoring data shows that percolation begins after relatively modest levels of rainfall. In the 2004-2005 HSPF model, bioretention soils were modeled using the van Genuchten relationship for water retention. This relationship dictates that percolation rates in sandy-loamy soils would be minimal until the soil reached about three-quarters saturation. However, water appeared in the gravel layer before that volume was reached.

Similar runoff and percolation characteristics were observed at the Fire Prevention Bureau and Walden Park Commons IMPs. The bioretention soils are faster-draining than we expected when creating HSPF models for the HMP.

Figure 6-1 shows an example percolation response for the March 16-18, 2012 storm event at IMP #2 at the Fire Prevention Bureau. The observed depths in the gravel storage layer begin to climb after the first 0.07 inches of rainfall. Based on the tributary area and our initial assumptions about the soil's water retention characteristics, we expected this initial runoff to be fully absorbed within the bioretention soils, filling the available pore spaces like water fills the void spaces in a sponge.

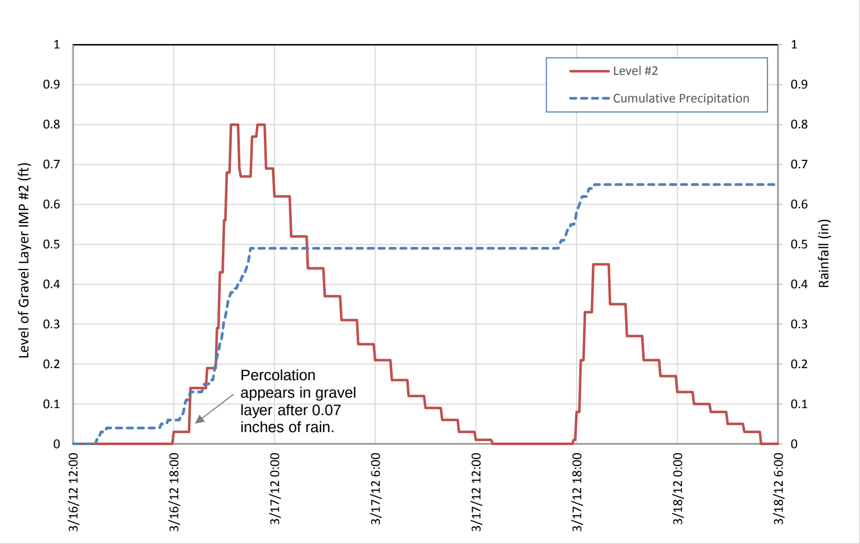


Figure 6-1. Percolation and infiltration, Fire Prevention Bureau IMP #2.

In general percolation in IMP #2 occurred after 0.07 to 0.16 inches of rain, except during an extended wet period from late-November through December 2012 when soils remained wet between storms and percolation began almost immediately after the start of a rain event. In IMP #6 percolation started later in storm events, usually after 0.3 to 0.8 inches of rain (Figure 6-2). IMP #4 is much smaller than the other IMPs and is about two-thirds larger the necessary, based on the HMP sizing factors. IMP #4 did not produce a consistent response to rainfall.

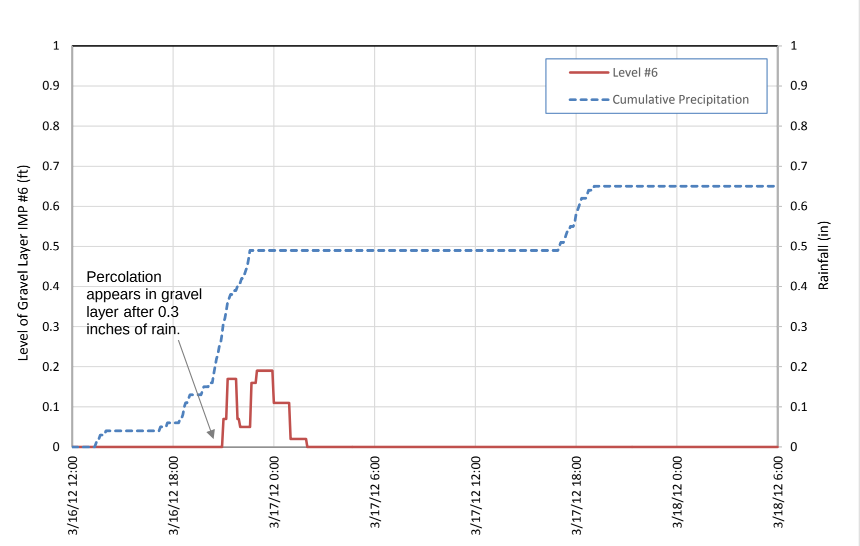
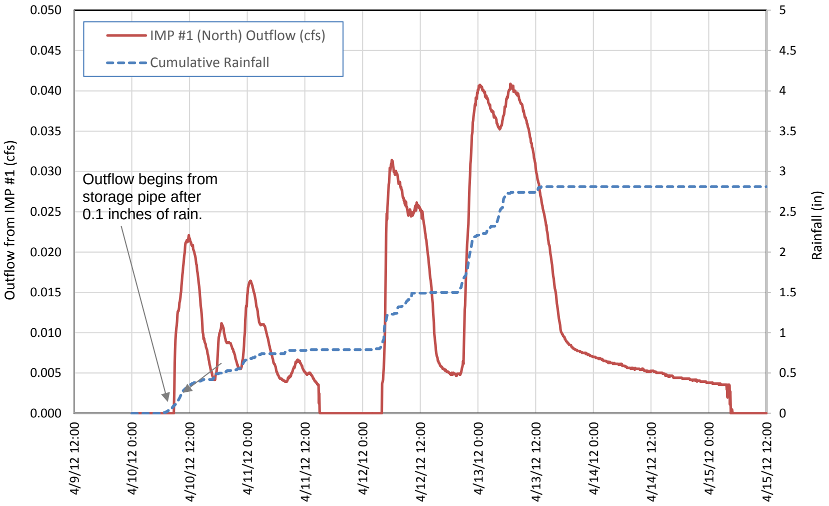


Figure 6-2. Percolation and Infiltration, Fire Prevention Bureau IMP #6.

The reasons for the different response times at IMP #2 and IMP #6 were evaluated. The large roof area adjacent to IMP #2 discharges water via three downspout connections. This water may be saturating the soils in the immediate vicinity of the downspouts and generating percolation to the gravel layer without wetting other portions of the bioretention facility.

Conversely, IMP #6 spreads inflows more broadly and provides a larger soil volume to capture stormwater runoff.

At Walden Park Commons stormwater quickly appears in the storage layer soon after rainfall begins. Figure 6-3 shows accumulated rainfall and IMP outflow for an April 2012 storm event at IMP #1 (North). The storage pipe has received enough percolation to produce outflow after 0.1 inches of rainfall is recorded.



Outflow begins from storage pipe after 0.1 inches of rain.

Figure 6-3. Stormwater appears in storage pipe shortly after rain begins IMP #1 (North).

Figure 6-4 shows the start of percolation at IMP #2 (South). The percolation starts later in IMP #2 (South) because a) bioretention area is larger and b) more of the tributary area contains pervious surfaces. The relative responses at IMP #1 (North) and IMP #2 (South) are similar for other storm events.

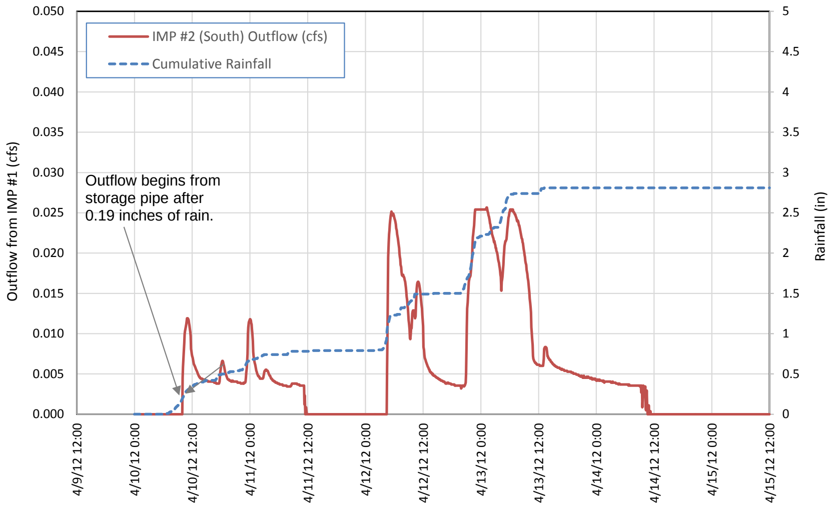
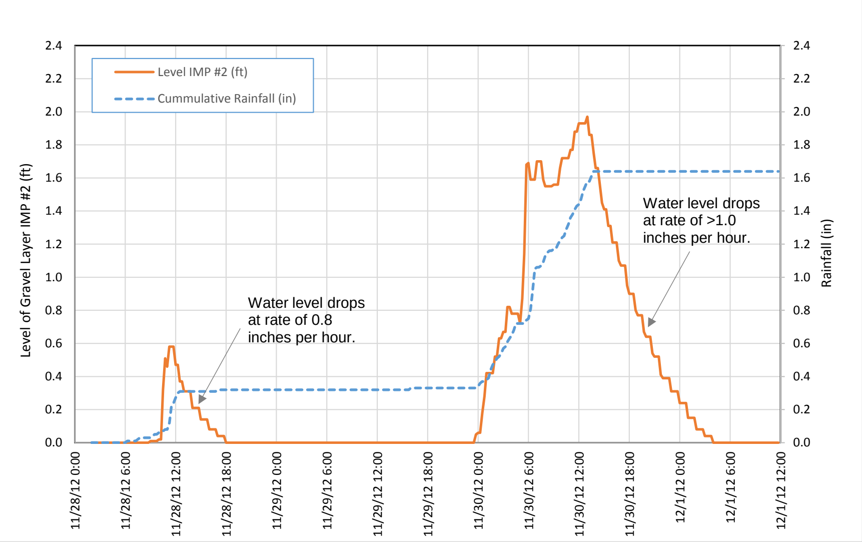


Figure 6-4. At IMP #2 (South) stormwater runoff appears in storage pipe more slowly than in IMP #1 (North)

In conclusion, the bioretention soils appear to allow percolation at lower soil moisture content levels than we expected when preparing the HMP. The effect is less pronounced in over-sized bioretention installations, such as Fire Prevention Bureau IMP #6 and Walden Park Commons IMP #2 (South). This characteristic will probably have a negligible effect on IMP performance. One potential benefit of the fast-percolating soils is the reduced likelihood stormwater building up in the ponding layer and spilling into the overflow in response to high-intensity rainfall.

Infiltration Characteristics

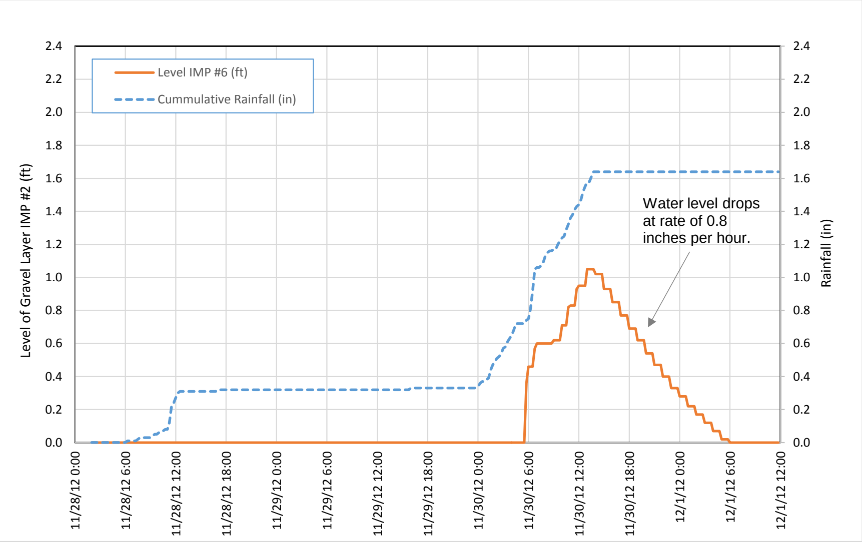
The infiltration characteristics of the surrounding soils were first evaluated at the Fire Prevention Bureau site, where the IMP gravel layers discharge directly to the surrounding soils. Figure 6-5 shows the recorded water levels in the storage layer at Fire Prevention Bureau IMP #2 for the November 28-30, 2012 storm event. Figure 6-6 shows the same storm event at IMP #6.



Water level drops at rate of 0.8 inches per hour.

Water level drops at rate of >1.0 inches per hour.

Figure 6-5. Storm recession rates at Pittsburg Site37 IMP #2



Water level drops at rate of 0.8 inches per hour.

Figure 6-6. Storm recession rates at Fire Prevention Bureau IMP #6

After the rain stops, the water level in the storage layer decreases quickly—at a rate between 0.8 inches per hour and more than 1 inch per hour. Several storm events were examined and while the rate varied by storm in all cases the recession rate was higher than expected for NRCS Group D soils. Even late in the winter season, there was no noticeable groundwater mounding-related reduction in infiltration capacity. The Fire Prevention Bureau infiltration rates surpass the assumed rate of 0.024 inches per hour used in the 2004-2005 HSPF model.

In conclusion, soils at the Fire Prevention Bureau infiltrate runoff more rapidly than the reference values for NRCS Group D soils. IMPs at this site will provide a higher overall onsite stormwater capture fraction than previously expected. These IMPs should also provide a higher level of performance relative to the NPDES permit's flow duration performance standard.

The native soil characteristics for the Walden Park Commons site were indirectly evaluated using a combination of monitoring data and modeling (see Section 6.1.3).

Storage Layer and Underdrain Performance

The Fire Prevention Bureau monitoring data for IMP #2, IMP #4 and IMP #6 were also examined to determine a) how often the flow monitoring equipment registered underdrain discharge, and b) whether these discharges were caused by the filling of the gravel layer.

The items below describe the monitoring data results, which are also summarized in Table 6-4.

- IMP #2: Small underdrain discharges were recorded at 10 separate days over the 20 month monitoring period. The total volume of these discharges was less than 3 cubic feet. None of the discharges lasted more than 15 minutes and only four occurred during the 10 largest rainfall events. In all cases the corresponding water depth did not reach the level of the discharge pipe. The mostly likely reasons for the underdrain discharge are that a small amount of water migrated into the underdrain pipe as it was descending into the gravel layer, and/or that rain fell directly into the tipping bucket.
- IMP #4: Small underdrain discharges were recorded on 16 separate days with the total discharge over 20 months of 4.4 cubic feet. Similar to IMP 2, the discharge volumes are very small and not continuous. The observed water level in the gravel layer never reached the elevation of the under-drain pipe.
- IMP #6: Small underdrain discharges were recorded on 21 separate days with the total discharge over 21 months of 6.6 cubic feet. Similar to IMP 2 and IMP 4, the discharge volumes are very small and not continuous. The observed water level in the gravel layer never reached the elevation of the underdrain pipe.

Table 6-4. Pittsburg Fire Prevention Bureau Monitored Discharge Events			
IMP	Number of Underdrain Discharge Events*	Number of Events Due to Filling of Underdrain Layer	Total Volume
IMP #2	10	0	2.7 ft^3
IMP #4	16	0	4.4 ft^3
IMP #6	21	0	6.6 ft^3

*These discharge events each produced a small volume of water and were most likely due to the migration of water into the underdrain pipe as the water descended into the gravel layer, and/or rain falling directly into the tipping bucket.

Evidence of IMP Performance Issues

No significant or systematic IMP performance issues were evident from the monitoring data or from anecdotal observations during storm events. As noted in Section 5, the overflow risers in the bioretention facilities at Walden Park Commons were installed using perforated pipe, rather than the specified solid pipe. This allowed an unknown portion of stormwater flow to bypass the bioretention treatment. The contractor for the Walden Park Commons project corrected the problem on March 6, 2012.

Summary of Observed IMP Performance

The IMPs at the Pittsburg Fire Prevention Bureau Building and Walden Park Commons successfully captured, treated, detained, and slowly discharged stormwater from all storms during the two-year monitoring period. There were no overflows or significant performance issues.

The infiltration capacity of the native soils at the Pittsburg site will provide a higher level of onsite stormwater control and should allow these IMPs to surpass the flow control requirements of the NPDES permit. Additionally, the bioretention soils allow for faster percolation than was assumed when preparing the HMP. While this difference is not likely to affect the IMP sizing factors, it will protect the system from overflows during periods of very intense rainfall.

6.1.3 Comparison of Model Predictions to Measured Results

Model predictions and monitoring data (primarily water level) were compared for the 10 largest storm events during the 20-month monitoring period at the Fire Prevention Bureau (see Table 6-2 above for list of events).

Figure 6-7 shows an example comparison for Fire Prevention Bureau Building IMP #2 for the April 10-14, 2012 storm event.

Figure 6-8 shows the same storm event for IMP #6. As expected from the monitoring data review, the models do not produce early-storm percolation to the gravel storage layer that was observed in the monitoring data. The models also allow water to remain in both IMP layers for longer periods, which will make the Pittsburg site's model simulations overstate the site's sensitivity to back-to-back storms.

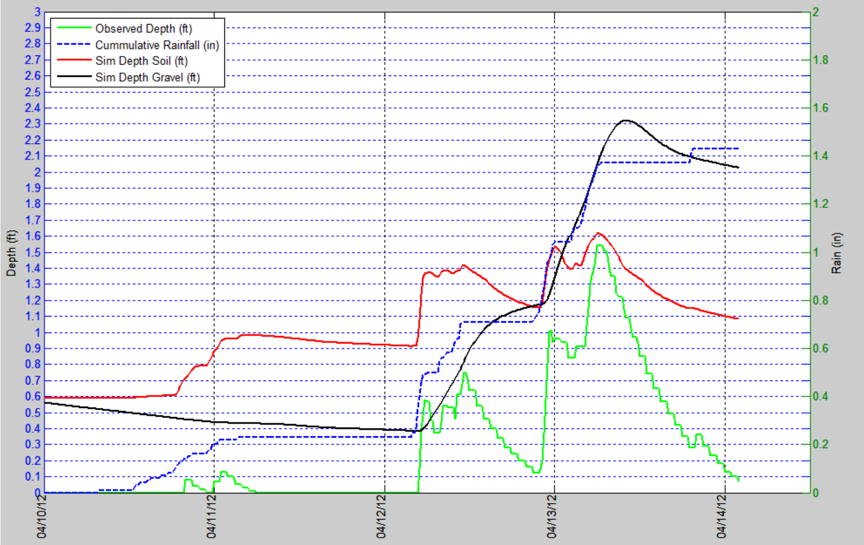


Figure 6-7. Model output and monitoring data comparison at IMP #2 from 4/10/12 to 4/14/12

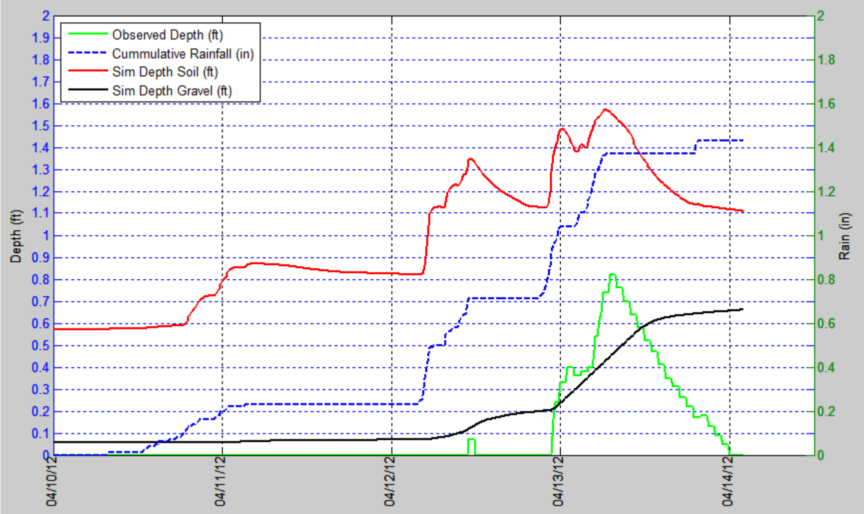


Figure 6-8. Model output and monitoring data comparison at IMP #6 from 4/10/12 to 4/14/12

The number of simulated and observed underdrain discharge events was also compared for IMP #2, IMP #4, and IMP #6. The

HSPF model predicts more frequent discharges through the underdrain pipe. Table 6-5 summarizes the model results.

Table 6-5. Pittsburg Fire Prevention Bureau Model Discharge Events

IMP	Number of Underdrain Discharge Events	Total Volume	Notes
IMP #2	6	2,700 ft3	Each event lasts several hours
IMP #4	0	0 ft3	
IMP #6	2	87 ft3	Each event lasts several hours

At the Walden Park Commons site, there were a limited number of storms with water level data, but flow rates were recorded through both monitoring seasons. Therefore the simulated and observed outflow volumes were compared for the 13 largest rainfall events during the monitoring period. Figure 6-9 and Figure 6-10 show example results for two separate storm events for IMP #1 (North), which is located in the northwest corner of the Walden Park Commons development. Similar to the initial Fire Prevention Bureau comparison, the monitoring data shows a faster percolation response in the IMP. The model simulation produces higher outflow volumes than were measured.

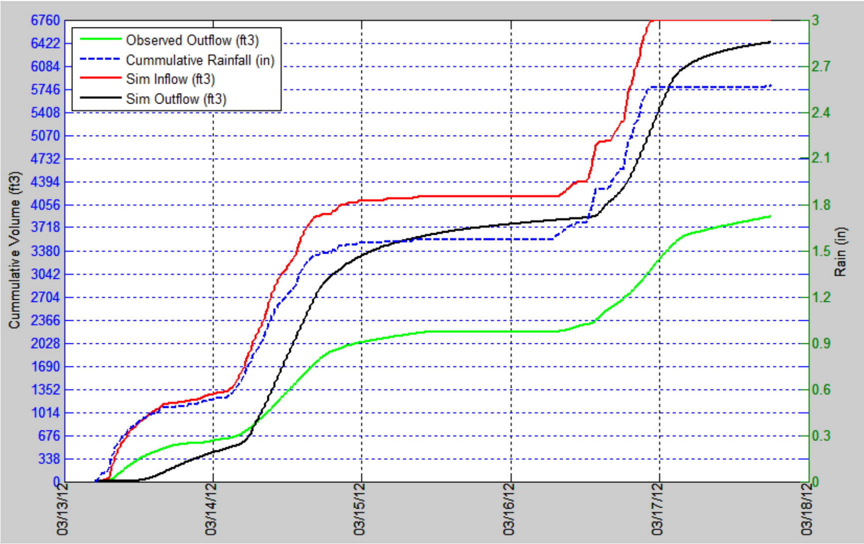


Figure 6-9. Model output and monitoring data comparison at Walden Park Commons IMP #1 (North) from 3/13/12 to 3/18/12

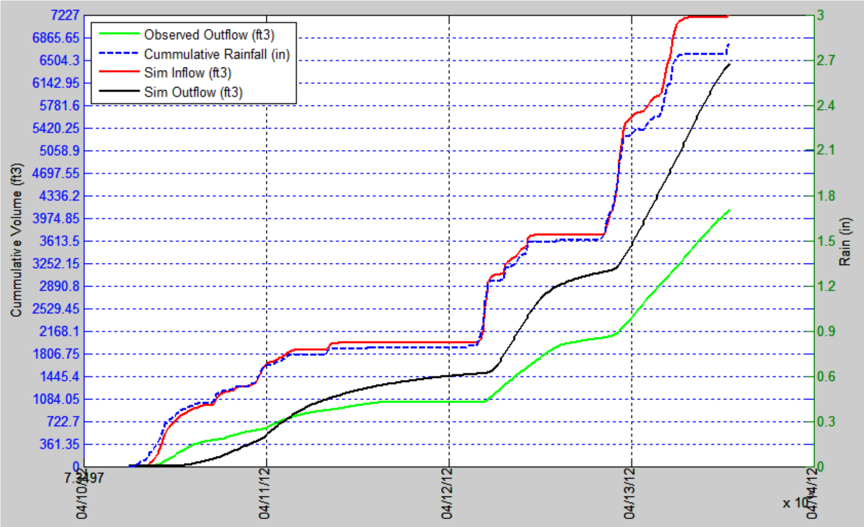


Figure 6-10. Model output and monitoring data comparison at Walden Park Commons IMP #1 (North) from 4/10/12 to 4/14/12

Figure 6-11 and Figure 6-12 compare the simulated and measured cumulative outflow volume for Walden Park Commons IMP #2 (South) for March and April 2012 storm events. The results of the comparison are similar to results for IMP #1 (North). The model simulation produces larger outflow volumes than were observed in the monitoring data.

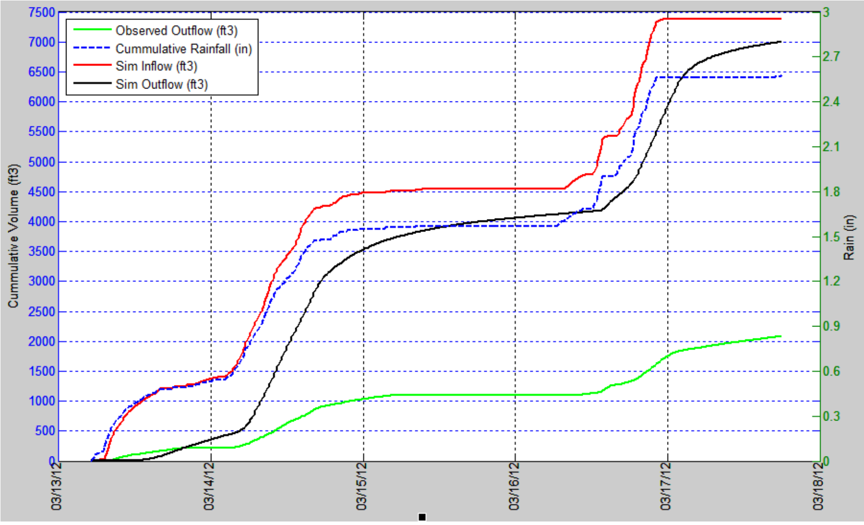


Figure 6-11. Model output and monitoring data comparison at Walden Park Commons IMP #2 (South) from 3/13/12 to 3/18/12

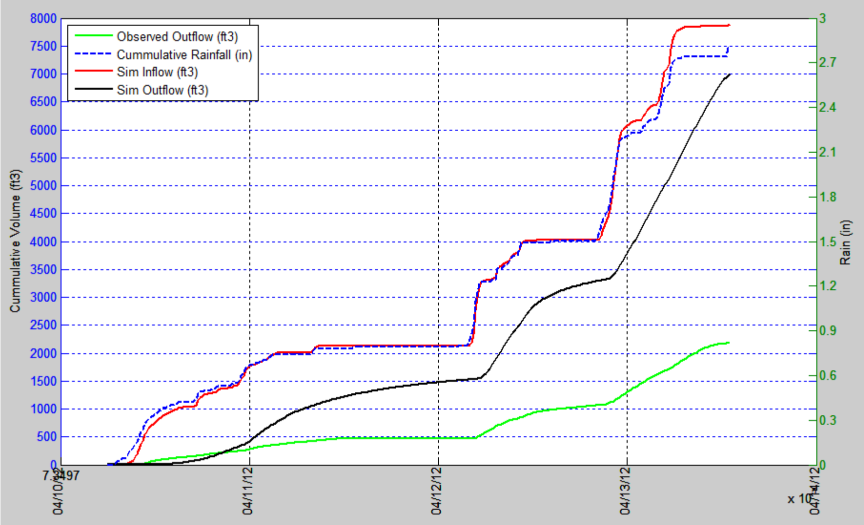


Figure 6-12. Model output and monitoring data comparison at Walden Park Commons IMP #2 (South) from 4/10/12 to 4/14/12

6.2 Adjustment of Model Parameter Values

To reduce the simulated IMP outflow and better match the monitoring data, the infiltration characteristics of each IMP were adjusted. The initial effort focused on the following revisions to Walden Park Commons IMP #1 (North):

1. The relationship between soil moisture and percolation in the bioretention soil was modified to allow percolation to begin soon after water enters the soil. The previous version of the HPSF model held back most percolation until the moisture content reached about 80 percent of saturation.
2. A zone of influence was established around the bioretention layer's underdrain. Because the monitored outflow was significantly less than the estimated inflow to the IMP, we assumed a portion of the stormwater entering the bioretention portion of IMP #1 (North) was infiltrating to surrounding soils. Similar losses to infiltration were evident in the data for IMP #2 (South).

The zone of influence value was iteratively modified until the IMP outflow volume better matched the monitoring data across a range of storm events. Figure 6-13 and Figure 6-14 show the updated results for the same two storm events included in the previous section (see Figures 6-9 and 6-10). For the zone of influence value selected, the simulated outflow volume closely matches the monitored outflow volume. For this value, 60 percent of the bioretention area drains to the underdrain and storage pipe, and the remainder infiltrates runoff to the underlying soils.

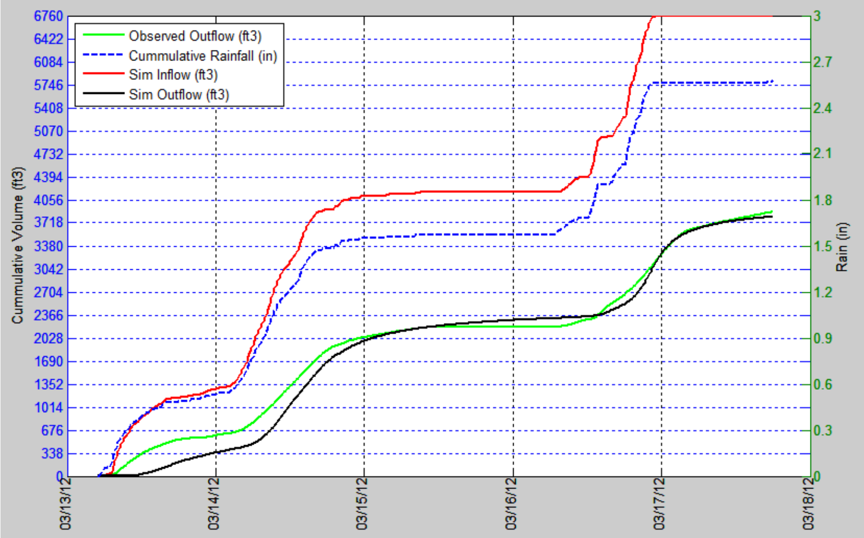


Figure 6-13. Updated model output and monitoring data comparison at Walden Park Commons IMP #1 (North) from 3/13/12 to 3/18/12

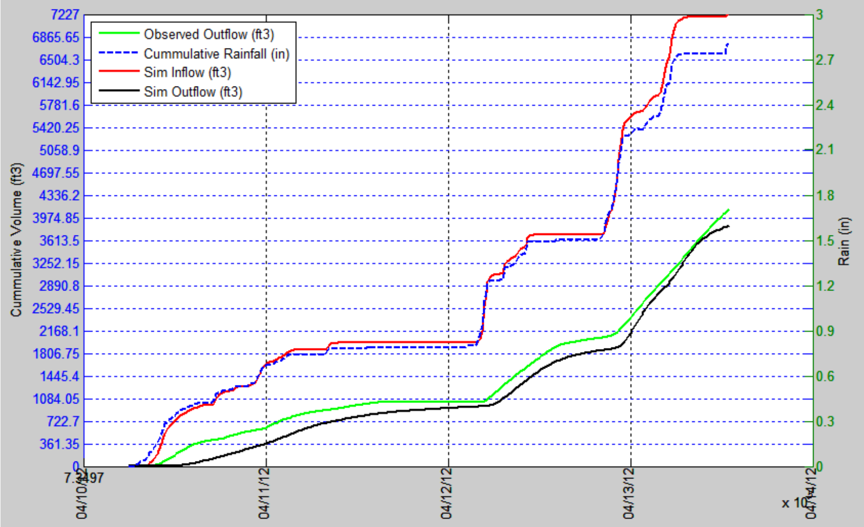


Figure 6-14. Updated model output and monitoring data comparison at Walden Park Commons IMP #1 (North) from 4/10/12 to 4/14/12

The model was also calibrated to match the response of IMP #6 at the Fire Prevention Bureau. The IMP model parameters were adjusted to a) represent the capacity of the bioretention soils to hold water prior to start of percolation, b) mimic the rapid percolation that occurs once the soil moisture threshold is met, and c) approximate the rate at which water drops in the gravel layer by adjusting the infiltration rate to surrounding soils. This parameter also affects the simulated water level in the gravel layer during storm events.

Figure 6-15 shows an example of the calibrated model’s response for the November 28, 2012 storm event. This was the largest event during the monitoring period and represents about a 2-year storm for the Pittsburg area. During the initial stages of the storm the simulated water moisture content rapidly accumulates in the bioretention soil while very little water appears in the gravel layer. When the second phase of the storm occurs, percolation occurs rapidly and the gravel layer fills with more than 1 foot of water (note: the underdrain is located about 2½ feet above the bottom of the gravel layer). The simulated maximum depth matches the monitored maximum depth to within 1 inch. The simulated gravel water level recession is a little more rapid than the monitored recession. In general, the simulated and observed recession rates are similar across the range of storm events.

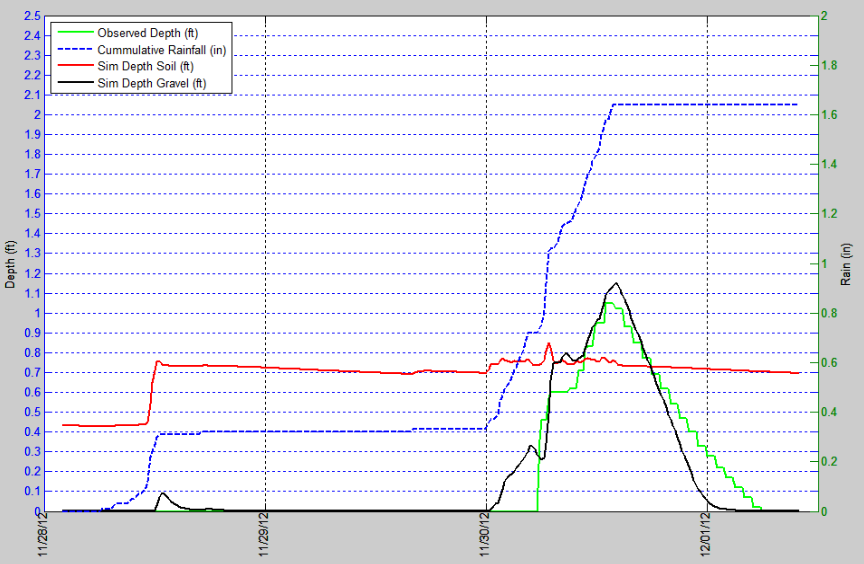


Figure 6-15. Updated model output and monitoring data comparison at Fire Prevention Bureau IMP #6 from 11/28/12 to 12/1/12

Figure 6-16 shows calibration results for a smaller storm event that occurred on March 25, 2012. This 0.65-inch event has about a 3-month (12-hour) recurrence interval. Similar to the larger event shown above, the initial rainfall is captured and held within the bioretention soils. Once the soil moisture threshold is met, stormwater percolates to the gravel layer. The simulated and monitored water levels match precisely and recession rates also agree very closely. There is an approximately one-hour offset between the simulated and monitored peak water levels, which will have no impact on the ability of the model to predict long-term IMP performance.

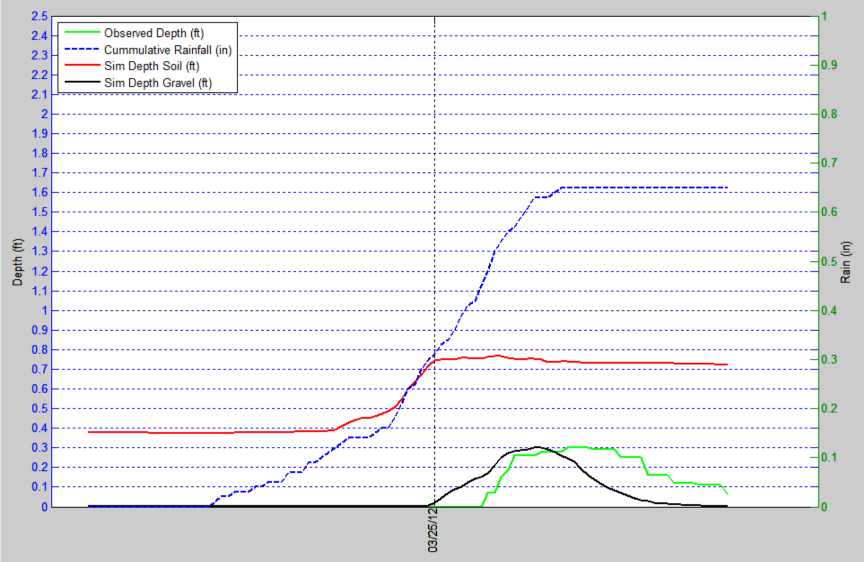


Figure 6-16. Updated model output and monitoring data comparison at Fire Prevention Bureau IMP #6 from 3/24/12 to 3/25/12

In conclusion, the bioretention characteristics were adjusted at the Walden Park Commons and Fire Prevention Bureau sites to achieve a closer agreement between the HSPF model predictions and the monitoring data. The infiltration rate to the surrounding soils was increased to 0.24 inches per hour for all the Fire Prevention Bureau IMPs.

The calibrated model adequately represents the key processing during and after storm events, specifically; a) the build-up of soil moisture, b) the percolation from bioretention soils to the storage layer and, c) the recovery of the IMP capacity through infiltration to surrounding soils (at the Fire Prevention Bureau). The calibrated model is suitable for the analysis of long-term IMP performance.

6.3 IMP Performance Compared to Flow Duration Standard

The IMP performance monitoring data review suggested the bioretention facilities at the Fire Prevention Bureau and the bioretention plus vault facilities at Walden Park Commons are likely to meet the NPDES permit requirements and may be performing in excess of these requirements by reducing flow durations below the pre-project flow durations for the specified range of flows (0.2Q2 to Q10).

Long-term HSPF simulations were run for the IMPs at both project sites to more fully test the IMP performance against the NPDES permit's flow control standard. The Fire Prevention Bureau simulations used hourly rainfall data collected at the Los Medanos gauge from 1972 through May 2013. The Walden Park Commons simulations used hourly data from the FCD 11 gauge in Martinez gauge from 1969 through May 2013. The following statistical analyses were then performed on the model outputs:

- Flow frequency statistics. The model outflow time series was divided into discrete flow events (i.e., a partial-duration series) using a 24-hour period of no flow to indicate the end of an event. The resulting table of events was sorted and ranked based on the peak flow rate. Each event was assigned a recurrence interval (sometimes referred to as a return period) using the Cunnane plotting position method. Partial duration series statistics were computed for the pre-project runoff and the post-project IMP outflows.
- Flow duration statistics. The model outflow time series was divided discrete bins (flow ranges). The number of hours – or duration – for which outflow occurred in each bin's flow range was then counted. These durations were computed for the pre-project runoff and the post-project IMP outflows.

Figure 6-17 shows the peak flow frequencies for the pre-project runoff and post-project (i.e., existing) outflow for Fire Prevention Bureau IMP #2.

Figure 6-18 compares flow durations for the pre-project and existing conditions. In both figures, the IMP outflows are below the pre-project flows between 0.2Q2 and Q10. Additionally, IMP #2 outflows are below the pre-project site flows down to the 0.1Q2 threshold. Because IMP #2 was constructed with dimensions that are very similar to the minimum required dimensions included in the HMP, this suggests IMP #2 would comply with a stricter lower control threshold of 0.1Q2. The infiltration rates at the Fire Prevention Bureau site allow for this level of performance.

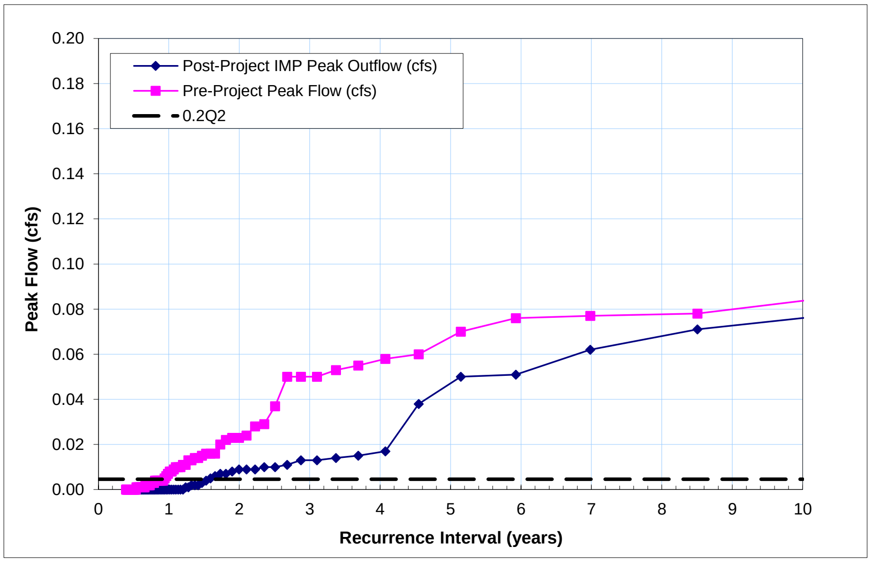


Figure 6-17. Peak flow frequency comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #2

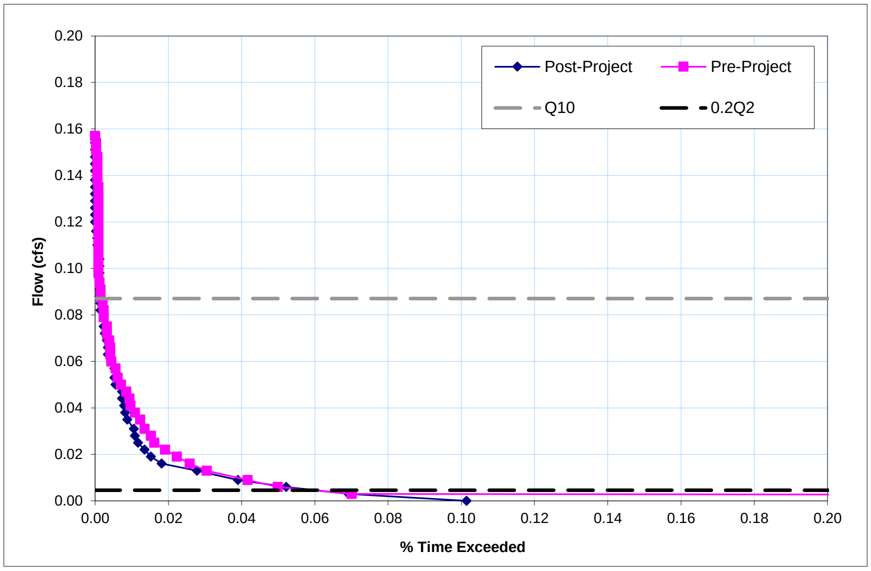


Figure 6-18. Flow duration comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #2

Figure 6-19 and Figure 6-20 compare peak flow frequencies and flow durations for Walden Park Commons IMP #1 (North), respectively. IMP #1 (North) reduces site runoff to levels below the pre-project conditions between 0.2Q2 and Q10. However, the model results indicate that IMP #1 (North) does not control flows down to the 0.1Q2 flow rate. To meet this standard, the flow control orifice diameter would need to be reduced and the storage volume potentially increased by a modest amount, and/or the storage volume would need to be allowed to infiltrate to subsurface soils—as in the *Guidebook* criteria for bioretention + vault facilities.

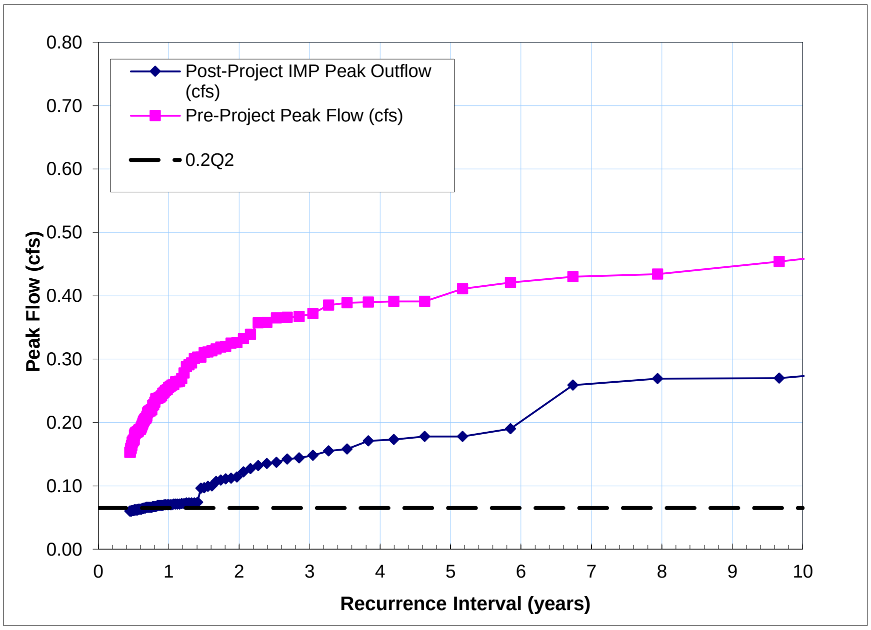


Figure 6-19. Peak flow frequency comparison for pre-project runoff and post-project outflows at IMP #1 (North)

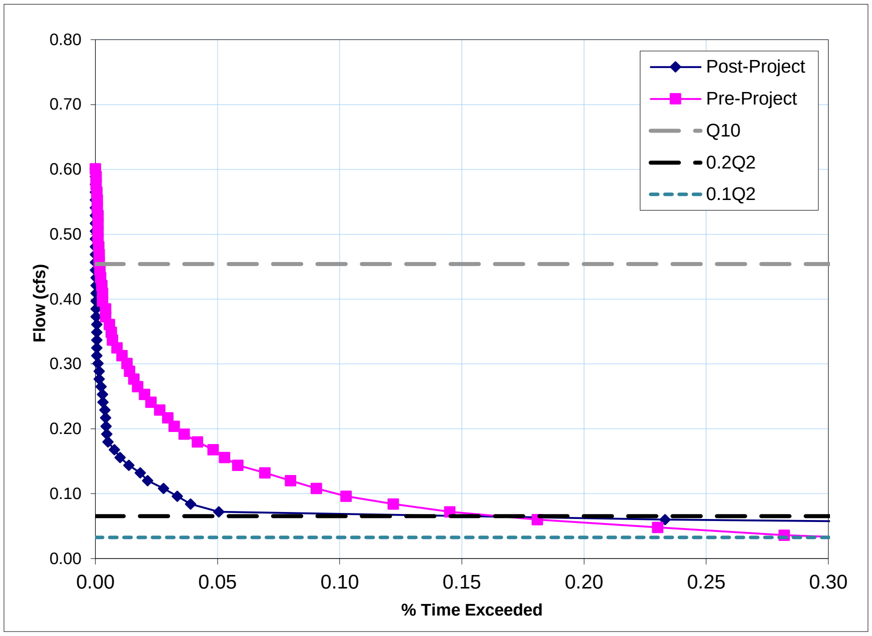


Figure 6-20. Flow duration comparison for pre-project runoff and post-project outflows IMP #1 (North)

All the IMPs successfully control outflows to their pre-project levels from 0.2Q2 to Q10. The Fire Prevention Bureau IMPs also control flows down to the 0.1Q2 threshold – benefitting from the infiltration capacity of site soil conditions. The Walden Park Commons do not control IMP outflows to the 0.1Q2 threshold, but the modeling results suggest this additional level of control could be achieved by a one or more of the following: modifying the orifice configuration, by allowing stored runoff to infiltrate to underlying soils, or by increasing the storage volume modestly.

7 · Discussion

7.1 Why These Results Are Important

The principal advantage of environmental modeling is the capability of modeling to extrapolate limited data sets to make predictions over an extended period and wide variety of conditions. However, because of limited data and the unpredictability of environmental conditions, a “garbage in, garbage out” scenario can occur, where model results are primarily a reflection of guesses and assumptions input to the model.

The 2004-2005 model used to determine CCCWP IMP sizing factors had the advantage of representing a relatively controlled system and the disadvantage of a paucity of available data representing bioretention system performance. That is, the model did, in concept, accurately represent the structure and function of bioretention facilities as they are actually built; however, there was a near-absence of data to inform the selection of values for the parameters that most strongly affect bioretention performance—most notably the rate at which treated runoff infiltrates to native soils.

Data collection for this project fills this gap, and greatly advances the CCCWP model. Previously the CCCWP model was dependent primarily on guessed and assumed values for the most important parameters; now it is based on empirically derived values. The CCCWP data may also be useful in updating similar models, such as the Bay Area Hydrology Model, that currently use guessed and assumed values for the model parameters that most strongly affect facility performance and HM compliance.

7.2 Percolation Through Bioretention Planting Media

As noted in Section 6, the model was set up with the assumption that the entire planting media layer would become mostly saturated before treated runoff proceeded to percolate into the underlying gravel layer. When modeled and measured results were compared, it was noted that runoff was measured in the gravel layer of the biorettention facilties (at the Pittsburg Fire Protection Bureau Building) and in the storage vaults (at Walden Park Commons) much more quickly than the model predicted.

This may be occurring either because runoff percolates rapidly downward near the inlet, and much of the planting media layer did not get wet, or because the soil media exhibits less moisture-holding capacity and matric head than the model predicted, or both.

7.3 Infiltration to Native Soils

The capability of a bioretention facility to control volumes and durations of discharge is dependent on, among other factors, the rate of infiltration to native clay soils. This study demonstrated that infiltration at the five test locations is approximately 10 times faster than estimated in the 2004-2005 CCCWP model.

The estimate in the 2004-2005 CCCWP model was drawn from guidance for the use of HSPF at the watershed scale. The values selected for continuous-simulation models are typically based on calibration of models of runoff at the watershed scale—that is, to data sets consisting of local rainfall data and stream gauge data. The stream gauges represent flows collected from watersheds ranging from tens of acres to hundreds of acres.

Importantly, the resulting calibrated model values for key parameters representing losses of surface runoff to infiltration (in HSPF, “INFILT” is such a key parameter) do not necessarily correspond to results of infiltrometer tests or other direct tests of soil permeability. In fact, surface runoff losses at the watershed scale and movement of water through the pores of saturated soil are somewhat different physical processes.

The data collected by this project provide rare (perhaps unique) infiltration rate data and represent actual bioretention performance, rather than using an estimate of performance extrapolated from watershed-scale model calibrations or soil testing. Although limited to three bioretention facilities around a single 1-acre site, the data show that silty clays can, at least in some circumstances, infiltrate at rates in excess of 0.2 inches per hour—as measured by the recovery of a bioretention subsurface reservoir—and that these higher-than-expected rates are consistent throughout the season, for a range of storm sizes, and from facility to facility.

7.4 Applicability of Results Region-wide

The five IMP monitored locations are representative of typical Bay Area development patterns and conditions.

As noted in Section 5, the two bioretention + vault facilities at Walden Park Commons were constructed with some exceptions to current *Guidebook* design recommendations; these exceptions were incorporated into the customized model for the purposes of model calibration. The three facilities at the Pittsburg Fire Prevention Bureau Building were built very close to current *Guidebook* design criteria and design recommendations.

As previously noted, the rate at which runoff infiltrates to soils beneath the facility is a key factor determining overall performance. Are the infiltration rates found at the Pittsburg site representative of development sites in Contra Costa, or in the Bay Area as a whole?

There are no observed characteristics that would suggest otherwise. The site soils, described as “stiff to hard, moderately to highly plastic silty clays” in the site geotechnical report (Kleinfelder 2004) are typical of development sites throughout the Bay Area. The site is quite flat. Only the lack of near-surface groundwater would tend to suggest this site’s soils could be better-draining than similarly classified soils at another Bay Area development site.

Collection of data from bioretention facilities at additional locations would be necessary to accurately estimate the average and variance of infiltration rates that might occur in similar soils.

8 · Conclusions and Recommendations

This project demonstrated that the IMPs and sizing factors approved by the Water Board in 2006—and updated in subsequent editions of the *Guidebook*—are adequate to meet current regulatory requirements.

8.1 Next Steps for Use of the Calibrated and Validated Model

MRP Attachment C requires:

> By April 1, 2014, the Contra Costa Clean Water Program shall submit a proposal containing one or a combination of the following three options (a.-c.) for implementation after the expiration and reissuance of this permit:
>
> a. Present model verification monitoring results demonstrating that the IMPs are sufficiently overdesigned and perform to meet the 0.1Q2 low flow design criteria; or
>
> b. Present study results of Contra Costa County streams geology and other factors that support the low flow design criteria of 0.2Q2 as the limiting HMP design low flow; or
>
> c. Propose redesigns of the IMPs to meet the low flow design criteria of 0.1Q2 to be implemented during the next permit term.

CCCWP intends to work with other Permittees (through BASMAA, the Bay Area Stormwater Management Agencies Association) and with Water Board staff to develop and agree upon revised HM permit requirements applicable to all MRP Permittees that:

- Favor, rather than constrain, the implementation of LID to meet HM requirements
- Consider a potential range of low flow thresholds for streams, with the aim of revising the thresholds to provide for reasonable protection of beneficial uses
- Have a more technically defensible basis for translation of in-stream criteria to LID facility discharge criteria; this basis should include consideration of the potential future

extent of watershed development and the proportion of the watershed that the proposed development represents

- Take into account that IMPs tend to reduce flow durations to below pre-project levels for flows in the middle of the range (the most geomorphically significant range, between 0.2Q2 and Q2)
- Consider the extent of potential Bay Area development that may be subject to HM requirements vs. the effort expended so far, and that may be expended in the future, on developing and implementing HM regulations
- Apply exceptions, exclusions, and thresholds uniformly among MRP Permittees
- Incorporate design requirements and sizing factors that reflect the results of this study

8.2 Insights Concerning Bioretention Design and Construction

The CCCWP project team worked with City of Pittsburg and City of Walnut Creek staff and with the engineers and construction project managers for each of the two developments. Overall cooperation was excellent and contributed greatly to the success of the CCCWP project.

The following insights are the author's but resulted from the work of all involved.

8.2.1 Bioretention Design

To maximize the volume of runoff infiltrated, the facility must be configured so that each layer "fills up like a bathtub." The top of gravel layer should be at a consistent elevation so that all pore areas within the gravel layer are filled evenly; likewise for the soil layer and for the surface reservoir. The surface reservoir should be surrounded by concrete curbs or landscape timbers to maximize its volume (as compared to sloping sides toward the center of the facility) and to facilitate verification that the reservoir is level and will fill evenly.

The project design should be reviewed prior to construction to ensure the stability of roads, walkways, and structures adjacent to bioretention facilities has been adequately considered. Because bioretention soils cannot be compacted, bioretention walls must effectively resist lateral pressure from surrounding soils. Where necessary, bioretention walls can be made impervious as a precautionary measure to protect adjacent roads, walkways, and structures while leaving the bottom of the bioretention facility open for infiltration.

Overflow structures are best constructed from precast manholes or catch basins. Construction crews have experience setting these structures at a precise elevation. Use of an adequately sized catch basin with a grate makes it possible to verify underdrain discharge visually and to access the underdrain pipe for cleaning or maintenance. Setting the underdrain discharge elevation at the top of the gravel layer may reduce the required depth of the overflow structure.

Overflow structures can also accommodate connections to site storm drainage pipes routed through the bioretention facilities.

Orifices on underdrains may be constructed of solid PVC pipe extending a few inches into the overflow catch basin structure, threaded, and equipped with a cap. The orifice is drilled into the cap as shown in Figure 4-4.

8.2.2 Bioretention Construction

It is necessary to have an engineer familiar with the structure, function, and details of bioretention to review construction at each stage (layout, excavation, installation of underdrains and overflows, installation of gravel and soil mix, irrigation systems, and planting). In particular, elevations should be checked and it should be ensured that the soils at the bottom of the excavation are ripped.

8.3 Recommendations for Instrumentation

Success in data collection was largely attributable to the participation of an experienced instrumentation technician (Scott McQuarrie, of the Contra Costa Flood Control and Water Conservation District). Installation of rain gauges, tipping buckets, magnetic flow meters, piezometers, dataloggers, and telemetry required considerable technical ingenuity and experience to configure at each site.

For future projects monitoring the hydrologic performance of bioretention facilities, including bioretention + vault facilities, it would be possible to rely on level sensors (piezometers) rather than flow sensors or tipping buckets. Piezometers are more reliable to operate and also provide information on saturation levels. Orifice factors and/or rating curves for each fabricated orifice could be determined prior to installation. This could be done by plumbing the fabricated orifices to a small tank or reservoir and timing the falling head. Once installed, the discharge rate through the orifice, for each time interval, could be calculated from the corresponding piezometer reading.

8.4 Further Research

As noted above, it would be meaningful to obtain data from bioretention facilities installed in clay soils at additional sites. An additional 3-8 sites could be sufficient to demonstrate the regional applicability of the results found here.

This study showed the value of obtaining time-series for (1) rainfall and (2) saturation depth of the subsurface storage (gravel layer). It is recommended to select, where possible, facilities located on public development projects, as it is easier to coordinate documentation of design and construction of bioretention facilities on these projects.

As noted above, the monitoring effort could be reduced by installing only rain gauges at each site and only piezometers in each facility. As a rough estimate, instrumentation could be installed at an equipment cost of $7,000 and about 12 hours of technical labor for each facility. This does not include the cost of maintaining the instrumentation and downloading the data.

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APPENDIX A
IMP Modeling Analysis and Results

This appendix supplements the modeling and data analysis results included in Section 6 of the HMP Model Calibration and Verification report. This appendix includes a detailed description of the project site model development, rainfall analysis, model calibration and long-term simulation results.

Section 1: Project Site HPSF Model Development

HSPF models were constructed for the Fire Prevention Bureau site in Pittsburg and the Walden Park Commons site in Walnut Creek. The models were adapted from the HPSF models that were developed for the HMP by including the drainage management area characteristics, IMP configurations of each site, and time series input data for each site.

The following site-specific modifications were made:

1. Setting up subcatchment areas within HSPF to represent the project site area
2. Modifying the bioretention IMP setup to represent the actual configurations of the IMPs – the constructed areas and volumes instead of the volumes required by the HMP.
3. Incorporating local time series data, including project site rainfall data in 15-minute increments.
4. Changing the model time step from 1 hour to 15 minutes. This also necessitated changing several conversion factors within HSPF – particularly for quantities that are calculated in HPSF as volumes or depths per time step (rather than per second or per hour).

Following these modifications, various QA/QC checks (e.g., comparing IMP inflow to rainfall volumes, comparing IMP layer 1 outflow and layer 2 inflow volumes) were performed to validate the model response.

1.1 Drainage Management Areas

The HPSF model's Drainage Management Area (DMA) characteristics were derived from drainage planning information provided by the Clean Water Program. For the Fire Prevention Bureau site, the Stormwater Treatment Plan (drawing sheet C-6, dated September 2009) included the drainage areas, soil types and other information needed for the model. For the Walden Park Commons site, the C.3 Plan – Stormwater Treatment Control Plan (drawing sheet C-1, dated July 2008) were used to characterize the DMAs. Table 1 lists the Fire Prevention Bureau DMA characteristics and Table 2 lists the Walden Park Commons DMA characteristics.

Table 1. Pittsburg Fire Prevention Bureau Site DMA Characteristics[A]

DMA	Impervious Area		Pervious Area		Total Area	
	ft2	acres	ft2	acres	ft2	acres
DMA 2 (trib. to IMP 2)	12,059	0.2768	2,415	0.0554	14,474	0.3323
DMA 4 (trib. to IMP 4)	627	0.0144	0	0.0000	627	0.0144
DMA 6 (trib. to IMP 6)	3,152	0.0724	562	0.0129	3,714	0.0853

A. All pervious areas were simulated as NRCS Group D soil (PERLND 102)

Table 2. Walden Park Commons Site DMA Characteristics[A]

DMA	Impervious Area		Pervious Area		Total Area	
	ft2	acres	ft2	acres	ft2	acres
Tributary to IMP #1 (North)						
M	11,606	0.2664	2,153	0.0494	13,759	0.3159
N	21,695	0.4980	3,795	0.0871	25,490	0.5852
Total IMP #1 (North)	33,301	0.7645	5,948	0.1365	39,249	0.9010
Tributary to IMP #2 (South)						
D	7,780	0.1786	1,381	0.0317	9,161	0.2103
E	7,574	0.1739	1,252	0.0287	8,826	0.2026
J	5,382	0.1236	2,120	0.0487	7,502	0.1722
K	8,996	0.2065	1,658	0.0381	10,654	0.2446
L	3,198	0.0734	575	0.0132	3,773	0.0866
P	3,597	0.0826	509	0.0117	4,106	0.0943
Total IMP #2 (South)	36,527	0.8385	7,495	0.1721	44,022	1.0106

A. All pervious areas were simulated as NRCS Group D soil (PERLND 102)

1.2 IMP Characteristics

The DMA source data also contained information about the site IMPs. For the Walden Park Commons site, the *SWQ and Hydrology Study for Subdivision 9147* drainage report, dated October 2010, was also reviewed to obtain the total volume included in the storage pipes. Table 3 lists the Fire Prevention Bureau IMP dimensions and Table 4 lists the Walden Park Commons IMP dimensions.

At the Fire Prevention Bureau site, the IMPs were generally constructed with dimensions that were close to the requirements of the HMP. For example, the A (area) and V2 (gravel volume) components are IMP #2 are close to the IMP requirements while the V1 (ponding layer) component was larger than required. IMP #4 and IMP #6 were constructed with larger plan areas (A) but the volume ponding layer volume and gravel volume were close to the amount required by the HMP. The underdrain piping for the Fire Prevention Bureau IMPs were located near the top of the gravel layer to provide an opportunity for more of the treated water to infiltrate to the surrounding soils.

Table 3. Pittsburg Fire Prevention Bureau Site IMP Dimensions

IMP	Required Areas, Volumes			Constructed Areas, Volumes			Constructed Depths			Orifice Diameter (in)
	A (ft2)	V1 (ft3)	V2 (ft3)	A (ft2)	V1 (ft3)	V2 (ft3)	Ponding (in)	Soil (in)	Gravel (in)	
IMP #2	873	734	960	886	886	975	12	18	33	0.81
IMP #4	40	34	44	82.5	41	41	6	18	15	0.17
IMP #6	225	189	247	340	170	215	6	18	19	0.41

The Walden Park Commons bioretention plus vault IMPs were constructed with storage volume (V) components that approximated the HMP requirements. IMP #2 (South) was constructed with a bioretention area that is approximately 20 percent larger than required by the HMP.

Table 4. Walden Park Commons Site IMP Dimensions

IMP	Bioretention Area (ft2)	Storage Volume (ft3)	Orifice Diameter (in)
IMP #1 (North)	1,500	2,419	1.24
IMP #2 (South)	1,917	2,698	1.31

1.3 Time Series Data

Time series data were used to provide rainfall and evapotranspiration inputs to the HSPF model. Table 5 lists the time series datasets used and the periods covered by these datasets.

Table 5. HPSF Model Time Series Datasets

Dataset	Type	Source	Period	Usage
Fire Prevention Bureau Rainfall	Rainfall tipping bucket processed in 15-min increments	Contra Costa Flood Control District	Oct-2011 to May-2013	IMP hydraulic review and model calibration
Walden Park Commons Rainfall	Rainfall tipping bucket processed in 15-min increments	Contra Costa Flood Control District	Nov-2011 to May-2013	IMP hydraulic review and model calibration
Los Medanos Rainfall	Long-term rainfall in hourly increments	Contra Costa Flood Control District	Jul-1974 to Aug-2013	Long-term model simulations for Fire Prevention Bureau site
FCD11 Rainfall in Martinez	Long-term rainfall in hourly increments	Contra Costa Flood Control District	Feb-1969 to Aug-2013	Long-term model simulations for Walden Park Commons site
Brentwood Evaporation	Long-term ET data in hourly increments	CIMIS	Jan-1986 to Aug-2013	Model calibration and long-term simulations (with Los Alamitos ET data)
Los Alamitos Evaporation	Long-term ET data in hourly increments	EPA Basins software	Jul-1948 to Dec-1985	Long-term simulations combined with Brentwood. Provided pre-1986 ET data.

1.4 Model Time Step Adjustment

The HSPF models were adapted to run in either 15-minute or hourly time steps. The shorter time step provided better resolution of the IMP hydraulic processes during the model calibration process whereas hourly time steps were needed for the long-term simulations to match the available input time series data sources. Several hydrologic variables are computed by HSPF in time-dependent units (e.g., inches per time step), so conversion factors were needed to allow the model to run with different time steps. These conversions are documented within the HPSF input files (i.e., the UCI files) and listed in Table 6.

Table 6. HSPF Model Time Step Adjustments and Conversion Factors

HSPF Block	Description	Conversion Factor Revision
NETWORK	Outflow from upper layer of IMP (HYDR) is computed in cfs whereas input to lower layer (IVOL) is computed in acre-feet per time step	For 15-minute time steps: CONVERSION = [1 FT3/S] * [1/43560 AC/FT2] * [900 S/TS] CONVERSION = 0.0207 For 1-hour time steps: CONVERSION = [1 FT3/S] * [1/43560 AC/FT2] * [3600 S/TS] CONVERSION = 0.0826
NETWORK	IMP inflows (IVOL) are computed in units of acre-foot per time step and these data are converted to cfs for reporting via the PLTGEN file	For 15-minute time steps: CONVERSION = [43560 FT3/AC-FT] * [1/900 TS/S] CONVERSION = 48.4 For 1-hour time steps: CONVERSION = [43560 FT3/AC-FT] * [1/3600 TS/S] CONVERSION = 12.1
NETWORK	Pre-project site runoff rates (PWATER SURO) are computed in units of inches per time step. These data are converted to cfs for reporting via the PLTGEN file	For 15-minute time steps: CONVERSION = [43560 FT2/AC] * [1/12 FT/IN] * [1/900 TS/S] * [AREA in AC] CONVERSION = 4.0333 * [AREA in AC] For 1-hour time steps: CONVERSION = [43560 FT2/AC] * [1/12 FT/IN] * [1/3600 TS/S] * [AREA in AC] CONVERSION = 1.0083 * [AREA in AC]

After the conversions were applied, the model outputs were tested through a QA/QC process to validate the results.

Section 2: Rainfall Characteristics

This section supplements the description included in Section 6.1.1 of the HMP Model Calibration and Verification report, specifically the estimate of recurrence intervals for the storms that were recorded during the monitoring period.

To understand the monitored storm events within the context of long-term local rainfall characteristics, depth-duration-frequency curves were developed from the long-term hourly datasets recorded at the Los Medanos gauge and the FCD11-Martinez gauge. The following method was used to develop the curves:

5. The rainfall data was parsed into discrete storm events. A dry period of 24-hours was used to separate rainfall into distinct, independent events. The resulting set of storm events is called as a partial-duration series.
6. Each rainfall event was examined to determine the maximum amount of rain that occurred within specific periods of the storm (e.g., the maximum 3-hour accumulation, 6-hour accumulation) from durations of 1-hour to 72-hours.
7. The accumulations for each duration were ranked and assigned a recurrence interval using the Cunnane plotting position method (e.g., all 12-hour accumulations were ranked, all 24-hour accumulations were ranked).
8. A logarithmic regression relationship was developed to relate rainfall depth to recurrence interval for each storm duration from 1-hour to 72-hour. The regression equations were then used to compute curves shown in Figure 1 and Figure 2. The plots only include the computed durations up to 24-hours.

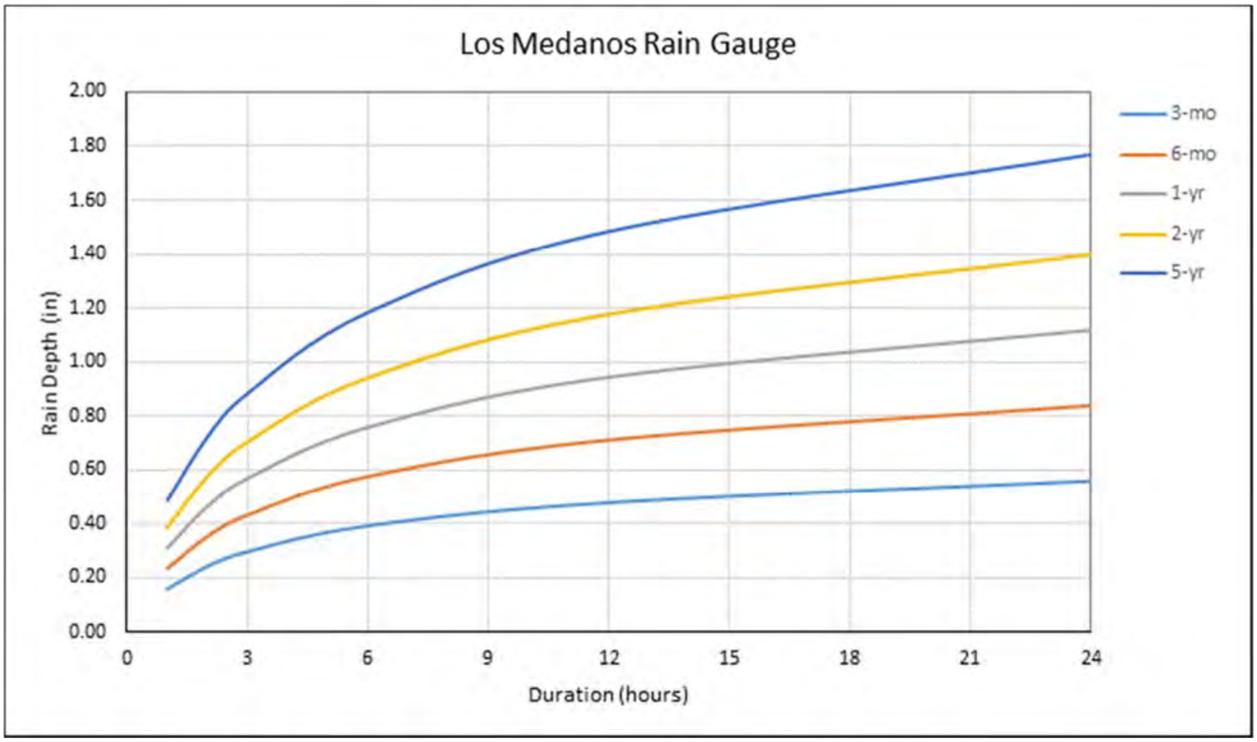

Figure 1. Depth-Duration Frequency curve for Los Medanos rain gauge. Curve was used to estimate the recurrence interval for storms monitored at the Fire Prevention Bureau site.

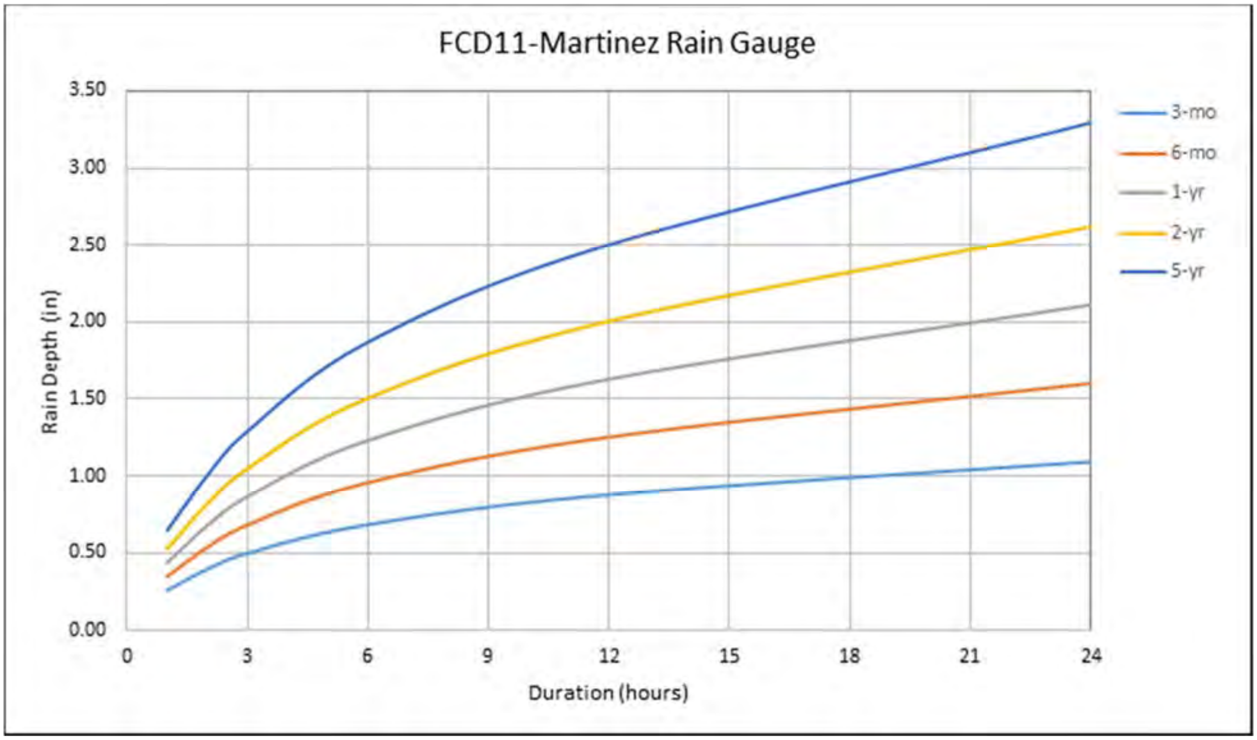

Figure 2. Depth-Duration Frequency curve for FCD11-Martinez rain gauge. Curve was used to estimate the recurrence interval for storms monitored at the Walden Park Commons site.

After the depth-duration-frequency curves were computed from the long-term rainfall datasets, similar partial-duration series rainfall accumulations were computed for the Fire Prevention Bureau and Walden Park Commons rain gauge data. The rainfall depth was computed for each significant storm for durations ranging from 1 hour to 72 hours. The accumulations were then compared to the long-term curves (either Figure 1 or Figure 2) to determine the recurrence interval for the monitored data.

Table 7 and Figure 3 provide an example of how the monitoring period storm recurrence intervals were estimated. The 11/28/2012 storm data provided a total of 1.64 inches of rain at the Fire Prevention Bureau gauge and Table 7 lists the maximum rainfall accumulation for specific periods within the storm event. These data are plotted over the long-term Los Medanos depth-duration-frequency curve in Figure 3 to provide context. The 11/28/2012 storm was approximately a 6-month to 1-year event for durations less than 6 hours. The 12-hour and 24-hour accumulations were approximately equal to a 2-year storm event.

Table 7. Rainfall Accumulations the 11/28/2012 Storm at the Fire Prevention Bureau

Duration (hour)	Rainfall (in)
1	0.31
2	0.38
3	0.44
6	0.69
12	1.20
24	1.32
48	1.33
72	1.64

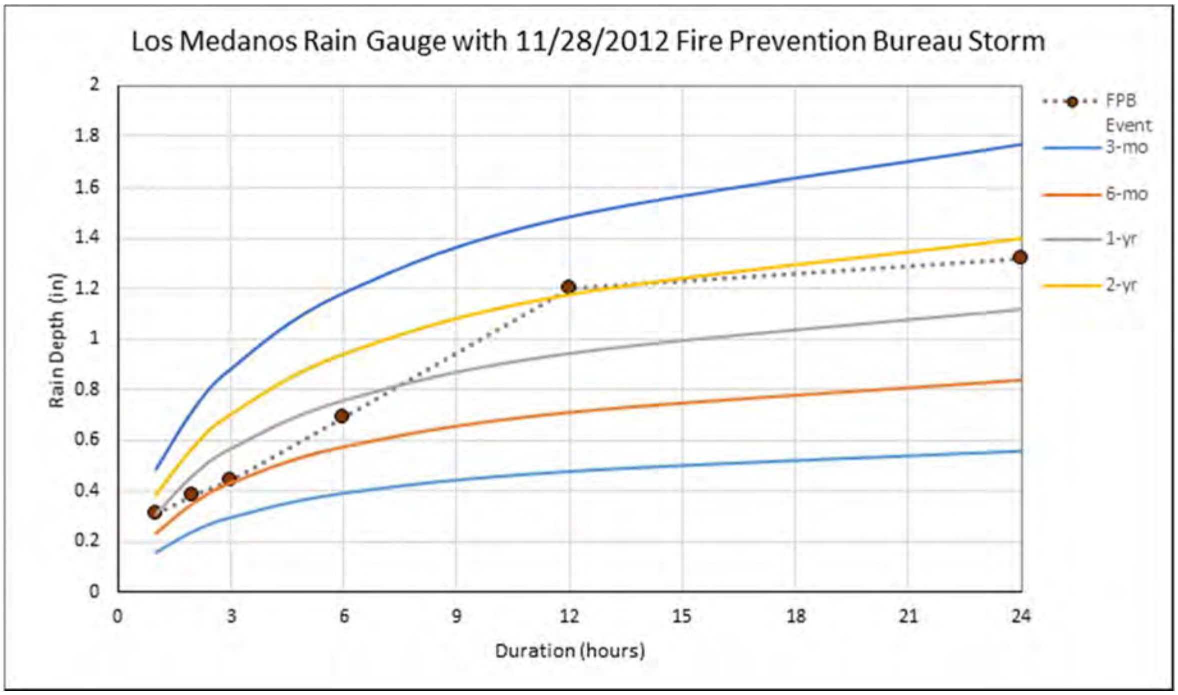

Figure 3. The 11/28/2012 storm event at the Fire Prevention Bureau was approximately a 2-year storm over a 12-hour duration.

Rainfall accumulations were compared to the depth-duration-frequency curves for all of the significant storm events listed in Table 6-2 and Table 6-3. The approximate recurrence interval was reported for 12-hour durations. This duration was selected because it balances both the short-term intensities and long-term accumulations that can affect IMP performance.

Section 3: HSPF Modeling Results

This section supplements the discussion included in Section 6.2 and 6.3 of the HMP Model Calibration and Verification report. It describes he model calibration process in greater detail and provides long-term simulation results for all IMPs.

3.1 Model Parameter Adjustments

This section describes how the model parameters were adjusted and provides additional example calibration results.

3.1.1 Bioretention Soil Characteristics

As described in Section 6.1.3, Fire Prevent Bureau bioretention soils produces faster percolation rates earlier and respond earlier in storm events than was predicted by the HPSF model used to develop the HMP. Additionally, the Fire Prevention Bureau IMPs produced significantly more infiltration to surrounding soils than the HPSF model predicted. The model calibration effort focused on these two key differences.

Rainfall and water level monitoring data and modeling results were examined to approximate a) what level of soil moisture is needed to initiative percolation from the bioretention soil to the gravel layer and b) at what rate does the percolation occur. The bioretention soils appear to produce little percolation until the soils reach about 50 percent of saturation. At this point, percolation occurs rapidly. While the precise rate was difficult to isolate, the monitoring data suggested percolation rates of up to 7.5 inches per hour could occur.

The HSPF model's representation of the bioretention soils was iteratively modified based on the percolation response of Fire Prevention Bureau IMP #6 for different storm events. The adjustments focused on a) allowing the bioretention soils to hold almost all runoff during small storm events and b) percolating the appropriate volume of stormwater to the gravel layer during large storm events.

Figure 4 illustrates how the percolation characteristics were adjusted by showing the soil moisture-percolation relationship used in the HMP models and the modified relationship that was developed by examining the Fire Prevention Bureau monitoring data. The calibrated relationship allows water to move rapidly into the gravel layer when the bioretention soils fill with water and provides the appropriate level of soil drying between storm events.

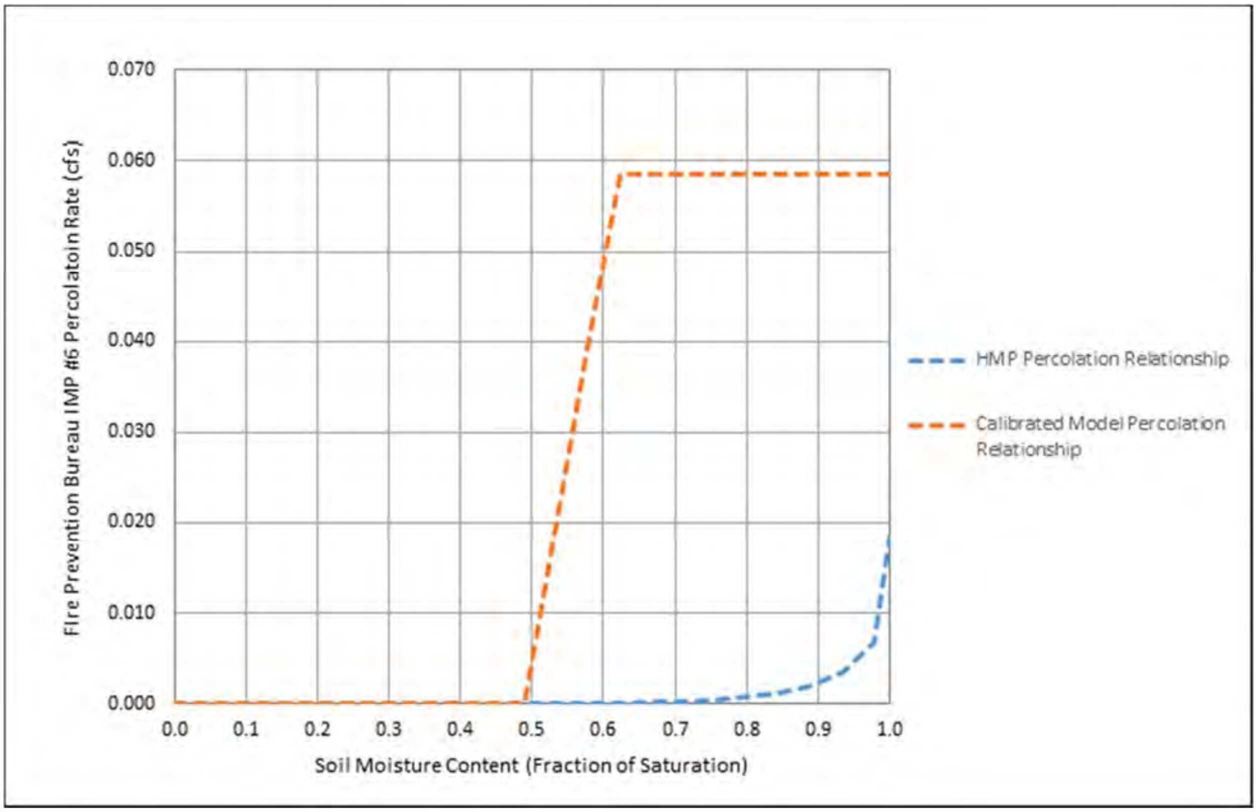

Figure 4. Soil moisture-percolation relationship for bioretention soils at the Fire Prevention Bureau

3.1.2 Infiltration to Surrounding Soils

The observed water level recession rates indicate that the NRCS Group D soils at the Fire Prevention Bureau allow for a greater level of infiltration than was expected when preparing the HMP. The HSPF model's rate of infiltration from the IMP gravel layer to the surrounding soils was adjusted iteratively until the shape of the water level curve approximated the level monitoring data across the largest storm events.

Several gravel layer-to-surrounding soils infiltration rates were tested and the best-fit rate for Fire Prevention Bureau IMP #6 was 0.24 inches per hour. Figure 5, Figure 6 and Figure 7 show the model results for the 11/28/2012 storm event with infiltration rates of 0.20 in/hr, 0.24 in/hr and 0.28 in/hr, respectively. The closest match occurs with the 0.24 in/hr simulation.

The IMP #6 calibration was then applied to the other Fire Prevention Bureau IMPs. The simulation results and monitoring data were compared for IMP #2 and the model results provided a good approximation of the monitoring data. A similar comparison was not practical at IMP #4 due to its small dimensions at IMP #4 and lack of a defined gravel layer response to rainfall.

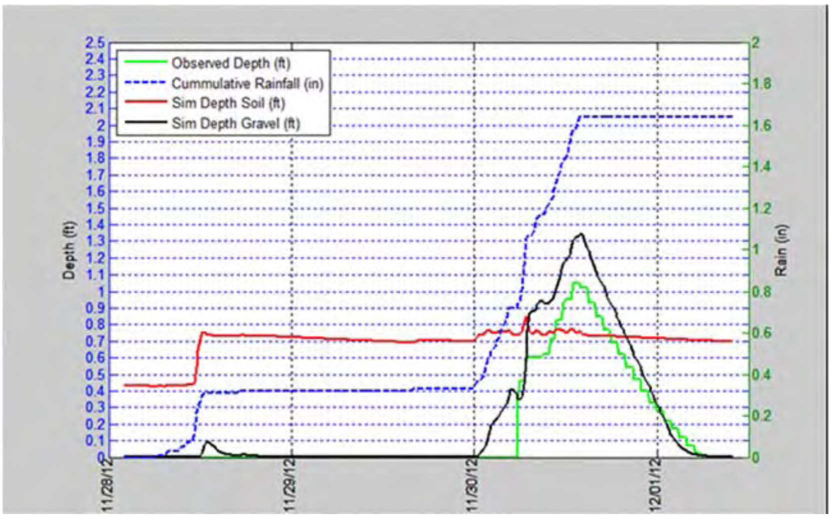

Figure 5. IMP #6 infiltration = 0.20 in/hr. Simulation > monitoring data

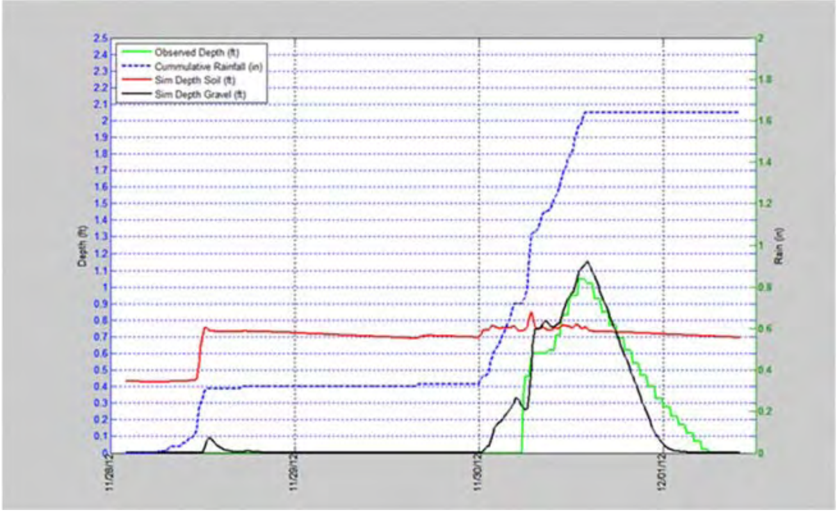

Figure 6. IMP #6 infiltration = 0.24 in/hr. Simulation ~ monitoring data

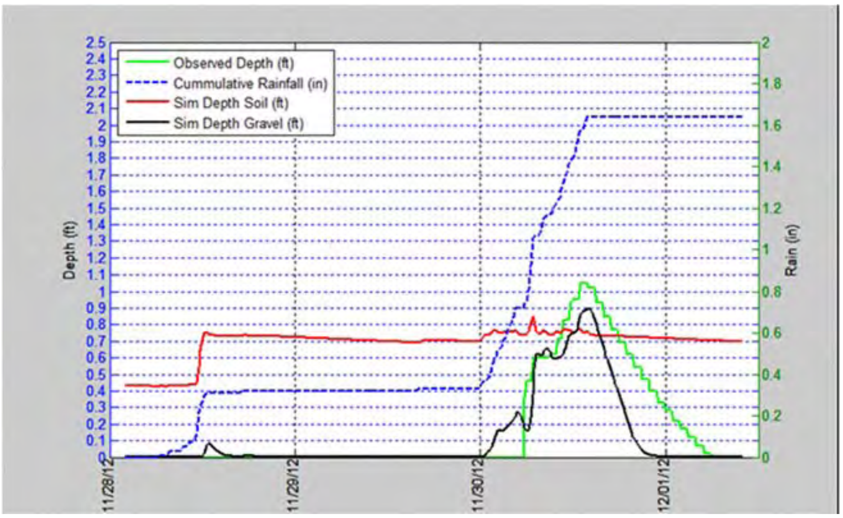

Figure 7. IMP #6 infiltration = 0.28 in/hr. Simulation < monitoring data

3.2 Long-Term Model Performance

This section describes the process for setting up the long-term model simulations and using the results to assess the performance of the Fire Prevention Bureau and Walden Park Commons IMPs in comparison to the HMP's peak flow and flow duration control standard.

3.2.1 Long-Term Simulation Setup

The calibrated models for the Fire Prevention Bureau IMPs and Walden Park Commons IMPs (see Section 6.3 for these examples) were used to prepare long-term simulations. The following steps were needed to prepare the long-term simulation models:

1. The FTABLE representations of the calibrated IMPs were copied into the HSPF long-term simulation input file.
2. The HSPF input file was linked to the long-term time series datasets described above in Table 5. The Fire Prevention Bureau simulations used hourly rainfall data collected at the Los Medanos gauge from 1974 through May 2013. The Walden Park Commons simulations used hourly data from the FCD11 gauge in Martinez from 1969 through May 2013. The evaporation time series dataset was composed of Los Alamitos data (pre-1985) and Brentwood data (1986 and later).
3. The HSPF input file unit conversions were applied as needed for the long-term simulations hourly time steps (see Table 6 for details).
4. The list of variables included model's time series output file (i.e., the PLTGEN file) were modified to allow for a comparison of pre-project and post-project conditions.

3.2.2 Long-Term Simulation Results

The long-term simulation outputs were evaluated using flow frequency statistics and flow duration statistics (see Section 6.3). Next, the IMP outflows were compared to pre-project flows to determine of the IMPs reduced peak flows and flow durations below pre-project levels. This section includes peak flow and flow duration graphics for all of the IMPs. Figure 8 through Figure 13 show results for the Fire Prevention Bureau site and Figure 14 through Figure 17 show results for the Walden Park Commons sites. All IMPs control flows to down to the current 0.2Q2 lower control threshold. Additionally, the Fire Prevention Bureau sites control flows down to the 0.1Q2 lower control threshold. The Walden Park Commons sites do not meet the stricter lower control threshold.

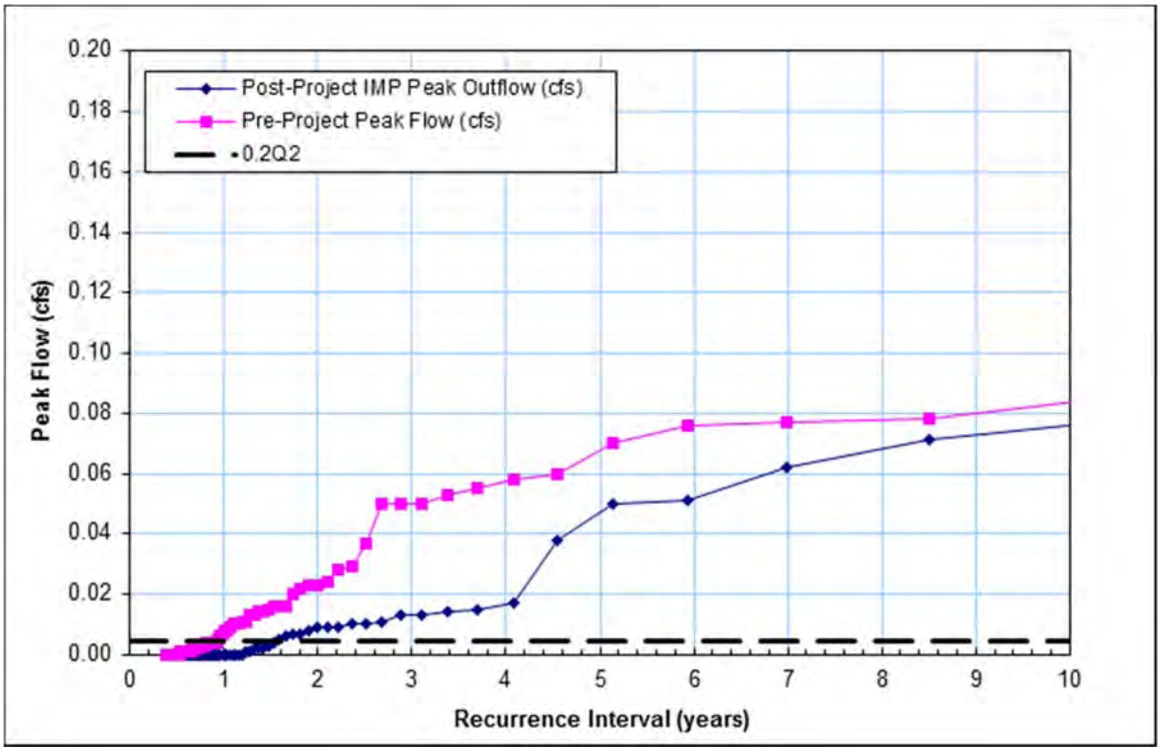

Figure 8. Peak flow frequency comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #2

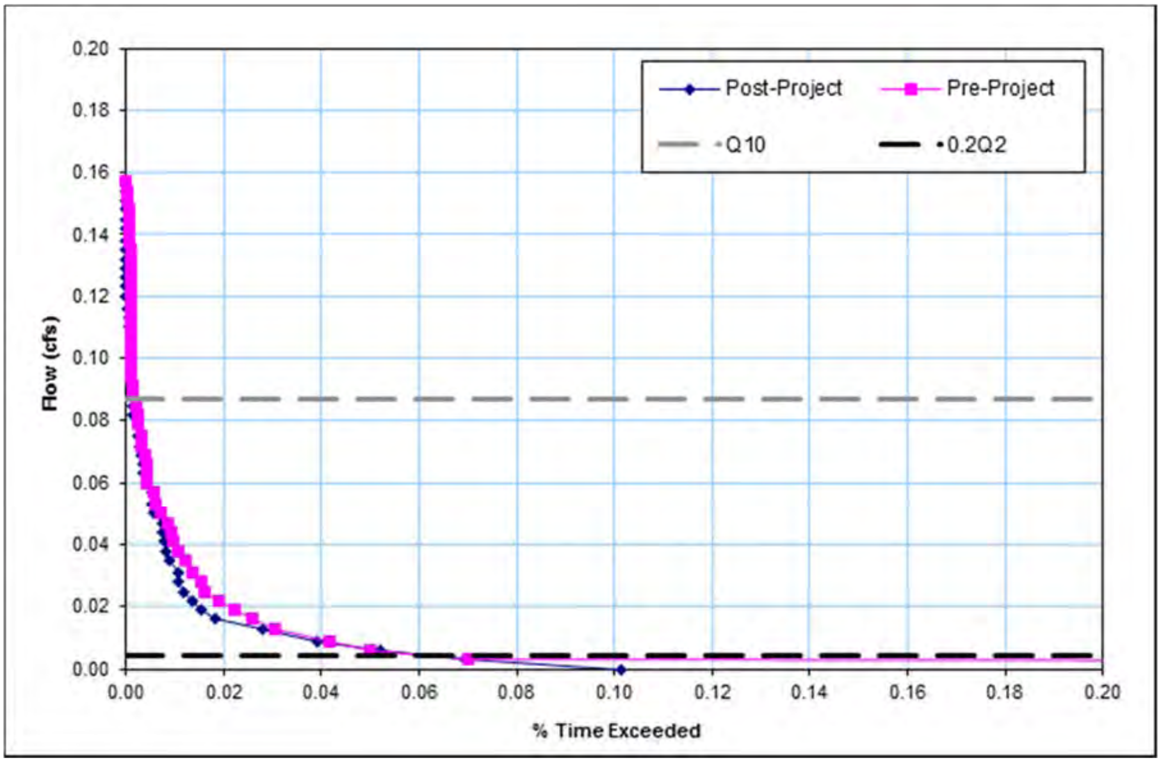

Figure 9. Flow duration comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #2

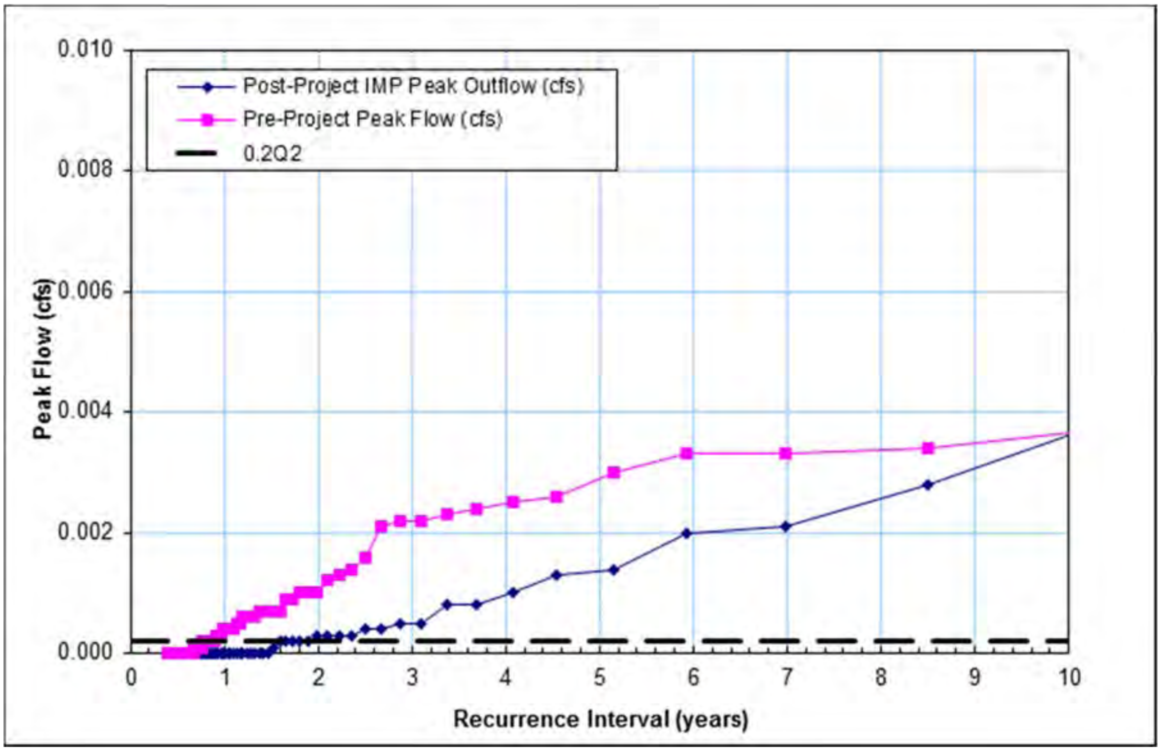

Figure 10. Peak flow frequency comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #4

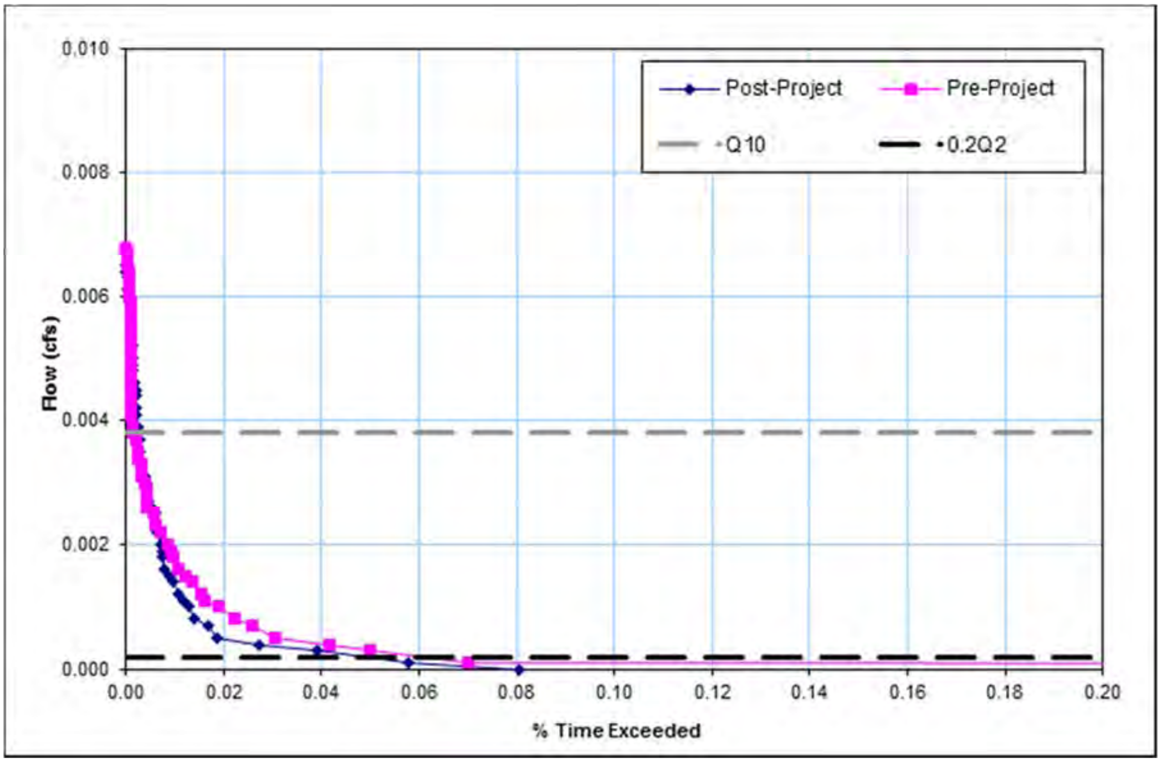

Figure 11. Flow duration comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #4

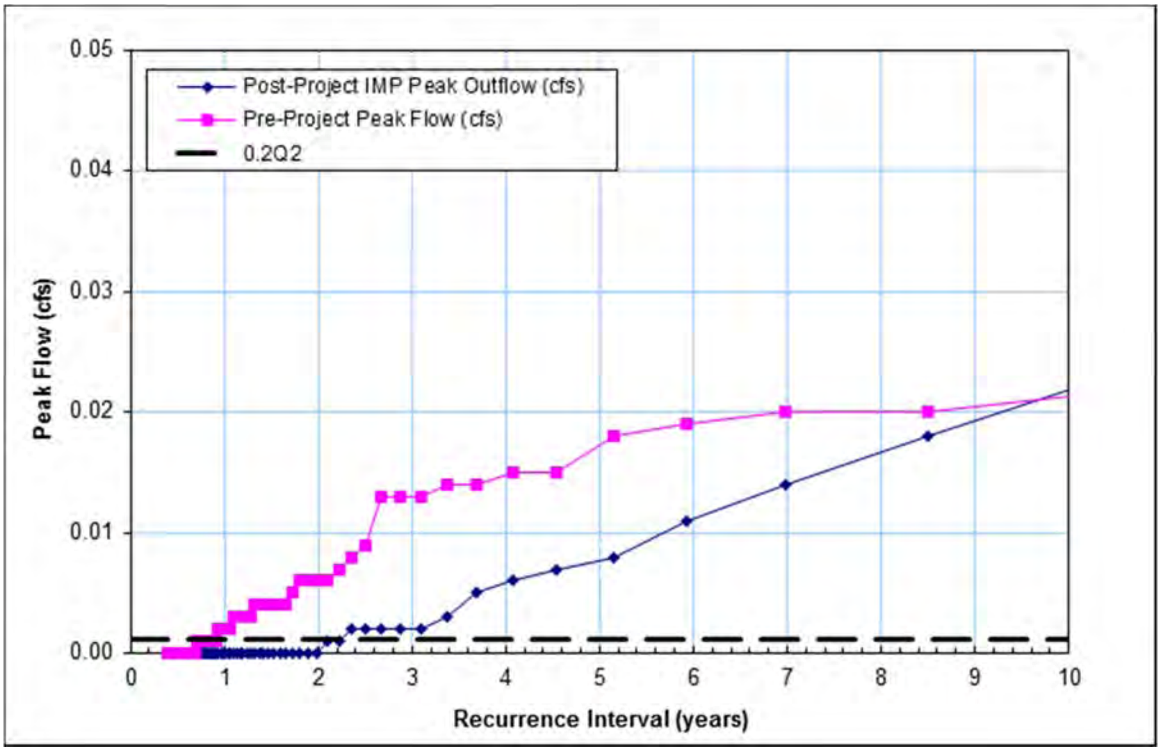

Figure 12. Peak flow frequency comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #6

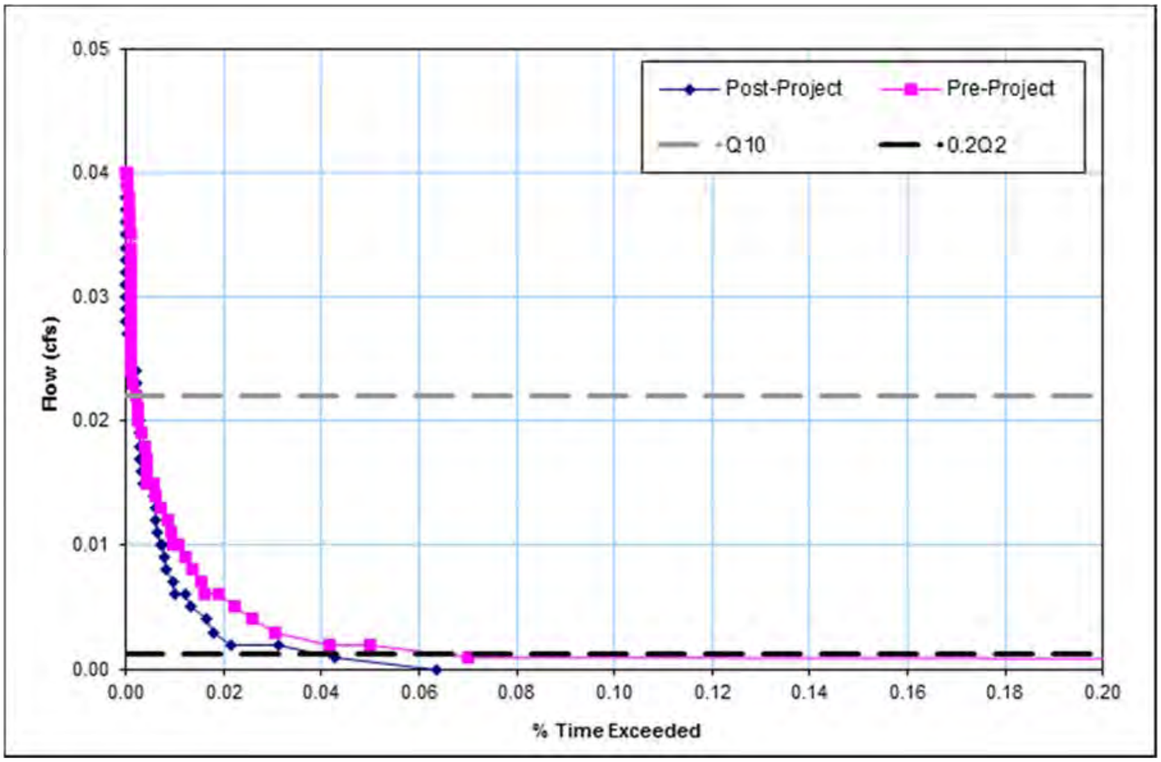

Figure 13. Flow duration comparison for pre-project runoff and post-project outflows for Fire Prevention Bureau IMP #6

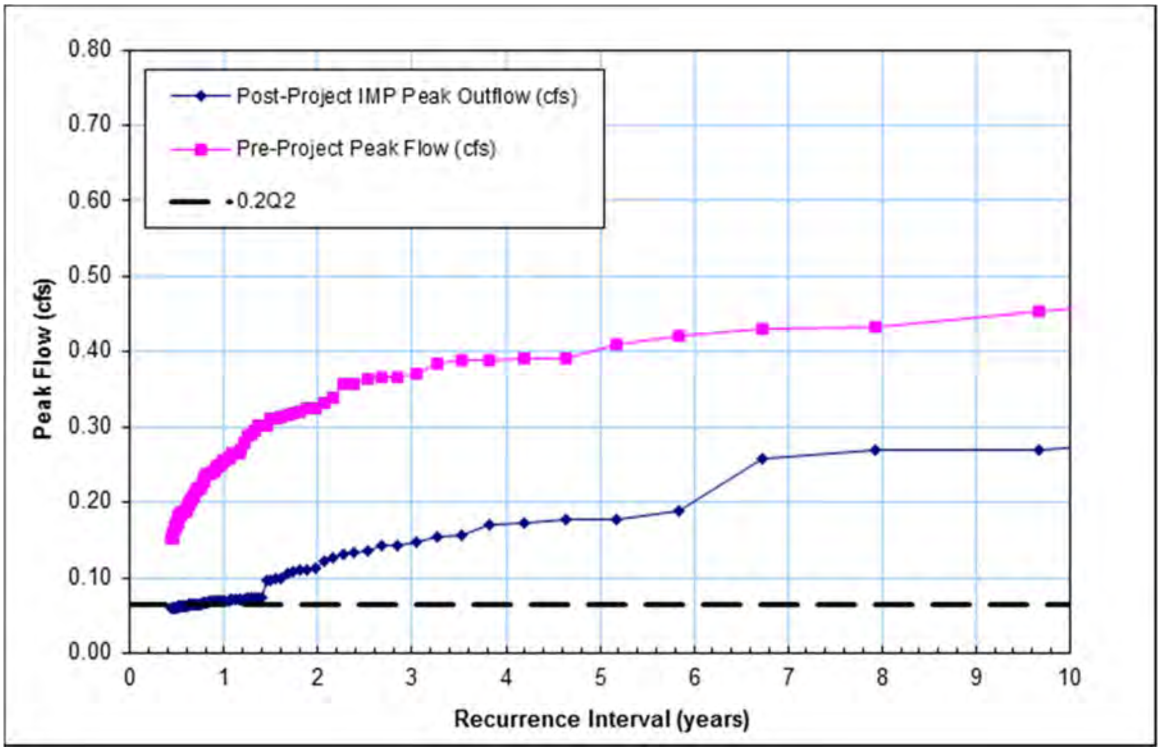

Figure 14. Peak flow frequency comparison for pre-project runoff and post-project outflows for Walden Park Commons IMP #1 (North)

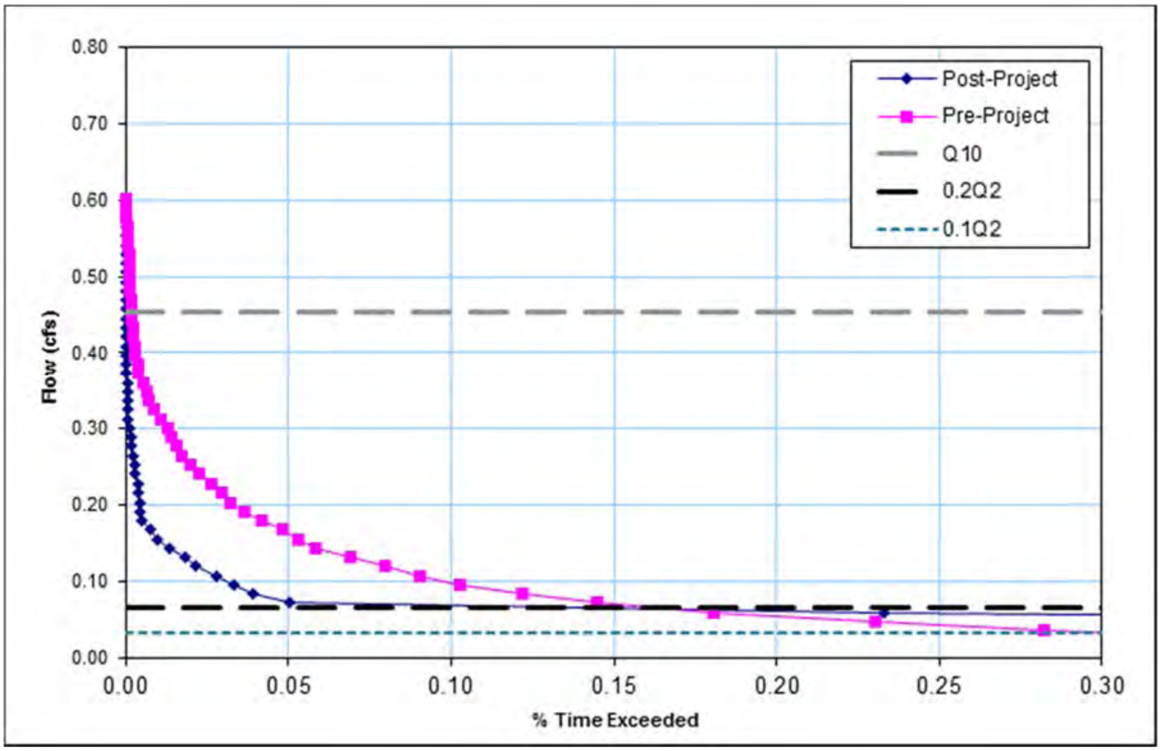

Figure 15. Flow duration comparison for pre-project runoff and post-project outflows for Walden Park Commons IMP #1 (North)

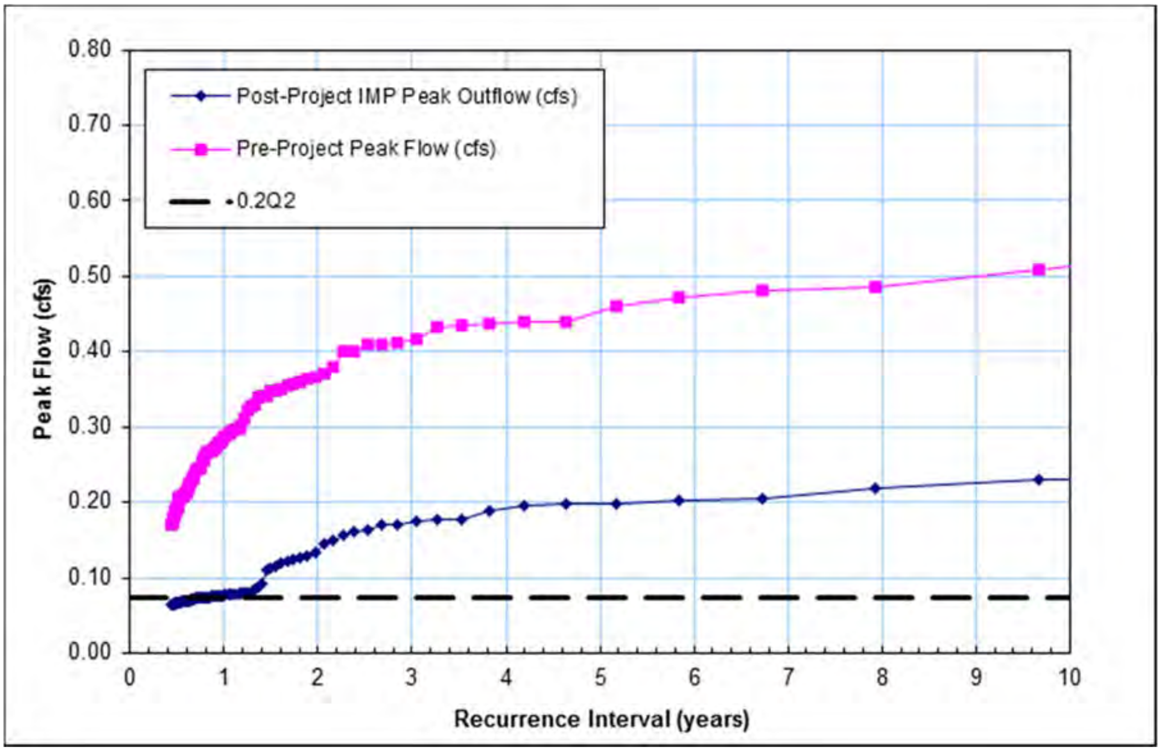

Figure 16. Peak flow frequency comparison for pre-project runoff and post-project outflows for Walden Park Commons IMP #2 (South)

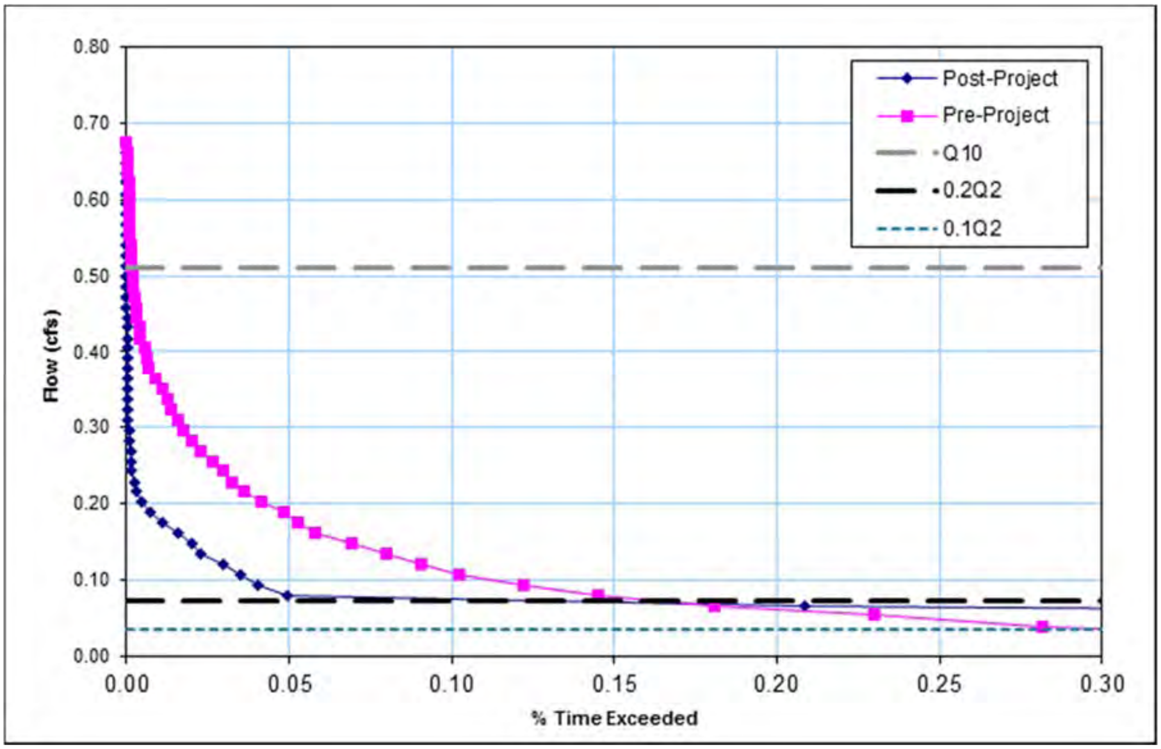

Figure 17. Flow duration comparison for pre-project runoff and post-project outflows for Walden Park Commons IMP #2 (South)

INTRODUCTION

In 2001, the Alhambra Creek Watershed Planning Group, consisting of stakeholders such as the East Bay Regional Park District, National Park Service, City of Martinez, Contra Costa County, and many others, developed the Alhambra Creek Watershed Management Plan.

The Management Plan highlighted nine priorities for the watershed that emphasized environmentally sustainable practices that will also meet community needs. These goals are:

1. Reduce flood damage and conserve stormwater.
2. Prevent excessive erosion and conserve soil resources.
3. Protect and improve water quality.
4. Reduce wildland fire damage.
5. Encourage coordination with the city and county, using the watershed as a planning unit.
6. Support economically and environmentally sustainable land uses while protecting private property rights.
7. Promote a sense of watershed community.
8. Maintain and restore fish and wildlife habitats and native plant communities consistent with environmentally and economically sustainable land use practices.
9. Maintain and enhance quality of life by increasing opportunities to appreciate and enjoy watershed resources.

Since that time, there have been extensive community activities to fulfill these goals. Citizen groups and volunteers have been active in carrying out monitoring projects such as bio-assessments and creek monitoring, as well as civil works projects like septic conversion to sewer system and bank stabilization. There has also been extensive engagement with public authorities to ensure that the watershed perspective is included in ongoing and future developments.

The goal of this report is to identify, through community consultation, “potential retrofit projects in which decentralized, landscape-based stormwater retention units can be installed,” as specified by the Geomorphic Project requirement of the Municipal Regional Stormwater Permit Order No. R2-2009-0074 Section C.8.d.iii. With these projects explicitly laid out, the hope is that when appropriate funding opportunities become available, these projects can be implemented aligned with the goals laid out by the Management Plan.

ALHAMBRA CREEK WATERSHED

The Alhambra Creek Watershed (ACW) is located in the central northern portion of Contra Costa County, bounded by the Martinez Ridge on the east and Franklin Ridge on the west (Figure 1). Spanning an area of 10,735 acres, Alhambra Creek begins its path at the headwaters of Briones Regional Park, at approximately 1470 ft elevation, and makes its way down 7.99 miles through residential and commercial areas in downtown Martinez before finally discharging into the Carquinez Strait. The higher elevations of the watershed and its upper reaches close to the headwaters are dominated by open space and agricultural lands, covered mostly by coastal oak woodland in the north facing slopes. This area has been crucial for maintaining important habitats in the watershed. Approximately 72% of the watershed is outside of the urban limit line, which prohibits the area for urban land use (Figure 2) and therefore encounter minimal disturbance.

Figure 1: Location of Alhambra Creek Watershed (Source: Alhambra Creek Watershed Planning Group, 2001)

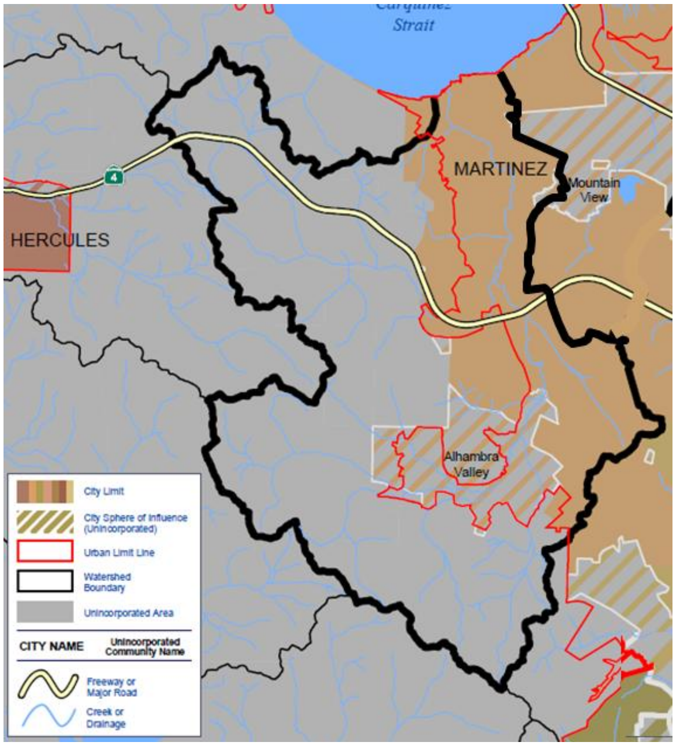

Figure 2: Alhambra Creek Watershed boundary demarcations (Source: Contra Costa Conservation and Development Department, 2004)

The lower elevations of the watershed has been steadily urbanizing since the late 1800's, resulting in 15% impervious surface coverage for the overall watershed. Combined with Franklin Creek and Arroyo Del Hambre, its two largest tributaries, as well as its smaller tributaries, the watershed is composed of over 48 miles of channels, where the majority of the development is clustered (Figure 3). 87% of the stream channels has no constructed reinforcement for its banks, with the remaining either concrete reinforced or routed underground. Portions of the watershed have a long history of flooding, with the most recent event occurring in 2005, in spite of extensive investments already expended for flood control.

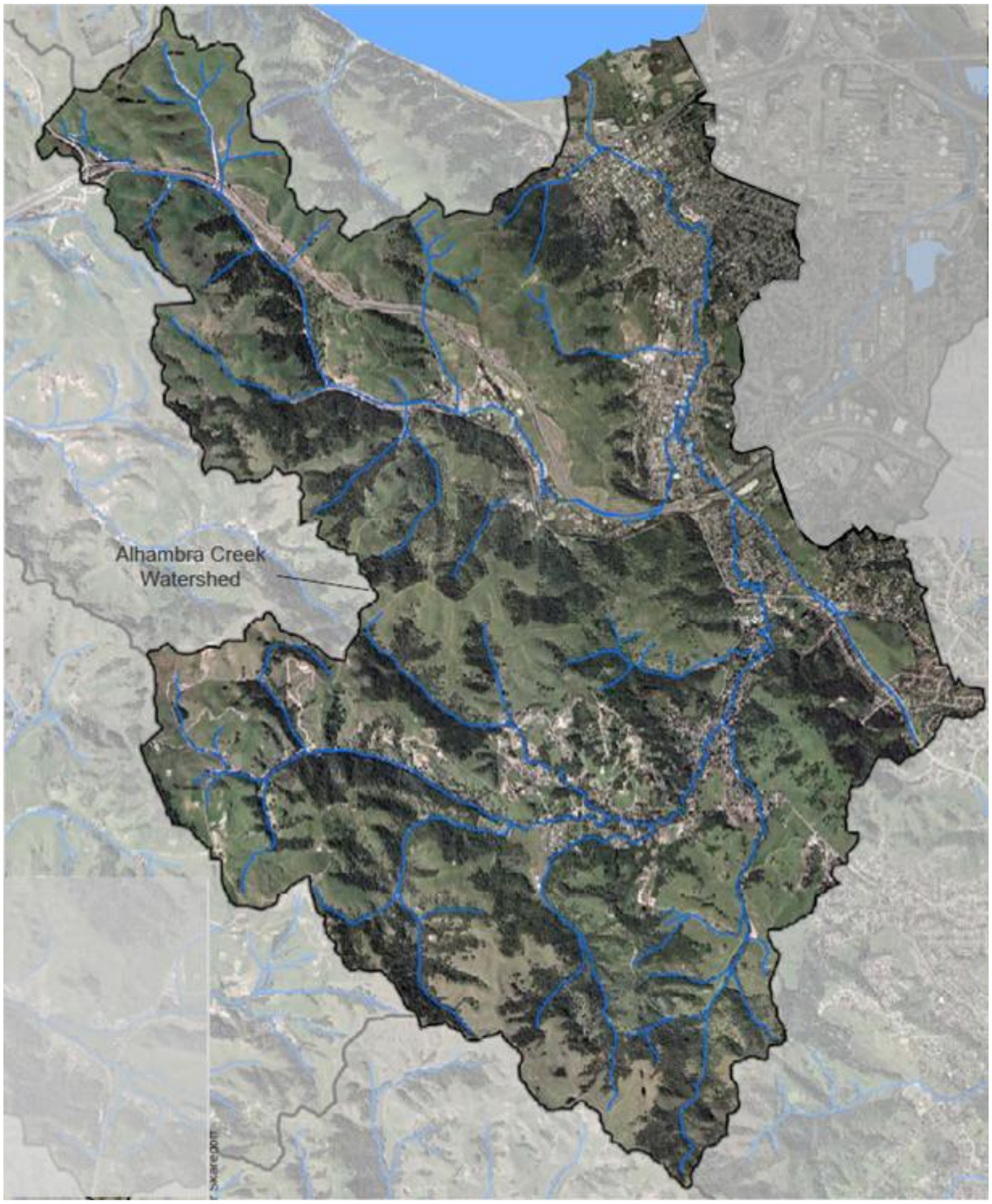

Figure 3: Alhambra Creek Watershed aerial view (Source: Contra Costa Development Department, 2004)

Flood protection is a major priority for the communities in the watershed. With a population of 14,200, the bulk of whom live in the lower watershed in the city of Martinez, extensive efforts have been made to mediate flood risks. Projects managed by the Alhambra Watershed Council (AWC) have been structured to target the goals set forth in the Management Plan, the first of which is to “reduce flood damage and conserve stormwater.” There has been significant community participation for managing the watershed with the formation of AWC, which received grants from California Department of Cosnervation, the Contra Costa Clean Water Program, and CALFED.

The Alhambra Creek Watershed Council has a grant-funded watershed coordinator and other community groups are also active in the Council. The Alhambra Valley Creek Coalition is a collaborative to improve stormwater drainage and reduce local flooding by restoring Strentzel Creek. Friends of Alhambra Creek is a volunteer group that carry out a variety of projects including environmental education, GPS mapping, and water quality monitoring throughout the entire watershed. These citizen groups have been instrumental for engaging the multiple stakeholders and agencies involved in the watershed, and bringing forth the broader perspective of watershed health in regional planning. Their participation will be critical to the success of any future work in the watershed.

VALUES

Fish and Wildlife

Alhambra Creek Watershed is an important resource for fish and wildlife, especially given its relatively pristine condition. The Creek supported a small run of steelheads historically, and continue to be visited by in-migrating individuals (Leidy et al., 2005). Surveys have been conducted and rehabilitation measures carried out to improve their habitat to explore the possibility of supporting a resident population. In 2006, beavers began populating the downtown Martinez reach of Alhambra Creek (Fig. 5), resulting in a six foot dam at its peak which attracted migratory birds and created habitat for other species such as spotted mink and otters (DeRobertis-Theye, 2009). Additionally, a 2011 biological habitat survey, conducted by the Alhambra Valley Coalition, found suitable habitat in the watershed for four protected species: the redlegged frog, western pond turtle, steelhead, and the Alameda whipsnake. Taking proactive measures to keep the creek off the 303(d) list of impaired water bodies will prove a significant asset for the ecosystem and for those that reside in and around it.

Figure 4: Beaver dam in Downtown Martinez.

Recreation

Recreational areas are interspersed throughout the watershed. The 6,117 acres of Briones Regional Park (Fig. 6) include the headwater of the watershed and are managed by the East Bay Regional Park District. Traversing downstream, Alhambra Creek passes through the John Muir National Historic Site, where the National Park Service, in coordination with Friends of Alhambra Creek, are investigating ways to manage stormwater at Strentzel Meadow by restoring the stream channel and floodplain with native vegetation. The mouth of Alhambra Creek (Fig. 7) is enclosed by the Martinez Regional Shoreline, also managed by the East Bay Regional Park District, and also has trail and fishing access from the pier. Because of the extensive marsh land in the park, the park is also a favorite site for local bird watchers.

METHODOLOGY

Given the limited scope of this work, the retrofit inventory was derived from review of existing plans and recent proposals, as well as stakeholders from the community, city engineers, county staff, and local non-profit groups. The latter was particularly productive given the work that has been initiated in the watershed and the extensive community involvement already in place.

Four integrated regional water management plans (IRWMP) for the Alhambra Creek watershed were catalogued in the Bay Area IRWMP database: 1) Alhambra Valley Creek Coalition – Erosion Control and Riparian Restoration Project, 2) Alhambra Valley Creek Coalition Restoration Project, 3) Alhambra Creek Restoration and Environmental Education Collaborative (ACREEC): John Swett Campus, and 4) Martinez Adult School Flood Protection & Creek Enhancement. There are also several active community groups within the watershed: Alhambra Watershed Council, Friends of Alhambra Creek, The Alhambra Valley Creek Coalition, and the Alhambra Creek Environmental Education Collaborative. Through these resources, stakeholders from these community groups, public authorities such as the City of Martinez and the Flood Control District, and non-profit group such as the Urban Creek Council and Muir Heritage Land Trust, were solicited for their insights on potential stormwater retrofit opportunities. The information was gathered through extensive meetings, correspondence, and a watershed tour.

FINDINGS

Five potential retrofit projects were identified through this survey.

John Swett Elementary School

Currently, the Alhambra Creek Restoration and Environmental Education Collaborative (ACREEC) is active in the John Swett campus, and sponsored by the Muir Heritage Land Trust. The focus of the current project is on slope stabilization and the construction of an outdoor classroom for the elementary school that consist of a trail with child and adult benches and native riparian plants. Alhambra Creek at the school constitute a channel that is 15 ft across, 3 ft deep, and runs 400 ft across the length of the school’s north end. Prone to flooding, the area potentially has the space for a retention basin along the play field and can benefit from such a retrofit. Once constructed, such a basin can be a good model for implementing similar retrofits in other urban areas of the watershed.

Brenkle Ranch

The owner of the ranch, Joe Brenkle, had discussed with the Alhambra Creek Council in 2001 the possibility of developing detention/retention basins on his property. The basins would be in addition to his existing basin (Fig. 8) and used for his cattle.

The ranch sits at the upper reaches of Franklin Creek, one of the main tributaries to Alhambra, which passes under the Highway 4 embankment through a culvert. The preliminary design was to install a standpipe at the inlet of the culvert, which required permission from the Department of Transportation and the adjacent landowner. Discussions on this project have not progressed since Mr. Brenkle had moved off the property; his son currently managing the ranch.

Figure 5: Brenkle Ranch detention basin.

Given the extensive open land in this area, in contrast to the lower watershed in the city of Martinez urban center, adding more retention basins remains a possibility, if the owner is still interested. One concern may be that because Brenkle Ranch is located far upstream, storm flow attenuation may not be significant enough to be measurable. However, since this retrofit would be constructed on a private land, it can serve as an important demonstration model for what other landowners can develop on their properties.

Martinez Adult School

Located adjacent to Alhambra Creek, the Martinez Adult School campus has been very susceptible to flooding during heavy rainfall. The Martinez Adult School Flood Protection & Creek Enhancement project is an IRWM project currently administered by the Martinez Unified School District. The original design called for the installation of “a protective berm with a robust spillway and vegetated swale” based on the buildings in its current location.

The project is currently put on hold due to larger improvement plans for the campus. The buildings will be moved to the higher elevation part of the property, which would render the original design for the IRWMP void. The concerns that motivated the IRWMP would still be valid, and thus would require a new design after the move. The vision at this point is to construct a permeable pavement parking lot in the lower lying section of the property, which is currently occupied by buildings, and route water in that direction through constructed berms and swales. These retrofits would then channel the ponded water to Alhambra Avenue rather than Castro Avenue, which is a smaller street and not able to handle high water volume influx.

Once constructed, this project can be used as an educational resource for the students as well as an outreach tool and demonstration project for the public. It has the potential of becoming vocational training for the students, given the school provides trade classes that may align with the needs of this project.

Bypass Channel

In 1967, the US Army Corp of Engineers (USACE) had evaluated several options for flood control of Alhambra Creek, including a bypass, reservoir, and a network of small detention basins/stock ponds. The bypass channel, with enough capacity to withstand a 100-year storm, would redirect Alhambra Creek away from the Martinez Adult School to obviate flooding in the urban center of Martinez. A more detailed study was developed by USACE in 1980. Though the measure that would have supplemented the cost of the project was voted down by the community, there has been a recent rejuvenation of interest in this project. Given the cost of such a bypass will be much more expensive now and most likely financially untenable, a task force determined that the most feasible alternative would be a scaled-back version of the bypass. The inlets would be near Highway 4, with the bypass running under Alhambra Avenue and reconnecting with Alhambra Creek below the Marina Vista crossing, where the channel has been enlarged to handle a 100-year storm flow. In this rendition of the bypass, the creek will have continuous flow, with the bypass utilized for peak shaving rather than a complete detour. As such, the habitat in that reach can continue to thrive while at the same time, urban flooding can be avoided.

In 2007, Philip Williams & Associates, LTD developed an initial assessment for an Alhambra Creek Bypass Culvert under the direction of the City of Martinez Engineering Department. This Bypass would route a portion of the flows in Alhambra Creek upstream of the city directly to the Carquinez Strait. Four flow capacities are considered, with the corresponding storm type each can withstand, and two bypass routes were presented. The proposed next steps were to conduct a detailed flood study that detail all the options feasible, including detention facilities, bypass system, and flood routing, as well as sediment transport analysis with hydraulic modeling.

Parking Lot #4, Downtown Martinez

In the September 3, 2013 Alhambra Creek Watershed Council meeting, the council discussed with the City Engineer for the City of Martinez, Tim Tucker, about the possibility of upgrading public parking lots to reduce and passively treat surface runoff. There are funds available for such a project, and “parking lot #4” in Downtown Martinez was identified as a possible candidate.

The plan is to replicate the water quality enhancement project that was carried out for Parking Lot #3, which is located at the corner of Ward Street and Las Junitas. A collaborative project between the Environmental Studies Academy and the City of Martinez, the design included several planter boxes and in-ground filtration planters, as well as pervious pavers (Figure 6). For public outreach, the students created interpretive signs and brochures to showcase the project’s environmental benefits

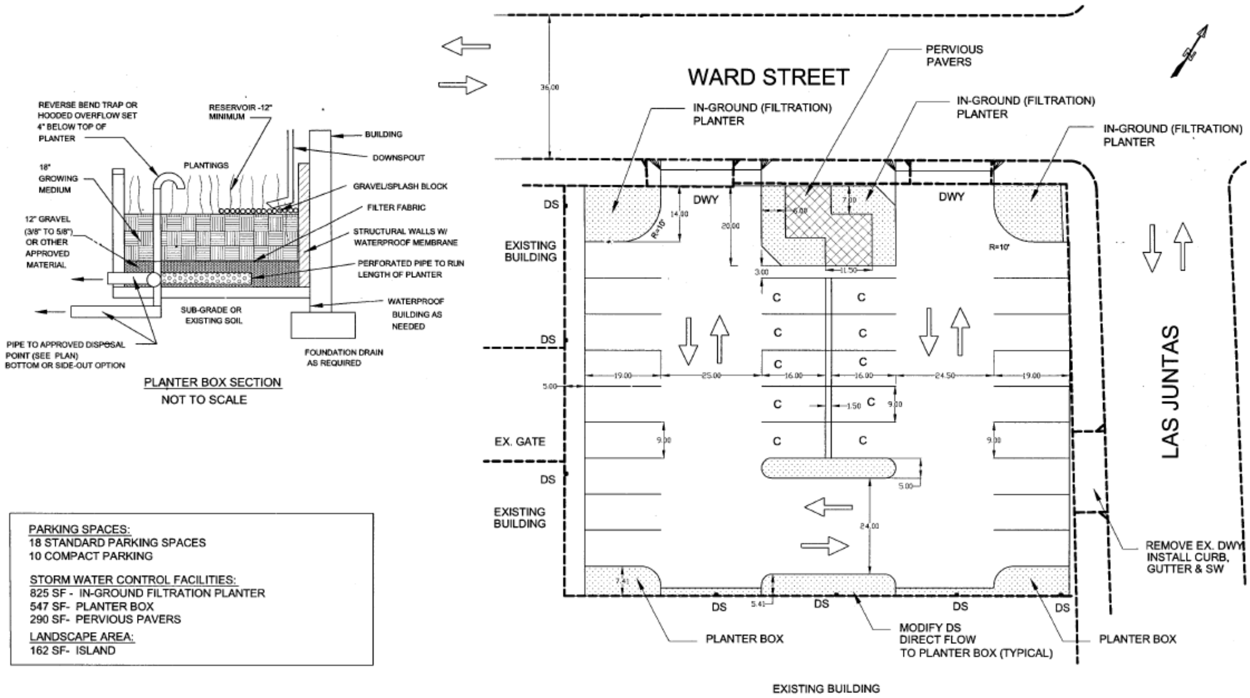

Figure 6: Water Quality Enhancement Project, Parking Lot Number 3 designed by the Environmental Studies Academy and the City of Martinez, Community Development Department

The planning for Parking Lot #4 is at a very early, conceptual stage. According to correspondence with Tim Tucker, the City of Martinez City Engineer, the renovations are currently confined to typical parking lot repair (e.g. fix bad areas and lot overlay) due to limited funding. Drainage into planted areas that can be retrofitted with water quality basins will be explored as funding becomes available. The hope is that the City will work with Environmental Studies Academy students to construct this lot.

RECOMMENDATIONS

Funding is available for some of these projects, and some of them are already underway. Several are on hold due to logistical reasons, and others are proposed here for the first time. Due to limited funding and the multiple jurisdictional authorities involved in these projects, how these projects move forward will depend on funding availability and watershed priorities. The watershed council should be fully integrated into any decisions on steps forward; these decisions may also guide the community for updating the watershed management plan if necessary.

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CCCWP Integrated Monitoring Report Appendix A-6:

Summary of Review of Dutch Slough / Marsh Creek Geomorphic Data.

The Dutch Slough project intends to re-route the mouth of Marsh Creek (the second largest creek in Contra Costa County) through constructed wetlands to provide riverine flows and a greater diversity of habitat types. This is the most significant change to the creek environment since the creek was channelized over 50 years ago.   As the owner and maintainer of this portion of Marsh Creek, the Flood Control District understandably had significant concerns about how the creek would function given this change.

To address these concerns, the District requested from the project team a number of specific items related to hydraulics, sediment transport, and long term stability of the channel, especially in light of expected climate change.   In response, the project team prepared a topographic and bathymetric survey of the existing conditions which were compared to the expected post project geometry.   Pre and post project hydraulic modelling was performed demonstrating no negative impacts.

To address the District's geomorphic concerns, the project team performed a number of specific tasks.

First, they assembled and compared historic and contemporary bathymetric data to identify long-term deposition or scour trends. The team determined that the watershed is generally sediment limited and proceeded to gather additional data.   Specifically, they investigated the tidal sediment supply, analyzed the distributary channel geometry to confirm adequate tidal flushing flows, and estimated expected sheer stresses under a channel forming discharge (Q2).

Finally, the team collected two bed load samples from Marsh Creek, and sampled suspended sediment during two discharge events.   Each event yielded five data points of suspended sediment concentration at different discharges.   This data was compared to prior data sampled by the San Francisco Estuary Institute as part of the recent Regional Monitoring Plan.   The resulting suspended sediment rating curve was compared to theoretical sediment transport capacity curves to confirm the hypothesis that the proposed channel modifications were sufficient for sediment to continue to properly move through the system, and that the design should be stable and free from excessive deposition.

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

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On

February 21, 2014

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)

Acknowledgements

We were glad for the support and guidance of the Sources, Pathways and Loadings Workgroup of the Regional Monitoring Program for Water Quality in San Francisco Bay. The detailed work plan behind this work was developed through the Small Tributaries Loading Strategy (STLS) during a series of meetings in the summer of 2011. Local members on the STLS are Arleen Feng, Lucy Buchan, Khalil Abusaba and Chris Sommers (for BASMAA) and Richard Looker, Jan O'Hara, and Tom Mumley (for the Water Board). Khalil Abusaba, AMEC Environment and Infrastructure and Chris Sommers, EOA INC. provided helpful written reviews on the draft report that we incorporated to improve this final report. This project was completed with funding provided by the Bay Area Stormwater Management Agencies Association (BASMAA) and the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP).

This progress report can be cited as:

Gilbreath, A.N., Gluchowski, D.C., Hunt, J.A., Wu, J., and McKee, L.J., 2014. Pollutants of concern (POC) loads monitoring data progress report, water year (WYs) 2012 and 2013. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 712. San Francisco Estuary Institute, Richmond, California.

Table of contents

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).

Bay Area Stormwater Programs, 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; SFEI in preparation), and pollutant characterization and loads monitoring in local tributaries beginning Water Year (WY) 2011 (McKee et al., 2012), that continued in WY 2012 (McKee et al., 2013), WY 2013 (this report), and is underway again for WY 2014.

The purpose of this report is to describe data collected during WYs 2012 and 2013 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;
- San Leandro Creek (Hg);
- Guadalupe River (Hg and PCBs);
- Sunnyvale East Channel (PCBs); and
- Pulgas Creek Pump Station.

Loads monitoring provides calibration 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 is 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; SFEI in preparation) was focused mainly on addressing MQ2. Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board (and discussion at the October 2013 SPLWG meeting) 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 intended to address this increasing management focus.

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 (Figure 1; Table 1). The sites were distributed throughout the counties where loads monitoring are required by the MRP. The selected watersheds include 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.

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 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 Street 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 (USGS data). In natural flowing rivers and urban creeks or storm drains, turbidity usually correlates with the concentrations of suspended sediments and hydrophobic pollutants. 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).

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 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; Quémerais et al., 1999; Wall et al., 2005; Gilbreath et al., 2012). 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 except mercury, methylmercury and a simultaneously collected suspended sediment concentration (SSC) sample were collected using the ISCO as a pump at all the sites besides Guadalupe. Discrete mercury and methylmercury samples (including a simultaneously collected SSC sample) 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, and by manually dipping an opened bottle from the side of the channel at San Leandro (in WY 2013 only) and Lower Marsh Creek (both WYs) (Table 1). Tubing for the ISCOs was installed using the clean hands technique, as was the 1 L Teflon bottle when used in the D-95. Composite samples, with the intent of representing average concentrations of storm runoff over each storm event sampled, were collected using the ISCO autosampler at all of the sites except Guadalupe River. 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 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. 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) or that use some kind of mathematical average concentration (e.g. simple mean; geometric mean; flow weighted mean) combined with monthly 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 manner:

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 are collected each year at the STLS monitoring sites, knowledge will improve about how concentrations vary with season and flow (improvements of the definition of the strata) and thus about how to apply loads computation techniques. Therefore, with each additional annual reporting year, a revision of loads is expected for the previous water year(s). This will occur in relation to improved flow information as well as an improved understanding of concentration variation in relation to seasonal characteristics and flow.

During the study, concentrations either measured or estimated were multiplied with the continuous estimates of flow (2-15 minute interval) to compute the load on a 2 to 15 minute basis and summed to monthly and wet season loads. Laboratory measured data was 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 and loads):

Linear interpolation: Linear interpolation is the primary technique used for interpolating concentrations between measured data points when storms are well sampled (Note, this method was not yet applied but will be applied when the final report for the data collection during WYs 2012, 2013, and 2014 is written – likely late 2014).

Linear Interpolation using particle ratios: 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 for pollutants which occur mainly in particulate form because it ensures that the

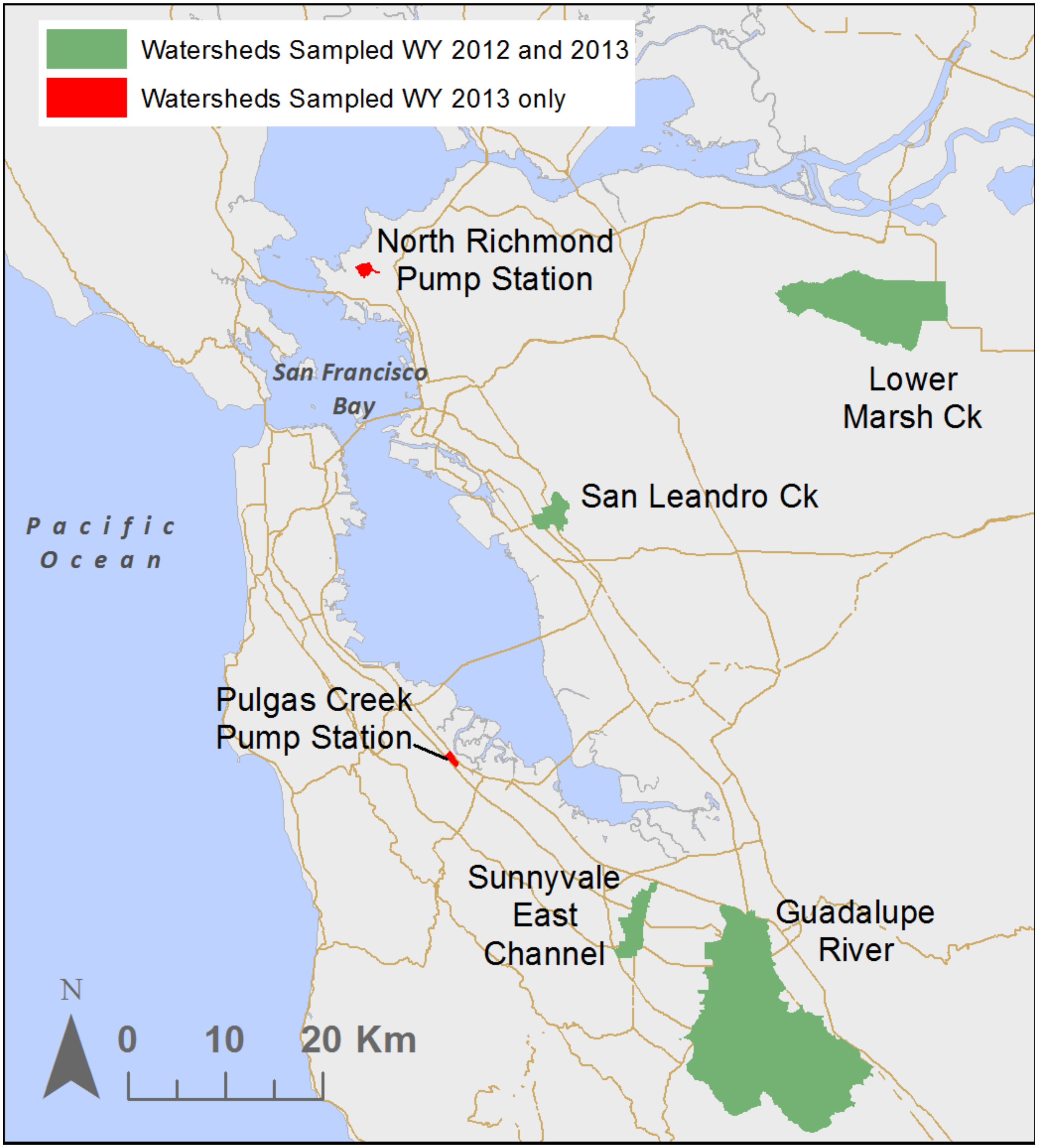

Figure 1. Water year 2012 and 2013 sampling watersheds.

Table 1. Sampling locations in relation to County 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 and 2013	99	Brentwood	37.990723	-122.16265	ADH	USGS Gauge Number: 11337600[2]	OBS-500[4]	Manual grab	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Contra Costa	North Richmond Pump Station	2013	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 and 2013	8.9	San Leandro	37.726073	-122.16265	SFEI WY2012 ADH WY2013	STLS creek stage/ velocity/ discharge rating	OBS-500[4]	FISP US D95[7] WY 2012 Manual grab WY 2013	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Santa Clara	Guadalupe River	2012 and 2013	236	San Jose	37.373543	-121.69612	SFEI WY2012 Balance WY 2013	USGS Gauge Number: 11169025[3]	DTS-12[5]	FISP US D95[7]	FISP US D95[7]	FISP US D95[7]
Santa Clara	Sunnyvale East Channel	2012 and 2013	14.8	Sunnyvale	37.394487	-122.01047	SFEI	STLS creek stage/ velocity/ discharge rating	OBS-500*[4] WY 2012 DTS-12[5] WY 2013	FISP US D95[7]	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
San Mateo	Pulgas Creek Pump Station	2013	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] FISP US DH-81 Depth integrating suspended hand line sampler
[7] FISP US D-95 Depth integrating suspended hand line sampler
[8] Teledyne ISCO 6712 Full Size Portable Sampler
*OBS-500 malfunctioned during WY 2012 due to low flow water depth. A DTS-12 was installed during WY 2013.

relationship between the derived concentration and varying turbidity that occurs between the two laboratory pollutant measurements results in particle ratios that at all time intervals are reasonable.

Linear Interpolation using water concentrations: Linear interpolation using water concentrations is the process by which the interpreter varies the concentrations between observed measurements using a linear time step. It is appropriately used for pollutants which occur mainly in dissolved phase because it does not incorporate any regard for varying turbidity or SSC.

Interpolation using a turbidity based regression equation with each POC: Turbidity surrogate regression can be considered the default standard for pollutants of concern that are primarily transported in a particulate form. These types of contaminants (for example PCBs and mercury) form strong linear relationships with either turbidity or SSC. Turbidity surrogate regression was applied to all unsampled flood flow conditions observed at each monitoring site.

Interpolation using a regression equation derived from two chemical species (e.g. TP:PO4): For pollutants primarily transported in dissolved phase, the turbidity regression estimator was not be appropriate. In this instance it may be possible to use an alternative surrogate such as electrical conductivity or a parent pollutant. A "chemical surrogate regression" estimator of this nature can be considered the default standard for pollutants of concern that are primarily transported in a dissolved form. This method was applied to unsampled flood flow conditions if a reliable regression was found.

Interpolation assuming a representative concentration (e.g. "dry weather lab measured" or "lowest measured"): To apply this method, an estimate of average of 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.

3. Continuous data quality assurance

3.1. Continuous data quality assurance methods

In 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. These protocols were established towards the end of the season and therefore some field checks now required in the QA protocol will not be implemented until WY 2014, specifically including precision checks on the instrumentation through replicate testing of equipment at high and low reference values. 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 the 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 through calibration, accuracy in relation to comparison with manual measurements, dataset representativeness relative to logging interval, and finally on completeness of the dataset (Table 2 and Table 3). 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., 2013).

Table 2. Continuous data quality assurance summary for accuracy and precision for each monitoring location. "NR" indicates that the QA procedure was not completed and "NA" indicates that the QA procedure was not applicable.

	Accuracy at Calibration			**Accuracy of Comparison**		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Sunnyvale	NR	NR	Excellent	Excellent	Excellent	Excellent
Pulgas	NR	NR	New instrument	Excellent	NR	Poor[1]
Richmond	NR	NR	Excellent	Poor	NR	Good
Guadalupe	NA	USGS maintained	USGS maintained	NA	USGS maintained	Excellent
San Leandro	NR	NR	Within Tolerance	Excellent	Excellent	NR
Lower Marsh	NR	USGS maintained	Excellent	Excellent	USGS maintained	NR

Table 3. Continuous data quality assurance summary for representativeness and completeness for each monitoring location.

	Representativeness of the population			**Completeness (Confidence in corrections)**		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Sunnyvale	Excellent	Good[2]	Excellent	Excellent	Excellent	Poor[6]
Pulgas	Excellent	Excellent	Good[3]	Excellent	Poor[7]	Excellent/Poor[8]
Richmond	Excellent	Excellent	Poor[4]	Poor	Excellent	Excellent
Guadalupe	NA	USGS maintained	Excellent	NA	USGS maintained	Excellent
San Leandro	Excellent	Excellent	Excellent	Good[5]	Excellent	Poor[9]
Lower Marsh	Excellent	USGS maintained	Excellent	Excellent	USGS maintained	Excellent

[1] Manual turbidity measurements against sensor measurements had a coefficient of determination of 0.25.

[2] 4.7% of records at Sunnyvale showed a >15% change between consecutive readings, and manual stage measurements were only made in the 4th quartile.

[3] 1.9% of the population (483 records) had greater than 20 NTU absolute value change and ≥15% relative change from the preceding record; 1.3% (328 records) had greater than 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.

[4] 4.2% of the population (251 records) had greater than 20 NTU absolute value change and ≥15% relative change from the preceding record; 2.9% (171 records) had greater than 20 NTU absolute value change and >50% relative change from the preceding record. Data intervals already set to minimum of 1 minute interval. Recommended action for improvement is to collect as many manual turbidity measurements as possible in order to better understand whether variability in the record is real or anomalous.

[5] Rainfall data at San Leandro Creek missing from 10/1/2012-11/6/2012, 12/6/2012-12/12/2012, and 1/4/2013-1/9/2013. Missing 10.6% of records.

[6] 31% of the period of record was missing turbidity due to the minimum stage criterion for turbidity measurement to be 0.4 ft and this amount of the record being during stages below 0.4 ft. An additional 8.3% of the turbidity record was rejected due to fouling.

[7] A large portion of the data record was on intervals greater than 15minutes.

[8] Completeness of the turbidity record was excellent during the period in which turbidity was measured, but a large portion of the wet season was missing data.

[9] 23% of records for stages > 1 ft have no corresponding turbidity record.

3.2. Continuous data quality assurance summary

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. Rain gauges were cleaned before and periodically during the season, but not calibrated. All sites except for the North Richmond Pump Station compared well to nearby rain gauges. Discrepancies between the rain gauge at North Richmond Pump Station and nearby gauges during December and January resulted in the accuracy of this data set to be labeled as “poor”. 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. Manual stage measurements made at Sunnyvale and San Leandro compared well with the corresponding record from the pressure transducer (R^2=0.99 at both sites). The entire stage dataset at Lower Marsh was compared to the USGS gauge on Marsh creek, and showed a regression with R^2=0.98. Percent differences between consecutive records were reasonable at all sites and the datasets were complete for the period where the equipment was installed. Manual stage measurements were not collected at either of the pump station sampling locations and could not be used to verify the accuracy or precision of those stage records, an improvement to be implemented in WY 2014.

Continuous turbidity data were rated excellent at Lower Marsh Creek and Guadalupe River. San Leandro Creek, Sunnyvale East Channel and Pulgas Creek Pump Station (qualified) all received poor quality ratings on completeness: the San Leandro Creek dataset was relatively free from spikes requiring censorship or correction but had a large portion of missing records; Sunnyvale East Channel had a full record but a large portion of data censored due to spikes; and Pulgas Creek Pump Station recorded turbidity during only three of the seven wet season months in large part due to instrumentation failures. The pump station sites both received poor ratings for representativeness given how records could fluctuate multiple times from one reading to the next. Both of these sites experience very rapidly changing conditions and may warrant unique rating criterion in the QA protocol; a topic for continued discussion and potential revision for future reporting. Pulgas Creek Pump Station also had poor repeatability between manual and sensor collected data and improvements to the monitoring set-up should be considered for next wet season.

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) (Table 4). In water year 2013, laboratory changes were made for the following chemical analyses:

- Total Mercury and total methylmercury from Moss Landing Marine Laboratory to Caltest
- Nutrients and SSC from East Bay MUD to Caltest

- Pyrethroids from AXYS Analytical Laboratory to Caltest
- Selenium, copper, and hardness from Brooks Rand Laboratory to Caltest

An inter-comparison study was designed to assess any impacts of laboratory change during the study. A subset of samples were collected in replicate in the field and sent to the previous laboratory and replacement laboratory. Acceptance limits for precision and recovery in QC samples (e.g., for matrix spikes or reference materials) in published methods provide practical guides for the expected

Table 4. Laboratory analysis methods

Analyte	Method	Field Filtration	Field Acidification	Laboratory
Carbaryl	EPA 632M	no	no	DFG WPCL
Fipronil	EPA 619M	no	no	DFG WPCL
Suspended Sediment Concentration	ASTM D3977-97B	no	no	Caltest Analytical Laboratory
Total Phosphorus	SM20 4500-P E	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Nitrate	EPA 353.2 / SM20 4500-NO3 F	yes	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Dissolved OrthoPhosphate	SM20 4500-P E	yes	no	Caltest Analytical Laboratory
PAHs	AXYS MLA-021 Rev 10	no	no	AXYS Analytical Services Ltd.
PBDEs	AXYS MLA-033 Rev 06	no	no	AXYS Analytical Services Ltd.
PCBs	AXYS MLA-010 Rev 11	no	no	AXYS Analytical Services Ltd.
Pyrethroids	EPA 8270Mod (NCI-SIM)	no	no	Caltest Analytical Laboratory
Total Methylmercury	EPA 1630M Rev 8	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Total Mercury	EPA 1631EM Rev 11	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Copper[1]	EPA 1638M	no	no	Caltest Analytical Laboratory
Selenium[1]	EPA 1638M	no	no	Caltest Analytical Laboratory
Total Hardness[1]	SM 2340	no	no	Caltest Analytical Laboratory
Total Organic Carbon	SM20 5310B	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Toxicity[3]	See 2 below	no	no	Pacific Eco-Risk Labs

[1] Dissolved selenium and dissolved copper were field filtered at the Lower Marsh Creek and San Leandro Creek stations in water year 2013. Dissolved selenium and dissolved copper field filtered for Lower Marsh Creek only in water year 2012. Field filtered samples are also field preserved.

[2] Hardness is a calculated property of water based on magnesium and calcium concentrations. The formula is: Hardness (mg/L) = (2.497 [Ca, mg/L] + 4.118 [Mg, mg/L])

[3] 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 (EPA 821/R-02-013), and10-day survival test with *Hyalella Azteca (*EPA 600/R-99-064M)

agreement between samples analyzed by different labs; differences between labs will reflect the aggregate of uncertainty for each measurement (the propagated error would be the square root of the sum of the squared errors), and thus may often be larger than the accepted limits of intra- (single) lab variation. Differences among locations or over time, that were smaller than these propagated errors, could not be distinguished from measurement variability, so results (e.g., calculated loads) should be interpreted with awareness of these uncertainties.

Mercury and methylmercury samples were analyzed during the inter-comparison study. Comparability for total mercury samples was good, averaging 26% RPD (similar to the expected 25% RPD for within lab replicates) and ranging from 2 to 42% RPD for individual pairs, with the previous laboratory reporting higher concentrations for all inter-compared sample pairs. Methylmercury comparability was even better, averaging 11% RPD (10.7 and 11.1% RPD on individual sample pairs), again with the previous laboratory reporting slightly higher concentrations.

Comparability of nutrient and conventional water quality parameters was usually good except for SSC. RPDs between nitrate results from the labs ranged 2 to 6% (average 4%), and orthophosphate results were identical within rounding error (reported to the nearest 0.01 mg/L). Total phosphorous was slightly more variable but averaged only 6% RPD (4 to 7% range). Only SSC showed a wide degree of variation, with RPDs ranging 0 to 60% (average 25%), illustrating some of the challenges of consistently representatively sampling particulate matter in stormwater flows.

For pyrethroids, the results were fairly similar for the most abundant compound, bifenthrin (17% RPD), with somewhat poorer agreement for the next most abundant compound, permethrin with 40% RPD. For two independent measurements each with up to 35% error, the propagated error would be the square root of the sum of the squared errors (i.e., SQRT[$0.35^2 + 0.35^2$]), approximately 49%, so 40% RPD was within this range of expected error. Comparability could not be assessed quantitatively (i.e., no RPDs were calculated) for the remaining pyrethroids. MDLs from the previous laboratory were mostly in the range 0.25-5 ng/L, with most samples reported as non-detect or as estimated results near MDL/below RL. Therefore RPDs (even if calculated) could not be quantitative.

Hardness, copper, and selenium were also analyzed. Although hardness reported by the current laboratory was censored due to poor matrix spike recovery (error 4 times over the 5% target; the error tolerance on hardness measurements are tighter due to the usual ease of good precision and accuracy on those measurements), raw results were compared to see if the bias reported in QC samples was also reflected in comparability between laboratories. The RPD for hardness was 16%, with the current laboratory reporting lower concentrations; a similar low bias is seen in their matrix spike samples, which reported 21% lower than their expected values. The concurrence between these IC results and the current laboratory’s MS results suggests a consistent low bias for hardness, so any use of the currently censored data should be made with full awareness and acknowledgement of this likely bias. Comparability on copper was much better, averaging 7% RPD (5 and 12% respectively for the total and dissolved samples compared), and similarly the comparability on selenium was quite good, averaging 6% (0.5 and 11% for the total and dissolved fractions of compared samples).

Where differences being sought are similar in magnitude to the uncertainty in precision around individual measurements, a large number of measurements may be needed to verify the significance of possible differences (or lack thereof) seen. When the uncertainty arises from bias, comparison to other laboratories' results (either through inter-comparison exercises or certified reference materials[1]) can provide an indication of the possible bias. The inter-comparability data provide greater confidence in individual measurements where there is better agreement; the results are less likely to reflect an artifact of any particular laboratory's sample handling and quantitation methods. Thus for this study, there is generally better confidence in the measurement of inorganic pollutants and water quality parameters (other than SSC). Overall, the results from the IC study (from a relatively small sub-set of samples) did not provide evidence to indicate non-comparability between the new laboratories for most analytes. Due to sample concentrations near MDL for pyrethriods, evidence is weaker and there was some concern with the SSC comparability; SSC inter-comparisons are likely most influenced among all the analytes by grain size and field sub-sampling techniques in addition to laboratory sample treatment. At this time, the results from the IC study have not been factored into loads computations; this will occur during the completion of the final report estimated to occur in late 2014.

4.2. Quality assurance methods for pollutants of concern concentration data

4.3.1. Sensitivity

The sensitivity review evaluated the percentage of field samples that were non-detects 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.

4.3.2. Blank Contamination

Blank contamination review was performed 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 this batch, were qualified as blank contaminated. If the field sample result was less than 3 times the average blank concentration (including those reported as ND) those results were "censored" and not reported or used for any data analyses.

4.3.3. Precision

Rather than evaluation by lab batch, precision review was performed 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

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[1] Although certified reference materials provide one indicator of possible bias, they in themselves provide no absolute guarantee of a particular measurement's accuracy; the certified values are consensus values that often have very wide confidence bands. This may depend on the particular labs participating in the certification and the methods used by those labs. Furthermore, concentrations of analytes and interfering matrices may differ from those in samples from a particular study.

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 - unlikely for wet-season runoff event samples unless collected simultaneously from a location). Replicates from 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 RPD is ≤25%) were qualified; those outside of 2 times the MQO were censored.

4.3.4. Accuracy

Accuracy review was also performed 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: Certified Reference Materials (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 flagged, 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.

4.3.5. Comparison of dissolved and total phases

This review was only conducted on water samples that reported dissolved and particulate 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 an MQO of RPD<25%, a dissolved sample result might easily be higher than a total result by that amount.

4.3.6. 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.

4.3.7. 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 is necessary to 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.

5. Results

The following sections present synthetic results from the six monitored tributaries. In this 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.

5.1. Project Quality Assurance Summary

The section below reports on WY 2013 data; for the WY 2012 quality assurance summary, refer to section 4.1 in McKee et al., 2013. Attachment 1 provides a detailed QAQC summary for WY 2013 data.

The PCB data were acceptable. MDLs were sufficient for the majority of PCBs with 22% (16 out of 71 congeners) having some non-detects (ND), but none were extensive. A number of PCB congeners were found in laboratory blanks. About 27% (19 out of 71) of the congeners had some contamination in at least one method blank. PCB congeners 18, 28, 31, 44, 49, 52, 66, 70, 87, 95, 118, and 153 had 3% of grab sample results flagged with the censoring contamination qualifier of “VRIP” (results with reported concentrations <3x the blank results (by batch) being censored for contamination). Precision and accuracy metrics were within MQOs.

Overall the total mercury and total methylmercury results were acceptable. MDLs were sufficient with only one ND for methylmercury. Total mercury and methylmercury were not detected in lab blanks, although total mercury was found in one field blank at .004 µg/L, about 20 times above the MDL, but still ~5 times lower than the average concentration for field samples in this data set. Precision and accuracy metrics were within MQOs. Methylmercury concentrations were generally in the range of 1% of total mercury concentrations which is fairly typical. No additional qualifiers were needed on the data set.

The nutrient data were generally acceptable. MDLs were sufficient to get quantitative results for most analytes at all stations. Nitrate had 7% non-detects and suspended sediment concentration had 3% non-detects. No blank contamination was found in either the method blanks or equipment blanks (3 batches). Field blanks were analyzed for 21 batches with blank contamination found for nitrate and phosphorus as in one batch each. Precision and accuracy metrics were within MQOs.

The carbaryl and fipronil data were acceptable. MDLs were sufficient with carbaryl having ≥50% NDs. Blank contamination was not found in either the method blanks or the field blanks. Precision and accuracy metrics were within MQOs.

The PAH dataset was acceptable with some minor QA issues. MDLs were sufficient for most of the PAHs, with <50% non-detects for 76% of the target PAHs; Acenaphthene, Acenaphthylene, Benz(a)anthracene, Dibenz(a,h)anthracene , Dibenzothiophene, and Fluorene had >50% NDs. Thirteen PAHs were found in at least one of the three lab blanks; subsequently Benz(a)anthracene, Benz(a)anthracenes/Chrysenes, C4- , Biphenyl, Dibenzothiophene, Fluorene, Methylnaphthalene, 1-, Naphthalene, and Trimethylnaphthalene, 2,3,5- had results flagged with the censoring qualifier VRIP for being <3x the average blank concentration. Precision was good with <35% RSD on lab or blank spike replicates for all analytes. Accuracy was evaluated using recoveries for the 43 PAHs in the laboratory control samples and were generally good, with only Tetramethylnaphthalene, 1,4,6,7- (40%) having a recovery averaging >35%.

Overall the PBDE data were acceptable. MDLs were sufficient with 29 of the 49 reported PBDE congeners having some level of non-detect, and 27% having ≥50% NDs. PBDE congeners 17, 28, 47, 49, 85, 99, 100, 138, 153, 154, 183 and 209 had some contamination in at least one method blank, but only PBDE 183 had 6% of its samples censored. Replicates on field samples were used to evaluate precision and were generally good, less than the target 35% average RSD, except for PBDE 8 and 12, which were flagged with the non-censoring qualifier. Accuracy metrics were within MQOs.

Overall the pyrethroids data were acceptable. MDLs were sufficient with 12 of the 13 pyrethroids reported having some level of non-detect (ranging from 5 to 95% non-detects) and 50% of the pyrethroids reported having ≥50% NDs (Allethrin, Deltamethrin/Tralomethrin, Diazinon, Fenpropathrin, Tetramethrin and T-Fluvalinate). Blank contamination was not found in any of the method blanks. Field blanks were examined, but not used in the evaluation, with blank contamination found in one of the field blanks for Chlorpyrifos and Diazon at a concentration equal to the MDL. Matrix spikes were used to assess accuracy with recovery errors less than the target 35% for all reported analytes, except Allethrin, Deltamethrin/Tralomethrin, and Tetramethrin, which were flagged with a non-censoring qualifier. Replicates on matrix spikes were used to evaluate precision and were generally good, less than the target 35% average RSD, except Allethrin and Cyhalothrin, lambda total, which were flagged with a non-censoring qualifier.

Overall the other trace elements dataset was acceptable. MDLs were sufficient with only dissolved selenium having non-detects (1 out of 21 samples; 5% ND). No blank contamination was observed except in two of the equipment blanks for total copper; one at a concentration equal to the MDL (0.08 µg/L), the other at less than two times the method blank (0.125 µg/L). Precision and accuracy metrics were within MQOs except for the metric accuracy for Hardness (recovery error 21%), which was flagged with a censoring qualifier. The ratio of dissolved to total concentrations can help characterize the sources and environmental processes of contaminants, and ratios >100% (i.e., dissolved concentrations greater than totals) may indicate some analytical problems with one or both fractions. Dissolved copper results ranged from 4% to 69% of the total results, with the majority being less than 50%. Dissolved selenium results ranged from 57% to 102% of the total results; dissolved and total selenium results for San Leandro Creek on 11/21/2012 were both 0.19 µg/L. Lower Marsh Creek selenium dissolved and total results from 4/5/2013 were 0.51 and 0.5 µg/L, respectively.

5.2. Climate and flow at the sampling locations during water years 2012 and 2013

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 (McKee et al., 2003). Given monitoring programs for concentrations or loads do not normally continue for such a long period, 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. In general, high magnitude (high intensity or long duration) events occur infrequently and thus are usually poorly represented in datasets yet for most pollutants, these types of events usually transport the majority of a decadal scale load. This occurs because the discharge-load relation is described by a power function and therefore storms and wet years with larger discharge have a profound influence on the estimate of mean annual load for a given site and will likely confound any comparisons of loads between sites unless adequately characterized. However, if it is assumed that this is consistently true for all sites, comparisons across sites will be more valid.

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 (the exemplary example in this group is Marsh Creek in relation to PCBs). In contrast, a longer sampling period spanning a wider climatic variability will be required 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) may also fall into this category.

Unfortunately, during the study to date, winter seasons have been very dry relative to average annual conditions with all observations to-date made during years of <89% mean annual precipitation or flow (Table 5). For example, Lower Marsh Creek experienced just 22% of mean annual runoff in WY 2012 and 73% of mean annual run-off in WY 2013. However, there have been some notable storms, particularly those occurring during late November and December of WY 2013. For example, approximately 65% of the total wet season rainfall fell on Sunnyvale East Channel in the span of less than one month. Loads of pollutants were disproportionately transported during such events; at Sunnyvale East Channel, 88%, 92% and 83% of the total wet season sediment, PCBs and mercury loads were transported during those larger November and December storms. However, despite these larger individual storm events, at this time, any effort to estimate long-term averages for each site will likely result in estimates that are biased low due to observations during relatively dry and therefore benign flow production, sediment erosion and transport conditions.

Table 5. Climate and flow during sampling years to-date at each sampling location.

		Marsh Creek[2]	**North Richmond Pump Station[3]**	**San Leandro Creek[4]**	**Guadalupe River[5]**	**Sunnyvale East Channel[6]**	**Pulgas Creek Pump Station[7]**
Rainfall (mm) (% mean annual)	WY 2012	321 (70%)	No data	486 (75%)	179 (47%)	224 (58%)	No data
	WY 2013	278 (61%)	508 (89%)	342* (52%)	223 (59%)	259* (67%)	378* (78%)
	Mean Annual	457	570	652	378	387	488
Runoff (Mm^3) (% mean annual)	WY 2012	1.87 (22%)	No data	5.47	38.0 (68%)	1.07	No data
	WY 2013	6.23 (73%)	0.76	8.81	45.45 (82%)	1.79	0.21
	Mean Annual	8.51	No data	No data	55.6	No data	No data

[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

5.3. 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. Sampling to-date 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). In some cases non-detects and quality assurance issues continue to confound robust interpretations. This section explores those issues through synthesis of data collected across all six sampling locations to date to provide support for rationale for continued sampling in relation to answering management questions.

Concentrations of pollutants typically vary over the course of a storm, between storms of varying magnitudes, and are dependent on related discharge, sediment and source-related transport processes. Thus, it is important to sample at 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 aims to collect pollutant concentration data from 12 storms over the span of three years, with priority pollutants sampled at an average of four samples per storm for a total of 48 samples collected during the monitoring term. Sampling at the six locations to date has included sampling between one and six storm events at each location. Given the small sample size and varying sample sizes between sites, the following synthesis should be considered qualitative at this time; data collection during WY 2014 will likely provide further insights into pollutant characteristics at single sites and between sites.

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 94% or better, as were detections of several of the "tier II" pollutants (total and dissolved copper and selenium, PAHs and PBDEs) (Table 6). 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 (except Pulgas Creek Pump Station where Fipronil was not detected in the one sample to-date).

The two sampling locations added this year (North Richmond and Pulgas Creek pump stations), have the lowest mean SSC; whereas pollutant concentrations are relatively high for these watersheds (e.g. PCBs at Pulgas Creek Pump Station). As a result, the particle ratio (turbidity or SSC to pollutant; discussed further in section 5.5) was higher relative to other watersheds with similar pollutant concentrations but greater SSC. Given the high imperviousness and small size of these watersheds, although few storms have been sampled at these locations, it is unlikely great variation in SSC will be observed in future sampling efforts.

The maximum PCB concentration of the dataset to date (176 ng/L) was collected in Sunnyvale East Channel, which also has the greatest mean PCB concentration of the six locations; consistent with the high ranking assigned to Sunnyvale East Channel based on the WY 2011 reconnaissance study of 17 watersheds distributed across four Bay Area counties (McKee et al., 2012). However, sampling at Pulgas Creek Pump Station has so far captured only one relatively small storm event; future monitoring at this location will likely indicate higher PCB concentrations until management actions take effect. Guadalupe River has mercury mines in the upper watershed and is a known mercury source to the San Francisco Bay, explaining the high mercury and, possibly, methylmercury concentrations in this watershed. Less well understood is San Leandro Creek, which has mercury and methylmercury concentrations nearly as high as Guadalupe River. Continued sampling under more variable storm and climatic conditions in San Leandro Creek may improve our understanding of source-release-transport processes of mercury in this watershed. It is also worth noting (with regard to the tier I priority analytes) that phosphorus

Table 6. Synthesis of concentrations of pollutants of concern based on all samples collected to-date at each sampling location.

		Marsh Creek		North Richmond Pump Station		San Leandro Creek		Guadalupe River		Sunnyvale East Channel		Pulgas Creek Pump Station	
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	81 (99%)	243 (27.5)	41 (95%)	45.7 (8.48)	81 (94%)	145 (18.5)	82 (100%)	161 (18.3)	62 (97%)	302 (66.1)	15 (100%)	33.3 (8.54)
∑PCB	ng/L	22 (100%)	1.25 (0.258)	12 (100%)	12.0 (2.05)	28 (100%)	9.45 (1.50)	23 (100%)	14.0 (3.63)	18 (100%)	51.3 (12.9)	4 (100%)	34.7 (10.1)
Total Hg	ng/L	25 (100%)	45.8 (11.5)	12 (100%)	27.7 (7.10)	28 (100%)	145 (35.7)	24 (100%)	210 (50.1)	18 (100%)	52.8 (12.9)	6 (100%)	10.5 (2.82)
Total MeHg	ng/L	19 (95%)	0.306 (0.076)	6 (100%)	0.118 (0.029)	18 (100%)	0.438 (0.099)	17 (100%)	0.438 (0.082)	12 (92%)	0.251 (0.061)	6 (100%)	0.178 (0.041)
TOC	mg/L	24 (100%)	7.13 (0.416)	12 (100%)	7.46 (0.970)	28 (100%)	7.13 (0.453)	24 (100%)	7.55 (0.657)	18 (100%)	6.10 (0.369)	4 (100%)	10.3 (2.26)
NO3	mg/L	24 (96%)	0.579 (0.045)	12 (100%)	1.13 (0.245)	29 (100%)	0.429 (0.094)	24 (83%)	0.919 (0.150)	18 (100%)	0.287 (0.022)	4 (100%)	0.358 (0.051)
Total P	mg/L	20 (100%)	0.438 (0.054)	12 (100%)	0.276 (0.013)	25 (100%)	0.34 (0.035)	20 (100%)	0.434 (0.044)	19 (100%)	0.422 (0.078)	4 (100%)	0.15 (0.035)
PO4	mg/L	24 (100%)	0.098 (0.008)	11 (100%)	0.168 (0.013)	29 (100%)	0.09 (0.005)	24 (100%)	0.105 (0.007)	18 (100%)	0.102 (0.005)	4 (100%)	0.066 (0.010)
Hardness	mg/L	4 (100%)	189 (8.86)	-	-	7 (100%)	46.0 (6.55)	4 (100%)	136 (9.31)	2 (100%)	56.3 (4.90)	-	-
Total Cu	µg/L	6 (100%)	16.7 (4.10)	3 (100%)	15.3 (2.94)	7 (100%)	19.6 (4.36)	6 (100%)	19.8 (3.74)	4 (100%)	20.0 (4.16)	1 (100%)	30.0 (-)
Dissolved Cu	µg/L	6 (100%)	2.868 (0.792)	3 (100%)	6.367 (1.819)	7 (100%)	6.459 (0.981)	6 (100%)	4.52 (0.852)	4 (100%)	6.79 (2.70)	1 (100%)	20.0 (-)
Total Se	µg/L	6 (100%)	0.783 (0.128)	3 (100%)	0.397 (0.098)	7 (100%)	0.213 (0.027)	6 (100%)	1.46 (0.392)	4 (100%)	0.450 (0.041)	1 (100%)	0.180 (-)
Dissolved Se	µg/L	6 (100%)	0.694 (0.111)	3 (100%)	0.363 (0.098)	7 (100%)	0.149 (0.018)	6 (100%)	1.21 (0.42)	4 (100%)	0.343 (0.018)	1 (100%)	0.17 (-)
Carbaryl	ng/L	6 (33%)	4.83 (3.08)	3 (100%)	23.7 (8.41)	7 (29%)	3.43 (2.26)	6 (83%)	27.1 (9.50)	4 (75%)	12.8 (4.77)	1 (100%)	204 (-)
Fipronil	ng/L	6 (100%)	11.6 (1.52)	3 (33%)	1.33 (1.33)	7 (86%)	6.14 (1.42)	6 (100%)	10.1 (2.34)	4 (75%)	6.00 (2.45)	1 (0)	-
∑PAH	ng/L	3 (100%)	267 (120)	3 (100%)	952 (397)	3 (100%)	3327 (1142)	4 (100%)	614 (194)	2 (100%)	1322 (32.8)	4 (100%)	614 (194)

		Marsh Creek		North Richmond Pump Station		San Leandro Creek		Guadalupe River		Sunnyvale East Channel		Pulgas Creek Pump Station	
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)**
∑PBDE	ng/L	3 (100%)	29.2 (13.9)	3 (100%)	2340 (2340)	4 (100%)	44.6 (18.0)	3 (100%)	39.1 (16.5)	2 (100%)	19.8 (15.0)	4 (100%)	45.8 (24.9)
Delta/ Tralo-methrin	ng/L	6 (83%)	1.70 (0.820)	3 (100%)	2.52 (0769)	6 (67%)	0.652 (0.308)	6 (50%)	0.737 (0.372)	3 (67%)	2.47 (1.23)	1 (0%)	-
Cypermethrin	ng/L	6 (83%)	14.6 (10.9)	3 (100%)	3.18 (0.651)	7 (29%)	0.214 (0.159)	6 (50%)	0.917 (0.547)	4 (50%)	2.10 (1.28)	1 (100%)	0.900 (-)
Cyhalothrin lambda	ng/L	6 (83%)	1.37 (0.551)	3 (100%)	0.767 (0.273)	6 (33%)	0.693 (0.635)	6 (67%)	0.483 (0.227)	3 (67%)	1.23 (0.722)	1 (0%)	-
Permethrin	ng/L	6 (83%)	7.70 (2.75)	3 (100%)	12.0 (2.88)	7 (71%)	4.86 (1.73)	6 (67%)	10.4 (3.95)	4 (100%)	24.1 (8.78)	1 (100%)	2.90 (-)
Bifenthrin	ng/L	6 (100%)	91.5 (38.1)	3 (100%)	5.98 (1.23)	7 (86%)	10.3 (4.07)	6 (83%)	5.64 (1.97)	4 (75%)	8.68 (3.68)	1 (100%)	1.30 (-)

Analyzed but not detected: Fenpropathrin, Esfenvalerate/ Fenvalerate, Cyfluthrin, Allethrin, Prallethrin, Phenothrin, and Resmethrin
All Hardness results in WY 2013 were censored.

concentrations in most of the six watersheds appear greater than elsewhere in the world under similar land use scenarios, perhaps attributable to geological sources (McKee and Krottje, 2005).

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 2-8 fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Maximum PBDE concentrations in North Richmond Pump Station were 37- to 96-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).

Concentration sampling to date at the six locations have in part confirmed previously known or suspected pollutant sources (e.g. mercury in Guadalupe, PCBs in Sunnyvale East Channel). Concentration results to date have also raised some questions about certain pollutants in certain 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 is necessary to more confidently characterize pollutants in those watersheds. With a more targeted sampling approach in future water years based on storm variability and data that are still lacking to answer management questions adequately (see section 6), it is expected that this monitoring study will produce a robust characterization of pollutants in these watersheds.

5.4. Loads of pollutants of concern computed for each sampling location

One of the primary goals of this project and key management questions 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 the relationship between climate (manifested as either rainfall and 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 is currently confounded by small sample datasets during climatically dry years. At this time, comparison should therefore be considered qualitative; with subsequent years of sampling an attempt at computing long-term average loads for each sampling location will likely be made. Accepting these caveats, the following observations are made on the total wet season loads estimates at the six locations.

Comparison of 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 Pump Station is the smallest watershed in the study and has the lowest total wet season load (except for TOC in which the load is similar to North Richmond Pump Station) (Table 7). As another example, methylmercury in San Leandro Creek (8.9 km2) and Guadalupe River (236 km2) have similar concentrations but Guadalupe River discharges 10x the total mass of methylmercury given the much greater overall discharge of runoff volume and sediments.

Table 7. Loads of pollutants of concern during the sampling years to-date 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)	Mean annual loads confidence	Main issues
Marsh Creek	2012	1.39	226	9,467	1.21	44.4	0.454	833	155	480	Moderate (PCBs) Low (Hg)	Lack of data on storms that cause run-off through the upper watershed reservoir.
	2013	5.82	2,600	39,682	16.2	594	1.90	3,491	652	4,020		
North Richmond Pump Station	2012	-	-	-	-	-	-	-	-	-	Moderate	Limited data on first flush conditions and generally during more intense storms. Surprisingly elevated PDBE concentrations.
	2013	0.763	34.4	5,709	7.90	16.1	0.113	863	130	211		
San Leandro Creek	2012	3.99	114	26,560	11.7	137	0.772	1,515	367	843	Low	Lack of a robust discharge rating curve; lack of sampling during reservoir release and during more intense storms.
	2013	8.81	218	58,674	22.6	280	1.52	3,348	811	1,671		
Guadalupe River	2012	25.8	2,116	146,483	113	2,033	8.20	16,347	2,243	7,042	High (PCBs) Low (Hg)	Lack of high intensity storms samples for Hg.
	2013	35.5	4,352	237,227	334	5,603	15.2	22,482	3,440	12,099		
Sunnyvale East Channel	2012	1.07	36.7	6192	14.6	18.4	0.181	263	114	241	Low	Few storms sampled.
	2013	1.79	672.5	10352	73.1	109	0.538	440	190	865		
Pulgas Creek Pump Station	2012	-	-	-	-	-	-	-	-	-	Low	Few storms sampled.
	2013	0.206	11.2	5967	9.3	3.2	0.050	75.6	32.4	34.3		

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12 and 10/19/12 – 4/18/13.

[b] North Richmond Pump Station (WY 2013 only) and Guadalupe River (WY 2012 and 2013) wet season loads are reported for the full period of record each water year (10/01/11 – 4/30/12 for WY 2012 and 10/01/12 – 4/30/13 for WY 2013).

[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 11/01/12 – 4/18/13.

[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 10/01/12 – 4/30/13.

[e] Pulgas Creek Pump Station South WY 2013 wet season loads are estimates provided for the entire wet season (10/01/12 – 4/30/13) however monitoring only occurred during the period 12/17/2012 – 3/15/2012. 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 with two years of data highlighted how loads estimates can be highly variable even during two drier than average years. Additionally, the size and intensity of the storm events in the different regions where the sampling sites are located greatly impacted the load variation from year to year and between sampling locations. For example PCBs and mercury in San Leandro Creek and Guadalupe River were approximately 2x greater in WY 2013 than WY 2012, whereas loads of those same pollutants were 5 – 20x larger in WY 2013 in Lower Marsh Creek and Sunnyvale East Channel, where the late November and December 2012 storms were moderately large events. Even when normalized to total discharge (in other words, the flow-weighted mean concentration [FWMC]), Sunnyvale East Channel transported 11x as much sediment in WY 2013 than WY 2012, whereas the FWMC of suspended sediment in San Leandro Creek was the same in both water years. This observation suggests that any attempt at this time to estimate long-term loads for Sunnyvale East channel will be biased low. In this manner, the relationship between FWMC and discharge (either at the annual or individual flood scale) can be used as an indicator of when enough data has been collected to characterize the site adequately to answer our management questions.

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 7 note our current level of confidence in the mean annual loads estimates as well as the main issues at each site which warrant the confidence level rating. 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.

5.5. 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). Unfortunately, the comparison of loading estimates between watersheds in relation to these key management needs is confounded by variations in climate and how well samples collected to date represent source-release-transport processes for each watershed and pollutant (see section 5.2). With these caveats accepted, a preliminary comparison based on data collected during water year 2012 and 2013 was provided in this section. It is anticipated that these comparisons will change as additional data are collected in WY 2014, and, should data be sufficient, the best comparisons will be made in next year's report update based on (where/if possible) climatically averaged data.

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 examples) and when there is relatively little variation in the particle ratios between water years or storms (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 portions of San Leandro Creek watershed and run-off from the Guadalupe River watershed exhibit the greatest particle ratios for total mercury (Figure 2). Sunnyvale East Channel, Marsh Creek and Pulgas Creek 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 and an insufficient number of samples have yet been collected from Pulgas Creek Pump Station to be confident that the mercury transport processes are adequately characterized. With the exception of the addition of two more sampling stations (North Richmond Pump Station and Pulgas Creek Pump Station), the relative nature of these rankings has not changed in relation to the previous report (McKee et al., 2013).

In contrast, for the sum of PCBs, Pulgas Creek Pump Station and Sunnyvale East Channel exhibit the highest particle ratios among these six watersheds, with urban sourced run-off from Guadalupe River and North Richmond Pump Station ranked 3rd and 4th as indicated by the turbidity-PCB graphical relation

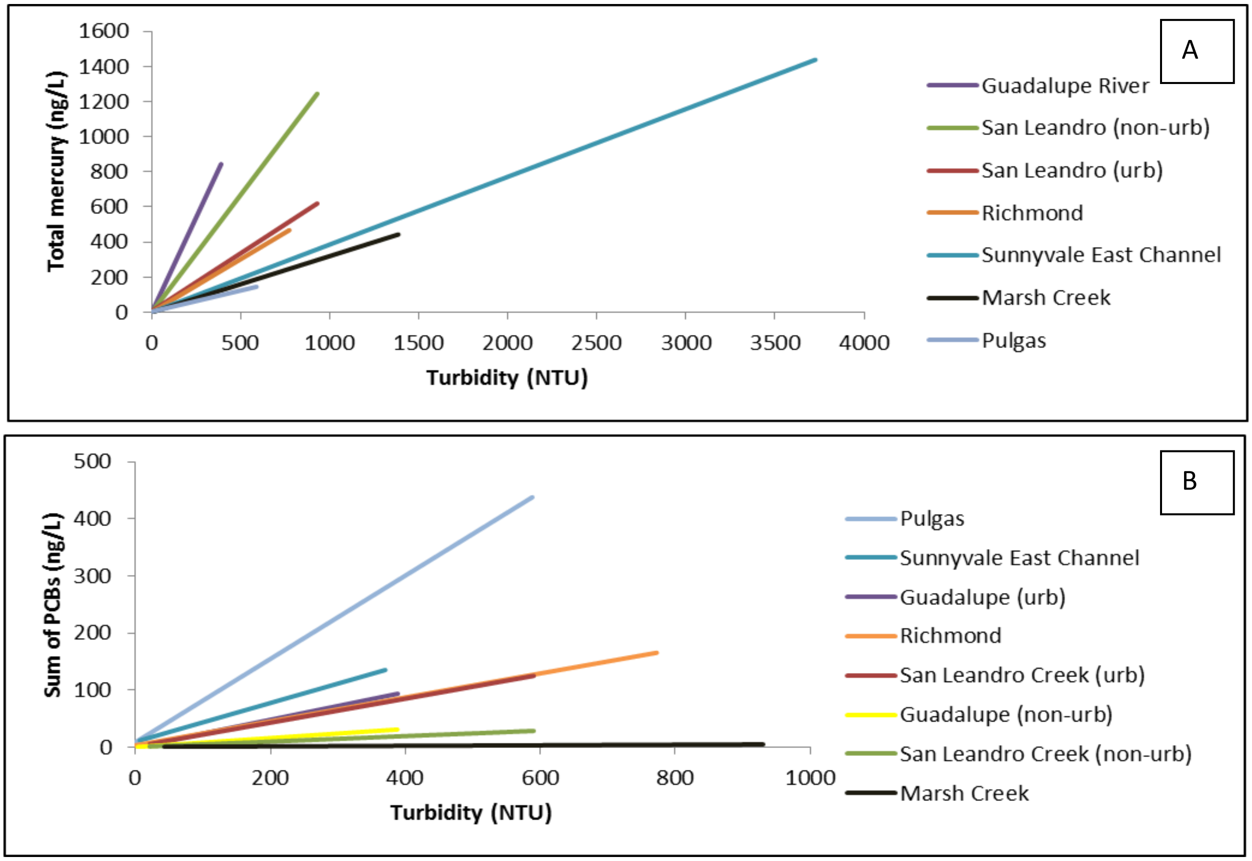

Figure 2. Comparison of regression slopes between watersheds based on data collected during sampling to-date A) total Mercury and B) PCBs (Note Sunnyvale, Richmond and Pulgas includes data for water year 2013 only; Pulgas turbidity maximum is storm maximum not record maximum). Note these comparisons will likely change once additional data are collected in subsequent water years.

(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 Hg, new data collected during WY 2013 did alter 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 large confidence intervals (not shown) and the relatively low numbers of samples collected to-date during relatively dry years, the relative nature of these regression equations may change in the future as more samples are collected.

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 8) in relation to ease of management. This method is much more highly subject to climatic variation than the turbidity function/particle ratio method for ranking and would ideally be done on climatically averaged loads (not yet done). Despite quite large differences in unit runoff between the watersheds during water year 2012 and 2013, in a general sense, the relative rankings for PCBs exhibit a similar ranking to the particle ratio method; Pulgas Creek 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, San Leandro Creek, and Richmond pump station exhibit the highest currently estimated yields corroborating the evidence from the particle ratio method. However, it is anticipated that the relative nature of the area-normalized loads will be subject to greater change in the event that sampling during WY 2014 captures rainstorms of greater magnitude and less frequent recurrence interval. In particular, the relative rankings for suspended sediment loads normalized by unit area could change substantially with the addition of data from a water year that is closer to or 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 to date 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.
- 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 will need to evolve.

Table 8. 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). Note these yield estimates are based on the average of data from water year 2012 and 2013. Quantitative comparison between watersheds is confounded by dry climatic conditions and differing unit runoff. With additional years of sampling, climatically-averaged area-normalized loads may be generated.

	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)**
Pulgas Creek Pump Station [e]	*0.35*	*19.1*	*10218*	*15.9*	*5.53*	*0.0858*	*130*	*55.6*	*58.8*
North Richmond Pump Station [b]	0.39	17.6	2913	4.03	8.22	0.0575	440	66.2	107
Sunnyvale East Channel [d]	0.10	24.0	559	2.96	4.31	0.0243	23.7	10.3	37.4
San Leandro Creek [c]	0.72	18.7	4788	1.93	23.4	0.129	273	66.1	141
Guadalupe River [b]	0.13	13.7	813	0.947	16.2	0.0496	82.3	12.0	40.6
Marsh Creek [a]	0.04	16.9	294	0.104	3.82	0.0141	25.9	4.83	26.9

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12 and 10/19/12 – 4/18/13.

[b] North Richmond Pump Station (WY 2013 only) and Guadalupe River (WY 2012 and 2013) wet season loads are reported for the full period of record each water year (10/01/11 – 4/30/12 for WY 2012 and 10/01/12 – 4/30/13 for WY 2013).

[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 11/01/12 – 4/18/13.

[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 10/01/12 – 4/30/13.

[e] Pulgas Creek Pump Station South WY 2013 wet season loads are estimates provided for the entire wet season (10/01/12 – 4/30/13) however monitoring only occurred during the period 12/17/2012 – 3/15/2012. 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.

6.2. What data gaps remain at current loads stations?

With regard to addressing the main management endpoints (single and regional watershed loads and baseline data for trends) that caused the monitoring design described by the MYP (BASMAA, 2011) and updated twice [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? Is the data representative of the source-release-transport processes of the pollutant of interest? In reality, these two factors tend to juxtapose and after two years of monitoring, some data gaps remain for each of the monitoring locations.

- Guadalupe River watershed has been sampled at the Hwy 101 location during eight water years (WY 2003-2006, 2010-2013) 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 high intensity storms only; further sampling of relatively frequent smaller runoff events is unnecessary. The current sampling design is not cost-effective for gathering improved information to support management decisions in this watershed.
- San Leandro Creek watershed has been sampled for two WYs to-date. San Leandro Creek, received poor quality ratings on the quality of discharge information and completeness of turbidity data. The largest weakness is the lack of velocity measurements to adequately describe the stage-discharge rating curve 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 release during WYs 2012 and 2013 has been proportionally large. 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.
- Marsh Creek watershed has been sampled for two WYs to-date. Continuous turbidity data were rated excellent at Lower Marsh Creek; no changes to monitor design for turbidity are necessary. Ample lower watershed stormwater runoff data are 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. Sampling during WY 2014 would ideally be focused on storms of greater intensity preferably when spillage is occurring from the upstream reservoir. Beyond WY 2014, the sampling design should be revisited with the objective of increased cost efficiency for data gathering to support management questions.
- North Richmond Pump Station watershed has been sampled for just one year (although data exists from a previous study [Hunt et al., 2012]). Although some data exist, further data in

relation to early season (seasonal 1^{st} flush or early season storms) would help estimate loads averted from diversion of early season storms to wastewater treatment. Further data collection in relation to high concentrations of PBDEs is necessary to verify the existence of PBDEs source in this watershed. Providing these types of data can be collected during WY 2014, an alternative sampling design could be considered.

- At Pulgas Creek Pump Station and Sunnyvale East Channel (two locations with much below average rainfall during sampling to date), more storm event water quality monitoring is needed for establishing confidence in particle ratios, pollutant loads, FWMCs, and yields. Sunnyvale East Channel and Pulgas Creek Pump Station received poor quality ratings on completeness of turbidity data: Sunnyvale East Channel had a full record but a large portion of data censored due to spikes and Pulgas Creek Pump Station recorded turbidity during only three of the seven wet season months in large part due to instrumentation failures. The Pulgas Creek sampling location also received a low rating on representativeness given how turbidity records could fluctuate multiple times from one reading to the next. Pulgas Creek Pump Station also had poor repeatability between manual and sensor collected data and improvements to the monitoring set-up should be considered for next wet season. Improvements have been recommended for the WY 2014 winter season for both sampling sites. The existing sampling design (with ongoing annual improvements as lessons are learned) may be warranted for these two watersheds for additional years.

6.3. Next Steps

Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board (and discussion at the October 2013 SPLWG meeting) 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 likely not appropriate for this increasing management focus. During the first quarter of 2014, the STLS will be reviewing lessons learned to-date and will be developing recommendations for alternative monitoring designs and sampling locations (in concert with the RWSM modeling design). Based on recent findings, there is evidence to support effort reduction at Lower Marsh Creek and Guadalupe River as well as development of monitoring decision points for determining when sufficient data has been collected to address MQ2 (single watershed and regional pollutant loads), and to provide baseline data to support MQ3 (future trends in relation to management actions). Additional information is needed for Pulgas Creek Pump Station, Sunnyvale East Channel, North Richmond Pump Station and San Leandro Creek, especially during early season/high-intensity rain events. If the right climatic conditions and field work focus occurs during WY 2014, these data gaps may be addressed sufficiently. A revised monitoring design will need to be robust enough to continue to support MQ 1, 2, and 3 for PCBs and Hg and emerging pollutants of interest as well as increasing information to support MQ4.

There are various alternative monitoring designs that are more cost-effective for the 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. The challenge for the STLS and SPWLG is finding the right balance between the different alternatives within budget constraints. Options include:

- Loads monitoring
    - Changing to a rotating site approach (e.g. all six monitoring locations are maintained for stage and turbidity but each monitored fewer years for pollutants)
    - Changing monitoring frequency (e.g. opportunistic sampling for specific events with overall reduction in effort but increased informational outcomes)
    - Reducing the number of sites (currently six)
    - Adding new sites of specific interest (e.g. to determine load magnitude in relation to upstream pollution or downstream beneficial use impact)
    - Dropping loads monitoring completely
- Reconnaissance monitoring design
    - Make improvements to the WY 2011 design:
        - Increase the number of samples from 4-7 to 8-14 per site
        - Selectively add measurements of stage and possibly velocity
    - Focus on sampling a subset of feasible pump stations downstream from industrial land use (73 possible locations identified). Pump stations have the advantage of forcing unidirectional flow very near the Bay margin but have disadvantages in terms of complex flow patterns, confined space, permission or limited access during work hours. Lessons learned at the North Richmond and Pulgas Creek Pump Stations during the current study will be valuable.
    - Rotate in single land use/ source area “high opportunity” sites.

It is likely that a sampling design that simultaneously addresses all four STLS management questions will require a compromise between the different monitoring options (i.e. some loads monitoring effort retained). However, 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. 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). Peak annual flows for the previous 13 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 Mm3 (WY 2009) and 26.8 Mm3 (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 as 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 WY 2012 and 2013 (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 water year 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 based on preliminary USGS data and was much greater relative to the first year of monitoring. 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 both water years of observations to-date are likely exceeded most years in this watershed. Rainfall data corroborates this assertion; rainfall during WY 2012 and 2013 respectively was 70% and 71% 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) 1992-2013. 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 water years 2012 and 2013, discharge through the reservoir occurred on March, November, and December 2012.

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 pm. 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 WY 2012 and 2013, 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 medium or larger storms.

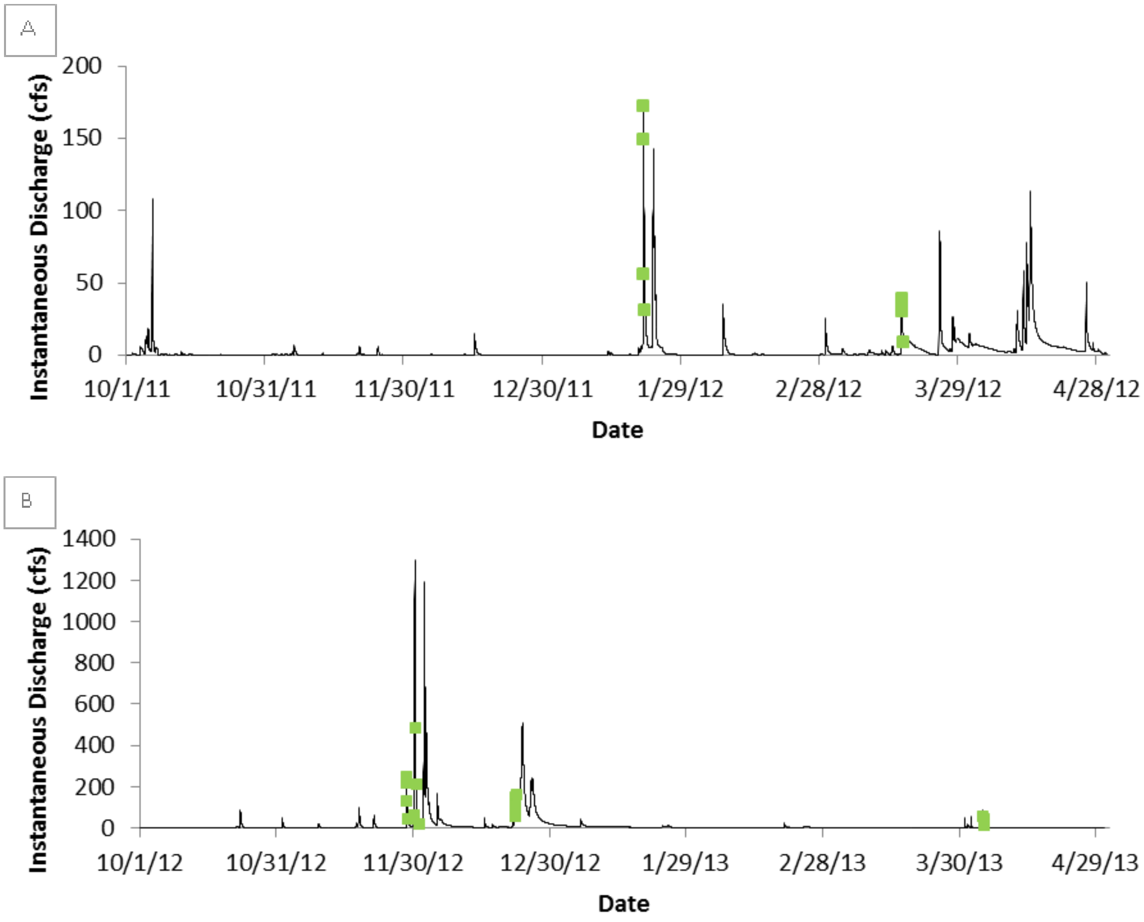

Figure 3. Flow characteristics in Marsh Creek during water year 2012 (A) based on published data and for the water year 2013 (B) based on preliminary 15 minute data provided by the United States Geological Survey, gauge number 11337600) with sampling events plotted in green. Note, USGS normally publishes finalized data for the permanent record in the spring following the end of each water year.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. SSC peaked at 1312 mg/L during the 4/13/12 late season storm and at 1849 mg/L on 12/02/12 at the same time 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. These 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 levels of urbanization but potentially impacted by mercury residues from historic mining upstream. Summary statistics (Table 9) 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 while maximum mercury concentrations (252 ng/L) were similar to concentrations found in mixed land use watersheds (Lent and McKee, 2011). Maximum MeHg concentrations (0.407 ng/L during WY 2012 and 1.2 ng/L during WY 2013 were greater 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). Nutrient concentrations appear to be reasonably typical of other Bay Area watersheds (McKee and Krottje, 2005). As is 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 (McKee and Krottje, 2005). 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 during both years.

A similar style of first order quality assurance 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. It was surprising to see PBDE concentrations so much greater in the second year of sampling relative to the first year, possibly just an artifact of the randomness sample capture and small sample numbers. 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). Pyrethroid concentrations of Delta/ Tralo-methrin 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). It was a little surprising to see cypermethrin concentrations more than 4-fold lower in WY 2013 relative to WY 2012. Again, this may just be an artifact of the randomness of sample capture. 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 Water Year 2012 and four storm events in Water Year 2013. No significant reductions in the survival, reproduction and growth of three of four test species were observed during WY 2012. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during both WY 2012 storm events. Water Year 2013 had complete mortality of *Hyalella Azteca* between 5 and 10 days of exposure to storm water (0% survival compared to a 100% laboratory survival rate) during all four storm events. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of sediments in receiving waters. Additionally,

Table 9. Summary of laboratory measured pollutant concentrations in Marsh Creek during WY 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	27	96%	ND	930	180	297	276	54	100%	3.3	1040	167	217	230
∑PCB	ng/L	7	100%	0.354	4.32	1.27	1.95	1.61	15	100%	0.240	3.46	0.676	0.927	0.856
Total Hg	ng/L	8	100%	8.31	252	34.6	74.3	85.2	17	100%	1.90	120	19.0	32.5	33.9
Total MeHg	ng/L	5	100%	0.085	0.407	0.185	0.218	0.120	14	94%	ND	1.20	0.185	0.337	0.381
TOC	mg/L	8	100%	4.6	12.4	8.55	8.34	2.37	16	100%	4.30	9.50	6.55	6.52	1.60
NO3	mg/L	8	100%	0.470	1.10	0.635	0.676	0.202	16	94%	ND	1.0	0.53	0.53	0.22
Total P	mg/L	8	100%	0.295	1.10	0.545	0.576	0.285	12	100%	0.140	0.670	0.305	0.346	0.166
PO4	mg/L	8	100%	0.022	0.120	0.056	0.065	0.030	16	100%	0.046	0.180	0.110	0.114	0.036
Hardness	mg/L	2	100%	200	203	189	202	2.12	-	-	-	-	-	-	-
Total Cu	µg/L	2	100%	13.8	27.5	20.6	20.6	9.70	4	100%	3.80	30.0	12.5	14.7	11.0
Dissolved Cu	µg/L	2	100%	4.99	5.62	5.31	5.31	0.445	4	100%	1.30	2.40	1.45	1.65	0.520
Total Se	µg/L	2	100%	0.647	0.784	0.716	0.716	0.097	4	100%	0.525	1.40	0.670	0.816	0.395
Dissolved Se	µg/L	2	100%	0.483	0.802	0.643	0.643	0.226	4	100%	0.510	1.20	0.585	0.720	0.323
Carbaryl	ng/L	2	50%	-	-	-	16.0	-	4	25%	ND	13.0	0	3.25	6.50
Fipronil	ng/L	2	100%	7.00	18.0	12.5	12.5	7.78	4	100%	10.0	13.0	10.8	11.1	1.44
∑PAH	ng/L	1	100%	-	-	-	494	-	2	100%	85.7	222	154	154	96
∑PBDE	ng/L	1	100%	-	-	-	20.0	-	2	100%	11.2	56.4	33.8	33.8	32.0
Delta/ Tralo-methrin	ng/L	2	100%	0.954	5.52	3.23	3.23	3.23	4	75%	ND	2.20	0.750	0.925	0.943
Cypermethrin	ng/L	2	50%	-	-	-	68.5	-	4	100%	1.80	13.0	2.15	4.78	5.49
Cyhalothrin lambda	ng/L	2	50%	-	-	-	2.92	-	4	100%	0.500	3.20	0.800	1.33	1.27
Permethrin	ng/L	2	100%	3.81	17.3	10.6	10.6	9.54	4	75%	ND	12.0	6.55	6.28	6.11
Bifenthrin	ng/L	2	100%	25.3	257	141	141	163	4	100%	27.0	150	45.0	66.8	56.2

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.

one Water Year 2013 sample showed a significant reduction in fathead minnow survival (57.5% compared to a 90% laboratory survival). No significant effects were observed for the crustacean *Ceriodaphnia dubia* or the algae *Selenastrum capricornutum* during these storms.

8.1.3. Marsh Creek preliminary loading estimates

Site-specific methods were developed for computed loads (Table 10). 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 an improving understanding of pollutant transport processes for the site. Preliminary monthly loading estimates correlate well with monthly discharge (Table 11). There are no data available for October and November 2011 because monitoring equipment was not installed until the end of November. 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. At this time, all load estimates should be considered preliminary. Additionally (and, in this case, more importantly), if data collected during WY 2014 is able 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. In any case, WY 2014 data will be used to improve our understanding of rainfall-runoff-pollutant transport processes for all the pollutants and used to recalculate and finalize loads for WYs 2012 and 2013. Regardless of these improvements however, given the very dry flow conditions of WY 2012 and 2013 (see discussion on flow above), preliminary loads presented here may be considered representative of dry conditions.

Table 10. Regression equations used for loads computations for Marsh Creek during water years 2012 and 2013. Note that regression equations will be reformulated with each future wet season of storm sampling.

Analyte	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	1.3	33	0.45	Regression with turbidity
Total PCBs (ng/NTU)	0.0089		0.84	Regression with turbidity
Total Mercury (ng/NTU)	0.32		0.65	Regression with turbidity
Total Methylmercury (ng/L)	0.327			Flow weighted mean concentration
Total Organic Carbon (mg/L)	6.82			Flow weighted mean concentration

Analyte	Slope	Intercept	Correlation coefficient (r^2)	Notes
Total Phosphorous (mg/NTU)	0.0016	0.19	0.57	Regression with turbidity
Nitrate (mg/L)	0.6			Flow weighted mean concentration
Phosphate (mg/L)	0.112			Flow weighted mean concentration

Table 11. Preliminary monthly loads for Marsh Creek during water years 2012 and 2013.

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	-	-	-	-	-	-	-	-	-
	11-Nov	26	-	-	-	-	-	-	-	-	-
	11-Dec	6	0.0252	1.57	172	0.00493	0.180	0.00823	15.1	2.82	5.63
	12-Jan	51	0.318	68.3	2,169	0.389	14.2	0.104	191	35.6	130
	12-Feb	22	0.0780	6.59	532	0.0269	0.983	0.0255	46.8	8.74	19.5
	12-Mar	60	0.361	31.8	2,458	0.133	4.87	0.118	216	40.4	91.9
	12-Apr[a]	59	0.606	118	4,136	0.658	24.1	0.198	364	67.9	233
	Wet season total	198	1.39	226	9,467	1.21	44.4	0.454	833	155	480
2013	12-Oct[b]	23	0.0875	10.0	596	0.0474	1.73	0.0286	52.5	9.79	25.0
	12-Nov	96	0.989	248	6,745	1.45	53.1	0.323	593	111	448
	12-Dec	75	4.00	2,297	27,291	14.6	534	1.31	2,401	448	3,384
	13-Jan	15	0.428	24.1	2,920	0.0660	2.41	0.140	257	48.0	92.5
	13-Feb	6	0.142	5.98	970	0.00825	0.302	0.0465	85.3	15.9	28.3
	13-Mar	9	0.0721	3.79	492	0.00932	0.341	0.0236	43.2	8.07	15.2
	13-Apr[c]	19	0.098	10.8	667	0.0506	1.85	0.0320	58.7	11.0	27.5
	Wet season total	243	5.82	2,600	39,682	16.2	594	1.90	3,491	652	4,020

[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.

8.2. North Richmond Pump Station

8.2.1. North Richmond Pump Station flow

Richmond flow and discharge estimates were calculated during periods of active pumping at the station from October 1, 2012 to April 30, 2013. Flow and discharge estimates include all data collected when where the pump rate was operating at is greater than 330 RPM. 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 would 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 0.76 Mm^3 for WY 2013 (Table 14). A discharge estimate at the station for WY 2011 was 1.1 Mm^3 (Hunt et al., 2012). The rainfall to run-off ratios between the two studies was similar supporting the hypothesis that the flows and resulting load estimates from the previous study remain valid. October 2012 exhibited a lower discharge per unit rainfall, perhaps caused by a dry watershed. Water quality samples were collected during three storm events (Figure 4). Most pump-outs had one operating pump except for a few storm events where two pumps were in operation.

A number of relatively minor storms occurred during WY 2013 except during the period late November to mid-December when 15 inches of rain fell in North Richmond (74% of October-April rainfall). During water year 2013, peak flow of 210 cfs occurred on December 2, 2013 after approximately 3.8 inches of rain fell over a 63 hour period. Approximately 20 inches of rain fell during Water Year 2013. Rainfall during 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.

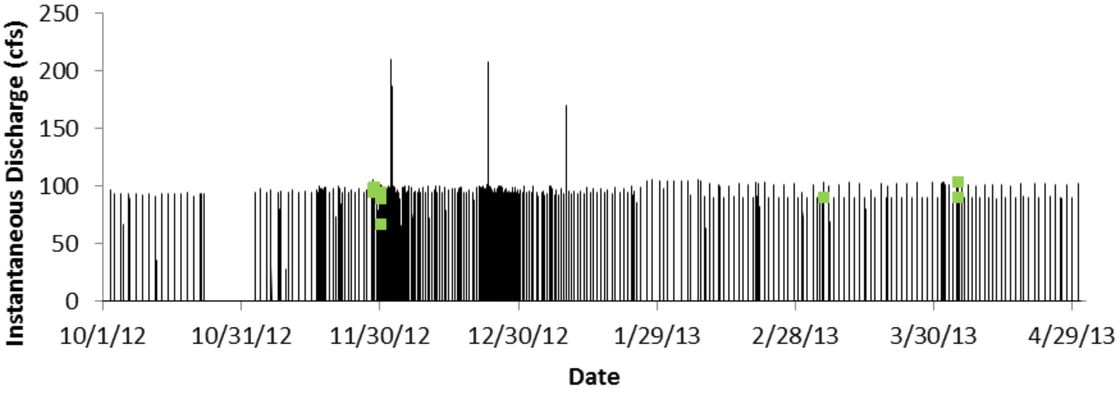

Figure 4. Preliminary flow characteristics at North Richmond Pump Station during Water Year 2013 with sampling events plotted in green. Note, flow information may be updated in the future as we continue to refine how we interpret the well depth, pump RMP, pump efficiency curves, and well geometry information.

8.2.2. North Richmond Pump Station turbidity and suspended sediment concentration

Maximum turbidity during Water Year 2013 was measured at 772 NTU which occurred during a dry flow pump out on January 24, 2013 following a low magnitude storm event of 0.22 inches on January 23. Maximum turbidity during other storm events ranged up to 428 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.

8.2.3. North Richmond Pump Station POC concentrations summary (summary statistics)

The North Richmond pump station is a 1.6 km watershed primarily comprised of industrial, transportation, and residential land uses. The land-use configuration results in a watershed that is approximately 62% covered by impervious surface. Summary statistics (Table 12) 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 in WY 2013 was 31.6 ng/L. In WY2011, the maximum concentration measured was 82 ng/L. PCB concentrations were in the range of other findings for urban locations (range 0.1-1120 ng/L) (Lent and McKee, 2011). Maximum mercury concentrations (98 ng/L) were approximately half the maximum observed concentrations during previous monitoring efforts (200 ng/L) (Hunt et al., 2012). Mercury concentrations were in the range of Zone 4 Line-A findings, another small urban impervious watershed (Gilbreath et al., 2012). Maximum MeHg concentrations in WY 2013 were 0.19 ng/L compared with WY 2011 concentrations of 0.6 ng/L (Hunt et al., 2012). 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; unlike Marsh Creek and San Leandro Creek, TOC also exhibited this pattern.

Copper, selenium, PAHs, carbaryl, fipronil, and PBDEs 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). Maximum PBDE concentrations were 50-fold greater than the greatest average observed in the five other locations of this current study and previously reported for Zone 4 Line (Gilbreath et al., 2012). These are the highest PBDE concentrations measured in Bay area stormwater to-date of any study. BDE 209 usually contributes at least 50% of the sum of BDE congeners to stormwater samples in the Bay Area. Richmond appears to be the exception to this rule. The highest concentration samples had approximately 45% BDE 209, and relatively larger amounts of 206-208 than normally observed in Bay Area stormwater samples. Although the relative contributions of 206-208 are a bit unusual, summing to approximately the 209 amount, that it occurred in two samples (albeit in the same event) in similar proportions makes it less likely that it is purely an analytical anomaly. Blanks were fairly low in 206-208 so it is unlikely that the high contribution in the Richmond samples was from blank contamination, as

Table 12. Summary of laboratory measured pollutant concentrations in North Richmond Pump Station during water year 2013.

		Water Year 2012	Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	0	41	95%	ND	213	26.5	45.7	54.3
∑PCB	ng/L	0	12	100%	4.85	31.6	10.1	12.0	7.09
Total Hg	ng/L	0	12	100%	13.0	98.0	18.5	27.7	24.6
Total MeHg	ng/L	0	6	100%	0.030	0.190	0.145	0.118	0.071
TOC	mg/L	0	12	100%	3.50	13.5	6.60	7.46	3.36
NO3	mg/L	0	12	100%	0.210	3.10	0.855	1.13	0.848
Total P	mg/L	0	12	100%	0.180	0.350	0.270	0.276	0.045
PO4	mg/L	0	11	100%	0.110	0.240	0.160	0.168	0.042
Hardness	mg/L	0	-	-	-	-	-	-	-
Total Cu	µg/L	0	3	100%	9.90	20.0	16.0	15.3	5.09
Dissolved Cu	µg/L	0	3	100%	4.40	10.0	4.70	6.37	3.15
Total Se	µg/L	0	3	100%	0.270	0.590	0.330	0.397	0.170
Dissolved Se	µg/L	0	3	100%	0.260	0.560	0.270	0.363	0.170
Carbaryl	ng/L	0	3	100%	12.0	40.0	19.0	23.7	14.6
Fipronil	ng/L	0	3	33%	ND	4.00	0	1.33	2.31
∑PAH	ng/L	0	2	100%	160	1349	754	754	840
∑PBDE	ng/L	0	2	100%	153	3362	1611	1757	2269
Delta/ Tralo-methrin	ng/L	0	3	100%	1.00	3.50	3.05	2.52	1.33
Cypermethrin	ng/L	0	3	100%	2.10	4.35	3.10	3.18	1.13
Cyhalothrin lambda	ng/L	0	3	100%	0.400	1.30	0.600	0.767	0.473
Permethrin	ng/L	0	3	100%	6.40	16.0	13.5	12.0	4.98
Bifenthrin	ng/L	0	3	100%	3.80	8.05	6.10	5.98	2.13

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.
All Hardness results in WY 2013 were censored.

those were also the samples with the highest total PBDEs of all those measured. The North Richmond watershed currently contains an auto dismantling yard and a junk/wrecking yard; possible source areas. At this time we are unwilling to sensor the data but anticipate data collected during WY 2014 helping to support or reject the magnitude of concentrations.

Similar to the other sites, carbaryl and fipronil 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). Pyrethroid concentrations of Delta/ Tralo-methrin were similar to those observed in Zone 4 Line A, whereas concentrations of Cyhalothrin lambda and Permethrin were about 6-fold and 7-fold lower respectively and concentrations of Bifenthrin were about 3-fold higher (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 (except PBDE has been flagged for further investigation).

8.2.4. North Richmond Pump Station toxicity

Composite water samples were collected at North Richmond Pump Station during three storms between Nov 28, 2012 and March 6, 2013. Two of these samples showed 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. No significant effects were observed for the crustacean *Ceriodaphnia dubia*, the algae *Selenastrum capricornutum* or fathead minnows during these storms.

8.2.5. North Richmond Pump Station preliminary loading estimates

The following methods were applied for calculating preliminary loading estimates (Table 13). During active pumpout conditions, regression equations between PCBs, total mercury, methylmercury, SSC and turbidity were used to estimate loads (Table 12). Load estimates for total phosphorous, nitrate, and phosphate utilized flow weighted mean concentration derivations. Preliminary monthly loading estimates correlate very well with monthly discharge (Table 14). Monthly discharge was greatest in December 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 (34.4 t) and PCB (7.90 g) load estimates were comparable to the Water Year 2011 estimates (29 t and 8.0 g, respectively) even thought it was a wetter year (134% MAP) (Hunt., 2012) helping to give us 1st order confidence that the computed loads are reasonable. Due to lessons learned from the previous study, there is much higher confidence in the Water Year 2013 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, loads from the present study may be considered representative of somewhat dry conditions.

Table 13. Regression equations used for loads computations for North Richmond Pump Station during water year 2013. Note that regression equations will be reformulated with each future wet season of storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mainly urban	1.293		0.78	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.21	3.1	0.71	Regression with turbidity
Total Mercury (ng/NTU)	Mainly urban	0.605		0.92	Regression with turbidity
Total Methylmercury (ng/NTU)	Mainly urban	0.0028	0.05	0.88	Regression with turbidity
Total Organic Carbon (mg/L)	Mainly urban	7.48			Flow weighted mean concentration
Total Phosphorous (mg/L)	Mainly urban	0.276			Flow weighted mean concentration
Nitrate (mg/L)	Mainly urban	1.13			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.17			Flow weighted mean concentration

Table 14. Preliminary monthly loads for North Richmond Pump Station.

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	54	0.0278	1.44	208	0.318	0.674	0.00451	31.4	4.72	7.67
	12-Nov	156	0.152	7.78	1138	1.72	3.64	0.0245	172	25.9	42.0
	12-Dec	232	0.374	20.5	2795	4.46	9.61	0.0632	422	63.5	103
	13-Jan	18	0.0641	1.29	479	0.406	0.605	0.00602	72.4	10.9	17.7
	13-Feb	18	0.0438	1.26	328	0.338	0.590	0.00493	49.5	7.45	12.1
	13-Mar	19	0.0418	0.409	312	0.195	0.191	0.00299	47.2	7.10	11.5
	13-Apr	26	0.0602	1.70	450	0.460	0.796	0.00670	68.0	10.2	16.6
	Wet season total	523	0.763	34.4	5,709	7.90	16.1	0.113	863	130	211

8.3. San Leandro Creek

8.3.1. San Leandro Creek flow

There is no historic flow record on San Leandro Creek. For the previous report that presented WY 2012 results only (McKee et al., 2013), a preliminary rating curve was developed based on discharge sampling during WY 2012 augmented by the Manning’s formula. This rating was improved this year by adding known reservoir release rates associated with consistent stage readings. However, the resulting discharge estimates are still challenged by the lack of velocity measurements at flow stages greater than 3.5 feet and therefore are deemed of poor accuracy and precision. Based on this latest version of a still preliminary rating curve, total runoff during WY 2012 for the period 11/7/11 to 4/30/12 was revised from the 4.13 Mm^3 reported previously (McKee et al., 2013) to a new estimate of 5.47 Mm^3. This total discharge was mostly a result of a series of relatively minor storms that occurred during WY 2012 (Figure 5). During WY 2012, flow peaked at 244 cfs on 1/20/12 22:50. During WY 2013, flow peaked at 338 cfs on 12/23/12 14:20 and total wet season flow was 8.81 Mm^3. 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 1600 cfs on 1/20/2012 at 23:00; a flow that has been exceeded 68% of the years on record. During, WY 2013, flow in San Lorenzo peaked at 2970 cfs on 12/2/2012 at 11:15 am; a flow of this magnitude has been exceeded 38% of the years on record. Annual flow for San Lorenzo Creek at San Lorenzo (gauge number 11181040) for WY 2012 and 2013 respectively was 95 and 99 Mm^3 both well below the long term average for the site of 169 Mm^3. Based on this evidence alone, we suggest flow in San Leandro Creek flow was likely much lower than average for both water years.

In addition to the flow response from rainfall, East Bay Municipal Utility District (EBMUD) made releases from Chabot Reservoir in the first half of the WY 2012 season indicated by the square and sustained nature of the hydrograph at the sampling location. This also occurred in December and January of WY 2013 also indicated by the square nature of the hydrograph. Despite this augmentation, it seems likely that annual flow in San Leandro Creek during both years of observation was below average and would be exceeded in 60-70% of years. Rainfall data corroborates this assertion; rainfall during WY 2012 was 19.02 inches, or 74% of mean annual precipitation (MAP = 25.55 in) based on a long-term record at Upper San Leandro Filter (gauge number 049185) for the period 1971-2010 [Climate Year (CY]). CY 2012 was ranked 17th driest in the available 57-year record (1949-present [Note 7-year data-gap during CY 1952-58]). Data for CY 2013 is not yet available.

8.3.1. 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 run-off devoid of sediment and pollutants was associated with the reservoir release. With each of the storms that occurred beginning 1/20/2012 in WY 2012, maximum storm turbidity increased in magnitude. 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. These observations provide evidence that during larger

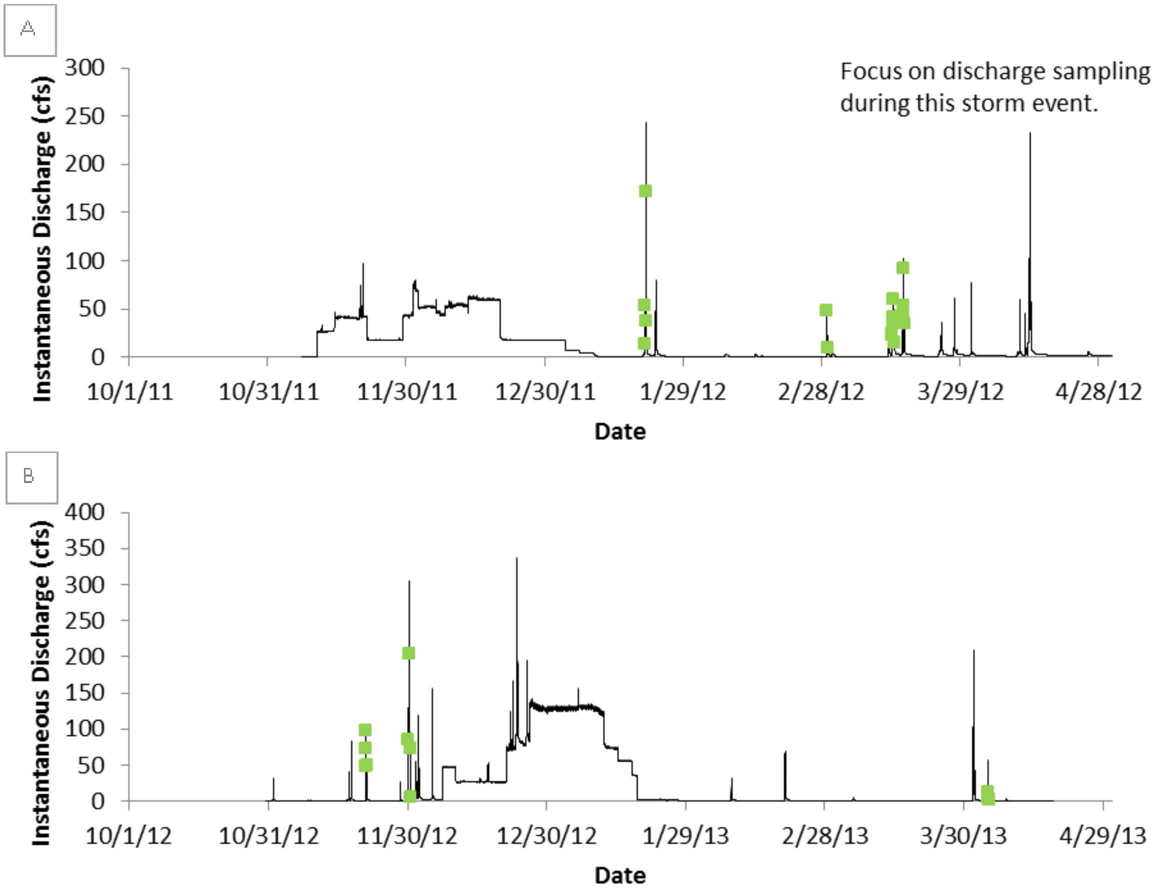

Figure 5. Preliminary flow characteristics (primary y axis) in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A) and WY 2013 (B) with sampling events plotted in green. Note, flow information will be updated in the future when additional data.

storms and wetter years, the San Leandro Creek watershed is likely capable of much greater sediment erosion and transport resulting in greater turbidity and concentrations of suspended sediment. At this time, we have no evidence to suggest that the OBS-500 instrument utilized at this sampling location (with a range of 0-4000 NTU) will not be sufficient to handle most future storms.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. Suspended sediment concentration during WY 2012 peaked at 1141 mg/L during the late season storm on 4/13/12 at 5:15 am; a peak SSC of 608 mg/L occurred on 11/30/12 at 9:45 am for WY 2013; although it should be noted that there was considerable scatter around the upper end of the turbidity-SSC regression relation thus it is possible that this will be reinterpreted with a subsequent year of data collection. 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 WY 2012 to determine if the relative concentrations are logical.

8.3.2. San Leandro Creek POC concentrations summary (summary statistics)

Summary statistics of pollutant concentrations measured in San Leandro Creek during WY 2012 and 2013 provide a basic understanding of general water quality and also allow a first order judgment of quality assurance (Table 15). 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 with the exception of organic carbon. The range of PCB concentrations were typical of mixed urban land use watersheds (Lent and McKee, 2011). 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). Nutrient concentrations were in the same range as measured in in Z4LA (Gilbreath et al., 2012), and as is typical in the Bay Area, phosphorus concentrations appear to be greater than reported elsewhere in the world under similar land use scenarios, an observation perhaps attributable to geological sources (McKee and Krottje, 2005). We find no reason to suspect data quality issues since the concentration ranges appear reasonable in relation to our conceptual models of water quality for these analytes.

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. During WY 2013, maximum concentrations of PAHs, PBDEs, and the pyrethroid pesticides were all considerably lower (around 5-fold) than observed during WY 2012. 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, hypotheses to explore further with additional data collection in WY 2014. Concentrations of many of these analytes were generally similar to concentrations observed in Z4LA (Gilbreath et al., 2012). Carbaryl and fipronil have not been measured previously by RMP studies but 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 total selenium concentrations in San Leandro Creek appear to be about double those observed in Z4LA (Gilbreath et al., 2012) but still not remarkable compared to other previous observations made in the Bay Area (e.g. North Richmond Pump station [Hunt et al., 2012] and Walnut and Marsh Creeks [McKee et al., 2012]). Pyrethroid concentrations of Delta/ Tralo-methrin, Cyhalothrin lambda, and Bifenthrin were similar to those observed in Z4LA whereas concentrations of Permethrin were about 10x lower (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. There does not appear to be any data quality issues.

8.3.1. San Leandro Creek toxicity

Composite water samples were collected at the San Leandro Creek station during four storm events in Water Year 2012 and three storm events during Water Year 2013. The survival of the freshwater fish species *Pimephales promelas* was significantly reduced during one of the four Water Year 2012 and one of the three Water Year 2013 events. Similar to the results for other POC monitoring stations, significant

Table 15. Summary of laboratory measured pollutant concentrations in San Leandro Creek during water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	53	98%	ND	590	100	162	100	28	86%	ND	904	48.0	114	202
∑PCB	ng/L	16	100%	2.91	29.4	10.5	12.3	41.5	12	100%	0.730	15.7	4.15	5.59	4.65
Total Hg	ng/L	16	100%	11.9	577	89.4	184	21.7	12	100%	7.50	590	44.0	93	162
Total MeHg	ng/L	9	100%	0.164	1.48	0.220	0.499	0.220	9	100%	0.150	1.40	0.200	0.377	0.397
TOC	mg/L	16	100%	4.50	12.7	7.95	7.79	1.40	12	100%	4.00	14.0	5.65	6.25	2.55
NO3	mg/L	16	100%	0.140	0.830	0.340	0.356	0.119	13	100%	0.130	2.80	0.230	0.520	0.732
Total P	mg/L	16	100%	0.200	0.760	0.355	0.393	0.098	9	100%	0.100	0.610	0.210	0.247	0.144
PO4	mg/L	16	100%	0.057	0.16	0.073	0.087	0.019	13	100%	0.069	0.130	0.093	0.094	0.019
Hardness	mg/L	4	100%	33.8	72.5	45.5	54.8	6.93	-	-	-	-	-	-	-
Total Cu	µg/L	4	100%	12.3	39.5	20.1	23.0	5.79	3	100%	5.90	28.0	11.0	15.0	11.6
Dissolved Cu	µg/L	4	100%	6.04	10.0	8.34	8.18	7.38	3	100%	3.50	4.90	4.10	4.17	0.702
Total Se	µg/L	4	100%	0.104	0.292	0.216	0.207	0.118	3	100%	0.180	0.290	0.190	0.220	0.061
Dissolved Se	µg/L	4	100%	0.068	0.195	0.131	0.131	0.012	3	100%	0.160	0.190	0.170	0.173	0.015
Carbaryl	ng/L	4	50%	ND	14.0	5.00	6.00	7.07	3	0%	ND	-	-	-	-
Fipronil	ng/L	4	100%	6.00	10.0	8.00	8.00	4.24	3	33%	ND	9.00	2.00	3.67	4.73
∑PAH	ng/L	2	100	3230	5352	4291	4291	1501	1	100%	1399	1399	1399	1399	-
∑PBDE	ng/L	2	100	64.9	82.0	73.5	73.5	12.1	2	100%	1.61	29.7	15.7	15.7	19.9
Delta/ Tralo-methrin	ng/L	3	100%	0.163	1.74	1.41	1.10	0.832	3	33%	ND	0.600	0	0.200	0.346
Cypermethrin	ng/L	4	0%	ND	-	-	-	-	3	67%	ND	0.800	0.700	0.500	0.436
Cyhalothrin lambda	ng/L	3	25%	ND	3.86	0	1.29	2.23	3	33%	ND	0.300	0	0.100	0.173
Permethrin	ng/L	4	100%	3.35	13.1	5.77	7.00	10.8	3	33%	ND	6.00	0	2.00	3.46
Bifenthrin	ng/L	4	75%	ND	32.4	12.1	14.1	5.66	3	100%	2.80	7.10	5.50	5.13	2.17

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.
All Hardness results in WY 2013 were censored.

reductions in the survival of the amphipod *Hyalella azteca* were observed, in this case in three of the four Water Year 2012 storm events sampled. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of sediments in receiving waters. 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.

8.3.2. San Leandro Creek preliminary loading estimates

Site specific methods were developed for computed loads (Table 16). Preliminary loads estimates generated for WY 2012 and reported by McKee et al. (2013) have now been revised based on revisions to the discharge estimates, additional pollutant concentration data collected in WY 2013 and an improving understanding of pollutant transport processes for the site. Preliminary monthly loading estimates correlate well with monthly discharge (Table 17). There are no data available for October of each water year because monitoring equipment was not installed. Discharge and rainfall are 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 run-off occurred from the upper watershed. At this time, all loads estimate should be considered preliminary. Additional data collected during WY 2014 will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate and finalize loads for WYs 2012 and 2013. Regardless of these improvements however, given the very dry flow conditions of WY 2012 and 2013 (see discussion on flow above), preliminary loads presented here may be considered representative of dry conditions.

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[2] 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

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[2] 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.

Table 16. Regression equations used for loads computations for San Leandro Creek during water year 2012 and 2013. Note that regression equations will be reformulated with future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mixed	1.2286		0.81	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.0871	4.097	0.58	Regression with turbidity
Total PCBs (ng/NTU)	Mainly non-urban	0.031	1.567	0.81	Regression with turbidity
Total Mercury urban (ng/NTU)	Mainly urban	0.66	6.17	0.83	Regression with turbidity
Total Mercury non-urban (ng/NTU)	Mainly non-urban	1.34		0.86	Regression with turbidity
Total Methylmercury (ng/NTU)	Mixed	0.0026	0.12	0.92	Regression with turbidity
TOC	Mixed	6.66			Flow weighted mean concentration
Total Phosphorous (mg/NTU)	Mixed	0.0012	0.18	0.64	Regression with turbidity
Nitrate (mg/L)	Mixed	0.38			Flow weighted mean concentration
Phosphate (mg/L)	Mixed	0.092			Flow weighted mean concentration

Table 17. Preliminary monthly loads for San Leandro Creek for water year 2012 and 2013.

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	-	-	-	-	-	-	-	-	-	-
	11-Nov	-	-	-	-	-	-	-	-	-	-
	11-Dec	0	3.14	23.9	20,909	5.66	32.1	0.438	1,193	289	587
	12-Jan	73	0.316	17.3	2,106	1.87	15.5	0.0827	120	29.1	76.7
	12-Feb	22	0.0206	0.591	137	0.0931	0.569	0.00329	7.81	1.89	3.32
	12-Mar	151	0.245	22.3	1,634	1.48	27.6	0.0863	93.2	22.6	69.0
	12-Apr	85	0.266	50.2	1,773	2.59	61.4	0.162	101	24.5	107
	Wet season total	332	5.47	120	36,423	14.2	145	0.965	2,078	503	1,113
2013	12-Oct	-	-	-	-	-	-	-	-	-	-
	12-Nov	121	0.238	32.9	1,587	1.93	40.6	0.113	90.5	21.9	80.5
	12-Dec	127	4.07	122	27,128	11.3	155	0.699	1,548	375	715
	13-Jan	7	4.37	54.6	29,111	8.54	73.1	0.665	1,661	402	842
	13-Feb	19	0.0359	1.46	239	0.155	1.61	0.00802	13.6	3.30	8.04
	13-Mar	11	0.0104	0.879	69.0	0.110	0.642	0.00347	3.94	0.954	2.82
	13-Apr[a]	41	0.0811	6.99	540	0.558	8.03	0.0277	30.8	7.46	22.6
	Wet season total	326	8.81	218	58,674	22.6	280	1.52	3,348	811	1,671

[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.

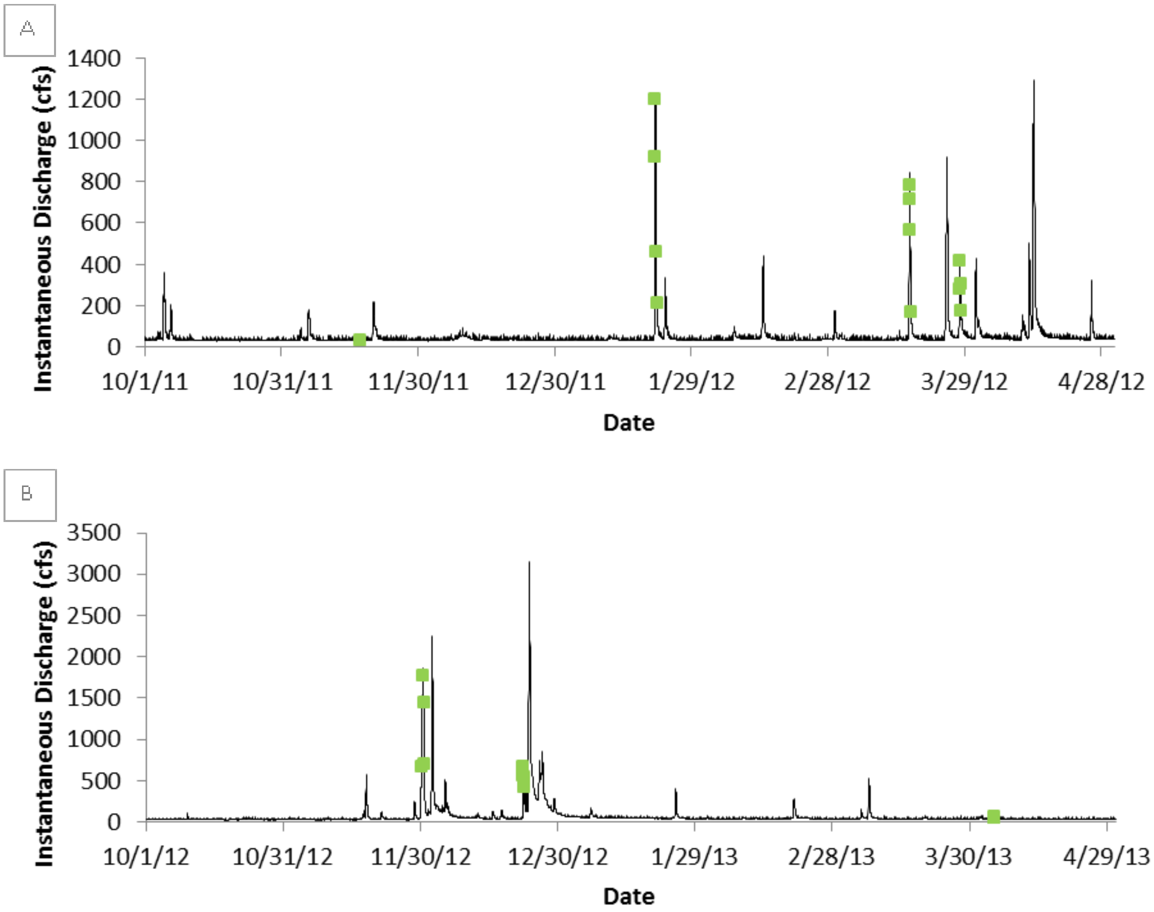

Figure 6. Flow characteristics in Guadalupe River during water year 2012 (A) based on published data and preliminary 15 minute data for water year 2013 (B) provided by the USGS (gauge number 11169025), with sampling events plotted in green. The fuzzy nature of the low flow data are caused by baseflow discharge fluctuations likely caused by pump station discharges near the gauge.

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 7:15 am 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 7.05 inches, or 47% of mean annual precipitation (MAP = 15.07 in) based on a long-term record at San Jose (NOAA gauge number 047821) for the period 1971-2010 (CY). CY 2012 was the driest year in the past 42 years and the 7th driest for the record beginning CY 1875 (138 years).

Water year 2013 was only slightly wetter, raining 8.78 inches as the San Jose gauge (58% 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 preliminary USGS data was 45.5 Mm^3; discharge of this magnitude is about 82% mean annual runoff (MAR) based on 83 years of record and equivalent to the MAR for the period WY1971-2010. Flow data and resulting loads calculations for WY 2013 will be updated once USGS publishes the official record. The USGS normally publishes finalized data for the permanent record in the spring following the end of each Water Year.

8.3.2. Guadalupe River turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. 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. Based on past years of record, turbidity can exceed 1000 FNU at the sampling location (e.g. McKee et al., 2004); the FTS DTS-12 turbidity probe used at this study location is quite capable of sampling most if not all future sediment transport conditions for the site.

A continuous record of SSC was computed by SFEI using the POC monitoring SSC data, the preliminary 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 844 mg/L during the 1/21/12 storm event at 3:15, and in WY 2013 at 933 mg/L on 12/23/12 at 19:00. 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 (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 WYs 2012 and 2013 are summarized (Table 18). 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 (Sunnyvale Channel > Pulgas Creek PS > Guadalupe River >North Richmond PS > San Leandro Creek >Lower Marsh Creek). 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) over the period of record at this location (2002-2010). Nutrient concentrations were in the same range as measured in in Z4LA

Table 18. Summary of laboratory measured pollutant concentrations in Guadalupe River for water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	100%	8.6	730	82.0	198	205	41	100%	5.9	342	128	124	104
∑PCB	ng/L	11	100%	2.70	59.1	6.96	17.7	21.5	12	100%	2.04	47.4	6.29	10.6	12.7
Total Hg	ng/L	12	100%	36.6	1000	125	268	324	12	100%	14.5	360	155	153	119
Total MeHg	ng/L	10	100%	0.086	1.15	0.381	0.445	0.352	7	100%	0.040	0.940	0.490	0.428	0.340
TOC	mg/L	12	100%	4.90	18.0	7.45	8.73	4.03	12	100%	5.30	11.0	6.05	6.36	1.55
NO3	mg/L	12	100%	0.560	1.90	0.815	0.918	0.380	12	67%	ND	2.30	0.520	0.921	0.992
Total P	mg/L	12	100%	0.190	0.810	0.315	0.453	0.247	8	100%	0.300	0.610	0.390	0.405	0.092
PO4	mg/L	12	100%	0.060	0.160	0.101	0.101	0.032	12	100%	0.061	0.180	0.120	0.109	0.034
Hardness	mg/L	3	100%	133	157	126	143	12.3	-	-	-	-	-	-	-
Total Cu	µg/L	3	100%	10.7	26.3	24.7	20.6	8.58	3	100%	5.90	28.0	23.0	19.0	11.6
Dissolved Cu	µg/L	3	100%	5.07	7.91	5.51	6.16	1.53	3	100%	2.50	3.60	2.50	2.87	0.635
Total Se	µg/L	3	100%	1.16	1.63	1.21	1.33	0.258	3	100%	0.700	3.30	0.780	1.59	1.48
Dissolved Se	µg/L	3	100%	0.772	1.32	1.04	1.04	0.274	3	100%	0.400	3.20	0.540	1.38	1.58
Carbaryl	ng/L	3	100%	13.0	57.0	57.0	41.4	24.7	3	67%	ND	21.0	17.0	12.7	11.2
Fipronil	ng/L	3	100%	6.50	20.0	11.0	12.5	6.87	3	100%	3.00	11.0	9.00	7.67	4.16
∑PAH	ng/L	1	100%	-	-	-	2186	-	8	100%	40.7	736	174	251	245
∑PBDE	ng/L	1	100%	-	-	-	34.5	-	2	100%	13.1	69.8	41.4	41.4	40.1
Delta/ Tralo-methrin	ng/L	3	100%	0.704	1.90	1.82	1.47	0.667	3	0%	ND	-	-	-	-
Cypermethrin	ng/L	3	0%	ND	-	-	-	-	3	100%	0.500	3.30	1.70	1.83	1.40
Cyhalothrin lambda	ng/L	3	33%	ND	-	-	1.20	-	3	100%	0.300	1.50	0.500	0.767	0.643
Permethrin	ng/L	3	100%	16.8	20.5	19.5	18.9	1.91	3	33%	ND	5.40	0	1.80	3.12
Bifenthrin	ng/L	3	67%	ND	13.3	6.16	6.47	6.63	3	100%	0.900	7.60	5.90	4.80	3.48

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.
All Hardness results in WY 2013 were censored.

(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). 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.

In a similar manner, summary statistics and comparisons were developed for the lower sample frequency analytes collected using composite sampling design (see the methods section). 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 2-8 fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Carbaryl and fipronil 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). Pyrethroid concentrations of Cyhalothrin lambda were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were on the lower end (Gilbreath et al., 2012). No quality issues appear from the comparisons.

8.3.4. Guadalupe River toxicity

Composite water samples were collected at the Guadalupe River station during three storm events in WY 2012 and three storm events in Water Year 2013. 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. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during two of the three storm Water Year 2012 events sampled. There were no significant effects observed for any samples collected during Water Year 2013. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of receiving water sediments.

8.3.5. Guadalupe River preliminary loading estimates

The following methods were applied to estimate loads for the Guadalupe River in WYs 2012 and 2013. Suspended sediment loads for WY 2012 were downloaded from USGS. Since the WY 2013 suspended sediment record has not yet been published, concentrations were estimated from the turbidity record using a linear relation (Table 19). Once the official USGS flow and SSC record is published for WY 2013, the suspended sediment load will be updated. Concentrations were estimated using regression equations between the contaminant and turbidity, except for nitrate in which a flow weighted mean concentration was used (Table 19). As found during other drier years (McKee et al., 2006), a separation of the data for PCBs and total mercury to form regression relations based on origin of flow was not possible with WY 2012 data, in which the majority of runoff was of urban origin. This separation was, however, possible for PCBs during WY 2013 flows.

Preliminary monthly loading estimates correlate fairly well with monthly discharge (Table 20). 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

Table 19. Regression equations used for loads computations for Guadalupe River during water year 2012 and 2013. 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 WY 2013 (mg/NTU)[a]	Mixed	1.69		0.92	Regression with turbidity
Total PCBs urban (ng/NTU)	Mainly urban	0.23898		0.76	Regression with turbidity
Total PCBs non-urban (ng/NTU)	Mainly non-urban	0.079123		0.84	Regression with turbidity
Total Mercury (ng/NTU)	Mixed	2.17		0.81	Regression with turbidity
Total Methylmercury (ng/NTU)	Mixed	0.0031	0.21	0.48	Regression with turbidity
Total Organic Carbon (mg/NTU)	Mixed	0.028	4.7	0.62	Regression with turbidity
Total Phosphorous (mg/NTU)	Mixed	0.0019	0.2	0.71	Regression with turbidity
Nitrate (mg/L)	Mixed	0.633			Flow weighted mean concentration
Phosphate (mg/NTU)	Mixed	0.00028	0.077	0.59	Regression with turbidity

[a]Suspended sediment loads in WY 2012 were downloaded from the USGS for this site.

2013 loads were approximately 3x higher than WY 2012. 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 several times lower. At this time, all loads estimates for WY 2013 should be considered preliminary. Once available, USGS official records for flow, turbidity, and SSC can be substituted for the preliminary data presented here. In addition pollutant data collected in future sampling years will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate these loads. Regardless of these improvements, overall, WY 2012 and 2013 loads may be considered representative of loads during dry conditions in this watershed.

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 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. Due to the knowledge of the poor quality runoff data for this channel, in WY 2012 discharge was estimated based on the continuous stage record and application of the Manning's formula. However, in WY 2013 additional velocity discharge measurements were collected in the field and corroborated the SCVWD rating curve up to stages of 2.9

Table 20. Preliminary monthly loads for Guadalupe River for water year 2012 and 2013.

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	15966	9.08	188	0.865	1840	247	757
	11-Nov	15	2.88	104	14844	5.68	110	0.750	1823	235	685
	11-Dec	1	2.73	76.4	13244	1.38	38.0	0.619	1730	215	593
	12-Jan	18	3.85	565	25069	29.2	555	1.58	2439	367	1268
	12-Feb	14	3.15	315	17766	10.0	240	0.989	1995	273	852
	12-Mar	50	5.08	404	29516	29.6	456	1.69	3213	448	1433
	12-Apr	44	5.23	485	30078	28.2	446	1.71	3307	458	1454
	Wet season total	161	25.8	2116	146483	113	2033	8.20	16347	2243	7042
2013	12-Oct	8	2.26	52.5	11406	3.44	67.5	0.56	1430	182	521
	12-Nov	48	5.23	913	39385	85.0	1175	2.73	3309	551	2082
	12-Dec	92	14.8	3100	119995	224	3991	8.67	9373	1643	6468
	13-Jan	15	4.14	98.4	20924	7.95	127	1.03	2618	334	957
	13-Feb	11	3.05	58.2	15186	4.45	75.0	0.74	1929	244	689
	13-Mar	21	3.47	93.6	17733	6.93	120	0.89	2196	282	815
	13-Apr	5	2.57	36.6	12598	2.12	47.2	0.60	1626	204	567
	Wet season total	201	35.5	4352	237227	334	5603	15.2	22482	3440	12099

feet (corresponding to flows of 190 cfs). Therefore, WY 2013 discharge was estimated based on continuous stage and application of the SCVWD rating curve, and WY 2012 discharge was recalculated using the same method. Efforts will be made in subsequent sampling years to evaluate the accuracy of the SCVWD rating curve at stages greater than 3 feet.

Both WY 2012 and 2013 were relatively dry years and discharge was likely lower than average. Rainfall during WY 2012 and 2013 was 8.82 and 10.2 inches, respectively, at Palo Alto (NOAA gauge number 046646). Relative to mean annual precipitation (MAP = 15.25 in) based on a long-term record for the period 1971-2010 (CY), WY 2012 was only 58% MAP and WY 2013 67% 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 for the period between 10/01/12 and 4/30/13 was 1.79 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

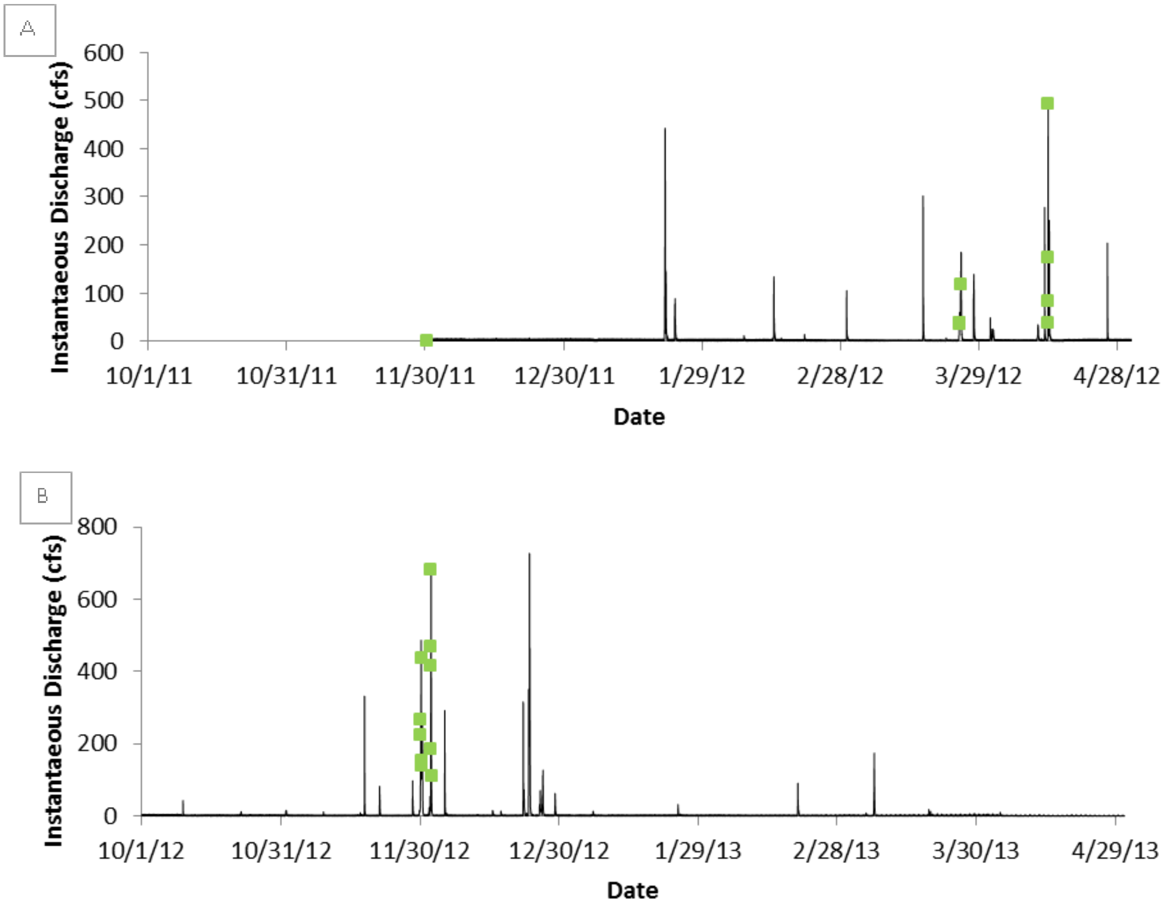

Figure 7. Preliminary flow characteristics in Sunnyvale East Channel at East Ahwanee Avenue during WY 2012 (A) and WY 2013 (B) with sampling events marked in green. The flow record is based on the District rating curve for this station as verified by velocity sampling completed to-date. The rating relationship may be improved in subsequent years as more velocity sampling is completed.

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).

8.3.2. Sunnyvale East Channel turbidity and suspended sediment concentration

The entire turbidity record for WY 2012 was censored due to problems with the installation design and the OBS-500 instrument reading the bottom of the channel. Suspended sediment concentration in WY 2012 could not be computed from the continuous turbidity data, and was alternatively computed as a function of flow (with much lower confidence due to the loss of hysteresis in the computational scheme). 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. During the period of record in which the turbidity sensor was functioning correctly, SSC was estimated based on regression with turbidity. During the period of record in which turbidity was censored, SSC was computed as a function of flow in a similar manner to estimates made in WY 2012.

Turbidity in Sunnyvale East Channel in WY 2013 remained low (<40 NTU) during base flows and increased to between 500 and 1000 NTU during storms. 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. The three large events in November and December resulted in turbidities in the 600-900 NTU range, providing evidence to suggest that the DTS-12 instrument now utilized at this sampling location will be sufficient to handle future storms.

Suspended sediment concentration in WY 2012 peaked at 352 mg/L on 4/13/12 just after midnight and at 3726 mg/L on 10/9/12 in response to the early season small but intense rainfall. 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) and in WY 2013 was 3120 mg/L (collected on 12/2/12; the 10/9/12 estimated peak SSC occurred during a non-sampled storm event). Note that the estimated SSC (estimated from the continuous turbidity record) for the 10/9/12 peak had a ratio to turbidity of 3.7:1. This ratio is higher than typical for urban creeks and resulted because the WY 2013 sampling occurred during two of the three largest storm events, at which time bank erosional processes led to mixed grain fractions in the samples and higher SSC per unit of turbidity. This observation suggests that as the Sunnyvale East Channel dataset grows in future sampling years, the data should be stratified between storms that do and do not exhibit bank erosional processes. The maximum concentration measured during the WY 2011 RMP reconnaissance study (McKee et al., 2012) was 1050 mg/L and was collected during a relatively small but intense rain event, but at this time we have not evaluated the relative storm magnitude between WY 2011, 2012 and 2013 to determine if the relative concentrations are logical.

8.3.3. Sunnyvale East Channel POC concentrations summary (summary statistics)

A wide range of pollutants were measured in Sunnyvale East Channel during WY 2012 and 2013 (Table 21). 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 organic carbon, nitrate and phosphate in WY 2013 in which the mean and median were similar. The range of PCB concentrations were typical of mixed urban land use watersheds

Table 21. Summary of laboratory measured pollutant concentrations in Sunnyvale East Channel during water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	28	97%	ND	370	49.0	81.6	100	34	97%	ND	3120	312	485	645
∑PCB	ng/L	8	100%	3.27	119	33.6	41.3	41.5	10	100%	9.16	176	31.3	59.3	64.3
Total Hg	ng/L	8	100%	6.30	64.1	21.7	27.7	21.7	10	100%	13	220	55.5	72.9	65.2
Total MeHg	ng/L	6	86%	ND	0.558	0.184	0.250	0.220	6	100%	0.020	0.540	0.290	0.252	0.220
TOC	mg/L	8	100%	4.91	8.60	5.94	6.41	1.40	10	100%	4.10	10.0	5.85	5.85	1.71
NO3	mg/L	8	100%	0.200	0.560	0.280	0.309	0.119	10	100%	0.150	0.370	0.280	0.269	0.069
Total P	mg/L	8	100%	0.190	0.500	0.250	0.278	0.098	11	100%	0.230	1.70	0.390	0.527	0.412
PO4	mg/L	8	100%	0.067	0.110	0.079	0.085	0.019	10	100%	0.094	0.130	0.120	0.115	0.010
Hardness	mg/L	2	100%	51.4	61.2	56.3	56.3	6.93	-	-	-	-	-	-	-
Total Cu	µg/L	2	100%	10.8	19.0	14.9	14.9	5.79	2	100%	19.0	31.0	25.0	25.0	8.49
Dissolved Cu	µg/L	2	100%	4.36	14.8	9.58	9.58	7.38	2	100%	3.10	4.90	4.00	4.00	1.27
Total Se	µg/L	2	100%	0.327	0.494	0.411	0.411	0.118	2	100%	0.490	0.490	0.490	0.490	0
Dissolved Se	µg/L	2	100%	0.308	0.325	0.317	0.317	0.012	2	100%	0.35	0.39	0.370	0.370	0.028
Carbaryl	ng/L	2	100%	11.0	21.0	16.0	16.0	7.07	2	50%	ND	19.0	9.50	9.5	13.4
Fipronil	ng/L	2	100%	6.00	12.0	9.00	9.00	4.24	2	50%	ND	6.00	3.00	3.00	4.24
∑PAH	ng/L	1	100%	-	-	-	1289	-	1	100%	-	-	-	1355	-
∑PBDE	ng/L	1	100%	-	-	-	4.77	-	1	100%	-	-	-	34.9	-
Delta/ Tralo-methrin	ng/L	1	0%	ND	-	-	-	-	2	100%	3.60	3.80	3.70	3.70	0.141
Cypermethrin	ng/L	2	0%	ND	-	-	-	-	2	100%	3.20	5.20	4.20	4.20	1.41
Cyhalothrin lambda	ng/L	1	0%	ND	-	-	-	-	2	100%	1.20	2.50	1.85	1.85	0.919
Permethrin	ng/L	2	100%	5.70	20.9	13.3	13.3	10.8	2	100%	22.0	48.0	35.0	35.0	18.4
Bifenthrin	ng/L	2	50%	ND	8	4	4.0	5.7	2	100%	8.70	18.0	13.4	13.4	6.58

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 Sunnyvale East Channel was two.
All Hardness results in WY 2013 were censored.

(Lent and McKee, 2011) and maximum PCB concentrations (176 ng/L) exceeded the maximum observed in Z4LA (110 ng/L) (Gilbreath et al., 2012). Similarly, the range of mercury concentrations were comparable to those observed in Z4LA while the maximum total mercury concentration in Sunnyvale East Channel (220 ng/L) was greater than sampled in Z4LA (150 ng/L). Nutrient concentrations were also in the same range as measured in 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.

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. Carbaryl and Fipronil (not measured previously by RMP studies) were lower or on the low end relative to 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). Concentrations of Bifenthrin, Cyhalothrin lambda, and Permethrin were within but on the low end of the range observed in Z4LA. Based on these first order comparisons, we see no quality issues with the data.

8.3.1. Sunnyvale East Channel toxicity

Composite water samples were collected in the Sunnyvale East Channel during two storm events in WY 2012 and two storm events in WY 2013. 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* was observed during both WY 2012 and WY 2013 storm events[3]. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used for assessments of receiving water sediment toxicity. No significant effects were observed for the crustacean *Ceriodaphnia dubia*, the algae *Selenastrum capricornutum* or the fathead minnow during these storms.

8.3.2. Sunnyvale East Channel preliminary loading estimates

Given that the turbidity record in WY 2012 was unreliable due to optical interference from bottom substrate (problem now rectified), and gaps 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 22). Concentrations of other POCs were estimated using regression equations between the contaminant 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.

Preliminary monthly loading estimates for Sunnyvale East Channel are presented in Table 23. This table highlights how monthly loads can be dominated by a few large storm events. Relative to discharge,

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[3] In one of the two samples where significant toxicity was observed, a holding time violation occurred and therefore the results should be considered in the context of this exceedance of measurement quality objectives.

Table 22. Regression equations used for loads computations for Sunnyvale East Channel during water year 2012 and 2013. 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/CFS)	Mainly urban	0.7145		0.97	Regression with flow
Suspended Sediment (WY2013) (mg/CFS)	Mainly urban	1.4421		0.67	Regression with flow
Suspended Sediment (WY2013) (mg/NTU)	Mainly urban	0.4913x1.2907		0.75	Regression with turbidity
Total PCBs (ng/CFS)	Mainly urban	0.23	2.7	0.62	Regression with flow
Total Mercury (ng/mg)	Mainly urban	0.13	13	0.93	Regression with estimated SSC
Total Methylmercury (ng/CFS)	Mainly urban	0.0011	0.12	0.77	Regression with flow
Total Organic Carbon (mg/L)	Mainly urban	5.77			Flow weighted mean concentration
Total Phosphorous (mg/mg)	Mainly urban	0.00076	0.2	0.86	Regression with estimated SSC
Nitrate (mg/L)	Mainly urban	0.245			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.106			Flow weighted mean concentration

suspended sediment load exerted quite high variability relative to some of the other sampling locations in the study. Although December 2012 only discharged 27% of the total volume for WYs 2012 and 2013 combined, 73% of the suspended sediment load was transported during this month as well as approximately 60% of the PCB and mercury loads. Normalized to total annual discharge, WY 2013 transported 11-fold more sediment than WY 2012, 3-fold the amount of PCBs and almost 4-fold the amount of Hg. Provided the context that both WY 2012 and 2013 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.

8.6. Pulgas Creek Pump Station

8.6.1. Pulgas Creek Pump Station flow

Flow into the Pulgas Creek Pump Station from the southern catchment has not historically been monitored. An ISCO area velocity flow meter situated directly in the incoming pipe was used to measure stage and flow in WY 2013. Total runoff during WY 2013 for the period of record 12/17/12 to 3/15/13 was 0.09 Mm^3. A monthly (or partial monthly for December 2012 and March 2013) rainfall to runoff regression was applied to the missing period of the wet season. Based on this regression estimator method, a coarse estimate total runoff during WY 2013 for the period 10/01/12 to 4/30/13 was 0.21

Table 23. Preliminary monthly loads for Sunnyvale East Channel during water years 2012 and 2013.

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	-	-	-	-	-	-	-	-	-	-
	11-Nov	-	-	-	-	-	-	-	-	-	-
	11-Dec	2	0.148	0.282	852	0.492	1.92	0.0175	36.2	15.7	29.6
	12-Jan	37	0.254	13.4	1468	4.98	4.96	0.0502	62.3	27.0	60.7
	12-Feb	22	0.151	1.36	872	0.846	2.10	0.0196	37.0	16.0	31.1
	12-Mar	69	0.260	8.29	1501	3.36	4.38	0.0429	63.7	27.6	58.0
	12-Apr	39	0.260	13.3	1498	4.95	5.01	0.0506	63.6	27.5	61.7
	Wet season total	169	1.07	36.7	6192	14.6	18.4	0.181	263	114	241
2013	12-Oct	13	0.125	7.33	722	0.445	2.53	0.0150	30.7	13.3	30.4
	12-Nov	61	0.456	130	2634	19.1	22.5	0.139	112	48.4	189
	12-Dec	101	0.786	516	4535	50.9	76.1	0.327	193	83.3	546
	13-Jan	8	0.115	2.78	664	0.407	1.82	0.0138	28.2	12.2	25.0
	13-Feb	10	0.102	7.15	591	0.536	2.22	0.0131	25.1	10.9	25.8
	13-Mar	20	0.150	8.80	867	1.51	3.04	0.0227	36.8	15.9	36.5
	13-Apr	6	0.059	0.238	339	0.187	0.780	0.007	14.4	6.24	11.9
	Wet season total	219	1.79	673	10352	73.1	109	0.538	440	190	865

Mm^3. This estimate will be improved as the monthly rainfall to runoff regression improves in future years with a larger dataset. Since runoff from this watershed is likely to highly correlate with rainfall due to its small drainage area and high imperviousness, but since MAP for the nearby Redwood City NCDC meteorologic gauge (gauge number 047339-4) was 78% of normal, total runoff for WY 2013 at Pulgas Creek was likely below average.

During the very short and incomplete period of record at Pulgas Creek pump station, a large storm series occurred towards the end of December 2012, followed by few and relatively minor storms for the remainder of the record. Flow peaked at 50 cfs on 12/23/12 at 17:04 (Figure 8). 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. However large the peak flows were for nearby creek systems such as San Francisquito Creek, flows in Pulgas Creek Pump Station south may respond differently again due to its very small size and high imperviousness. Pulgas Creek Pump Station south would be less affected by antecedent saturation conditions than San Francisquito Creek and more by hourly and sub-hourly

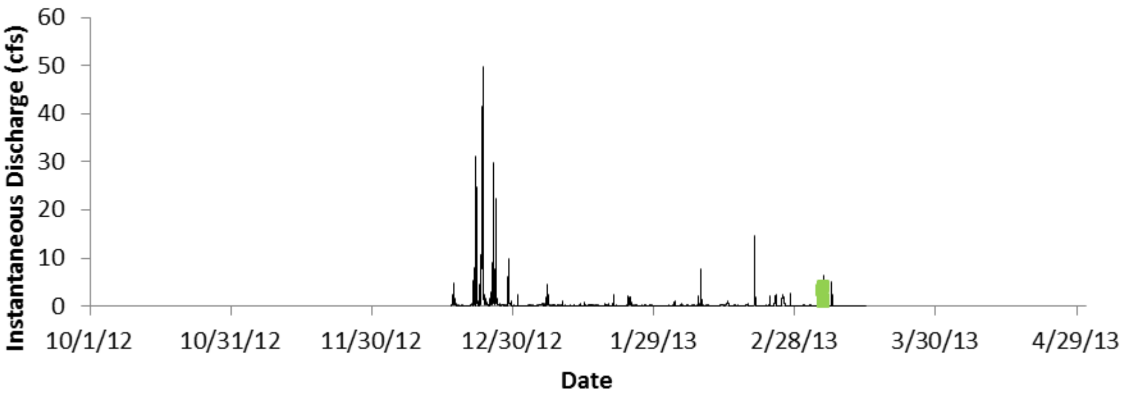

Figure 8. Preliminary flow characteristics at Pulgas Creek Pump Station South during Water Year 2013 with sampling events plotted in green. Pulgas Creek Pump Station turbidity and suspended sediment concentration

rainfall intensities. The maximum 1-hour rainfall intensity at Pulgas Creek was 0.43 inches per hour and occurred on 12/23/12 at 17:10, concurrent with the peak flow. Relative to the Redwood City NCDC meteorologic gauge and based on the partial duration series, the maximum 1-hour rainfall intensity at Pulgas has approximately a 1-year recurrence interval. Based on this rainfall intensity recurrence, we suggest peak flows in Pulgas Creek Pump Station South watershed were approximately average.

8.6.2. Pulgas Creek Pump Station turbidity and suspended sediment concentration

Turbidity in Pulgas Creek Pump Station south watershed generally responded to rainfall events in a similar manner to runoff. During non-storm periods, turbidity 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[4] and did not return to readings below 20 NTU for 18 hours. Storm-associated turbidity peaked at 588 NTU on 1/6/13 during the first storm following the 12/30/12 spike. During all storm events after the 12/30/12 spike, storm maximum turbidities were all greater than maximum turbidities in the large storm series around 12/23/12. Two hypotheses are suggested 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. Future monitoring at Pulgas Creek will help elucidate which of these current hypotheses are more likely and what the typical range of turbidity is for this watershed sampling location as water passes through to the Bay. Despite the turbidity measurements being out of the sensor range during the 12/30/12 spike, at this time we have no evidence to suggest that the DTS-12 instrument utilized at this sampling location (with a range of 0-1600 NTU) will not be sufficient to handle most future storms.

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[4] 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.

Suspended sediment concentration was computed from the continuous turbidity data and therefore follows the same patterns as turbidity in relation to discharge and the non-storm associated spike on 12/20/12. Suspended sediment concentration peaked at 2693 mg/L during the spike on 12/30/12 at 23:00. Storm-associated suspended sediment concentration peaked at 647 mg/L and occurred in the first subsequent storm event on 1/6/13 at 6:15. These concentration estimates based on the continuous turbidity record are much greater than observed during collection events. The maximum SSC concentration was 110 mg/L measured on 3/6/13 L while the maximum concentration measured during the RMP reconnaissance study (McKee et al., in review) was 60 mg/L. At this time we have chosen to censor the data minimally, however future sampling may indicate that further censorship or reinterpretation is necessary.

8.6.3. Pulgas Creek Pump Station POC concentrations summary (summary statistics)

Summary statistics of pollutant concentrations measured in Pulgas Creek Pump Station South in WY 2013 are presented in Table 24. Except for total methylmercury, in which two dry flow samples were additionally collected, these samples were collected during a single small storm event. Due to the small size of this dataset and relatively low SSC during sample collection, it is likely that samples collected in future years will yield higher concentrations for many pollutants of concern. Therefore, the following statements provide a first order judgment of quality assurance, but are heavily caveated by the currently unrepresentative sample dataset.

For all pollutants sampled with the exception of total methylmercury and total phosphorous, concentrations followed the typical pattern of median < mean. The range of PCB concentrations were 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, reported in Lent and McKee, 2011). Mean total mercury concentrations (10.5 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). Nutrient concentrations were in the same range as measured in in Z4LA, but generally lower than the other watersheds in this study. Although the dataset is possibly unrepresentative of the broader range of concentrations we might see in subsequent years as the dataset grows, we find no reason to suspect data quality issues since the concentration ranges appear reasonable in relation to our conceptual models of water quality for these analytes.

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). Carbaryl and fipronil 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). Concentrations of Cypermethrin were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were about 20x and 10x lower, respectively (Gilbreath et al., 2012). In summary, concentrations measured at Pulgas Creek Pump Station South during WY 2013 are in a the typical range of Bay Area urban watersheds, however the dataset is currently very small and is probably unrepresentative of the full range of concentrations for this site.

Table 24. Summary of laboratory measured pollutant concentrations in Pulgas Creek Pump Station during water year 2013.

		Water Year 2012	Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	0	15	100%	4.3	110	24.0	33.3	33.1
∑PCB	ng/L	0	4	100%	15.1	62.7	30.5	34.7	20.1
Total Hg	ng/L	0	6	100%	4.20	23.0	7.45	10.53	6.90
Total MeHg	ng/L	0	6	100%	0.040	0.280	0.215	0.178	0.100
TOC	mg/L	0	4	100%	7.30	17.0	8.35	10.3	4.53
NO3	mg/L	0	4	100%	0.240	0.490	0.350	0.358	0.102
Total P	mg/L	0	4	100%	0.100	0.250	0.125	0.150	0.071
PO4	mg/L	0	4	100%	0.051	0.094	0.059	0.066	0.020
Hardness	mg/L	0	-	-	-	-	-	-	-
Total Cu	µg/L	0	1	100%	-	-	-	30.0	-
Dissolved Cu	µg/L	0	1	100%	-	-	-	20.0	-
Total Se	µg/L	0	1	100%	-	-	-	0.180	-
Dissolved Se	µg/L	0	1	100%	-	-	-	0.170	-
Carbaryl	ng/L	0	1	100%	-	-	-	204	-
Fipronil	ng/L	0	1	0%	ND	-	-	-	-
∑PAH	ng/L	0	4	100%	211	1138	552	614	389
∑PBDE	ng/L	0	4	100%	5.18	89.8	32.5	40.0	39.7
Delta/ Tralomethrin	ng/L	0	1	0%	ND	-	-	-	-
Cypermethrin	ng/L	0	1	100%	-	-	-	0.9	-
Cyhalothrin lambda	ng/L	0	1	0%	ND	-	-	-	-
Permethrin	ng/L	0	1	100%	-	-	-	2.9	-
Bifenthrin	ng/L	0	1	100%	-	-	-	1.3	-

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 Pump Station was four.
All Hardness results in WY 2013 were censored.

8.6.4. Pulgas Creek Pump Station toxicity

A composite water sample was collected at Pulgas Creek on March 6, 2013. No significant effects were observed on any of the four test organisms.

8.6.5. Pulgas Creek Pump Station preliminary loading estimates

Continuous concentrations of suspended sediment, PCBs, total mercury and methylmercury, and total phosphorous were computed using regression equations of each contaminant with turbidity (Table 25). Similarly, continuous concentrations of TOC and phosphate were computed using regression equations with instantaneous flow. A flow weighted mean concentration (FWMC) was computed for nitrate and the static concentration was applied to the entire record. These equations and FWMC were applied during both storm and baseflow conditions as there was no data to support using a different method for base flow conditions. The monthly (or partial monthly for December 2012 and March 2013) load for each POC was regressed with monthly (or partial monthly) rainfall. The resulting equation was used to estimate the monthly POC load for the non-monitored period of record. This is considered a coarse method of estimation and the resulting loads are shown for uses of preliminary comparison between the six monitored watersheds and should not be considered accurate at this time. As the dataset for this site grows in future monitoring years, these estimates will be recalculated.

Preliminary monthly loading estimates are dominated by the two wet months of WY 2013 (November and December) (Table 26), during which time 65% of the total discharge volume occurred and 67 – 83% of the total load for each POC passed through the system. At this time, all loads estimates should be considered preliminary and data collected in subsequent water years will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate and finalize loads for WY 2013.

Table 25. Regression equations used for loads computations for Pulgas Creek Pump Station during water year 2013. 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 (mg/NTU)	Mainly urban	1.102		0.84	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.73	8.6	0.77	Regression with turbidity
Total Mercury (ng/NTU)	Mainly urban	0.24	3.4	0.94	Regression with turbidity
Total Methylmercury (ng/NTU)	Mainly urban	0.00094	0.2	0.53	Regression with turbidity
Total Organic Carbon (mg/CFS)	Mainly urban	1.8	5.8	0.4	Regression with flow
Total Phosphorous (mg/NTU)	Mainly urban	0.0016	0.081	0.47	Regression with turbidity
Nitrate (mg/L)	Mainly urban	0.34			Flow weighted mean concentration
Phosphate (mg/CFS)	Mainly urban	0.0086	0.045	0.41	Regression with flow

Table 26. Preliminary monthly loads for Pulgas Creek Pump Station during water year 2013.

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[a]	25	*0.0165*	*0.779*	*339*	*0.667*	*0.233*	*0.00394*	*6.00*	*1.93*	*2.56*
	12-Nov[a]	121	*0.0548*	*3.28*	*1947*	*2.69*	*0.932*	*0.0135*	*20.5*	*10.4*	*9.67*
	12-Dec[a]	183	*0.0797*	*4.90*	*2992*	*4.00*	*1.39*	*0.0197*	*29.9*	*15.9*	*14.3*
	13-Jan	8	0.0103	0.253	68.8	0.256	0.0908	0.00230	3.49	0.503	1.20
	13-Feb	10	0.0168	0.735	159	0.631	0.220	0.00403	5.70	1.05	2.43
	13-Mar[a]	20	*0.0143*	*0.640*	*249*	*0.555*	*0.194*	*0.00341*	*5.19*	*1.46*	*2.17*
	13-Apr[a]	18	*0.0134*	*0.580*	*211*	*0.506*	*0.177*	*0.00318*	*4.84*	*1.25*	*2.00*
	Wet season total	386	*0.206*	*11.2*	*5967*	*9.30*	*3.23*	*0.0501*	*75.6*	*32.4*	*34.3*

[a] As described in the text, discharge and loads for these months (data italicized) were computed based on monthly or partial monthly regressions between rainfall and discharge/load. These loads are considered coarse estimates and will be updated in future sampling years.

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	Average Lab Blank	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	ug/L	0	0.01-0.01; 0.01	0.02	75.71-75.71; 75.71	1.39-83.55; 42.47	NA	90-116; 102.3
Fipronil	ug/L	0	0-0.01; 0	0.0064	NA	0-141.42; 37.68	NA	45-112.5; 74.4
NH4	mg/L	0.0018	0.01-0.02; 0.01	0	0-9.87; 1.89	0-9.87; 2.43	NA	NA
NO3	mg/L	0	0-0.02; 0.01	0.046	NA	0-4.47; 0.35	NA	105-105; 105
NO2	mg/L	0	0-0; 0	0.013	0-0.73; 0.29	0-4.04; 0.56	NA	89-103.5; 96.5
TKN	mg/L	0	0.07-0.4; 0.23	0.1	0-47.88; 13.65	0-36.35; 14.94	NA	NA
PO4	mg/L	0	0-0.06; 0.01	0.011	0-1.61; 0.9	0-5.29; 1.16	NA	83.5-107; 97.8
Total P	mg/L	0	0.01-0.1; 0.03	0.01	0-2.4; 0.79	0-14.24; 3.86	NA	86-86; 86
SSC	mg/L	470	0.23-6.8; 2.55	3	NA	0-50.63; 13.23	99.8-99.8; 99.8	NA
Benz(a)anthracenes /Chrysenes, C1-	pg/L	102	99-75500; 3661.22	NA	1.01-6.77; 3.96	1.01-27.92; 8.64	NA	NA
Benz(a)anthracenes /Chrysenes, C2-	pg/L	164	118-43100; 2374.97	NA	2.59-16.42; 9.24	0.64-25.76; 9.46	NA	NA
Fluoranthene	pg/L	106	57.9-2580; 481.01	NA	1.26-15.98; 6.48	2.21-33.15; 17.99	NA	NA
Fluoranthene/Pyrenes, C1-	pg/L	430	138-25400; 2277.5	NA	2.63-4.4; 3.3	2.63-24.68; 13.55	NA	NA
Fluorenes, C3-	pg/L	1588	45.1-29400; 1888.57	NA	0.13-5.43; 2.09	0.69-15.99; 8.69	NA	NA
Naphthalenes, C4-	pg/L	2864	95.5-3540; 918.73	NA	2.44-10.96; 6.45	2.44-78.83; 18.97	NA	NA
Phenanthrene/Anthracene, C4-	pg/L	1565	208-27100; 3350.34	NA	0-6.39; 2.27	0.43-23.46; 8.75	NA	NA
Pyrene	pg/L	77.4	57.4-5960; 662.16	NA	0.99-14.38; 5.71	1.59-31.82; 16.25	NA	NA
PBDE 047	pg/L	40.9	0.37-0.87; 0.41	NA	0.39-18.19; 6.09	1.2-13.82; 6.86	NA	NA
PBDE 099	pg/L	43.4	0.47-12.4; 3.19	NA	1.99-9.88; 5.14	1.81-15.1; 7.31	NA	NA
PBDE 209	pg/L	76	12.7-146; 49.83	NA	2.21-42.31; 17.67	1.39-45.22; 19.57	NA	NA
PCB 087	pg/L	0.834	0.18-5.42; 0.87	NA	0-31.19; 13.75	0-31.19; 12.29	NA	NA
PCB 095	pg/L	1.31	0.18-6.23; 1	NA	3.89-37.99; 16.43	0.59-37.99; 14.24	NA	NA
PCB 110	pg/L	1.27	0.18-4.58; 0.74	NA	0.27-25.61; 12.31	0.27-27.4; 12.04	NA	NA
PCB 138	pg/L	2.36	0.25-19.8; 2.26	NA	3.01-25.44; 11.74	0.34-25.44; 9.04	NA	NA
PCB 149	pg/L	1.3	0.26-21.3; 2.45	NA	1.97-31.09; 11.26	1.97-28.66; 10.39	NA	NA
PCB 151	pg/L	0.56	0.18-8.38; 0.75	NA	0.26-29.2; 8.97	0.26-39.81; 10.25	NA	NA
PCB 153	pg/L	2.44	0.22-17.4; 2	NA	1.21-24.37; 10.36	0.59-23.88; 9.57	NA	NA
PCB 174	pg/L	0.039	0.2-4; 0.78	NA	0.25-36.32; 6.22	0.25-37.01; 7.79	NA	NA
PCB 180	pg/L	0.91	0.18-4.52; 0.68	NA	0.43-29.54; 6.15	0.43-23.7; 8.7	NA	NA
Bifenthrin	pg/L	274	1500-5520; 2830	NA	NA	4.8-34.98; 16.11	NA	NA
Cypermethrin	pg/L	0	968-5290; 2694.53	NA	NA	27.58-27.58; 27.58	NA	NA
Delta/Tralomethrin	pg/L	243	185-862; 353.6	NA	NA	22.99-32.44; 27.71	NA	NA
Total Cu	ug/L	0	0.04-0.42; 0.16	0.55	0.2-2.68; 0.88	0.2-10.56; 3.31	104.2-104.2; 104.2	100-100.6; 100.3
Dissolved Cu	ug/L	0	0.04-0.42; 0.12	0.5	NA	3.01-27.52;	104.2-104.2;	100-100.6; 100.3

Analyte	Unit	Average Lab Blank	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)
						10.41	104.2	
Total Hg	ug/L	0	0-0; 0	0.0005	2.12-2.12; 2.12	1.07-31.06; 8.59	98.5-98.5; 98.5	100-100.8; 100.4
Total MeHg	ng/L	0.006	0.01-0.02; 0.02	0.033	0.97-5.87; 3.35	0-37.52; 6.34	NA	74.2-90.4; 85.4
Total Se	ug/L	0.006	0.02-0.06; 0.04	0.086	0-2.4; 0.79	0-14.24; 3.86	103.4-103.4; 103.4	86.5-90.3; 88.4
Dissolved Se	ug/L	0	0.02-0.06; 0.04	0.15	6.18-6.18; 6.18	0-8.59; 4.72	103.4-103.4; 103.4	86.5-90.3; 88.4
TOC	ug/L	0	0.3-0.35; 0.32	462	NA	NA	NA	NA

Table A2: Field blank data from all sites.

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Carbaryl	ug/L	0.01	0.02	ND	ND	ND
Fipronil	ug/L	0.000875	0.004	ND	ND	ND
Fipronil Desulfinyl	ug/L	0.000625	0.0028	ND	ND	ND
Fipronil Sulfide	ug/L	0.000625	0.0028	ND	ND	ND
Fipronil Sulfone	ug/L	0.000875	0.004	ND	ND	ND
NH4	mg/L	0.01	-	0.01	0.01	0.01
NO3	mg/L	0.0164	0.041	ND	0.039	0.0078
NO2	mg/L	0.001142	0.01	ND	0.025	0.005
TKN	mg/L	0.18	0.1	ND	ND	ND
PO4	mg/L	0.006	0.01	ND	ND	ND
Total P	mg/L	0.0076	0.01	ND	0.018	0.0052
SSC	pg/L	653	-	ND	ND	ND
Acenaphthene	pg/L	147	-	ND	ND	ND
Acenaphthylene	pg/L	119.5	-	ND	ND	ND
Anthracene	pg/L	230	-	ND	ND	ND
Benz(a)anthracene	pg/L	68.5	-	ND	ND	ND
Benz(a)anthracenes/Chrysenes, C1-	pg/L	31	-	69.5	109	89.25
Benz(a)anthracenes/Chrysenes, C2-	pg/L	63.05	-	171	393	282
Benz(a)anthracenes/Chrysenes, C3-	pg/L	64.9	-	149	389	269
Benz(a)anthracenes/Chrysenes, C4-	pg/L	66.35	-	449	1030	739.5
Benzo(a)pyrene	pg/L	199	-	ND	ND	ND
Benzo(b)fluoranthene	pg/L	82.05	-	ND	ND	ND
Benzo(e)pyrene	pg/L	182.5	-	ND	ND	ND
Benzo(g,h,i)perylene	pg/L	123.9	-	ND	ND	ND
Benzo(k)fluoranthene	pg/L	110	-	ND	ND	ND
Chrysene	pg/L	72.3	-	ND	86.5	43.25
Dibenz(a,h)anthracene	pg/L	119	-	ND	ND	ND
Dibenzothiophene	pg/L	78.6	-	ND	ND	ND
Dibenzothiophenes, C1-	pg/L	63.85	-	ND	ND	ND

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Dibenzothiophenes, C2-	pg/L	62.9	-	278	582	430
Dibenzothiophenes, C3-	pg/L	48.95	-	576	771	673.5
Dimethylnaphthalene, 2,6-	pg/L	422	-	ND	ND	ND
Fluoranthene	pg/L	45.15	-	238	343	290.5
Fluoranthene/Pyrenes, C1-	pg/L	90.05	-	82.8	716	399.4
Fluorene	pg/L	207.5	-	ND	ND	ND
Fluorenes, C2-	pg/L	139.15	-	2080	2730	2405
Fluorenes, C3-	pg/L	133.5	-	2950	4130	3540
Indeno(1,2,3-c,d)pyrene	pg/L	43.1	-	ND	ND	ND
Methylnaphthalene, 2-	pg/L	479.5	-	ND	677	338.5
Methylphenanthrene, 1-	pg/L	210.7	-	ND	89.5	44.75
Naphthalene	pg/L	207	-	2330	21200	11765
Naphthalenes, C1-	pg/L	129	-	ND	1120	560
Naphthalenes, C3-	pg/L	298.5	-	941	3940	2440.5
Perylene	pg/L	213.5	-	ND	ND	ND
Phenanthrene	pg/L	101.6	-	469	608	538.5
Phenanthrene/Anthracene, C1-	pg/L	210.7	-	ND	335	167.5
Phenanthrene/Anthracene, C2-	pg/L	82.95	-	423	843	633
Pyrene	pg/L	43.25	-	179	229	204
Trimethylnaphthalene, 2,3,5-	pg/L	154.5	-	ND	189	94.5
PBDE 007	pg/L	0.3775	-	ND	1.64	0.82
PBDE 008	pg/L	0.3775	-	ND	1.3	0.65
PBDE 010	pg/L	0.527	-	ND	ND	ND
PBDE 011	pg/L	-	-	-	-	-
PBDE 012	pg/L	0.3775	-	ND	0.793	0.3965
PBDE 013	pg/L	-	-	-	-	-
PBDE 015	pg/L	0.3775	-	ND	4.16	2.08
PBDE 017	pg/L	0.3905	-	ND	23.6	11.8
PBDE 025	pg/L	-	-	-	-	-
PBDE 028	pg/L	0.3775	-	0.811	29	14.9055
PBDE 030	pg/L	0.4105	-	ND	ND	ND
PBDE 032	pg/L	0.3775	-	ND	ND	ND
PBDE 033	pg/L	-	-	-	-	-
PBDE 035	pg/L	1.7285	-	ND	ND	ND
PBDE 047	pg/L	0.3775	-	26.4	1040	533.2
PBDE 049	pg/L	0.3775	-	0.845	86.3	43.5725
PBDE 051	pg/L	0.3775	-	ND	8.65	4.325
PBDE 066	pg/L	0.3775	-	ND	49.4	24.7
PBDE 071	pg/L	0.3775	-	ND	14.3	7.15
PBDE 075	pg/L	1.6885	-	ND	ND	ND
PBDE 077	pg/L	0.529	-	ND	ND	ND

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PBDE 079	pg/L	0.3775	-	ND	ND	ND
PBDE 085	pg/L	0.8735	-	1.49	57.8	29.645
PBDE 099	pg/L	0.6535	-	29.9	1200	614.95
PBDE 100	pg/L	0.505	-	6.47	281	143.735
PBDE 105	pg/L	1.0985	-	ND	ND	ND
PBDE 116	pg/L	1.557	-	ND	11.3	5.65
PBDE 119	pg/L	0.9635	-	ND	6.86	3.43
PBDE 120	pg/L	-	-	-	-	-
PBDE 126	pg/L	0.619	-	ND	1.21	0.605
PBDE 128	pg/L	9.519	-	ND	ND	ND
PBDE 140	pg/L	0.5205	-	ND	6.77	3.385
PBDE 153	pg/L	0.4765	-	3.34	135	69.17
PBDE 155	pg/L	0.382	-	ND	9.43	4.715
PBDE 166	pg/L	-	-	-	-	-
PBDE 181	pg/L	2.3685	-	ND	ND	ND
PBDE 183	pg/L	1.715	-	ND	43.7	21.85
PBDE 190	pg/L	6.1835	-	ND	ND	ND
PBDE 197	pg/L	4.52	-	2.36	97.3	49.83
PBDE 203	pg/L	4.9135	-	5.08	123	64.04
PBDE 204	pg/L	-	-	-	-	-
PBDE 205	pg/L	8.683	-	ND	ND	ND
PBDE 206	pg/L	24.92	-	ND	1400	700
PBDE 207	pg/L	2.2935	-	75.6	2330	1202.8
PBDE 208	pg/L	25.115	-	ND	1690	845
PBDE 209	pg/L	9.99	-	1240	22900	12070
PCB 008	pg/L	1.4536	-	ND	1.33	0.4176
PCB 018	pg/L	0.5882	-	ND	1.37	0.748
PCB 020	pg/L	-	-	-	-	-
PCB 021	pg/L	-	-	-	-	-
PCB 028	pg/L	0.2558	-	1.58	2.43	2.05
PCB 030	pg/L	-	-	-	-	-
PCB 031	pg/L	0.4338	-	ND	1.61	1.082
PCB 033	pg/L	0.2446	-	0.617	0.915	0.7782
PCB 044	pg/L	0.7	-	ND	2.94	1.85
PCB 047	pg/L	-	-	-	-	-
PCB 049	pg/L	0.2668	-	0.782	2.07	1.1386
PCB 052	pg/L	0.734	-	ND	2.65	2.06
PCB 056	pg/L	0.3356	-	0.408	0.909	0.6332
PCB 060	pg/L	0.3888	-	ND	1.3	0.3304
PCB 061	pg/L	-	-	-	-	-
PCB 065	pg/L	-	-	-	-	-

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 066	pg/L	0.4328	-	ND	4.87	1.5982
PCB 069	pg/L	-	-	-	-	-
PCB 070	pg/L	0.317	-	2.33	5.91	3.478
PCB 074	pg/L	-	-	-	-	-
PCB 076	pg/L	-	-	-	-	-
PCB 083	pg/L	-	-	-	-	-
PCB 086	pg/L	-	-	-	-	-
PCB 087	pg/L	0.3138	-	2.53	3.74	2.962
PCB 090	pg/L	-	-	-	-	-
PCB 093	pg/L	-	-	-	-	-
PCB 095	pg/L	0.354	-	2.76	4.39	3.568
PCB 097	pg/L	-	-	-	-	-
PCB 098	pg/L	-	-	-	-	-
PCB 099	pg/L	0.3666	-	1.39	2.4	1.952
PCB 100	pg/L	-	-	-	-	-
PCB 101	pg/L	0.3208	-	3.14	3.92	3.422
PCB 102	pg/L	-	-	-	-	-
PCB 105	pg/L	0.7304	-	ND	2.16	1.048
PCB 108	pg/L	-	-	-	-	-
PCB 110	pg/L	0.2704	-	3.43	6.53	4.968
PCB 113	pg/L	-	-	-	-	-
PCB 115	pg/L	-	-	-	-	-
PCB 118	pg/L	0.355	-	1.72	3.74	2.778
PCB 119	pg/L	-	-	-	-	-
PCB 125	pg/L	-	-	-	-	-
PCB 128	pg/L	0.401	-	0.28	1.27	0.7448
PCB 129	pg/L	-	-	-	-	-
PCB 132	pg/L	0.4912	-	0.846	2.72	1.6392
PCB 135	pg/L	-	-	-	-	-
PCB 138	pg/L	0.3996	-	1.76	5.37	3.33
PCB 141	pg/L	0.4506	-	ND	0.78	0.2378
PCB 147	pg/L	-	-	-	-	-
PCB 149	pg/L	0.4212	-	1.63	3.64	2.39
PCB 151	pg/L	0.3766	-	ND	1.65	0.978
PCB 153	pg/L	0.355	-	1.19	3.08	1.826
PCB 154	pg/L	-	-	-	-	-
PCB 156	pg/L	0.409	-	ND	0.581	0.2076
PCB 157	pg/L	-	-	-	-	-
PCB 158	pg/L	0.3134	-	ND	0.602	0.1204
PCB 160	pg/L	-	-	-	-	-
PCB 163	pg/L	-	-	-	-	-

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 166	pg/L	-	-	-	-	-
PCB 168	pg/L	-	-	-	-	-
PCB 170	pg/L	0.3922	-	ND	1.09	0.5358
PCB 174	pg/L	0.4822	-	ND	0.58	0.2824
PCB 177	pg/L	0.3628	-	ND	0.645	0.1854
PCB 180	pg/L	0.6086	-	ND	1.66	0.4408
PCB 183	pg/L	0.4356	-	ND	0.24	0.048
PCB 185	pg/L	-	-	-	-	-
PCB 187	pg/L	0.3644	-	ND	1.31	0.3662
PCB 193	pg/L	-	-	-	-	-
PCB 194	pg/L	0.3704	-	ND	ND	ND
PCB 195	pg/L	0.3968	-	ND	ND	ND
PCB 201	pg/L	0.295	-	ND	ND	ND
PCB 203	pg/L	0.3798	-	ND	ND	ND
Allethrin	pg/L	2790	-	ND	ND	ND
Bifenthrin	pg/L	949	-	ND	ND	ND
Cyfluthrin, total	pg/L	7020	-	ND	ND	ND
Cyhalothrin,lambda, total	pg/L	748	-	ND	ND	ND
Cypermethrin, total	pg/L	997	-	ND	ND	ND
Delta/Tralomethrin	pg/L	539	-	ND	ND	ND
Esfenvalerate/Fenvalerate, total	pg/L	845	-	ND	ND	ND
Fenpropathrin	pg/L	1770	-	ND	ND	ND
Permethrin, total	pg/L	287	-	ND	ND	ND
Phenothrin	pg/L	525	-	ND	ND	ND
Prallethrin	pg/L	7020	-	ND	ND	ND
Resmethrin	pg/L	653	-	ND	ND	ND
Calcium	ug/L	6.32	31.6	ND	ND	ND
Total Cu	ug/L	0.063	0.4013	ND	1.13	0.365
Dissolved Cu	ug/L	0.063	0.4013	ND	0.681	0.17025
Magnesium	pg/L	43.1	-	ND	ND	ND
Total Hg	ug/L	0.000198	0.0004	ND	0.0044	0.00092
Total MeHg	ng/L	0.018571429	0.0314	ND	0.021	0.003
Dissolved Se	ug/L	0.051	0.093	ND	ND	ND
Total Se	ug/L	0.051	0.093	ND	ND	ND
Total Hardness (calc)	mg/L	0.02	0.09	ND	ND	ND
TOC	mg/L	-	-	-	-	-

Table A3: Average RSD of field and lab duplicates at each site.

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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	-	-	-	-	-	-	83.5%	75.7%	-	-	1.4%	-
Fipronil	79.5%	-	-	-	9.2%	-	10.9%	-	-	-	-	-
Fipronil Desulfinyl	10.9%	-	0.0%	-	15.5%	-	-	-	-	-	-	-
Fipronil Sulfide	0.0%	-	-	-	-	-	-	-	-	-	-	-
Fipronil Sulfone	0.0%	-	-	-	4.9%	-	-	-	-	-	-	-
NH4	3.1%	0.0%	1.8%	1.5%	4.0%	4.9%	0.0%	0.0%	3.3%	-	-	-
NO3	0.0%	0.0%	0.0%	0.0%	1.1%	-	0.0%	0.0%	0.0%	-	0.0%	-
NO2	1.0%	0.7%	0.0%	0.0%	1.0%	-	0.0%	0.0%	0.0%	-	0.0%	-
TKN	10.2%	3.4%	-	-	14.5%	23.9%	12.0%	-	31.4%	-	-	-
PO4	0.3%	0.8%	0.9%	0.9%	0.3%	-	1.5%	1.1%	0.0%	-	4.7%	-
Total P	7.1%	0.0%	0.0%	0.0%	3.0%	2.4%	0.0%	0.0%	2.9%	-	-	-
SSC	12.3%	-	11.9%	-	11.5%	-	8.6%	-	19.6%	-	19.9%	-
Acenaphthene	20.1%	-	-	-	-	-	10.0%	0.4%	1.5%	1.5%	-	-
Acenaphthylene	10.7%	-	-	-	-	-	31.8%	18.1%	5.5%	5.5%	-	-
Anthracene	14.2%	-	24.6%	9.4%	43.4%	-	39.1%	23.4%	5.7%	5.7%	-	-
Benz(a)anthracene	15.3%	-	-	-	-	-	-	-	-	-	-	-
Benz(a)anthracenes/Chrysenes, C1-	5.7%	-	6.9%	4.1%	2.9%	-	17.3%	6.8%	1.0%	1.0%	-	-
Benz(a)anthracenes/Chrysenes, C2-	4.3%	-	7.5%	8.7%	6.0%	-	19.0%	16.4%	2.6%	2.6%	-	-
Benz(a)anthracenes/Chrysenes, C3-	23.6%	-	6.3%	6.9%	11.1%	-	40.2%	8.9%	0.7%	0.7%	-	-
Benz(a)anthracenes/Chrysenes, C4-	5.9%	-	25.2%	20.6%	10.6%	-	16.7%	7.0%	0.3%	0.3%	-	-
Benzo(a)pyrene	16.7%	-	19.5%	7.0%	20.8%	-	23.6%	6.5%	1.1%	1.1%	-	-
Benzo(b)fluoranthene	9.3%	-	10.2%	2.7%	26.6%	-	17.5%	5.2%	4.7%	4.7%	-	-
Benzo(e)pyrene	13.5%	-	7.0%	4.4%	9.9%	-	28.4%	5.9%	0.9%	0.9%	-	-
Benzo(g,h,i)perylene	16.6%	-	8.8%	0.0%	4.6%	-	14.2%	5.3%	4.5%	4.5%	-	-
Benzo(k)fluoranthene	36.4%	-	20.6%	1.8%	-	-	33.0%	2.8%	2.0%	2.0%	-	-
Chrysene	8.4%	-	11.6%	1.3%	9.5%	-	19.0%	7.5%	2.2%	2.2%	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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
Dibenz(a,h)anthracene	39.9%	-	31.9%	9.9%	-	-	-	-	2.1%	2.1%	-	-
Dibenzothiophene	-	-	8.5%	2.1%	-	-	15.9%	13.0%	-	-	-	-
Dibenzothiophenes, C1-	8.9%	-	6.3%	1.7%	5.1%	-	24.6%	2.9%	2.5%	2.5%	-	-
Dibenzothiophenes, C2-	4.5%	-	3.8%	0.7%	10.2%	-	12.2%	2.9%	6.1%	6.1%	-	-
Dibenzothiophenes, C3-	4.8%	-	7.3%	2.1%	8.0%	-	14.7%	0.8%	0.5%	0.5%	-	-
Dimethylnaphthalene, 2,6-	22.2%	-	4.7%	1.6%	0.4%	-	12.2%	13.8%	7.1%	7.1%	-	-
Fluoranthene	16.0%	-	16.3%	1.3%	33.2%	-	17.2%	16.0%	2.2%	2.2%	-	-
Fluoranthene/Pyrenes, C1-	16.3%	-	10.5%	4.4%	8.7%	-	17.4%	2.9%	2.6%	2.6%	-	-
Fluorene	15.3%	-	-	-	-	-	15.8%	9.1%	3.7%	3.7%	-	-
Fluorenes, C2-	14.0%	-	7.3%	8.9%	0.8%	-	9.4%	1.2%	1.8%	1.8%	-	-
Fluorenes, C3-	7.0%	-	8.6%	5.4%	9.0%	-	12.3%	0.1%	0.7%	0.7%	-	-
Indeno(1,2,3-c,d)pyrene	21.9%	-	14.5%	0.4%	14.9%	-	18.1%	5.3%	8.9%	8.9%	-	-
Methylnaphthalene, 2-	9.3%	-	3.3%	1.1%	2.1%	-	10.6%	6.3%	3.4%	3.4%	-	-
Methylphenanthrene, 1-	16.7%	-	12.7%	13.6%	11.6%	-	14.6%	10.7%	0.0%	0.0%	-	-
Naphthalene	10.3%	-	7.6%	1.5%	3.2%	-	2.1%	3.8%	0.5%	0.5%	-	-
Naphthalenes, C1-	14.5%	-	-	-	0.5%	-	7.5%	5.7%	3.4%	3.4%	-	-
Naphthalenes, C3-	17.2%	-	1.3%	1.9%	0.6%	-	8.9%	11.2%	8.5%	8.5%	-	-
Perylene	17.6%	-	20.8%	4.2%	5.0%	-	25.6%	8.6%	-	-	-	-
Phenanthrene	5.8%	-	33.9%	6.1%	29.0%	-	21.3%	26.5%	1.6%	1.6%	-	-
Phenanthrene/Anthracene, C1-	28.7%	-	12.0%	2.1%	13.7%	-	13.0%	0.2%	2.5%	2.5%	-	-
Phenanthrene/Anthracene, C2-	15.6%	-	6.0%	8.4%	7.1%	-	12.9%	8.1%	3.9%	3.9%	-	-
Pyrene	16.7%	-	13.4%	1.0%	19.5%	-	19.2%	14.4%	1.7%	1.7%	-	-
Trimethylnaphthalene, 2,3,5-	22.1%	-	3.6%	0.3%	2.3%	-	17.6%	9.0%	-	-	-	-
PBDE 007	-	-	-	-	-	-	-	11.2%	15.4%	15.6%	2.0%	2.0%
PBDE 008	8.3%	4.7%	-	-	-	-	-	-	56.9%	65.0%	6.5%	6.5%
PBDE 010	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 011	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 012	-	-	-	-	-	-	-	11.7%	68.7%	73.4%	9.5%	9.5%
PBDE 013	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 015	11.7%	9.5%	-	-	-	-	3.2%	4.3%	13.8%	15.4%	7.5%	7.5%
PBDE 017	5.9%	12.7%	7.6%	-	-	-	-	-	9.1%	5.0%	12.9%	12.9%
PBDE 025	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 028	4.5%	7.0%	0.9%	-	-	-	15.6%	20.7%	5.8%	2.0%	14.9%	14.9%
PBDE 030	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 032	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 033	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 035	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 047	2.9%	1.2%	5.9%	-	-	-	13.8%	18.2%	12.0%	0.4%	4.6%	4.6%
PBDE 049	5.0%	0.7%	1.7%	-	-	-	10.2%	8.6%	5.7%	0.7%	12.4%	12.4%
PBDE 051	5.7%	5.7%	-	-	-	-	-	-	16.2%	7.8%	15.3%	15.3%
PBDE 066	2.3%	0.5%	1.0%	-	-	-	13.8%	14.1%	6.2%	1.7%	8.4%	8.4%
PBDE 071	1.9%	1.9%	-	-	-	-	-	-	-	-	32.7%	32.7%
PBDE 075	0.7%	0.7%	9.8%	-	-	-	-	-	-	-	22.0%	22.0%
PBDE 077	15.8%	15.8%	-	-	-	-	-	-	-	-	-	-
PBDE 079	16.4%	16.4%	-	-	-	-	-	-	11.3%	13.2%	-	-
PBDE 085	6.3%	5.2%	5.7%	-	-	-	4.6%	5.7%	19.6%	2.4%	2.9%	2.9%
PBDE 099	4.8%	3.9%	6.2%	-	-	-	8.1%	9.9%	15.1%	2.0%	4.8%	4.8%
PBDE 100	2.8%	0.3%	6.5%	-	-	-	9.2%	11.7%	14.6%	0.0%	6.0%	6.0%
PBDE 105	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 116	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 119	6.8%	6.3%	-	-	-	-	-	21.0%	34.7%	13.6%	-	-
PBDE 120	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 126	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 128	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 140	-	-	-	-	-	-	12.1%	12.5%	10.0%	1.6%	9.8%	9.8%
PBDE 153	6.9%	6.6%	5.5%	-	-	-	6.2%	7.1%	12.5%	1.4%	3.5%	3.5%
PBDE 155	8.1%	12.5%	-	-	-	-	6.4%	7.8%	15.2%	1.0%	6.0%	6.0%
PBDE 166	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 181	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 183	21.3%	1.5%	-	-	-	-	27.4%	32.6%	17.6%	11.2%	11.0%	11.0%
PBDE 190	-	-	-	-	-	-	-	-	-	-	1.7%	1.7%
PBDE 197	42.2%	12.3%	15.8%	-	-	-	-	-	-	-	1.7%	1.7%
PBDE 203	26.6%	17.6%	-	-	-	-	-	3.3%	33.4%	21.4%	4.6%	4.6%
PBDE 204	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 205	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 206	9.0%	23.9%	8.8%	-	-	-	6.1%	7.6%	34.1%	17.3%	37.3%	37.3%
PBDE 207	12.8%	25.5%	5.8%	-	-	-	2.0%	2.1%	34.9%	24.4%	28.2%	28.2%
PBDE 208	17.6%	23.7%	13.0%	-	-	-	3.5%	4.1%	36.6%	25.3%	30.5%	30.5%
PBDE 209	22.5%	19.4%	2.2%	-	-	-	2.1%	2.2%	35.6%	6.7%	42.3%	42.3%
PCB 008	15.5%	10.4%	13.6%	13.6%	20.0%	-	5.0%	0.3%	6.8%	3.1%	10.4%	11.9%
PCB 018	13.9%	4.1%	10.0%	10.0%	15.9%	-	4.2%	0.7%	12.3%	5.2%	6.5%	6.5%
PCB 020	-	-	-	-	-	-	-	-	-	-	-	-
PCB 021	-	-	-	-	-	-	-	-	-	-	-	-
PCB 028	10.8%	12.5%	5.9%	7.5%	4.7%	-	3.8%	1.2%	10.9%	3.6%	8.8%	5.4%
PCB 030	-	-	-	-	-	-	-	-	-	-	-	-
PCB 031	11.1%	9.1%	5.1%	7.5%	8.5%	-	4.7%	0.7%	11.3%	2.7%	7.1%	0.8%
PCB 033	13.8%	7.2%	6.4%	8.2%	13.2%	-	3.1%	0.4%	11.3%	7.0%	10.4%	0.4%
PCB 044	4.9%	9.9%	6.6%	10.0%	2.9%	-	6.5%	13.3%	13.0%	8.6%	9.0%	0.2%
PCB 047	-	-	-	-	-	-	-	-	-	-	-	-
PCB 049	6.6%	9.6%	5.6%	8.5%	5.5%	-	5.1%	13.6%	14.3%	12.8%	10.0%	2.0%
PCB 052	8.0%	13.8%	7.6%	10.4%	9.9%	-	7.0%	14.4%	19.2%	22.6%	11.9%	6.6%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 056	6.4%	5.1%	13.7%	7.3%	2.2%	-	5.5%	12.0%	7.2%	1.6%	11.9%	3.8%
PCB 060	6.1%	4.3%	16.9%	7.8%	2.0%	-	6.1%	13.6%	3.1%	3.1%	11.8%	3.2%
PCB 061	-	-	-	-	-	-	-	-	-	-	-	-
PCB 065	-	-	-	-	-	-	-	-	-	-	-	-
PCB 066	7.0%	8.0%	7.5%	8.9%	1.5%	-	8.2%	15.0%	2.3%	1.9%	11.5%	1.6%
PCB 069	-	-	-	-	-	-	-	-	-	-	-	-
PCB 070	8.9%	11.1%	7.8%	10.7%	2.2%	-	6.4%	15.5%	5.2%	9.9%	12.8%	5.5%
PCB 074	-	-	-	-	-	-	-	-	-	-	-	-
PCB 076	-	-	-	-	-	-	-	-	-	-	-	-
PCB 083	-	-	-	-	-	-	-	-	-	-	-	-
PCB 086	-	-	-	-	-	-	-	-	-	-	-	-
PCB 087	11.3%	10.2%	8.7%	9.9%	16.3%	-	6.3%	17.6%	17.3%	22.4%	16.7%	23.2%
PCB 090	-	-	-	-	-	-	-	-	-	-	-	-
PCB 093	-	-	-	-	-	-	-	-	-	-	-	-
PCB 095	13.9%	14.3%	6.2%	7.5%	18.2%	-	11.5%	18.8%	19.8%	29.8%	16.8%	27.1%
PCB 097	-	-	-	-	-	-	-	-	-	-	-	-
PCB 098	-	-	-	-	-	-	-	-	-	-	-	-
PCB 099	11.9%	10.9%	7.6%	7.4%	15.0%	-	8.1%	18.7%	19.6%	24.7%	18.5%	28.6%
PCB 100	-	-	-	-	-	-	-	-	-	-	-	-
PCB 101	10.8%	9.0%	7.6%	8.4%	19.9%	-	13.0%	18.6%	18.0%	23.9%	16.8%	33.0%
PCB 102	-	-	-	-	-	-	-	-	-	-	-	-
PCB 105	7.7%	7.9%	8.5%	11.0%	13.4%	-	7.7%	19.2%	8.1%	17.8%	18.6%	22.5%
PCB 108	-	-	-	-	-	-	-	-	-	-	-	-
PCB 110	10.7%	9.1%	6.9%	6.1%	16.3%	-	8.4%	18.2%	15.9%	20.9%	17.2%	23.3%
PCB 113	-	-	-	-	-	-	-	-	-	-	-	-
PCB 115	-	-	-	-	-	-	-	-	-	-	-	-
PCB 118	8.5%	8.6%	8.6%	8.7%	15.0%	-	8.1%	20.8%	9.2%	21.2%	17.2%	27.9%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 119	-	-	-	-	-	-	-	-	-	-	-	-
PCB 125	-	-	-	-	-	-	-	-	-	-	-	-
PCB 128	7.6%	8.3%	5.5%	4.2%	29.2%	-	10.0%	26.9%	9.6%	15.0%	7.9%	7.7%
PCB 129	-	-	-	-	-	-	-	-	-	-	-	-
PCB 132	10.5%	9.2%	8.2%	4.7%	18.5%	-	11.8%	25.8%	6.5%	14.2%	7.4%	11.4%
PCB 135	-	-	-	-	-	-	-	-	-	-	-	-
PCB 138	8.5%	11.0%	7.6%	4.5%	12.4%	-	12.1%	25.2%	4.2%	10.8%	10.7%	16.8%
PCB 141	10.3%	10.3%	8.4%	3.5%	14.8%	-	14.0%	22.9%	4.6%	6.7%	12.8%	15.9%
PCB 147	-	-	-	-	-	-	-	-	-	-	-	-
PCB 149	10.2%	7.6%	8.7%	5.0%	13.5%	-	15.7%	31.1%	4.8%	10.4%	9.6%	19.3%
PCB 151	9.1%	4.9%	8.4%	5.2%	9.0%	-	25.9%	29.2%	2.8%	5.9%	7.3%	15.6%
PCB 153	8.3%	8.3%	9.7%	4.2%	12.6%	-	14.4%	24.4%	5.1%	7.6%	9.2%	19.8%
PCB 154	-	-	-	-	-	-	-	-	-	-	-	-
PCB 156	9.1%	9.9%	6.3%	3.1%	16.1%	-	10.0%	25.1%	11.2%	18.6%	8.0%	13.2%
PCB 157	-	-	-	-	-	-	-	-	-	-	-	-
PCB 158	9.9%	11.0%	6.5%	3.8%	16.7%	-	11.1%	24.8%	6.9%	13.8%	11.5%	16.7%
PCB 160	-	-	-	-	-	-	-	-	-	-	-	-
PCB 163	-	-	-	-	-	-	-	-	-	-	-	-
PCB 166	-	-	-	-	-	-	-	-	-	-	-	-
PCB 168	-	-	-	-	-	-	-	-	-	-	-	-
PCB 170	6.9%	4.7%	5.4%	1.4%	11.3%	-	13.2%	24.7%	8.5%	1.0%	6.8%	7.7%
PCB 174	4.9%	1.7%	5.6%	2.2%	11.5%	-	21.8%	36.3%	1.4%	1.3%	5.1%	7.2%
PCB 177	4.2%	3.7%	6.1%	3.4%	18.9%	-	22.1%	-	4.6%	4.6%	4.8%	6.0%
PCB 180	9.2%	1.7%	6.2%	3.0%	5.0%	-	15.4%	29.5%	8.1%	4.4%	7.0%	8.9%
PCB 183	3.6%	3.3%	6.6%	4.6%	16.7%	-	20.0%	31.6%	2.5%	5.5%	6.2%	11.3%
PCB 185	-	-	-	-	-	-	-	-	-	-	-	-
PCB 187	3.0%	3.8%	6.2%	3.9%	6.4%	-	23.8%	34.9%	3.1%	2.7%	6.0%	10.5%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 193	-	-	-	-	-	-	-	-	-	-	-	-
PCB 194	7.9%	3.3%	6.1%	5.6%	14.4%	-	16.1%	38.7%	12.4%	13.5%	5.9%	8.2%
PCB 195	4.7%	2.0%	7.1%	3.4%	29.7%	-	15.3%	26.9%	14.8%	14.1%	4.4%	3.8%
PCB 201	11.0%	2.4%	4.0%	1.1%	10.1%	-	24.4%	-	10.3%	5.6%	4.9%	8.2%
PCB 203	9.2%	6.7%	6.7%	5.4%	14.3%	-	18.2%	44.1%	10.7%	14.4%	6.0%	12.9%
Allethrin	-	-	-	-	-	-	-	-	-	-	-	-
Bifenthrin	35.0%	-	-	-	8.5%	-	4.8%	-	9.7%	-	-	-
Cyfluthrin, total	-	-	-	-	-	-	-	-	4.3%	-	-	-
Cyhalothrin,lambda, total	-	-	-	-	-	-	-	-	-	-	-	-
Cypermethrin, total	-	-	-	-	27.6%	-	-	-	1.6%	-	-	-
Delta/Tralomethrin	-	-	-	-	32.4%	-	23.0%	-	1.6%	-	-	-
Esfenvalerate/Fenvalerate, total	-	-	-	-	-	-	-	-	24.4%	-	-	-
Fenpropathrin	-	-	-	-	-	-	-	-	-	-	-	-
Permethrin, total	12.9%	-	2.4%	-	10.6%	-	2.1%	-	5.2%	-	-	-
Phenothrin	-	-	-	-	-	-	-	-	0.4%	0.4%	-	-
Prallethrin	-	-	-	-	-	-	-	-	0.0%	-	-	-
Resmethrin	-	-	-	-	-	-	-	-	1.7%	1.7%	-	-
Calcium	0.5%	0.4%	-	-	0.5%	0.5%	1.0%	1.0%	1.3%	1.3%	-	-
Total Cu	1.5%	1.1%	0.2%	0.2%	7.3%	0.8%	-	-	-	-	-	-
Dissolved Cu	9.8%	-	-	-	27.5%	-	-	-	3.0%	-	-	-
Magnesium	0.8%	0.6%	0.3%	0.3%	0.5%	0.5%	1.3%	1.3%	8.9%	8.9%	-	-
Total Hg	13.8%	2.1%	11.5%	-	5.7%	-	5.8%	-	-	-	10.1%	-
Total MeHg	14.4%	4.1%	3.1%	-	3.3%	-	6.1%	2.6%	-	-	0.0%	-
Dissolved Se	3.7%	6.2%	-	-	8.6%	-	-	-	5.2%	-	-	-
Total Se	14.0%	10.1%	-	-	6.4%	1.5%	1.4%	1.4%	-	-	-	-
Total Hardness (calc)	0.4%	-	-	-	-	-	-	-	-	-	-	-
TOC	1.3%	-	-	-	3.8%	-	-	-	15.7%	-	-	-

SEDIMENT DELIVERY ESTIMATE / BUDGET (C.8.e.vi)

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
- 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 () and provided a June 2013 internal update to BASMAA on the sediment model. In December 2013 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.

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

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On

February 21, 2014

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)

Acknowledgements

We were glad for the support and guidance of the Sources, Pathways and Loadings Workgroup of the Regional Monitoring Program for Water Quality in San Francisco Bay. The detailed work plan behind this work was developed through the Small Tributaries Loading Strategy (STLS) during a series of meetings in the summer of 2011. Local members on the STLS are Arleen Feng, Lucy Buchan, Khalil Abusaba and Chris Sommers (for BASMAA) and Richard Looker, Jan O'Hara, and Tom Mumley (for the Water Board). Khalil Abusaba, AMEC Environment and Infrastructure and Chris Sommers, EOA INC. provided helpful written reviews on the draft report that we incorporated to improve this final report. This project was completed with funding provided by the Bay Area Stormwater Management Agencies Association (BASMAA) and the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP).

This progress report can be cited as:

Gilbreath, A.N., Gluchowski, D.C., Hunt, J.A., Wu, J., and McKee, L.J., 2014. Pollutants of concern (POC) loads monitoring data progress report, water year (WYs) 2012 and 2013. A technical report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Sources, Pathways and Loadings Workgroup (SPLWG), Small Tributaries Loading Strategy (STLS). Contribution No. 712. San Francisco Estuary Institute, Richmond, California.

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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).

Bay Area Stormwater Programs, 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; SFEI in preparation), and pollutant characterization and loads monitoring in local tributaries beginning Water Year (WY) 2011 (McKee et al., 2012), that continued in WY 2012 (McKee et al., 2013), WY 2013 (this report), and is underway again for WY 2014.

The purpose of this report is to describe data collected during WYs 2012 and 2013 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;
- San Leandro Creek (Hg);
- Guadalupe River (Hg and PCBs);
- Sunnyvale East Channel (PCBs); and
- Pulgas Creek Pump Station.

Loads monitoring provides calibration 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 is 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; SFEI in preparation) was focused mainly on addressing MQ2. Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board (and discussion at the October 2013 SPLWG meeting) 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 intended to address this increasing management focus.

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 (Figure 1; Table 1). The sites were distributed throughout the counties where loads monitoring are required by the MRP. The selected watersheds include 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.

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 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 Street 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 (USGS data). In natural flowing rivers and urban creeks or storm drains, turbidity usually correlates with the concentrations of suspended sediments and hydrophobic pollutants. 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).

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 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; Quémerais et al., 1999; Wall et al., 2005; Gilbreath et al., 2012). 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 except mercury, methylmercury and a simultaneously collected suspended sediment concentration (SSC) sample were collected using the ISCO as a pump at all the sites besides Guadalupe. Discrete mercury and methylmercury samples (including a simultaneously collected SSC sample) 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, and by manually dipping an opened bottle from the side of the channel at San Leandro (in WY 2013 only) and Lower Marsh Creek (both WYs) (Table 1). Tubing for the ISCOs was installed using the clean hands technique, as was the 1 L Teflon bottle when used in the D-95. Composite samples, with the intent of representing average concentrations of storm runoff over each storm event sampled, were collected using the ISCO autosampler at all of the sites except Guadalupe River. 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 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. 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) or that use some kind of mathematical average concentration (e.g. simple mean; geometric mean; flow weighted mean) combined with monthly 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 manner:

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 are collected each year at the STLS monitoring sites, knowledge will improve about how concentrations vary with season and flow (improvements of the definition of the strata) and thus about how to apply loads computation techniques. Therefore, with each additional annual reporting year, a revision of loads is expected for the previous water year(s). This will occur in relation to improved flow information as well as an improved understanding of concentration variation in relation to seasonal characteristics and flow.

During the study, concentrations either measured or estimated were multiplied with the continuous estimates of flow (2-15 minute interval) to compute the load on a 2 to 15 minute basis and summed to monthly and wet season loads. Laboratory measured data was 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 and loads):

Linear interpolation: Linear interpolation is the primary technique used for interpolating concentrations between measured data points when storms are well sampled (Note, this method was not yet applied but will be applied when the final report for the data collection during WYs 2012, 2013, and 2014 is written – likely late 2014).

Linear Interpolation using particle ratios: 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 for pollutants which occur mainly in particulate form because it ensures that the

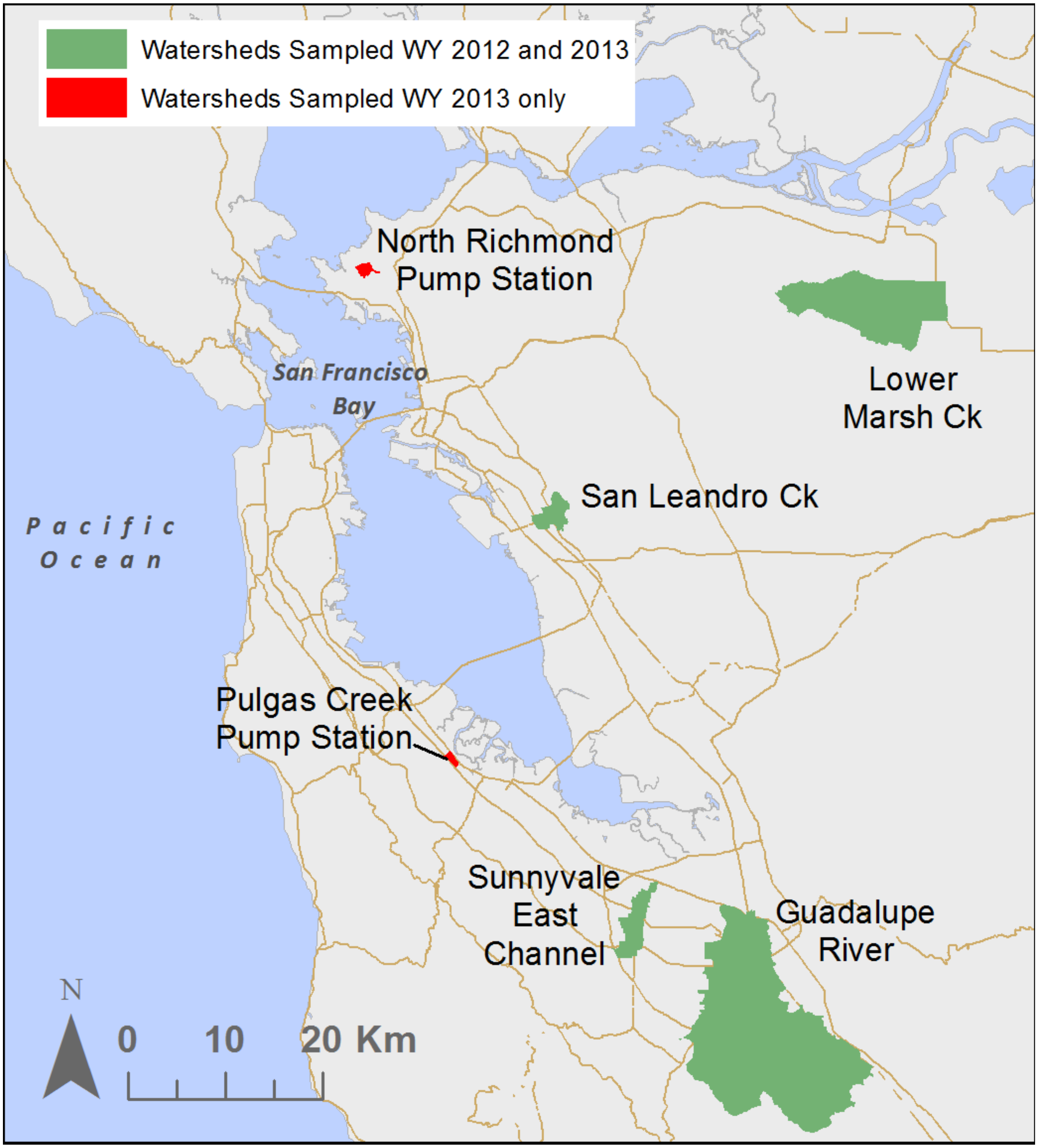

Figure 1. Water year 2012 and 2013 sampling watersheds.

Table 1. Sampling locations in relation to County 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 and 2013	99	Brentwood	37.990723	-122.16265	ADH	USGS Gauge Number: 11337600[2]	OBS-500[4]	Manual grab	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Contra Costa	North Richmond Pump Station	2013	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 and 2013	8.9	San Leandro	37.726073	-122.16265	SFEI WY2012 ADH WY2013	STLS creek stage/ velocity/ discharge rating	OBS-500[4]	FISP US D95[7] WY 2012 Manual grab WY 2013	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
Santa Clara	Guadalupe River	2012 and 2013	236	San Jose	37.373543	-121.69612	SFEI WY2012 Balance WY 2013	USGS Gauge Number: 11169025[3]	DTS-12[5]	FISP US D95[7]	FISP US D95[7]	FISP US D95[7]
Santa Clara	Sunnyvale East Channel	2012 and 2013	14.8	Sunnyvale	37.394487	-122.01047	SFEI	STLS creek stage/ velocity/ discharge rating	OBS-500*[4] WY 2012 DTS-12[5] WY 2013	FISP US D95[7]	ISCO auto pump sampler[8]	ISCO auto pump sampler[8]
San Mateo	Pulgas Creek Pump Station	2013	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] FISP US DH-81 Depth integrating suspended hand line sampler

[7] FISP US D-95 Depth integrating suspended hand line sampler

[8] Teledyne ISCO 6712 Full Size Portable Sampler

*OBS-500 malfunctioned during WY 2012 due to low flow water depth. A DTS-12 was installed during WY 2013.

relationship between the derived concentration and of varying turbidity that occurs between the two laboratory derived pollutant measurements results in particle ratios that at all times intervals are reasonable.

Linear Interpolation using water concentrations: Linear interpolation using water concentrations is the process by which the interpreter varies the concentrations between observed measurements using a linear time step. It is appropriately used for pollutants which occur mainly in dissolved phase because it does not incorporate any regard for varying turbidity or SSC.

Interpolation using a turbidity based regression equation with each POC: Turbidity surrogate regression can be considered the default standard for pollutants of concern that are primarily transported in a particulate form. These types of contaminants (for example PCBs and mercury) form strong linear relationships with either turbidity or SSC. Turbidity surrogate regression was applied to all unsampled flood flow conditions observed at each monitoring site.

Interpolation using a regression equation derived from two chemical species (e.g. TP:PO4): For pollutants primarily transported in dissolved phase, the turbidity regression estimator was not be appropriate. In this instance it may be possible to use an alternative surrogate such as electrical conductivity or a parent pollutant. A “chemical surrogate regression” estimator of this nature can be considered the default standard for pollutants of concern that are primarily transported in a dissolved form. This method was applied to unsampled flood flow conditions if a reliable regression was found.

Interpolation assuming a representative concentration (e.g. “dry weather lab measured” or “lowest measured”): To apply this method, an estimate of average of 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.

3. Continuous data quality assurance

3.1. Continuous data quality assurance methods

In 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. These protocols were established towards the end of the season and therefore some field checks now required in the QA protocol will not be implemented until WY 2014, specifically including precision checks on the instrumentation through replicate testing of equipment at high and low reference values. 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 the 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 through calibration, accuracy in relation to comparison with manual measurements, dataset representativeness relative to logging interval, and finally on completeness of the dataset (Table 2 and

Table 3). 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., 2013).

Table 2. Continuous data quality assurance summary for accuracy and precision for each monitoring location. "NR" indicates that the QA procedure was not completed and "NA" indicates that the QA procedure was not applicable.

	Accuracy at Calibration			**Accuracy of Comparison**		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Sunnyvale	NR	NR	Excellent	Excellent	Excellent	Excellent
Pulgas	NR	NR	New instrument	Excellent	NR	Poor[1]
Richmond	NR	NR	Excellent	Poor	NR	Good
Guadalupe	NA	USGS maintained	USGS maintained	NA	USGS maintained	Excellent
San Leandro	NR	NR	Within Tolerance	Excellent	Excellent	NR
Lower Marsh	NR	USGS maintained	Excellent	Excellent	USGS maintained	NR

Table 3. Continuous data quality assurance summary for representativeness and completeness for each monitoring location.

	Representativeness of the population			**Completeness (Confidence in corrections)**		
	Rainfall	**Stage**	**Turbidity**	**Rainfall**	**Stage**	**Turbidity**
Sunnyvale	Excellent	Good[2]	Excellent	Excellent	Excellent	Poor[6]
Pulgas	Excellent	Excellent	Good[3]	Excellent	Poor[7]	Excellent/Poor[8]
Richmond	Excellent	Excellent	Poor[4]	Poor	Excellent	Excellent
Guadalupe	NA	USGS maintained	Excellent	NA	USGS maintained	Excellent
San Leandro	Excellent	Excellent	Excellent	Good[5]	Excellent	Poor[9]
Lower Marsh	Excellent	USGS maintained	Excellent	Excellent	USGS maintained	Excellent

[1] Manual turbidity measurements against sensor measurements had a coefficient of determination of 0.25.

[2] 4.7% of records at Sunnyvale showed a >15% change between consecutive readings, and manual stage measurements were only made in the 4th quartile.

[3] 1.9% of the population (483 records) had greater than 20 NTU absolute value change and ≥15% relative change from the preceding record; 1.3% (328 records) had greater than 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.

[4] 4.2% of the population (251 records) had greater than 20 NTU absolute value change and ≥15% relative change from the preceding record; 2.9% (171 records) had greater than 20 NTU absolute value change and >50% relative change from the preceding record. Data intervals already set to minimum of 1 minute interval. Recommended action for improvement is to collect as many manual turbidity measurements as possible in order to better understand whether variability in the record is real or anomalous.

[5] Rainfall data at San Leandro Creek missing from 10/1/2012-11/6/2012, 12/6/2012-12/12/2012, and 1/4/2013-1/9/2013. Missing 10.6% of records.

[6] 31% of the period of record was missing turbidity due to the minimum stage criterion for turbidity measurement to be 0.4 ft and this amount of the record being during stages below 0.4 ft. An additional 8.3% of the turbidity record was rejected due to fouling.

[7] A large portion of the data record was on intervals greater than 15minutes.

[8] Completeness of the turbidity record was excellent during the period in which turbidity was measured, but a large portion

of the wet season was missing data.

[9] 23% of records for stages > 1 ft have no corresponding turbidity record.

3.2. Continuous data quality assurance summary

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. Rain gauges were cleaned before and periodically during the season, but not calibrated. All sites except for the North Richmond Pump Station compared well to nearby rain gauges. Discrepancies between the rain gauge at North Richmond Pump Station and nearby gauges during December and January resulted in the accuracy of this data set to be labeled as “poor”. 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. Manual stage measurements made at Sunnyvale and San Leandro compared well with the corresponding record from the pressure transducer (R^2=0.99 at both sites). The entire stage dataset at Lower Marsh was compared to the USGS gauge on Marsh creek, and showed a regression with R^2=0.98. Percent differences between consecutive records were reasonable at all sites and the datasets were complete for the period where the equipment was installed. Manual stage measurements were not collected at either of the pump station sampling locations and could not be used to verify the accuracy or precision of those stage records, an improvement to be implemented in WY 2014.

Continuous turbidity data were rated excellent at Lower Marsh Creek and Guadalupe River. San Leandro Creek, Sunnyvale East Channel and Pulgas Creek Pump Station (qualified) all received poor quality ratings on completeness: the San Leandro Creek dataset was relatively free from spikes requiring censorship or correction but had a large portion of missing records; Sunnyvale East Channel had a full record but a large portion of data censored due to spikes; and Pulgas Creek Pump Station recorded turbidity during only three of the seven wet season months in large part due to instrumentation failures. The pump station sites both received poor ratings for representativeness given how records could fluctuate multiple times from one reading to the next. Both of these sites experience very rapidly changing conditions and may warrant unique rating criterion in the QA protocol; a topic for continued discussion and potential revision for future reporting. Pulgas Creek Pump Station also had poor repeatability between manual and sensor collected data and improvements to the monitoring set-up should be considered for next wet season.

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) (Table 4). In water year 2013, laboratory changes were made for the following chemical analyses:

- Total Mercury and total methylmercury from Moss Landing Marine Laboratory to Caltest
- Nutrients and SSC from East Bay MUD to Caltest

Table 4. Laboratory analysis methods

Analyte	Method	Field Filtration	Field Acidification	Laboratory
Carbaryl	EPA 632M	no	no	DFG WPCL
Fipronil	EPA 619M	no	no	DFG WPCL
Suspended Sediment Concentration	ASTM D3977-97B	no	no	Caltest Analytical Laboratory
Total Phosphorus	SM20 4500-P E	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Nitrate	EPA 353.2 / SM20 4500-NO3 F	yes	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Dissolved OrthoPhosphate	SM20 4500-P E	yes	no	Caltest Analytical Laboratory
PAHs	AXYS MLA-021 Rev 10	no	no	AXYS Analytical Services Ltd.
PBDEs	AXYS MLA-033 Rev 06	no	no	AXYS Analytical Services Ltd.
PCBs	AXYS MLA-010 Rev 11	no	no	AXYS Analytical Services Ltd.
Pyrethroids	EPA 8270Mod (NCI-SIM)	no	no	Caltest Analytical Laboratory
Total Methylmercury	EPA 1630M Rev 8	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Total Mercury	EPA 1631EM Rev 11	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Copper[1]	EPA 1638M	no	no	Caltest Analytical Laboratory
Selenium[1]	EPA 1638M	no	no	Caltest Analytical Laboratory
Total Hardness[1]	SM 2340	no	no	Caltest Analytical Laboratory
Total Organic Carbon	SM20 5310B	no	yes (bottle pre-preserved)	Caltest Analytical Laboratory
Toxicity[3]	See 2 below	no	no	Pacific Eco-Risk Labs

[1] Dissolved selenium and dissolved copper were field filtered at the Lower Marsh Creek and San Leandro Creek stations in water year 2013. Dissolved selenium and dissolved copper field filtered for Lower Marsh Creek only in water year 2012. Field filtered samples are also field preserved.

[2] Hardness is a calculated property of water based on magnesium and calcium concentrations. The formula is: Hardness (mg/L) = (2.497 [Ca, mg/L] + 4.118 [Mg, mg/L])

[3] 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 (EPA 821/R-02-013), and10-day survival test with *Hyalella Azteca (*EPA 600/R-99-064M)

- Pyrethroids from AXYS Analytical Laboratory to Caltest
- Selenium, copper, and hardness from Brooks Rand Laboratory to Caltest

An inter-comparison study was designed to assess any impacts of laboratory change during the study. A subset of samples were collected in replicate in the field and sent to the previous laboratory and replacement laboratory. Acceptance limits for precision and recovery in QC samples (e.g., for matrix spikes or reference materials) in published methods provide practical guides for the expected agreement between samples analyzed by different labs; differences between labs will reflect the aggregate of uncertainty for each measurement (the propagated error would be the square root of the sum of the squared errors), and thus may often be larger than the accepted limits of intra- (single) lab variation. Differences among locations or over time, that were smaller than these propagated errors, could not be distinguished from measurement variability, so results (e.g., calculated loads) should be interpreted with awareness of these uncertainties.

Mercury and methylmercury samples were analyzed during the inter-comparison study. Comparability for total mercury samples was good, averaging 26% RPD (similar to the expected 25% RPD for within lab replicates) and ranging from 2 to 42% RPD for individual pairs, with the previous laboratory reporting higher concentrations for all inter-compared sample pairs. Methylmercury comparability was even better, averaging 11% RPD (10.7 and 11.1% RPD on individual sample pairs), again with the previous laboratory reporting slightly higher concentrations.

Comparability of nutrient and conventional water quality parameters was usually good except for SSC. RPDs between nitrate results from the labs ranged 2 to 6% (average 4%), and orthophosphate results were identical within rounding error (reported to the nearest 0.01 mg/L). Total phosphorous was slightly more variable but averaged only 6% RPD (4 to 7% range). Only SSC showed a wide degree of variation, with RPDs ranging 0 to 60% (average 25%), illustrating some of the challenges of consistently representatively sampling particulate matter in stormwater flows.

For pyrethroids, the results were fairly similar for the most abundant compound, bifenthrin (17% RPD), with somewhat poorer agreement for the next most abundant compound, permethrin with 40% RPD. For two independent measurements each with up to 35% error, the propagated error would be the square root of the sum of the squared errors (i.e., SQRT[$0.35^2 + 0.35^2$]), approximately 49%, so 40% RPD was within this range of expected error. Comparability could not be assessed quantitatively (i.e., no RPDs were calculated) for the remaining pyrethroids. MDLs from the previous laboratory were mostly in the range 0.25-5 ng/L, with most samples reported as non-detect or as estimated results near MDL/below RL. Therefore RPDs (even if calculated) could not be quantitative.

Hardness, copper, and selenium were also analyzed. Although hardness reported by the current laboratory was censored due to poor matrix spike recovery (error 4 times over the 5% target; the error tolerance on hardness measurements are tighter due to the usual ease of good precision and accuracy on those measurements), raw results were compared to see if the bias reported in QC samples was also reflected in comparability between laboratories. The RPD for hardness was 16%, with the current laboratory reporting lower concentrations; a similar low bias is seen in their matrix spike samples, which reported 21% lower than their expected values. The concurrence between these IC results and the current laboratory's MS results suggests a consistent low bias for hardness, so any use of the currently censored data should be made with full awareness and acknowledgement of this likely bias. Comparability on copper was much better, averaging 7% RPD (5 and 12% respectively for the total and dissolved samples compared), and similarly the comparability on selenium was quite good, averaging 6% (0.5 and 11% for the total and dissolved fractions of compared samples).

Where differences being sought are similar in magnitude to the uncertainty in precision around individual measurements, a large number of measurements may be needed to verify the significance of possible differences (or lack thereof) seen. When the uncertainty arises from bias, comparison to other laboratories' results (either through inter-comparison exercises or certified reference materials[1]) can provide an indication of the possible bias. The inter-comparability data provide greater confidence in individual measurements where there is better agreement; the results are less likely to reflect an artifact of any particular laboratory's sample handling and quantitation methods. Thus for this study, there is generally better confidence in the measurement of inorganic pollutants and water quality parameters (other than SSC). Overall, the results from the IC study (from a relatively small sub-set of samples) did not provide evidence to indicate non-comparability between the new laboratories for most analytes. Due to sample concentrations near MDL for pyrethriods, evidence is weaker and there was some concern with the SSC comparability; SSC inter-comparisons are likely most influenced among all the analytes by grain size and field sub-sampling techniques in addition to laboratory sample treatment. At this time, the results from the IC study have not been factored into loads computations; this will occur during the completion of the final report estimated to occur in late 2014.

4.2. Quality assurance methods for pollutants of concern concentration data

4.3.1. Sensitivity

The sensitivity review evaluated the percentage of field samples that were non-detects 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.

4.3.2. Blank Contamination

Blank contamination review was performed 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 this batch, were qualified as blank contaminated. If the field sample result was less than 3 times the average blank concentration (including those reported as ND) those results were "censored" and not reported or used for any data analyses.

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[1] Although certified reference materials provide one indicator of possible bias, they in themselves provide no absolute guarantee of a particular measurement's accuracy; the certified values are consensus values that often have very wide confidence bands. This may depend on the particular labs participating in the certification and the methods used by those labs. Furthermore, concentrations of analytes and interfering matrices may differ from those in samples from a particular study.

4.3.3. Precision

Rather than evaluation by lab batch, precision review was performed 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 - unlikely for wet-season runoff event samples unless collected simultaneously from a location). Replicates from 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 RPD is ≤25%) were qualified; those outside of 2 times the MQO were censored.

4.3.4. Accuracy

Accuracy review was also performed 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: Certified Reference Materials (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 flagged, 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.

4.3.5. Comparison of dissolved and total phases

This review was only conducted on water samples that reported dissolved and particulate 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 an MQO of RPD<25%, a dissolved sample result might easily be higher than a total result by that amount.

4.3.6. 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.

4.3.7. 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 is necessary to 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.

5. Results

The following sections present synthetic results from the six monitored tributaries. In this 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.

5.1. Project Quality Assurance Summary

The section below reports on WY 2013 data; for the WY 2012 quality assurance summary, refer to section 4.1 in McKee et al., 2013. Attachment 1 provides a detailed QAQC summary for WY 2013 data.

The PCB data were acceptable. MDLs were sufficient for the majority of PCBs with 22% (16 out of 71 congeners) having some non-detects (ND), but none were extensive. A number of PCB congeners were found in laboratory blanks. About 27% (19 out of 71) of the congeners had some contamination in at least one method blank. PCB congeners 18, 28, 31, 44, 49, 52, 66, 70, 87, 95, 118, and 153 had 3% of grab sample results flagged with the censoring contamination qualifier of “VRIP” (results with reported concentrations <3x the blank results (by batch) being censored for contamination). Precision and accuracy metrics were within MQOs.

Overall the total mercury and total methylmercury results were acceptable. MDLs were sufficient with only one ND for methylmercury. Total mercury and methylmercury were not detected in lab blanks, although total mercury was found in one field blank at .004 µg/L, about 20 times above the MDL, but still ~5 times lower than the average concentration for field samples in this data set. Precision and accuracy metrics were within MQOs. Methylmercury concentrations were generally in the range of 1% of total mercury concentrations which is fairly typical. No additional qualifiers were needed on the data set.

The nutrient data were generally acceptable. MDLs were sufficient to get quantitative results for most analytes at all stations. Nitrate had 7% non-detects and suspended sediment concentration had 3% non-detects. No blank contamination was found in either the method blanks or equipment blanks (3 batches). Field blanks were analyzed for 21 batches with blank contamination found for nitrate and phosphorus as in one batch each. Precision and accuracy metrics were within MQOs.

The carbaryl and fipronil data were acceptable. MDLs were sufficient with carbaryl having ≥50% NDs. Blank contamination was not found in either the method blanks or the field blanks. Precision and accuracy metrics were within MQOs.

The PAH dataset was acceptable with some minor QA issues. MDLs were sufficient for most of the PAHs, with <50% non-detects for 76% of the target PAHs; Acenaphthene, Acenaphthylene, Benz(a)anthracene, Dibenz(a,h)anthracene , Dibenzothiophene, and Fluorene had >50% NDs. Thirteen PAHs were found in at least one of the three lab blanks; subsequently Benz(a)anthracene, Benz(a)anthracenes/Chrysenes, C4- , Biphenyl, Dibenzothiophene, Fluorene, Methylnaphthalene, 1-, Naphthalene, and Trimethylnaphthalene, 2,3,5- had results flagged with the censoring qualifier VRIP for being <3x the average blank concentration. Precision was good with <35% RSD on lab or blank spike replicates for all analytes. Accuracy was evaluated using recoveries for the 43 PAHs in the laboratory control samples and were generally good, with only Tetramethylnaphthalene, 1,4,6,7- (40%) having a recovery averaging >35%.

Overall the PBDE data were acceptable. MDLs were sufficient with 29 of the 49 reported PBDE congeners having some level of non-detect, and 27% having ≥50% NDs. PBDE congeners 17, 28, 47, 49, 85, 99, 100, 138, 153, 154, 183 and 209 had some contamination in at least one method blank, but only PBDE 183 had 6% of its samples censored. Replicates on field samples were used to evaluate precision and were generally good, less than the target 35% average RSD, except for PBDE 8 and 12, which were flagged with the non-censoring qualifier. Accuracy metrics were within MQOs.

Overall the pyrethroids data were acceptable. MDLs were sufficient with 12 of the 13 pyrethroids reported having some level of non-detect (ranging from 5 to 95% non-detects) and 50% of the pyrethroids reported having ≥50% NDs (Allethrin, Deltamethrin/Tralomethrin, Diazinon, Fenpropathrin, Tetramethrin and T-Fluvalinate). Blank contamination was not found in any of the method blanks. Field blanks were examined, but not used in the evaluation, with blank contamination found in one of the field blanks for Chlorpyrifos and Diazon at a concentration equal to the MDL. Matrix spikes were used to assess accuracy with recovery errors less than the target 35% for all reported analytes, except Allethrin, Deltamethrin/Tralomethrin, and Tetramethrin, which were flagged with a non-censoring qualifier. Replicates on matrix spikes were used to evaluate precision and were generally good, less than the target 35% average RSD, except Allethrin and Cyhalothrin, lambda total, which were flagged with a non-censoring qualifier.

Overall the other trace elements dataset was acceptable. MDLs were sufficient with only dissolved selenium having non-detects (1 out of 21 samples; 5% ND). No blank contamination was observed except in two of the equipment blanks for total copper; one at a concentration equal to the MDL (0.08 µg/L), the other at less than two times the method blank (0.125 µg/L). Precision and accuracy metrics were within MQOs except for the metric accuracy for Hardness (recovery error 21%), which was flagged with a censoring qualifier. The ratio of dissolved to total concentrations can help characterize the sources and environmental processes of contaminants, and ratios >100% (i.e., dissolved concentrations greater than totals) may indicate some analytical problems with one or both fractions. Dissolved copper results ranged from 4% to 69% of the total results, with the majority being less than 50%. Dissolved selenium results ranged from 57% to 102% of the total results; dissolved and total selenium results for San Leandro Creek on 11/21/2012 were both 0.19 µg/L. Lower Marsh Creek selenium dissolved and total results from 4/5/2013 were 0.51 and 0.5 µg/L, respectively.

5.2. Climate and flow at the sampling locations during water years 2012 and 2013

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 (McKee et al., 2003). Given monitoring programs for concentrations or loads do not normally continue for such a long period, 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. In general, high magnitude (high intensity or long duration) events occur infrequently and thus are usually poorly represented in datasets yet for most pollutants, these types of events usually transport the majority of a decadal scale load. This occurs because the discharge-load relation is described by a power function and therefore storms and wet years with larger discharge have a profound influence on the estimate of mean annual load for a given site and will likely confound any comparisons of loads between sites unless adequately characterized. However, if it is assumed that this is consistently true for all sites, comparisons across sites will be more valid.

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 (the exemplary example in this group is Marsh Creek in relation to PCBs). In contrast, a longer sampling period spanning a wider climatic variability will be required 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) may also fall into this category.

Unfortunately, during the study to date, winter seasons have been very dry relative to average annual conditions with all observations to-date made during years of <89% mean annual precipitation or flow (Table 5). For example, Lower Marsh Creek experienced just 22% of mean annual runoff in WY 2012 and 73% of mean annual run-off in WY 2013. However, there have been some notable storms, particularly those occurring during late November and December of WY 2013. For example, approximately 65% of the total wet season rainfall fell on Sunnyvale East Channel in the span of less than one month. Loads of pollutants were disproportionately transported during such events; at Sunnyvale East Channel, 88%, 92% and 83% of the total wet season sediment, PCBs and mercury loads were transported during those larger November and December storms. However, despite these larger individual storm events, at this time, any effort to estimate long-term averages for each site will likely result in estimates that are

Table 5. Climate and flow during sampling years to-date at each sampling location.

		Marsh Creek[2]	North Richmond Pump Station[3]	San Leandro Creek[4]	Guadalupe River[5]	Sunnyvale East Channel[6]	Pulgas Creek Pump Station[7]
Rainfall (mm) (% mean annual)	WY 2012	321 (70%)	No data	486 (75%)	179 (47%)	224 (58%)	No data
	WY 2013	278 (61%)	508 (89%)	342* (52%)	223 (59%)	259* (67%)	378* (78%)
	Mean Annual	457	570	652	378	387	488
Runoff (Mm^3) (% mean annual)	WY 2012	1.87 (22%)	No data	5.47	38.0 (68%)	1.07	No data
	WY 2013	6.23 (73%)	0.76	8.81	45.45 (82%)	1.79	0.21
	Mean Annual	8.51	No data	No data	55.6	No data	No data

[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

biased low due to observations during relatively dry and therefore benign flow production, sediment erosion and transport conditions.

5.3. 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. Sampling to-date 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). In some cases non-detects and quality assurance issues continue to confound robust interpretations. This section explores those issues through synthesis of data collected across all six sampling locations to date to provide support for rationale for continued sampling in relation to answering management questions.

Concentrations of pollutants typically vary over the course of a storm, between storms of varying magnitudes, and are dependent on related discharge, sediment and source-related transport processes. Thus, it is important to sample at 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 aims to collect pollutant concentration data from 12 storms over the span of three years, with priority pollutants sampled at an average of four samples per storm for a total of 48 samples collected during the monitoring term. Sampling at the six locations to date has included sampling between one and six storm events at each location. Given the small sample size and varying sample sizes between sites, the following synthesis should be considered qualitative at this time; data collection during WY 2014 will likely provide further insights into pollutant characteristics at single sites and between sites.

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 94% or better, as were detections of several of the “tier II” pollutants (total and dissolved copper and selenium, PAHs and PBDEs) (Table 6). 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 (except Pulgas Creek Pump Station where Fipronil was not detected in the one sample to-date).

The two sampling locations added this year (North Richmond and Pulgas Creek pump stations), have the lowest mean SSC; whereas pollutant concentrations are relatively high for these watersheds (e.g. PCBs at Pulgas Creek Pump Station). As a result, the particle ratio (turbidity or SSC to pollutant; discussed further in section 5.5) was higher relative to other watersheds with similar pollutant concentrations but greater SSC. Given the high imperviousness and small size of these watersheds, although few storms have been sampled at these locations, it is unlikely great variation in SSC will be observed in future sampling efforts.

The maximum PCB concentration of the dataset to date (176 ng/L) was collected in Sunnyvale East Channel, which also has the greatest mean PCB concentration of the six locations; consistent with the high ranking assigned to Sunnyvale East Channel based on the WY 2011 reconnaissance study of 17 watersheds distributed across four Bay Area counties (McKee et al., 2012). However, sampling at Pulgas Creek Pump Station has so far captured only one relatively small storm event; future monitoring at this location will likely indicate higher PCB concentrations until management actions take effect. Guadalupe River has mercury mines in the upper watershed and is a known mercury source to the San Francisco Bay, explaining the high mercury and, possibly, methylmercury concentrations in this watershed. Less well understood is San Leandro Creek, which has mercury and methylmercury concentrations nearly as high as Guadalupe River. Continued sampling under more variable storm and climatic conditions in San Leandro Creek may improve our understanding of source-release-transport processes of mercury in this watershed. 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 (McKee and Krottje, 2005).

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 2-8 fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Maximum PBDE concentrations in North Richmond Pump Station were 37- to 96-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).

Concentration sampling to date at the six locations have in part confirmed previously known or suspected pollutant sources (e.g. mercury in Guadalupe, PCBs in Sunnyvale East Channel). Concentration results to date have also raised some questions about certain pollutants in certain 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 is necessary to more confidently characterize pollutants in those watersheds. With a more targeted sampling approach in future water years based on storm variability and data that are still lacking to answer management questions adequately (see section 6), it is expected that this monitoring study will produce a robust characterization of pollutants in these watersheds.

2.1. Loads of pollutants of concern computed for each sampling location

One of the primary goals of this project and key management questions 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 the relationship between climate (manifested as either rainfall and 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 is currently confounded by small sample datasets during climatically dry years. At this time, comparison should therefore be considered qualitative; with subsequent years of sampling an attempt at computing long-term average loads for each sampling location will likely be made. Accepting these caveats, the following observations are made on the total wet season loads estimates at the six locations.

Comparison of 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 Pump Station is the smallest watershed in the study and has the lowest total wet season load (except for TOC in which the load is similar to North Richmond Pump Station) (Table 7). 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 10x the total mass of methylmercury given the much greater overall discharge of runoff volume and sediments.

Comparison of total wet season loads between water years at the sites with two years of data highlighted how loads estimates can be highly variable even during two drier than average years. Additionally, the size and intensity of the storm events in the different regions where the sampling sites are located greatly impacted the load variation from year to year and between sampling locations. For example PCBs and mercury in San Leandro Creek and Guadalupe River were approximately 2x greater in WY 2013 than WY 2012, whereas loads of those same pollutants were 5 – 20x larger in WY 2013 in Lower Marsh Creek and Sunnyvale East Channel, where the late November and December 2012 storms were moderately large events. Even when normalized to total discharge (in other words, the flow-weighted mean concentration [FWMC]), Sunnyvale East Channel transported 11x as much sediment in WY 2013 than WY 2012, whereas the FWMC of suspended sediment in San Leandro Creek was the same in both water years. This observation suggests that any attempt at this time to estimate long-term loads for Sunnyvale East channel will be biased low. In this manner, the relationship between FWMC and discharge (either at the annual or individual flood scale) can be used as an indicator of when enough data has been collected to characterize the site adequately to answer our management questions.

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 7 note our current level of confidence in the mean annual loads estimates as well as the main issues at each site which warrant the confidence level rating. 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.

2.1. 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). Unfortunately, the comparison of loading estimates between watersheds in relation to these key management needs is confounded by variations in climate and how well samples collected to date represent source-release-transport processes for each watershed and pollutant (see section 5.2). With these caveats accepted, a preliminary comparison based on data collected during water year 2012 and 2013 was provided in this section. It is anticipated that these comparisons will change as additional data are collected in WY 2014, and, should data be sufficient, the best comparisons will be made in next year's report update based on (where/if possible) climatically averaged data.

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 examples) and when there is relatively little variation in the particle ratios between water years or storms (note data presented at the October 2013 SPLWG meeting demonstrated that this assumption is sometimes violated and influences our perception of relative ranking).

Table 6. Synthesis of concentrations of pollutants of concern based on all samples collected to-date at each sampling location.

		Marsh Creek		North Richmond Pump Station		San Leandro Creek		Guadalupe River		Sunnyvale East Channel		Pulgas Creek Pump Station	
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	81 (99%)	243 (27.5)	41 (95%)	45.7 (8.48)	81 (94%)	145 (18.5)	82 (100%)	161 (18.3)	62 (97%)	302 (66.1)	15 (100%)	33.3 (8.54)
∑PCB	ng/L	22 (100%)	1.25 (0.258)	12 (100%)	12.0 (2.05)	28 (100%)	9.45 (1.50)	23 (100%)	14.0 (3.63)	18 (100%)	51.3 (12.9)	4 (100%)	34.7 (10.1)
Total Hg	ng/L	25 (100%)	45.8 (11.5)	12 (100%)	27.7 (7.10)	28 (100%)	145 (35.7)	24 (100%)	210 (50.1)	18 (100%)	52.8 (12.9)	6 (100%)	10.5 (2.82)
Total MeHg	ng/L	19 (95%)	0.306 (0.076)	6 (100%)	0.118 (0.029)	18 (100%)	0.438 (0.099)	17 (100%)	0.438 (0.082)	12 (92%)	0.251 (0.061)	6 (100%)	0.178 (0.041)
TOC	mg/L	24 (100%)	7.13 (0.416)	12 (100%)	7.46 (0.970)	28 (100%)	7.13 (0.453)	24 (100%)	7.55 (0.657)	18 (100%)	6.10 (0.369)	4 (100%)	10.3 (2.26)
NO3	mg/L	24 (96%)	0.579 (0.045)	12 (100%)	1.13 (0.245)	29 (100%)	0.429 (0.094)	24 (83%)	0.919 (0.150)	18 (100%)	0.287 (0.022)	4 (100%)	0.358 (0.051)
Total P	mg/L	20 (100%)	0.438 (0.054)	12 (100%)	0.276 (0.013)	25 (100%)	0.34 (0.035)	20 (100%)	0.434 (0.044)	19 (100%)	0.422 (0.078)	4 (100%)	0.15 (0.035)
PO4	mg/L	24 (100%)	0.098 (0.008)	11 (100%)	0.168 (0.013)	29 (100%)	0.09 (0.005)	24 (100%)	0.105 (0.007)	18 (100%)	0.102 (0.005)	4 (100%)	0.066 (0.010)
Hardness	mg/L	4 (100%)	189 (8.86)	-	-	7 (100%)	46.0 (6.55)	4 (100%)	136 (9.31)	2 (100%)	56.3 (4.90)	-	-
Total Cu	µg/L	6 (100%)	16.7 (4.10)	3 (100%)	15.3 (2.94)	7 (100%)	19.6 (4.36)	6 (100%)	19.8 (3.74)	4 (100%)	20.0 (4.16)	1 (100%)	30.0 (-)
Dissolved Cu	µg/L	6 (100%)	2.868 (0.792)	3 (100%)	6.367 (1.819)	7 (100%)	6.459 (0.981)	6 (100%)	4.52 (0.852)	4 (100%)	6.79 (2.70)	1 (100%)	20.0 (-)
Total Se	µg/L	6 (100%)	0.783 (0.128)	3 (100%)	0.397 (0.098)	7 (100%)	0.213 (0.027)	6 (100%)	1.46 (0.392)	4 (100%)	0.450 (0.041)	1 (100%)	0.180 (-)
Dissolved Se	µg/L	6 (100%)	0.694 (0.111)	3 (100%)	0.363 (0.098)	7 (100%)	0.149 (0.018)	6 (100%)	1.21 (0.42)	4 (100%)	0.343 (0.018)	1 (100%)	0.17 (-)
Carbaryl	ng/L	6 (33%)	4.83 (3.08)	3 (100%)	23.7 (8.41)	7 (29%)	3.43 (2.26)	6 (83%)	27.1 (9.50)	4 (75%)	12.8 (4.77)	1 (100%)	204 (-)
Fipronil	ng/L	6 (100%)	11.6 (1.52)	3 (33%)	1.33 (1.33)	7 (86%)	6.14 (1.42)	6 (100%)	10.1 (2.34)	4 (75%)	6.00 (2.45)	1 (0)	-
∑PAH	ng/L	3 (100%)	267 (120)	3 (100%)	952 (397)	3 (100%)	3327 (1142)	4 (100%)	614 (194)	2 (100%)	1322 (32.8)	4 (100%)	614 (194)

		Marsh Creek		**North Richmond Pump Station**		**San Leandro Creek**		**Guadalupe River**		**Sunnyvale East Channel**		**Pulgas Creek Pump Station**	
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)**
∑PBDE	ng/L	3 (100%)	29.2 (13.9)	3 (100%)	2340 (2340)	4 (100%)	44.6 (18.0)	3 (100%)	39.1 (16.5)	2 (100%)	19.8 (15.0)	4 (100%)	45.8 (24.9)
Delta/ Tralo-methrin	ng/L	6 (83%)	1.70 (0.820)	3 (100%)	2.52 (0769)	6 (67%)	0.652 (0.308)	6 (50%)	0.737 (0.372)	3 (67%)	2.47 (1.23)	1 (0%)	-
Cypermethrin	ng/L	6 (83%)	14.6 (10.9)	3 (100%)	3.18 (0.651)	7 (29%)	0.214 (0.159)	6 (50%)	0.917 (0.547)	4 (50%)	2.10 (1.28)	1 (100%)	0.900 (-)
Cyhalothrin lambda	ng/L	6 (83%)	1.37 (0.551)	3 (100%)	0.767 (0.273)	6 (33%)	0.693 (0.635)	6 (67%)	0.483 (0.227)	3 (67%)	1.23 (0.722)	1 (0%)	-
Permethrin	ng/L	6 (83%)	7.70 (2.75)	3 (100%)	12.0 (2.88)	7 (71%)	4.86 (1.73)	6 (67%)	10.4 (3.95)	4 (100%)	24.1 (8.78)	1 (100%)	2.90 (-)
Bifenthrin	ng/L	6 (100%)	91.5 (38.1)	3 (100%)	5.98 (1.23)	7 (86%)	10.3 (4.07)	6 (83%)	5.64 (1.97)	4 (75%)	8.68 (3.68)	1 (100%)	1.30 (-)

Analyzed but not detected: Fenpropathrin, Esfenvalerate/ Fenvalerate, Cyfluthrin, Allethrin, Prallethrin, Phenothrin, and Resmethrin
All Hardness results in WY 2013 were censored.

Table 7. Loads of pollutants of concern during the sampling years to-date 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)	Mean annual loads confidence	Main issues
Marsh Creek	2012	1.39	226	9,467	1.21	44.4	0.454	833	155	480	Moderate (PCBs) Low (Hg)	Lack of data on storms that cause run-off through the upper watershed reservoir.
	2013	5.82	2,600	39,682	16.2	594	1.90	3,491	652	4,020		
North Richmond Pump Station	2012	-	-	-	-	-	-	-	-	-	Moderate	Limited data on first flush conditions and generally during more intense storms. Surprisingly elevated PDBE concentrations.
	2013	0.763	34.4	5,709	7.90	16.1	0.113	863	130	211		
San Leandro Creek	2012	3.99	114	26,560	11.7	137	0.772	1,515	367	843	Low	Lack of a robust discharge rating curve; lack of sampling during reservoir release and during more intense storms.
	2013	8.81	218	58,674	22.6	280	1.52	3,348	811	1,671		
Guadalupe River	2012	25.8	2,116	146,483	113	2,033	8.20	16,347	2,243	7,042	High (PCBs) Low (Hg)	Lack of high intensity storms samples for Hg.
	2013	35.5	4,352	237,227	334	5,603	15.2	22,482	3,440	12,099		
Sunnyvale East Channel	2012	1.07	36.7	6192	14.6	18.4	0.181	263	114	241	Low	Few storms sampled.
	2013	1.79	672.5	10352	73.1	109	0.538	440	190	865		
Pulgas Creek Pump Station	2012	-	-	-	-	-	-	-	-	-	Low	Few storms sampled.
	2013	0.206	11.2	5967	9.3	3.2	0.050	75.6	32.4	34.3		

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12 and 10/19/12 – 4/18/13.

[b] North Richmond Pump Station (WY 2013 only) and Guadalupe River (WY 2012 and 2013) wet season loads are reported for the full period of record each water year (10/01/11 – 4/30/12 for WY 2012 and 10/01/12 – 4/30/13 for WY 2013).

[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 11/01/12 – 4/18/13.

[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 10/01/12 – 4/30/13.

[e] Pulgas Creek Pump Station South WY 2013 wet season loads are estimates provided for the entire wet season (10/01/12 – 4/30/13) however monitoring only occurred during the period 12/17/2012 – 3/15/2012. 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.

These issues accepted, based on the ratios between turbidity and Hg, runoff derived from less urbanized portions of San Leandro Creek watershed and run-off from the Guadalupe River watershed exhibit the greatest particle ratios for total mercury (Figure 2). Sunnyvale East Channel, Marsh Creek and Pulgas Creek 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 and an insufficient number of samples have yet been collected from Pulgas Creek Pump Station to be confident that the mercury transport processes are adequately characterized. With the exception of the addition of two more sampling stations (North Richmond Pump Station and Pulgas Creek Pump Station), the relative nature of these rankings has not changed in relation to the previous report (McKee et al., 2013).

In contrast, for the sum of PCBs, Pulgas Creek Pump Station and Sunnyvale East Channel exhibit the highest particle ratios among these six watersheds, with urban sourced run-off 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 Hg, new data collected during WY 2013 did alter 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 large confidence intervals (not shown) and the relatively low numbers of samples collected to-date during relatively dry years, the relative nature of these regression equations may change in the future as more samples are collected.

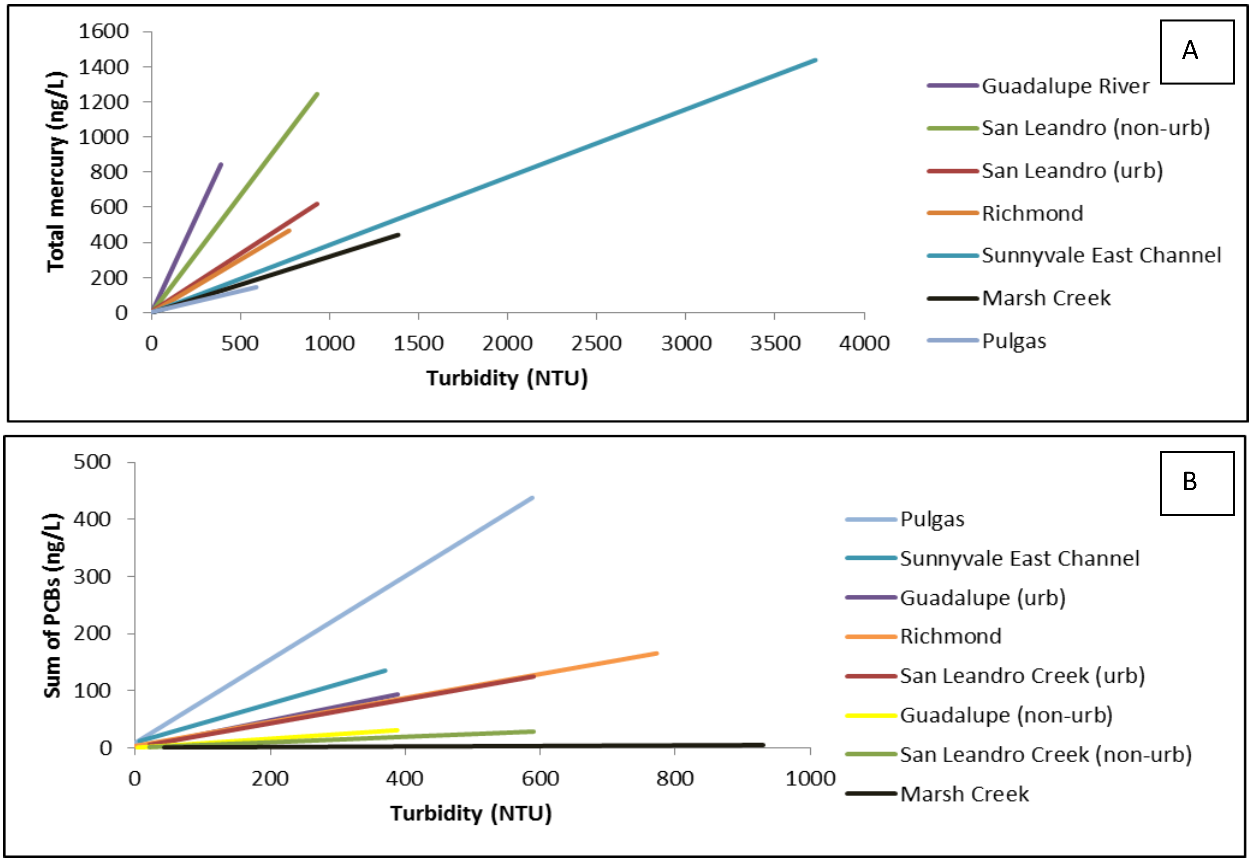

Figure 2. Comparison of regression slopes between watersheds based on data collected during sampling to-date A) total Mercury and B) PCBs (Note Sunnyvale, Richmond and Pulgas includes data for water year 2013 only; Pulgas turbidity maximum is storm maximum not record maximum). Note these comparisons will likely change once additional data are collected in subsequent water years.

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 8) in relation to ease of management. This method is much more highly subject to climatic variation than the turbidity function/particle ratio method for ranking and would ideally be done on climatically averaged loads (not yet done). Despite quite large differences in unit runoff between the watersheds during water year 2012 and 2013, in a general sense, the relative rankings for PCBs exhibit a similar ranking to the particle ratio method; Pulgas Creek 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, San Leandro Creek, and Richmond pump station exhibit the highest currently estimated yields corroborating the evidence from the particle ratio method. However, it is anticipated that the relative nature of the area-normalized loads will be subject to greater change in the event that sampling during WY 2014 captures rainstorms of greater magnitude and less frequent recurrence interval. In particular, the relative rankings for suspended sediment loads normalized by unit area could change substantially with the addition of data from a water year that is closer to or 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 to date that has occurred under relatively dry conditions.

3. Conclusions and next steps

3.1. 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.

Table 8. 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). Note these yield estimates are based on the average of data from water year 2012 and 2013. Quantitative comparison between watersheds is confounded by dry climatic conditions and differing unit runoff. With additional years of sampling, climatically-averaged area-normalized loads may be generated.

	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)
Pulgas Creek Pump Station [e]	*0.35*	*19.1*	*10218*	*15.9*	*5.53*	*0.0858*	*130*	*55.6*	*58.8*
North Richmond Pump Station [b]	0.39	17.6	2913	4.03	8.22	0.0575	440	66.2	107
Sunnyvale East Channel [d]	0.10	24.0	559	2.96	4.31	0.0243	23.7	10.3	37.4
San Leandro Creek [c]	0.72	18.7	4788	1.93	23.4	0.129	273	66.1	141
Guadalupe River [b]	0.13	13.7	813	0.947	16.2	0.0496	82.3	12.0	40.6

Marsh Creek [a]	0.04	16.9	294	0.104	3.82	0.0141	25.9	4.83	26.9

[a] Marsh Creek wet season loads are reported for the period of record 12/01/11 – 4/26/12 and 10/19/12 – 4/18/13.

[b] North Richmond Pump Station (WY 2013 only) and Guadalupe River (WY 2012 and 2013) wet season loads are reported for the full period of record each water year (10/01/11 – 4/30/12 for WY 2012 and 10/01/12 – 4/30/13 for WY 2013).

[c] San Leandro Creek wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 11/01/12 – 4/18/13.

[d] Sunnyvale East Channel wet season loads are reported for the period of record 12/01/11 – 4/30/12 and 10/01/12 – 4/30/13.

[e] Pulgas Creek Pump Station South WY 2013 wet season loads are estimates provided for the entire wet season (10/01/12 – 4/30/13) however monitoring only occurred during the period 12/17/2012 – 3/15/2012. 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.

- Pollutant area yields: Pollutant yields can help identify pollutant sources and relates to treatment potential.
- 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 will need to evolve.

3.2. What data gaps remain at current loads stations?

With regard to addressing the main management endpoints (single and regional watershed loads and baseline data for trends) that caused the monitoring design described by the MYP (BASMAA, 2011) and updated twice [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? Is the data representative of the source-release-transport processes of the pollutant of interest? In reality, these two factors tend to juxtapose and after two years of monitoring, some data gaps remain for each of the monitoring locations.

- Guadalupe River watershed has been sampled at the Hwy 101 location during eight water years (WY 2003-2006, 2010-2013) 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 high intensity storms only; further sampling of relatively frequent smaller runoff events is unnecessary. The current sampling design is not cost-effective for gathering improved information to support management decisions in this watershed.
- San Leandro Creek watershed has been sampled for two WYs to-date. San Leandro Creek, received poor quality ratings on the quality of discharge information and completeness of

turbidity data. The largest weakness is the lack of velocity measurements to adequately describe the stage-discharge rating curve 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 release during WYs 2012 and 2013 has been proportionally large. 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.

- Marsh Creek watershed has been sampled for two WYs to-date. Continuous turbidity data were rated excellent at Lower Marsh Creek; no changes to monitor design for turbidity are necessary. Ample lower watershed stormwater runoff data are 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. Sampling during WY 2014 would ideally be focused on storms of greater intensity preferably when spillage is occurring from the upstream reservoir. Beyond WY 2014, the sampling design should be revisited with the objective of increased cost efficiency for data gathering to support management questions.
- North Richmond Pump Station watershed has been sampled for just one year (although data exists from a previous study [Hunt et al., 2012]). Although some data exist, further data in relation to early season (seasonal 1st flush or early season storms) would help estimate loads averted from diversion of early season storms to wastewater treatment. Further data collection in relation to high concentrations of PBDEs is necessary to verify the existence of PBDEs source in this watershed. Providing these types of data can be collected during WY 2014, an alternative sampling design could be considered.
- At Pulgas Creek Pump Station and Sunnyvale East Channel (two locations with much below average rainfall during sampling to date), more storm event water quality monitoring is needed for establishing confidence in particle ratios, pollutant loads, FWMCs, and yields. Sunnyvale East Channel and Pulgas Creek Pump Station received poor quality ratings on completeness of turbidity data: Sunnyvale East Channel had a full record but a large portion of data censored due to spikes and Pulgas Creek Pump Station recorded turbidity during only three of the seven wet season months in large part due to instrumentation failures. The Pulgas Creek sampling location also received a low rating on representativeness given how turbidity records could fluctuate multiple times from one reading to the next. Pulgas Creek Pump Station also had poor repeatability between manual and sensor collected data and improvements to the monitoring set-up should be considered for next wet season. Improvements have been recommended for the WY 2014 winter season for both sampling sites. The existing sampling design (with ongoing annual improvements as lessons are learned) may be warranted for these two watersheds for additional years.

3.3. Next Steps

Recent discussions between BASMAA and the Region 2 Regional Water Quality Control Board (and discussion at the October 2013 SPLWG meeting) 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 likely not appropriate for this increasing management focus. During the first quarter of 2014, the STLS will be reviewing lessons learned to-date and will be developing recommendations for alternative monitoring designs and sampling locations (in concert with the RWSM modeling design). Based on recent findings, there is evidence to support effort reduction at Lower Marsh Creek and Guadalupe River as well as development of monitoring decision points for determining when sufficient data has been collected to address MQ2 (single watershed and regional pollutant loads), and to provide baseline data to support MQ3 (future trends in relation to management actions). Additional information is needed for Pulgas Creek Pump Station, Sunnyvale East Channel, North Richmond Pump Station and San Leandro Creek, especially during early season/high-intensity rain events. If the right climatic conditions and field work focus occurs during WY 2014, these data gaps may be addressed sufficiently. A revised monitoring design will need to be robust enough to continue to support MQ 1, 2, and 3 for PCBs and Hg and emerging pollutants of interest as well as increasing information to support MQ4.

There are various alternative monitoring designs that are more cost-effective for the 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. The challenge for the STLS and SPWLG is finding the right balance between the different alternatives within budget constraints. Options include:

- Loads monitoring
    - Changing to a rotating site approach (e.g. all six monitoring locations are maintained for stage and turbidity but each monitored fewer years for pollutants)
    - Changing monitoring frequency (e.g. opportunistic sampling for specific events with overall reduction in effort but increased informational outcomes)
    - Reducing the number of sites (currently six)
    - Adding new sites of specific interest (e.g. to determine load magnitude in relation to upstream pollution or downstream beneficial use impact)
    - Dropping loads monitoring completely
- Reconnaissance monitoring design
    - Make improvements to the WY 2011 design:
        - Increase the number of samples from 4-7 to 8-14 per site
        - Selectively add measurements of stage and possibly velocity
    - Focus on sampling a subset of feasible pump stations downstream from industrial land use (73 possible locations identified). Pump stations have the advantage of forcing unidirectional flow very near the Bay margin but have disadvantages in terms of complex flow patterns, confined space, permission or limited access during work hours.

Lessons learned at the North Richmond and Pulgas Creek Pump Stations during the current study will be valuable.

- Rotate in single land use/ source area “high opportunity” sites.

It is likely that a sampling design that simultaneously addresses all four STLS management questions will require a compromise between the different monitoring options (i.e. some loads monitoring effort retained). However, 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. 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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5. Detailed information for each sampling location

5.1. Marsh Creek

5.1.1. Marsh Creek flow

The US geological survey has maintained a flow record on Marsh Creek (gauge number 11337600) since October 1, 2000 (13 WYs). Peak annual flows for the previous 13 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 Mm3 (WY 2009) and 26.8 Mm3 (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 as 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 WY 2012 and 2013 (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 water year 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 based on preliminary USGS data and was much greater relative to the first year of monitoring. 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 both water years of observations to-date are likely exceeded most years in this watershed. Rainfall data corroborates this assertion; rainfall during WY 2012 and 2013 respectively was 70% and 71% 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) 1992-2013. 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 water years 2012 and 2013, discharge through the reservoir occurred on March, November, and December 2012.

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 pm. 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 WY 2012 and 2013, 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 medium or larger storms.

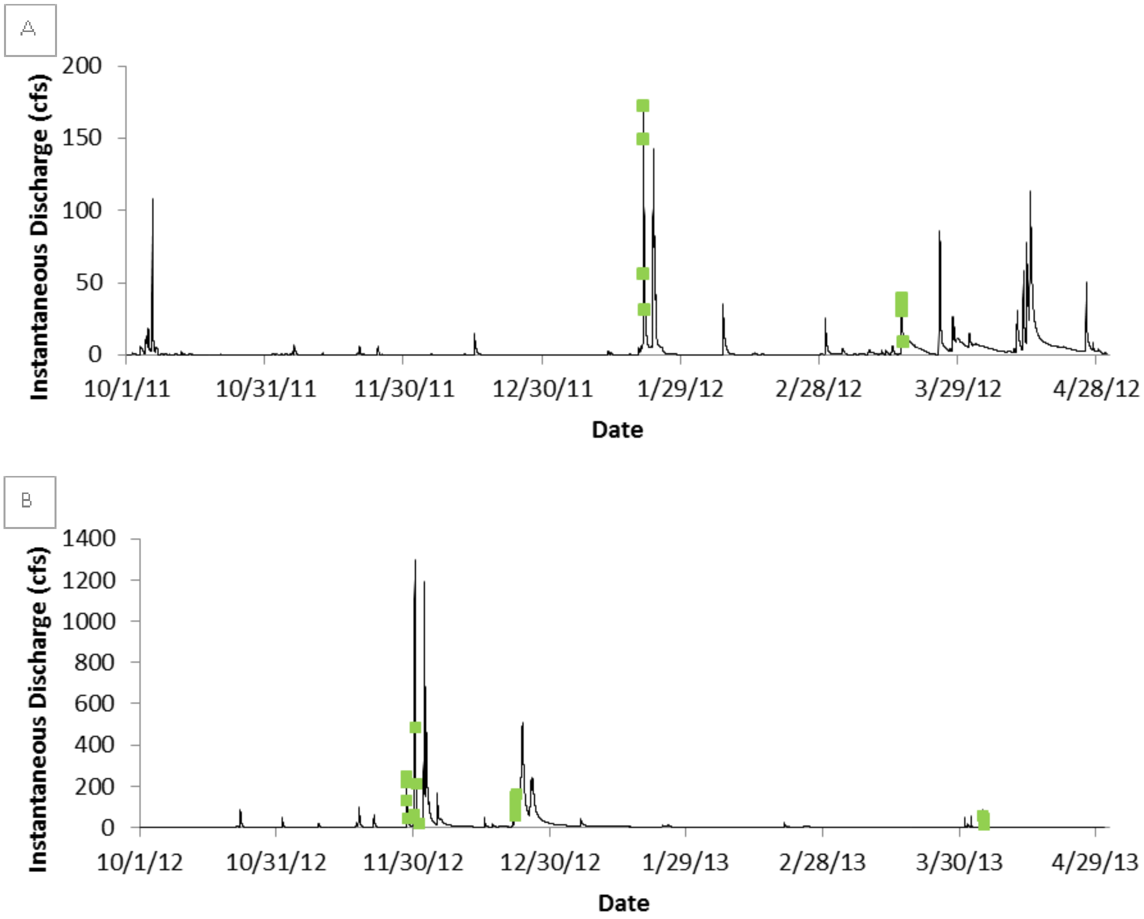

Figure 3. Flow characteristics in Marsh Creek during water year 2012 (A) based on published data and for the water year 2013 (B) based on preliminary 15 minute data provided by the United States Geological Survey, gauge number 11337600) with sampling events plotted in green. Note, USGS normally publishes finalized data for the permanent record in the spring following the end of each water year.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. SSC peaked at 1312 mg/L during the 4/13/12 late season storm and at 1849 mg/L on 12/02/12 at the same time 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. These 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 levels of urbanization but potentially impacted by mercury residues from historic mining upstream. Summary statistics (Table 9) 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 while maximum mercury concentrations (252 ng/L) were similar to concentrations found in mixed land use watersheds (Lent and McKee, 2011). Maximum MeHg concentrations (0.407 ng/L during WY 2012 and 1.2 ng/L during WY 2013 were greater 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). Nutrient concentrations appear to be reasonably typical of other Bay Area watersheds (McKee and Krottje, 2005). As is 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 (McKee and Krottje, 2005). 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 during both years.

A similar style of first order quality assurance 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. It was surprising to see PBDE concentrations so much greater in the second year of sampling relative to the first year, possibly just an artifact of the randomness sample capture and small sample numbers. 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). Pyrethroid concentrations of Delta/ Tralo-methrin 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). It was a little surprising to see cypermethrin concentrations more than 4-fold lower in WY 2013 relative to WY 2012. Again, this may just be an artifact of the randomness of sample capture. 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 Water Year 2012 and four storm events in Water Year 2013. No significant reductions in the survival, reproduction and growth of three of four test species were observed during WY 2012. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during both WY 2012 storm events. Water Year 2013 had complete mortality of *Hyalella Azteca* between 5 and 10 days of exposure to storm water (0% survival compared to a 100% laboratory survival rate) during all four storm events. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of sediments in receiving waters. Additionally,

Table 9. Summary of laboratory measured pollutant concentrations in Marsh Creek during WY 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	27	96%	ND	930	180	297	276	54	100%	3.3	1040	167	217	230
∑PCB	ng/L	7	100%	0.354	4.32	1.27	1.95	1.61	15	100%	0.240	3.46	0.676	0.927	0.856
Total Hg	ng/L	8	100%	8.31	252	34.6	74.3	85.2	17	100%	1.90	120	19.0	32.5	33.9
Total MeHg	ng/L	5	100%	0.085	0.407	0.185	0.218	0.120	14	94%	ND	1.20	0.185	0.337	0.381
TOC	mg/L	8	100%	4.6	12.4	8.55	8.34	2.37	16	100%	4.30	9.50	6.55	6.52	1.60
NO3	mg/L	8	100%	0.470	1.10	0.635	0.676	0.202	16	94%	ND	1.0	0.53	0.53	0.22
Total P	mg/L	8	100%	0.295	1.10	0.545	0.576	0.285	12	100%	0.140	0.670	0.305	0.346	0.166
PO4	mg/L	8	100%	0.022	0.120	0.056	0.065	0.030	16	100%	0.046	0.180	0.110	0.114	0.036
Hardness	mg/L	2	100%	200	203	189	202	2.12	-	-	-	-	-	-	-
Total Cu	µg/L	2	100%	13.8	27.5	20.6	20.6	9.70	4	100%	3.80	30.0	12.5	14.7	11.0
Dissolved Cu	µg/L	2	100%	4.99	5.62	5.31	5.31	0.445	4	100%	1.30	2.40	1.45	1.65	0.520
Total Se	µg/L	2	100%	0.647	0.784	0.716	0.716	0.097	4	100%	0.525	1.40	0.670	0.816	0.395
Dissolved Se	µg/L	2	100%	0.483	0.802	0.643	0.643	0.226	4	100%	0.510	1.20	0.585	0.720	0.323
Carbaryl	ng/L	2	50%	-	-	-	16.0	-	4	25%	ND	13.0	0	3.25	6.50
Fipronil	ng/L	2	100%	7.00	18.0	12.5	12.5	7.78	4	100%	10.0	13.0	10.8	11.1	1.44
∑PAH	ng/L	1	100%	-	-	-	494	-	2	100%	85.7	222	154	154	96
∑PBDE	ng/L	1	100%	-	-	-	20.0	-	2	100%	11.2	56.4	33.8	33.8	32.0
Delta/ Tralo-methrin	ng/L	2	100%	0.954	5.52	3.23	3.23	3.23	4	75%	ND	2.20	0.750	0.925	0.943
Cypermethrin	ng/L	2	50%	-	-	-	68.5	-	4	100%	1.80	13.0	2.15	4.78	5.49
Cyhalothrin lambda	ng/L	2	50%	-	-	-	2.92	-	4	100%	0.500	3.20	0.800	1.33	1.27
Permethrin	ng/L	2	100%	3.81	17.3	10.6	10.6	9.54	4	75%	ND	12.0	6.55	6.28	6.11
Bifenthrin	ng/L	2	100%	25.3	257	141	141	163	4	100%	27.0	150	45.0	66.8	56.2

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.

one Water Year 2013 sample showed a significant reduction in fathead minnow survival (57.5% compared to a 90% laboratory survival). No significant effects were observed for the crustacean *Ceriodaphnia dubia* or the algae *Selenastrum capricornutum* during these storms.

8.1.3. Marsh Creek preliminary loading estimates

Site-specific methods were developed for computed loads (

Table 10). 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 an improving understanding of pollutant transport processes for the site. Preliminary monthly loading estimates correlate well with monthly discharge (Table 11). There are no data available for October and November 2011 because monitoring equipment was not installed until the end of November. 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. At this time, all load estimates should be considered preliminary. Additionally (and, in this case, more importantly), if data collected during WY 2014 is able 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. In any case, WY 2014 data will be used to improve our understanding of rainfall-runoff-pollutant transport processes for all the pollutants and used to recalculate and finalize loads for WYs 2012 and 2013. Regardless of these improvements however, given the very dry flow conditions of WY 2012 and 2013 (see discussion on flow above), preliminary loads presented here may be considered representative of dry conditions.

Table 10. Regression equations used for loads computations for Marsh Creek during water years 2012 and 2013. Note that regression equations will be reformulated with each future wet season of storm sampling.

Analyte	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	1.3	33	0.45	Regression with turbidity
Total PCBs (ng/NTU)	0.0089		0.84	Regression with turbidity
Total Mercury (ng/NTU)	0.32		0.65	Regression with turbidity
Total Methylmercury (ng/L)	0.327			Flow weighted mean concentration

Analyte	Slope	Intercept	Correlation coefficient (r^2)	Notes
Total Organic Carbon (mg/L)	6.82			Flow weighted mean concentration
Total Phosphorous (mg/NTU)	0.0016	0.19	0.57	Regression with turbidity
Nitrate (mg/L)	0.6			Flow weighted mean concentration
Phosphate (mg/L)	0.112			Flow weighted mean concentration

Table 11. Preliminary monthly loads for Marsh Creek during water years 2012 and 2013.

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	-	-	-	-	-	-	-	-	-
	11-Nov	26	-	-	-	-	-	-	-	-	-
	11-Dec	6	0.0252	1.57	172	0.00493	0.180	0.00823	15.1	2.82	5.63
	12-Jan	51	0.318	68.3	2,169	0.389	14.2	0.104	191	35.6	130
	12-Feb	22	0.0780	6.59	532	0.0269	0.983	0.0255	46.8	8.74	19.5
	12-Mar	60	0.361	31.8	2,458	0.133	4.87	0.118	216	40.4	91.9
	12-Apr[a]	59	0.606	118	4,136	0.658	24.1	0.198	364	67.9	233
	Wet season total	198	1.39	226	9,467	1.21	44.4	0.454	833	155	480
2013	12-Oct[b]	23	0.0875	10.0	596	0.0474	1.73	0.0286	52.5	9.79	25.0
	12-Nov	96	0.989	248	6,745	1.45	53.1	0.323	593	111	448
	12-Dec	75	4.00	2,297	27,291	14.6	534	1.31	2,401	448	3,384
	13-Jan	15	0.428	24.1	2,920	0.0660	2.41	0.140	257	48.0	92.5
	13-Feb	6	0.142	5.98	970	0.00825	0.302	0.0465	85.3	15.9	28.3
	13-Mar	9	0.0721	3.79	492	0.00932	0.341	0.0236	43.2	8.07	15.2
	13-Apr[c]	19	0.098	10.8	667	0.0506	1.85	0.0320	58.7	11.0	27.5
	Wet season total	243	5.82	2,600	39,682	16.2	594	1.90	3,491	652	4,020

[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.

5.2. North Richmond Pump Station

8.2.1. North Richmond Pump Station flow

Richmond flow and discharge estimates were calculated during periods of active pumping at the station from October 1, 2012 to April 30, 2013. Flow and discharge estimates include all data collected when where the pump rate was operating at is greater than 330 RPM. 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 would 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 0.76 Mm^3 for WY 2013 (Table 14). A discharge estimate at the station for WY 2011 was 1.1 Mm^3 (Hunt et al., 2012). The rainfall to run-off ratios between the two studies was similar supporting the hypothesis that the flows and resulting load estimates from the previous study remain valid. October 2012 exhibited a lower discharge per unit rainfall, perhaps caused by a dry watershed. Water quality samples were collected during three storm events (Figure 4). Most pump-outs had one operating pump except for a few storm events where two pumps were in operation.

A number of relatively minor storms occurred during WY 2013 except during the period late November to mid-December when 15 inches of rain fell in North Richmond (74% of October-April rainfall). During water year 2013, peak flow of 210 cfs occurred on December 2, 2013 after approximately 3.8 inches of rain fell over a 63 hour period. Approximately 20 inches of rain fell during Water Year 2013. Rainfall during 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.

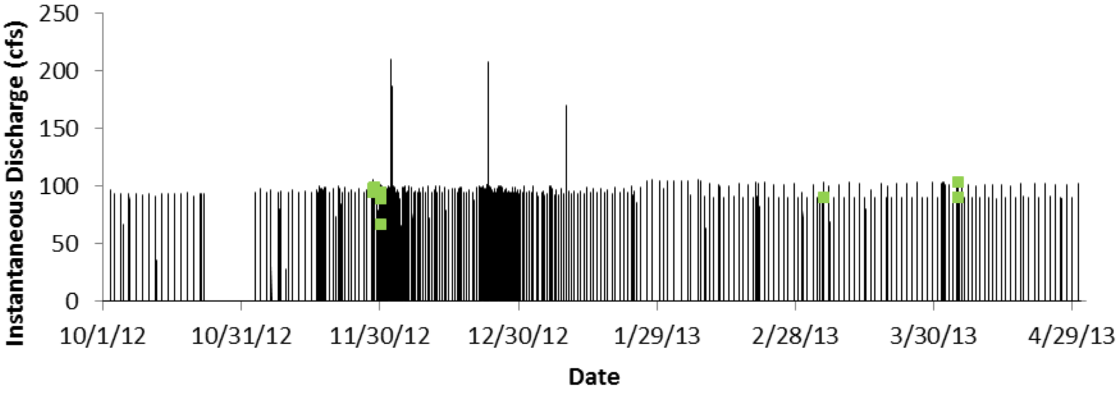

Figure 4. Preliminary flow characteristics at North Richmond Pump Station during Water Year 2013 with sampling events plotted in green. Note, flow information may be updated in the future as we continue to refine how we interpret the well depth, pump RMP, pump efficiency curves, and well geometry information.

8.2.2. North Richmond Pump Station turbidity and suspended sediment concentration

Maximum turbidity during Water Year 2013 was measured at 772 NTU which occurred during a dry flow pump out on January 24, 2013 following a low magnitude storm event of 0.22 inches on January 23. Maximum turbidity during other storm events ranged up to 428 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.

8.2.3. North Richmond Pump Station POC concentrations summary (summary statistics)

The North Richmond pump station is a 1.6 km watershed primarily comprised of industrial, transportation, and residential land uses. The land-use configuration results in a watershed that is approximately 62% covered by impervious surface. Summary statistics (Table 12) 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 in WY 2013 was 31.6 ng/L. In WY2011, the maximum concentration measured was 82 ng/L. PCB concentrations were in the range of other findings for urban locations (range 0.1-1120 ng/L) (Lent and McKee, 2011). Maximum mercury concentrations (98 ng/L) were approximately half the maximum observed concentrations during previous monitoring efforts (200 ng/L) (Hunt et al., 2012). Mercury concentrations were in the range of Zone 4 Line-A findings, another small urban impervious watershed (Gilbreath et al., 2012). Maximum MeHg concentrations in WY 2013 were 0.19 ng/L compared with WY 2011 concentrations of 0.6 ng/L (Hunt et al., 2012). 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; unlike Marsh Creek and San Leandro Creek, TOC also exhibited this pattern.

Copper, selenium, PAHs, carbaryl, fipronil, and PBDEs 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). Maximum PBDE concentrations were 50-fold greater than the greatest average observed in the five other locations of this current study and previously reported for Zone 4 Line (Gilbreath et al., 2012). These are the highest PBDE concentrations measured in Bay area stormwater to-date of any study. BDE 209 usually contributes at least 50% of the sum of BDE congeners to stormwater samples in the Bay Area. Richmond appears to be the exception to this rule. The highest concentration samples had approximately 45% BDE 209, and relatively larger amounts of 206-208 than normally observed in Bay Area stormwater samples. Although the relative contributions of 206-208 are a bit unusual, summing to approximately the 209 amount, that it occurred in two samples (albeit in the same event) in similar proportions makes it less likely that it is purely an analytical anomaly. Blanks were fairly low in 206-208 so it is unlikely that the high contribution in the Richmond samples was from blank contamination, as

Table 12. Summary of laboratory measured pollutant concentrations in North Richmond Pump Station during water year 2013

		Water Year 2012	Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	0	41	95%	ND	213	26.5	45.7	54.3
∑PCB	ng/L	0	12	100%	4.85	31.6	10.1	12.0	7.09
Total Hg	ng/L	0	12	100%	13.0	98.0	18.5	27.7	24.6
Total MeHg	ng/L	0	6	100%	0.030	0.190	0.145	0.118	0.071
TOC	mg/L	0	12	100%	3.50	13.5	6.60	7.46	3.36
NO3	mg/L	0	12	100%	0.210	3.10	0.855	1.13	0.848
Total P	mg/L	0	12	100%	0.180	0.350	0.270	0.276	0.045
PO4	mg/L	0	11	100%	0.110	0.240	0.160	0.168	0.042
Hardness	mg/L	0	-	-	-	-	-	-	-
Total Cu	µg/L	0	3	100%	9.90	20.0	16.0	15.3	5.09
Dissolved Cu	µg/L	0	3	100%	4.40	10.0	4.70	6.37	3.15
Total Se	µg/L	0	3	100%	0.270	0.590	0.330	0.397	0.170
Dissolved Se	µg/L	0	3	100%	0.260	0.560	0.270	0.363	0.170
Carbaryl	ng/L	0	3	100%	12.0	40.0	19.0	23.7	14.6
Fipronil	ng/L	0	3	33%	ND	4.00	0	1.33	2.31
∑PAH	ng/L	0	2	100%	160	1349	754	754	840
∑PBDE	ng/L	0	2	100%	153	3362	1611	1757	2269
Delta/ Tralo-methrin	ng/L	0	3	100%	1.00	3.50	3.05	2.52	1.33
Cypermethrin	ng/L	0	3	100%	2.10	4.35	3.10	3.18	1.13
Cyhalothrin lambda	ng/L	0	3	100%	0.400	1.30	0.600	0.767	0.473
Permethrin	ng/L	0	3	100%	6.40	16.0	13.5	12.0	4.98
Bifenthrin	ng/L	0	3	100%	3.80	8.05	6.10	5.98	2.13

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.
All Hardness results in WY 2013 were censored.

those were also the samples with the highest total PBDEs of all those measured. The North Richmond watershed currently contains an auto dismantling yard and a junk/wrecking yard; possible source areas. At this time we are unwilling to sensor the data but anticipate data collected during WY 2014 helping to support or reject the magnitude of concentrations.

Similar to the other sites, carbaryl and fipronil 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). Pyrethroid concentrations of Delta/ Tralo-methrin were similar to those observed in Zone 4 Line A, whereas concentrations of Cyhalothrin lambda and Permethrin were about 6-fold and 7-fold lower respectively and concentrations of Bifenthrin were about 3-fold higher (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 (except PBDE has been flagged for further investigation).

8.2.4. North Richmond Pump Station toxicity

Composite water samples were collected at North Richmond Pump Station during three storms between Nov 28, 2012 and March 6, 2013. Two of these samples showed 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. No significant effects were observed for the crustacean *Ceriodaphnia dubia*, the algae *Selenastrum capricornutum* or fathead minnows during these storms.

8.2.5. North Richmond Pump Station preliminary loading estimates

8.3. The following methods were applied for calculating preliminary loading estimates (San Leandro Creek

8.3.1. San Leandro Creek flow

There is no historic flow record on San Leandro Creek. For the previous report that presented WY 2012 results only (McKee et al., 2013), a preliminary rating curve was developed based on discharge sampling during WY 2012 augmented by the Manning's formula. This rating was improved this year by adding

Table 13). During active pumpout conditions, regression equations between PCBs, total mercury, methylmercury, SSC and turbidity were used to estimate loads (Table 12). Load estimates for total phosphorous, nitrate, and phosphate utilized flow weighted mean concentration derivations. Preliminary monthly loading estimates correlate very well with monthly discharge (Table 14). Monthly discharge was greatest in December 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 (34.4 t) and PCB (7.90 g) load estimates were comparable to the Water Year 2011 estimates (29 t and 8.0 g, respectively) even thought it was a wetter year (134% MAP) (Hunt., 2012) helping to give us 1st order confidence that the computed loads are reasonable. Due to lessons learned from the previous study, there is much higher confidence in the Water Year 2013 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, loads from the present study may be considered representative of somewhat dry conditions.

8.3. San Leandro Creek

8.3.2. San Leandro Creek flow

There is no historic flow record on San Leandro Creek. For the previous report that presented WY 2012 results only (McKee et al., 2013), a preliminary rating curve was developed based on discharge sampling during WY 2012 augmented by the Manning's formula. This rating was improved this year by adding

Table 13. Regression equations used for loads computations for North Richmond Pump Station during water year 2013. Note that regression equations will be reformulated with each future wet season of storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mainly urban	1.293		0.78	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.21	3.1	0.71	Regression with turbidity
Total Mercury (ng/NTU)	Mainly urban	0.605		0.92	Regression with turbidity
Total Methylmercury (ng/NTU)	Mainly urban	0.0028	0.05	0.88	Regression with turbidity
Total Organic Carbon (mg/L)	Mainly urban	7.48			Flow weighted mean concentration
Total Phosphorous (mg/L)	Mainly urban	0.276			Flow weighted mean concentration
Nitrate (mg/L)	Mainly urban	1.13			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.17			Flow weighted mean concentration

Table 14. Preliminary monthly loads for North Richmond Pump Station.

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	54	0.0278	1.44	208	0.318	0.674	0.00451	31.4	4.72	7.67
	12-Nov	156	0.152	7.78	1138	1.72	3.64	0.0245	172	25.9	42.0
	12-Dec	232	0.374	20.5	2795	4.46	9.61	0.0632	422	63.5	103
	13-Jan	18	0.0641	1.29	479	0.406	0.605	0.00602	72.4	10.9	17.7
	13-Feb	18	0.0438	1.26	328	0.338	0.590	0.00493	49.5	7.45	12.1
	13-Mar	19	0.0418	0.409	312	0.195	0.191	0.00299	47.2	7.10	11.5
	13-Apr	26	0.0602	1.70	450	0.460	0.796	0.00670	68.0	10.2	16.6
	Wet season total	523	0.763	34.4	5,709	7.90	16.1	0.113	863	130	211

known reservoir release rates associated with consistent stage readings. However, the resulting discharge estimates are still challenged by the lack of velocity measurements at flow stages greater than 3.5 feet and therefore are deemed of poor accuracy and precision. Based on this latest version of a still preliminary rating curve, total runoff during WY 2012 for the period 11/7/11 to 4/30/12 was revised from the 4.13 Mm^3 reported previously (McKee et al., 2013) to a new estimate of 5.47 Mm^3. This total discharge was mostly a result of a series of relatively minor storms that occurred during WY 2012 (

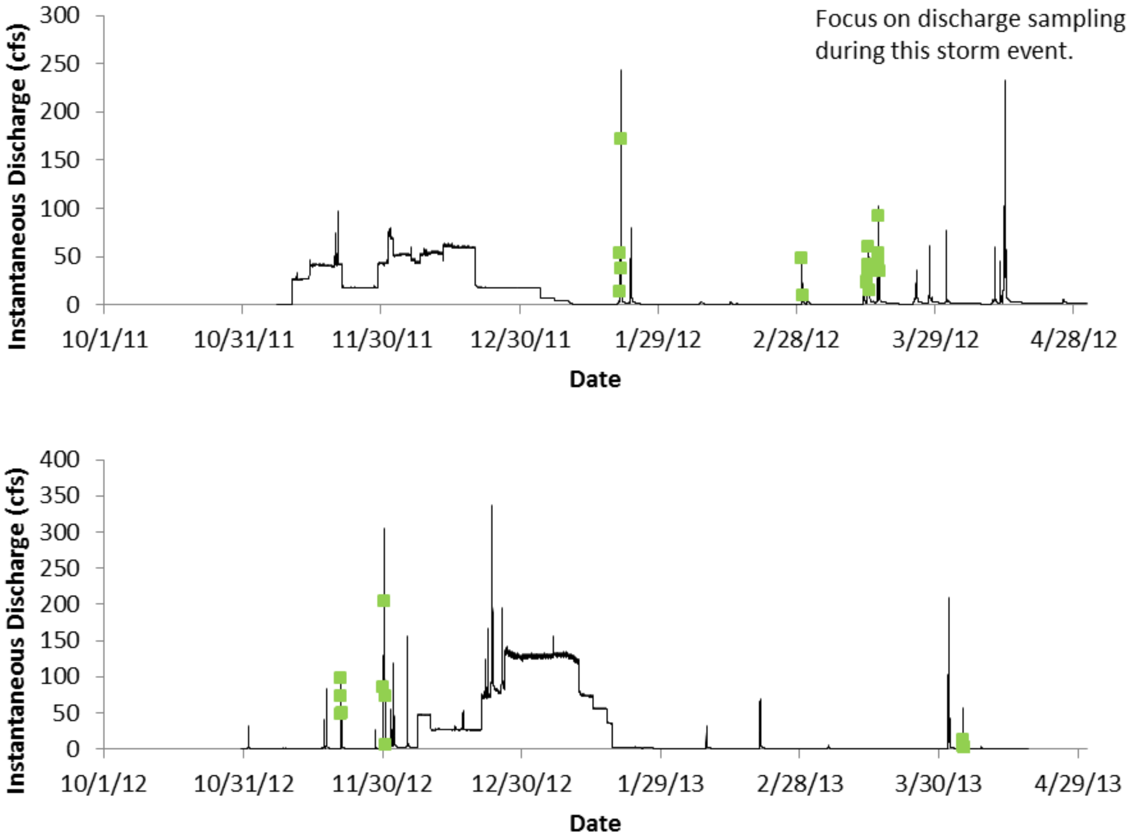

Figure 5. Preliminary flow characteristics (primary y axis) in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A) and WY 2013 (B) with sampling events plotted in green. Note, flow information will be updated in the future when additional data). Flow peaked at 244 cfs on 1/20/12 22:50. During WY 2013, flow peaked at 338 cfs on 12/23/12 14:20

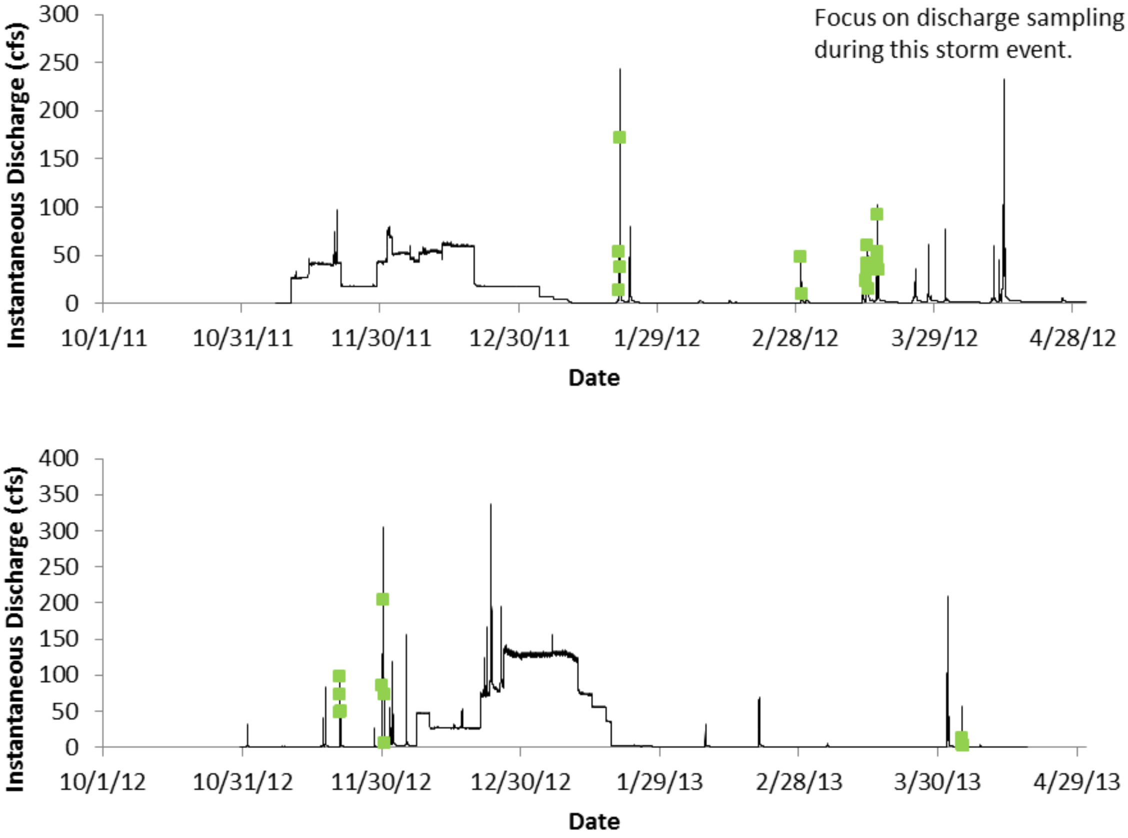

Figure 5. Preliminary flow characteristics (primary y axis) in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A) and WY 2013 (B) with sampling events plotted in green. Note, flow information will be updated in the future when additional data

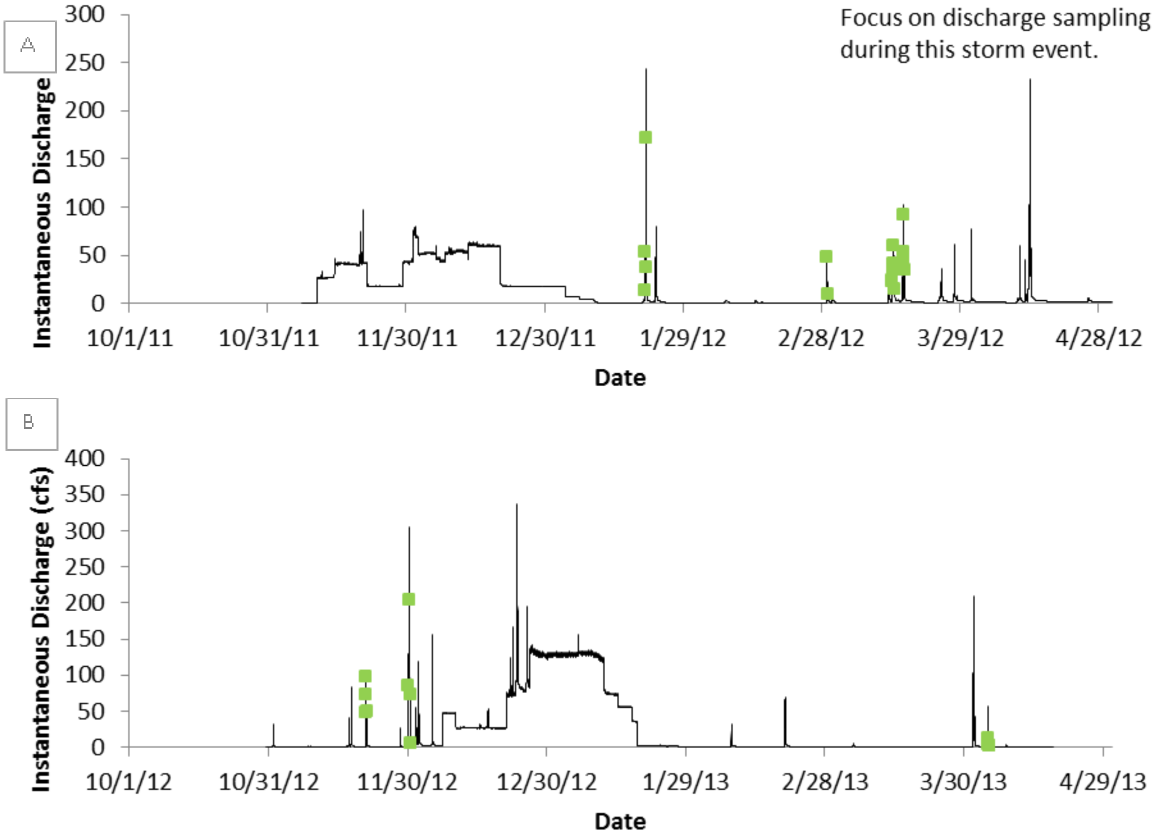

Figure 5. Preliminary flow characteristics (primary y axis) in San Leandro Creek at San Leandro Boulevard during Water Year 2012 (A) and WY 2013 (B) with sampling events plotted in green. Note, flow information will be updated in the future when additional data

and total wet season flow was 8.81 Mm^3. 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 1600 cfs on 1/20/2012 at 23:00; a flow that has been exceeded 68% of the years on record. During, WY 2013, flow in San Lorenzo peaked at 2970 cfs on 12/2/2012 at 11:15 am; a flow of this magnitude has been exceeded 38% of the years on record. Annual flow for San Lorenzo Creek at San Lorenzo (gauge number 11181040) for WY 2012 and 2013 respectively was 95 and 99 Mm^3 both well below the long term average for the site of 169 Mm^3. Based on this evidence alone, we suggest flow in San Leandro Creek flow was likely much lower than average for both water years.

In addition to the flow response from rainfall, East Bay Municipal Utility District (EBMUD) made releases from Chabot Reservoir in the first half of the WY 2012 season indicated by the square and sustained nature of the hydrograph at the sampling location. This also occurred in December and January of WY 2013 also indicated by the square nature of the hydrograph. Despite this augmentation, it seems likely that annual flow in San Leandro Creek during both years of observation was below average and would be exceeded in 60-70% of years. Rainfall data corroborates this assertion; rainfall during WY 2012 was 19.02 inches, or 74% of mean annual precipitation (MAP = 25.55 in) based on a long-term record at Upper San Leandro Filter (gauge number 049185) for the period 1971-2010 [Climate Year (CY]). CY 2012 was ranked 17th driest in the available 57-year record (1949-present [Note 7-year data-gap during CY 1952-58]). Data for CY 2013 is not yet available.

8.3.3. 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 run-off devoid of sediment and pollutants was associated with the reservoir release. With each of the storms that occurred beginning 1/20/2012 in WY 2012, maximum storm turbidity increased in magnitude. 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. These observations provide evidence that during larger storms and wetter years, the San Leandro Creek watershed is likely capable of much greater sediment erosion and transport resulting in greater turbidity and concentrations of suspended sediment. At this time, we have no evidence to suggest that the OBS-500 instrument utilized at this sampling location (with a range of 0-4000 NTU) will not be sufficient to handle most future storms.

Suspended sediment concentration, since it was computed from the continuous turbidity data, follows the same patterns as turbidity in relation to discharge. Suspended sediment concentration during WY 2012 peaked at 1141 mg/L during the late season storm on 4/13/12 at 5:15 am; a peak SSC of 608 mg/L occurred on 11/30/12 at 9:45 am for WY 2013; although it should be noted that there was considerable scatter around the upper end of the turbidity-SSC regression relation thus it is possible that this will be reinterpreted with a subsequent year of data collection. 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 WY 2012 to determine if the relative concentrations are logical.

8.3.4. San Leandro Creek POC concentrations summary (summary statistics)

Summary statistics of pollutant concentrations measured in San Leandro Creek during WY 2012 and 2013 provide a basic understanding of general water quality and also allow a first order judgment of quality assurance (Table 15). 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 with the exception of organic carbon. The range of PCB concentrations were typical of mixed urban land use watersheds (Lent and McKee, 2011). Maximum mercury concentrations (590 ng/L) were greater than observed in Zone 4 Line A in Hayward

Table 15. Summary of laboratory measured pollutant concentrations in San Leandro Creek during water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	53	98%	ND	590	100	162	100	28	86%	ND	904	48.0	114	202
∑PCB	ng/L	16	100%	2.91	29.4	10.5	12.3	41.5	12	100%	0.730	15.7	4.15	5.59	4.65
Total Hg	ng/L	16	100%	11.9	577	89.4	184	21.7	12	100%	7.50	590	44.0	93	162
Total MeHg	ng/L	9	100%	0.164	1.48	0.220	0.499	0.220	9	100%	0.150	1.40	0.200	0.377	0.397
TOC	mg/L	16	100%	4.50	12.7	7.95	7.79	1.40	12	100%	4.00	14.0	5.65	6.25	2.55
NO3	mg/L	16	100%	0.140	0.830	0.340	0.356	0.119	13	100%	0.130	2.80	0.230	0.520	0.732
Total P	mg/L	16	100%	0.200	0.760	0.355	0.393	0.098	9	100%	0.100	0.610	0.210	0.247	0.144
PO4	mg/L	16	100%	0.057	0.16	0.073	0.087	0.019	13	100%	0.069	0.130	0.093	0.094	0.019
Hardness	mg/L	4	100%	33.8	72.5	45.5	54.8	6.93	-	-	-	-	-	-	-
Total Cu	µg/L	4	100%	12.3	39.5	20.1	23.0	5.79	3	100%	5.90	28.0	11.0	15.0	11.6
Dissolved Cu	µg/L	4	100%	6.04	10.0	8.34	8.18	7.38	3	100%	3.50	4.90	4.10	4.17	0.702
Total Se	µg/L	4	100%	0.104	0.292	0.216	0.207	0.118	3	100%	0.180	0.290	0.190	0.220	0.061
Dissolved Se	µg/L	4	100%	0.068	0.195	0.131	0.131	0.012	3	100%	0.160	0.190	0.170	0.173	0.015
Carbaryl	ng/L	4	50%	ND	14.0	5.00	6.00	7.07	3	0%	ND	-	-	-	-
Fipronil	ng/L	4	100%	6.00	10.0	8.00	8.00	4.24	3	33%	ND	9.00	2.00	3.67	4.73
∑PAH	ng/L	2	100	3230	5352	4291	4291	1501	1	100%	1399	1399	1399	1399	-
∑PBDE	ng/L	2	100	64.9	82.0	73.5	73.5	12.1	2	100%	1.61	29.7	15.7	15.7	19.9
Delta/ Tralo-methrin	ng/L	3	100%	0.163	1.74	1.41	1.10	0.832	3	33%	ND	0.600	0	0.200	0.346
Cypermethrin	ng/L	4	0%	ND	-	-	-	-	3	67%	ND	0.800	0.700	0.500	0.436
Cyhalothrin lambda	ng/L	3	25%	ND	3.86	0	1.29	2.23	3	33%	ND	0.300	0	0.100	0.173
Permethrin	ng/L	4	100%	3.35	13.1	5.77	7.00	10.8	3	33%	ND	6.00	0	2.00	3.46
Bifenthrin	ng/L	4	75%	ND	32.4	12.1	14.1	5.66	3	100%	2.80	7.10	5.50	5.13	2.17

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.
All Hardness results in WY 2013 were censored.

(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). Nutrient concentrations were in the same range as measured in in Z4LA (Gilbreath et al., 2012), and as is typical in the Bay Area, phosphorus concentrations appear to be greater than reported elsewhere in the world under similar land use scenarios, an observation perhaps attributable to geological sources (McKee and Krottje, 2005). We find no reason to suspect data quality issues since the concentration ranges appear reasonable in relation to our conceptual models of water quality for these analytes.

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. During WY 2013, maximum concentrations of PAHs, PBDEs, and the pyrethroid pesticides were all considerably lower (around 5-fold) than observed during WY 2012. 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, hypotheses to explore further with additional data collection in WY 2014. Concentrations of many of these analytes were generally similar to concentrations observed in Z4LA (Gilbreath et al., 2012). Carbaryl and fipronil have not been measured previously by RMP studies but 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 total selenium concentrations in San Leandro Creek appear to be about double those observed in Z4LA (Gilbreath et al., 2012) but still not remarkable compared to other previous observations made in the Bay Area (e.g. North Richmond Pump station [Hunt et al., 2012] and Walnut and Marsh Creeks [McKee et al., 2012]). Pyrethroid concentrations of Delta/ Tralo-methrin, Cyhalothrin lambda, and Bifenthrin were similar to those observed in Z4LA whereas concentrations of Permethrin were about 10x lower (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. There does not appear to be any data quality issues.

8.3.5. San Leandro Creek toxicity

Composite water samples were collected at the San Leandro Creek station during four storm events in Water Year 2012 and three storm events during Water Year 2013. The survival of the freshwater fish species *Pimephales promelas* was significantly reduced during one of the four Water Year 2012 and one of the three Water Year 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 Water Year 2012 storm events sampled. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of sediments in receiving waters. 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.

8.3.6. San Leandro Creek preliminary loading estimates

Site specific methods were developed for computed loads (Table 16). Preliminary loads estimates generated for WY 2012 and reported by McKee et al. (2013) have now been revised based on revisions to the discharge estimates, additional pollutant concentration data collected in WY 2013 and an improving understanding of pollutant transport processes for the site. Preliminary monthly loading estimates correlate well with monthly discharge (Table 17). There are no data available for October of each water year because monitoring equipment was not installed. Discharge and rainfall are 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 run-off occurred from the upper watershed. At this time, all loads estimate should be considered preliminary. Additional data collected during WY 2014 will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate and finalize loads for WYs 2012 and 2013. Regardless of these improvements however, given the very dry flow conditions of WY 2012 and 2013 (see discussion on flow above), preliminary loads presented here may be considered representative of dry conditions.

Table 16. Regression equations used for loads computations for San Leandro Creek during water year 2012 and 2013. Note that regression equations will be reformulated with future wet season storm sampling.

Analyte	Origin of runoff	Slope	Intercept	Correlation coefficient (r^2)	Notes
Suspended Sediment (mg/NTU)	Mixed	1.2286		0.81	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.0871	4.097	0.58	Regression with turbidity
Total PCBs (ng/NTU)	Mainly non-urban	0.031	1.567	0.81	Regression with turbidity
Total Mercury urban (ng/NTU)	Mainly urban	0.66	6.17	0.83	Regression with turbidity
Total Mercury non-urban (ng/NTU)	Mainly non-urban	1.34		0.86	Regression with turbidity
Total Methylmercury (ng/NTU)	Mixed	0.0026	0.12	0.92	Regression with turbidity
TOC	Mixed	6.66			Flow weighted mean concentration
Total Phosphorous (mg/NTU)	Mixed	0.0012	0.18	0.64	Regression with turbidity
Nitrate (mg/L)	Mixed	0.38			Flow weighted mean concentration
Phosphate (mg/L)	Mixed	0.092			Flow weighted mean concentration

Table 17. Preliminary monthly loads for San Leandro Creek for water year 2012 and 2013.

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	-	-	-	-	-	-	-	-	-	-
	11-Nov	-	-	-	-	-	-	-	-	-	-
	11-Dec	0	3.14	23.9	20,909	5.66	32.1	0.438	1,193	289	587
	12-Jan	73	0.316	17.3	2,106	1.87	15.5	0.0827	120	29.1	76.7
	12-Feb	22	0.0206	0.591	137	0.0931	0.569	0.00329	7.81	1.89	3.32
	12-Mar	151	0.245	22.3	1,634	1.48	27.6	0.0863	93.2	22.6	69.0
	12-Apr	85	0.266	50.2	1,773	2.59	61.4	0.162	101	24.5	107
	Wet season total	332	5.47	120	36,423	14.2	145	0.965	2,078	503	1,113
2013	12-Oct	-	-	-	-	-	-	-	-	-	-
	12-Nov	121	0.238	32.9	1,587	1.93	40.6	0.113	90.5	21.9	80.5
	12-Dec	127	4.07	122	27,128	11.3	155	0.699	1,548	375	715
	13-Jan	7	4.37	54.6	29,111	8.54	73.1	0.665	1,661	402	842
	13-Feb	19	0.0359	1.46	239	0.155	1.61	0.00802	13.6	3.30	8.04
	13-Mar	11	0.0104	0.879	69.0	0.110	0.642	0.00347	3.94	0.954	2.82
	13-Apr[a]	41	0.0811	6.99	540	0.558	8.03	0.0277	30.8	7.46	22.6
	Wet season total	326	8.81	218	58,674	22.6	280	1.52	3,348	811	1,671

[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.

8.4. Guadalupe River

8.4.1. 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[2] 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.,

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[2] 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.

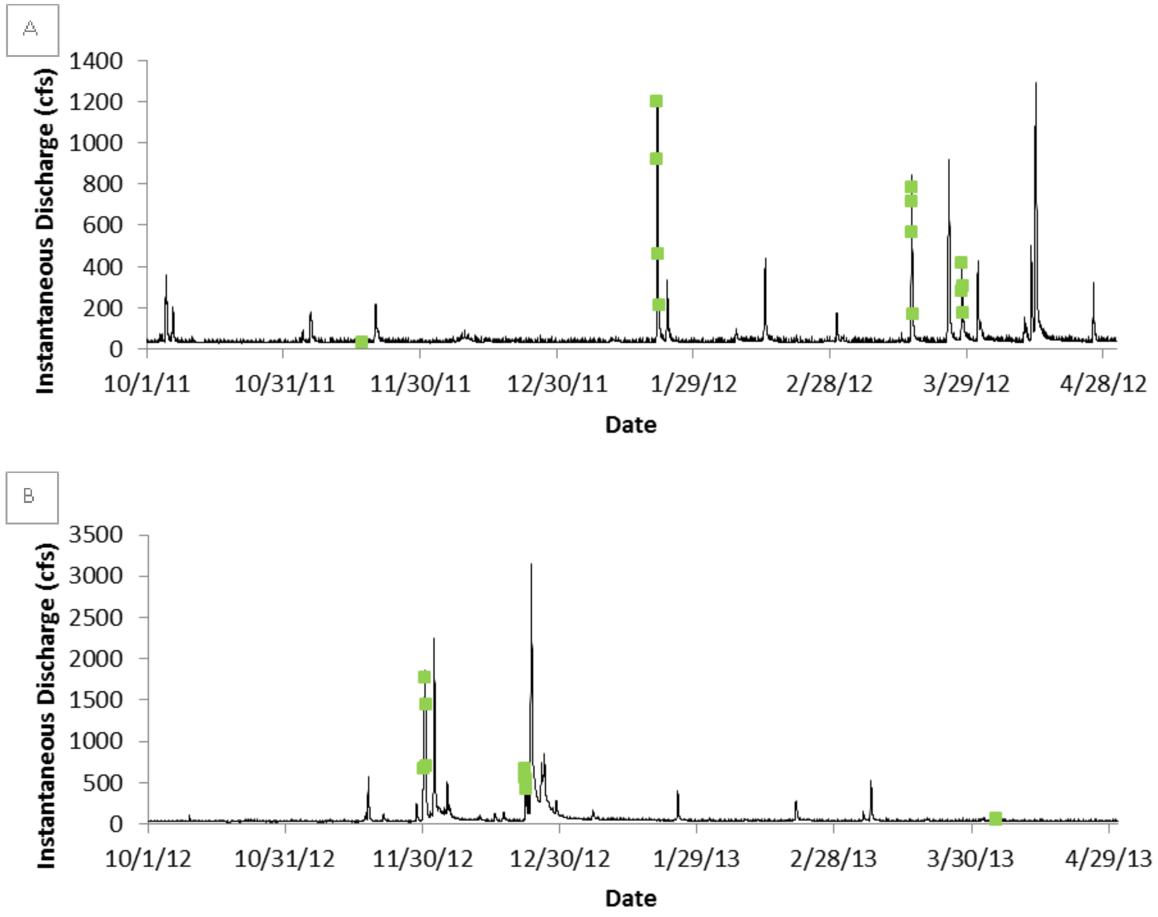


Figure 6. Flow characteristics in Guadalupe River during water year 2012 (A) based on published data and preliminary 15 minute data for water year 2013 (B) provided by the USGS (gauge number 11169025), with sampling events plotted in green. The fuzzy nature of the low flow data are caused by baseflow discharge fluctuations likely caused by pump station discharges near the gauge.

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 7:15 am 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 7.05 inches, or 47% of mean annual precipitation (MAP = 15.07 in) based on a long-term record at San Jose (NOAA gauge number 047821) for the period 1971-2010 (CY). CY 2012 was the driest year in the past 42 years and the 7th driest for the record beginning CY 1875 (138 years).

Water year 2013 was only slightly wetter, raining 8.78 inches as the San Jose gauge (58% 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 preliminary USGS data was 45.5 Mm^3; discharge of this magnitude is about 82% mean annual runoff (MAR) based on 83 years of record and equivalent to the MAR for the period WY1971-2010. Flow data and resulting loads calculations for WY 2013 will be updated once USGS publishes the official record. The USGS normally publishes finalized data for the permanent record in the spring following the end of each Water Year.

8.4.2. Guadalupe River turbidity and suspended sediment concentration

Turbidity generally responded to rainfall events in a similar manner to runoff. 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. Based on past years of record, turbidity can exceed 1000 FNU at the sampling location (e.g. McKee et al., 2004); the FTS DTS-12 turbidity probe used at this study location is quite capable of sampling most if not all future sediment transport conditions for the site.

A continuous record of SSC was computed by SFEI using the POC monitoring SSC data, the preliminary 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 844 mg/L during the 1/21/12 storm event at 3:15, and in WY 2013 at 933 mg/L on 12/23/12 at 19:00. 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).

8.4.3. Guadalupe River POC concentrations summary (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 WYs 2012 and 2013 are summarized (Table 18). 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 (Sunnyvale Channel > Pulgas Creek PS > Guadalupe River >North Richmond PS > San Leandro Creek >Lower Marsh Creek). 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) over the period of record at this location (2002-2010). Nutrient concentrations were in the same range as measured in in Z4LA

Table 18. Summary of laboratory measured pollutant concentrations in Guadalupe River for water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	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	100%	8.6	730	82.0	198	205	41	100%	5.9	342	128	124	104
∑PCB	ng/L	11	100%	2.70	59.1	6.96	17.7	21.5	12	100%	2.04	47.4	6.29	10.6	12.7
Total Hg	ng/L	12	100%	36.6	1000	125	268	324	12	100%	14.5	360	155	153	119
Total MeHg	ng/L	10	100%	0.086	1.15	0.381	0.445	0.352	7	100%	0.040	0.940	0.490	0.428	0.340
TOC	mg/L	12	100%	4.90	18.0	7.45	8.73	4.03	12	100%	5.30	11.0	6.05	6.36	1.55
NO3	mg/L	12	100%	0.560	1.90	0.815	0.918	0.380	12	67%	ND	2.30	0.520	0.921	0.992
Total P	mg/L	12	100%	0.190	0.810	0.315	0.453	0.247	8	100%	0.300	0.610	0.390	0.405	0.092
PO4	mg/L	12	100%	0.060	0.160	0.101	0.101	0.032	12	100%	0.061	0.180	0.120	0.109	0.034
Hardness	mg/L	3	100%	133	157	126	143	12.3	-	-	-	-	-	-	-
Total Cu	µg/L	3	100%	10.7	26.3	24.7	20.6	8.58	3	100%	5.90	28.0	23.0	19.0	11.6
Dissolved Cu	µg/L	3	100%	5.07	7.91	5.51	6.16	1.53	3	100%	2.50	3.60	2.50	2.87	0.635
Total Se	µg/L	3	100%	1.16	1.63	1.21	1.33	0.258	3	100%	0.700	3.30	0.780	1.59	1.48
Dissolved Se	µg/L	3	100%	0.772	1.32	1.04	1.04	0.274	3	100%	0.400	3.20	0.540	1.38	1.58
Carbaryl	ng/L	3	100%	13.0	57.0	57.0	41.4	24.7	3	67%	ND	21.0	17.0	12.7	11.2
Fipronil	ng/L	3	100%	6.50	20.0	11.0	12.5	6.87	3	100%	3.00	11.0	9.00	7.67	4.16
∑PAH	ng/L	1	100%	-	-	-	2186	-	8	100%	40.7	736	174	251	245
∑PBDE	ng/L	1	100%	-	-	-	34.5	-	2	100%	13.1	69.8	41.4	41.4	40.1
Delta/ Tralo-methrin	ng/L	3	100%	0.704	1.90	1.82	1.47	0.667	3	0%	ND	-	-	-	-
Cypermethrin	ng/L	3	0%	ND	-	-	-	-	3	100%	0.500	3.30	1.70	1.83	1.40
Cyhalothrin lambda	ng/L	3	33%	ND	-	-	1.20	-	3	100%	0.300	1.50	0.500	0.767	0.643
Permethrin	ng/L	3	100%	16.8	20.5	19.5	18.9	1.91	3	33%	ND	5.40	0	1.80	3.12
Bifenthrin	ng/L	3	67%	ND	13.3	6.16	6.47	6.63	3	100%	0.900	7.60	5.90	4.80	3.48

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.
All Hardness results in WY 2013 were censored.

(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). 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.

In a similar manner, summary statistics and comparisons were developed for the lower sample frequency analytes collected using composite sampling design (see the methods section). 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 2-8 fold greater than the other five locations; elevated groundwater concentrations have been observed in Santa Clara County previously (Anderson, 1998). Carbaryl and fipronil 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). Pyrethroid concentrations of Cyhalothrin lambda were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were on the lower end (Gilbreath et al., 2012). No quality issues appear from the comparisons.

8.4.4. Guadalupe River toxicity

Composite water samples were collected at the Guadalupe River station during three storm events in WY 2012 and three storm events in Water Year 2013. 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. Significant reductions in the survival of the amphipod *Hyalella azteca* was observed during two of the three storm Water Year 2012 events sampled. There were no significant effects observed for any samples collected during Water Year 2013. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used by scientists to assess the toxicity of receiving water sediments.

8.4.5. Guadalupe River preliminary loading estimates

The following methods were applied to estimate loads for the Guadalupe River in WYs 2012 and 2013. Suspended sediment loads for WY 2012 were downloaded from USGS. Since the WY 2013 suspended sediment record has not yet been published, concentrations were estimated from the turbidity record using a linear relation (Table 19). Once the official USGS flow and SSC record is published for WY 2013, the suspended sediment load will be updated. Concentrations were estimated using regression equations between the contaminant and turbidity, except for nitrate in which a flow weighted mean concentration was used (Table 19). As found during other drier years (McKee et al., 2006), a separation of the data for PCBs and total mercury to form regression relations based on origin of flow was not possible with WY 2012 data, in which the majority of runoff was of urban origin. This separation was, however, possible for PCBs during WY 2013 flows.

Preliminary monthly loading estimates correlate fairly well with monthly discharge (Table 20). 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

Table 19. Regression equations used for loads computations for Guadalupe River during water year 2012 and 2013. 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 WY 2013 (mg/NTU)[a]	Mixed	1.69		0.92	Regression with turbidity
Total PCBs urban (ng/NTU)	Mainly urban	0.23898		0.76	Regression with turbidity
Total PCBs non-urban (ng/NTU)	Mainly non-urban	0.079123		0.84	Regression with turbidity
Total Mercury (ng/NTU)	Mixed	2.17		0.81	Regression with turbidity
Total Methylmercury (ng/NTU)	Mixed	0.0031	0.21	0.48	Regression with turbidity
Total Organic Carbon (mg/NTU)	Mixed	0.028	4.7	0.62	Regression with turbidity
Total Phosphorous (mg/NTU)	Mixed	0.0019	0.2	0.71	Regression with turbidity
Nitrate (mg/L)	Mixed	0.633			Flow weighted mean concentration
Phosphate (mg/NTU)	Mixed	0.00028	0.077	0.59	Regression with turbidity

[a] Suspended sediment loads in WY 2012 were downloaded from the USGS for this site.

2013 loads were approximately 3x higher than WY 2012. 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 several times lower. At this time, all loads estimates for WY 2013 should be considered preliminary. Once available, USGS official records for flow, turbidity, and SSC can be substituted for the preliminary data presented here. In addition pollutant data collected in future sampling years will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate these loads. Regardless of these improvements, overall, WY 2012 and 2013 loads may be considered representative of loads during dry conditions in this watershed.

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 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. Due to the knowledge of the poor quality runoff data for this channel, in WY 2012 discharge was estimated based on the continuous stage record and application of the Manning's formula. However, in WY 2013 additional velocity discharge measurements were collected in the field and corroborated the SCVWD rating curve up to stages of 2.9

Table 20. Preliminary monthly loads for Guadalupe River for water year 2012 and 2013.

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	15966	9.08	188	0.865	1840	247	757
	11-Nov	15	2.88	104	14844	5.68	110	0.750	1823	235	685
	11-Dec	1	2.73	76.4	13244	1.38	38.0	0.619	1730	215	593
	12-Jan	18	3.85	565	25069	29.2	555	1.58	2439	367	1268
	12-Feb	14	3.15	315	17766	10.0	240	0.989	1995	273	852
	12-Mar	50	5.08	404	29516	29.6	456	1.69	3213	448	1433
	12-Apr	44	5.23	485	30078	28.2	446	1.71	3307	458	1454
	Wet season total	161	25.8	2116	146483	113	2033	8.20	16347	2243	7042
2013	12-Oct	8	2.26	52.5	11406	3.44	67.5	0.56	1430	182	521
	12-Nov	48	5.23	913	39385	85.0	1175	2.73	3309	551	2082
	12-Dec	92	14.8	3100	119995	224	3991	8.67	9373	1643	6468
	13-Jan	15	4.14	98.4	20924	7.95	127	1.03	2618	334	957
	13-Feb	11	3.05	58.2	15186	4.45	75.0	0.74	1929	244	689
	13-Mar	21	3.47	93.6	17733	6.93	120	0.89	2196	282	815
	13-Apr	5	2.57	36.6	12598	2.12	47.2	0.60	1626	204	567
	Wet season total	201	35.5	4352	237227	334	5603	15.2	22482	3440	12099

feet (corresponding to flows of 190 cfs). Therefore, WY 2013 discharge was estimated based on continuous stage and application of the SCVWD rating curve, and WY 2012 discharge was recalculated using the same method. Efforts will be made in subsequent sampling years to evaluate the accuracy of the SCVWD rating curve at stages greater than 3 feet.

Both WY 2012 and 2013 were relatively dry years and discharge was likely lower than average. Rainfall during WY 2012 and 2013 was 8.82 and 10.2 inches, respectively, at Palo Alto (NOAA gauge number 046646). Relative to mean annual precipitation (MAP = 15.25 in) based on a long-term record for the period 1971-2010 (CY), WY 2012 was only 58% MAP and WY 2013 67% MAP. A series of relatively minor storms occurred during WY 2012 (

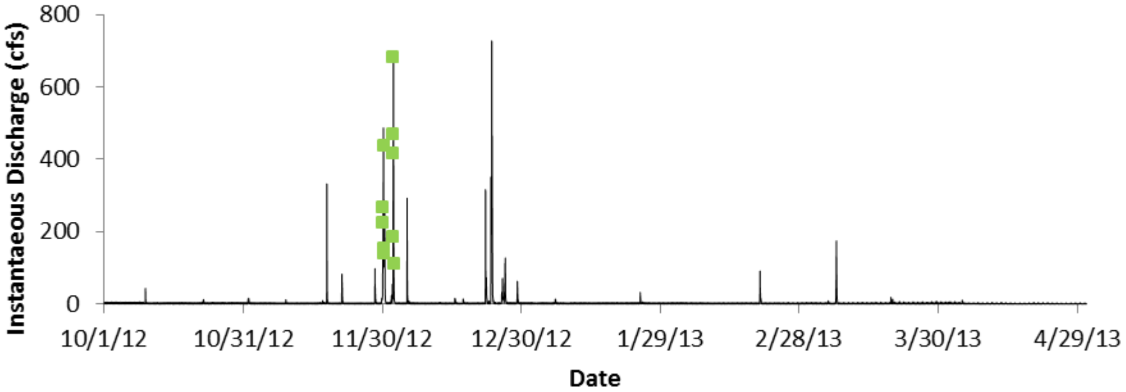
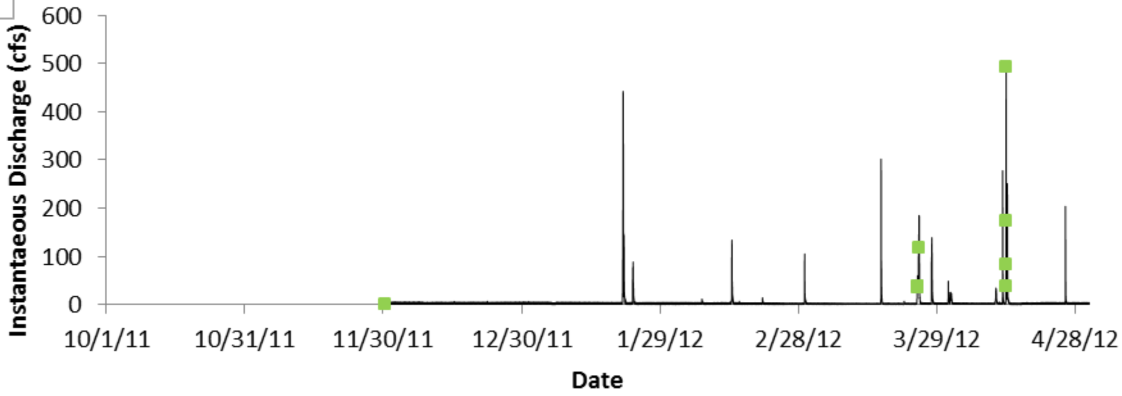


Figure 7Figure 7). Flow peaked at 492 cfs overnight on 4/12/12- 4/13/12 at midnight. Total runoff during WY 2012 for the period 12/1/11 to 4/30/12 was 1.07 Mm^3 based on our stage record and the SCVWD rating curve. Total annual runoff for the period between 10/01/12 and 4/30/13 was 1.79 Mm^3 and likely 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

A



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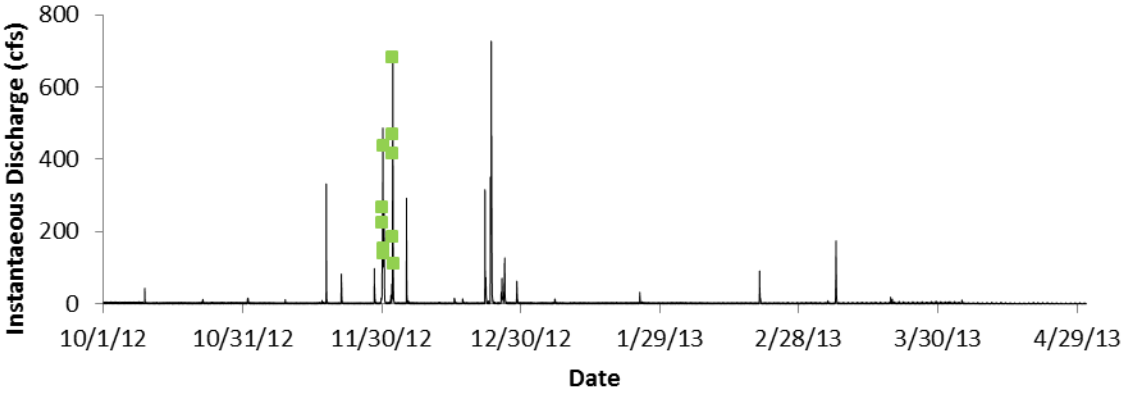

Figure 7. Preliminary flow characteristics in Sunnyvale East Channel at East Ahwanee Avenue during WY 2012 (A) and WY 2013 (B) with sampling events marked in green. The flow record is based on the District rating curve for this station as verified by velocity sampling completed to-date. The rating relationship may be improved in subsequent years as more velocity sampling is completed.

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).

8.3.2. Sunnyvale East Channel turbidity and suspended sediment concentration

The entire turbidity record for WY 2012 was censored due to problems with the installation design and the OBS-500 instrument reading the bottom of the channel. Suspended sediment concentration in WY 2012 could not be computed from the continuous turbidity data, and was alternatively computed as a function of flow (with much lower confidence due to the loss of hysteresis in the computational scheme). 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. During the period of record in which the turbidity sensor was functioning correctly, SSC was estimated based on regression with turbidity. During the period of record in which turbidity was censored, SSC was computed as a function of flow in a similar manner to estimates made in WY 2012.

Turbidity in Sunnyvale East Channel in WY 2013 remained low (<40 NTU) during base flows and increased to between 500 and 1000 NTU during storms. 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. The three large events in November and December resulted in turbidities in the 600-900 NTU range, providing evidence to suggest that the DTS-12 instrument now utilized at this sampling location will be sufficient to handle future storms.

Suspended sediment concentration in WY 2012 peaked at 352 mg/L on 4/13/12 just after midnight and at 3726 mg/L on 10/9/12 in response to the early season small but intense rainfall. 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) and in WY 2013 was 3120 mg/L (collected on 12/2/12; the 10/9/12 estimated peak SSC occurred during a non-sampled storm event). Note that the estimated SSC (estimated from the continuous turbidity record) for the 10/9/12 peak had a ratio to turbidity of 3.7:1. This ratio is higher than typical for urban creeks and resulted because the WY 2013 sampling occurred during two of the three largest storm events, at which time bank erosional processes led to mixed grain fractions in the samples and higher SSC per unit of turbidity. This observation suggests that as the Sunnyvale East Channel dataset grows in future sampling years, the data should be stratified between storms that do and do not exhibit bank erosional processes. The maximum concentration measured during the WY 2011 RMP reconnaissance study (McKee et al., 2012) was 1050 mg/L and was collected during a relatively small but intense rain event, but at this time we have not evaluated the relative storm magnitude between WY 2011, 2012 and 2013 to determine if the relative concentrations are logical.

8.3.3. Sunnyvale East Channel POC concentrations summary (summary statistics)

A wide range of pollutants were measured in Sunnyvale East Channel during WY 2012 and 2013 (Table 21). 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 organic carbon, nitrate and phosphate in WY 2013 in which the mean and median were similar. The range of PCB concentrations were typical of mixed urban land use watersheds

Table 21. Summary of laboratory measured pollutant concentrations in Sunnyvale East Channel during water years 2012 and 2013.

		Water Year 2012							Water Year 2013						
Analyte Name	**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	28	97%	ND	370	49.0	81.6	100	34	97%	ND	3120	312	485	645
∑PCB	ng/L	8	100%	3.27	119	33.6	41.3	41.5	10	100%	9.16	176	31.3	59.3	64.3
Total Hg	ng/L	8	100%	6.30	64.1	21.7	27.7	21.7	10	100%	13	220	55.5	72.9	65.2
Total MeHg	ng/L	6	86%	ND	0.558	0.184	0.250	0.220	6	100%	0.020	0.540	0.290	0.252	0.220
TOC	mg/L	8	100%	4.91	8.60	5.94	6.41	1.40	10	100%	4.10	10.0	5.85	5.85	1.71
NO3	mg/L	8	100%	0.200	0.560	0.280	0.309	0.119	10	100%	0.150	0.370	0.280	0.269	0.069
Total P	mg/L	8	100%	0.190	0.500	0.250	0.278	0.098	11	100%	0.230	1.70	0.390	0.527	0.412
PO4	mg/L	8	100%	0.067	0.110	0.079	0.085	0.019	10	100%	0.094	0.130	0.120	0.115	0.010
Hardness	mg/L	2	100%	51.4	61.2	56.3	56.3	6.93	-	-	-	-	-	-	-
Total Cu	µg/L	2	100%	10.8	19.0	14.9	14.9	5.79	2	100%	19.0	31.0	25.0	25.0	8.49
Dissolved Cu	µg/L	2	100%	4.36	14.8	9.58	9.58	7.38	2	100%	3.10	4.90	4.00	4.00	1.27
Total Se	µg/L	2	100%	0.327	0.494	0.411	0.411	0.118	2	100%	0.490	0.490	0.490	0.490	0
Dissolved Se	µg/L	2	100%	0.308	0.325	0.317	0.317	0.012	2	100%	0.35	0.39	0.370	0.370	0.028
Carbaryl	ng/L	2	100%	11.0	21.0	16.0	16.0	7.07	2	50%	ND	19.0	9.50	9.5	13.4
Fipronil	ng/L	2	100%	6.00	12.0	9.00	9.00	4.24	2	50%	ND	6.00	3.00	3.00	4.24
∑PAH	ng/L	1	100%	-	-	-	1289	-	1	100%	-	-	-	1355	-
∑PBDE	ng/L	1	100%	-	-	-	4.77	-	1	100%	-	-	-	34.9	-
Delta/ Tralo-methrin	ng/L	1	0%	ND	-	-	-	-	2	100%	3.60	3.80	3.70	3.70	0.141
Cypermethrin	ng/L	2	0%	ND	-	-	-	-	2	100%	3.20	5.20	4.20	4.20	1.41
Cyhalothrin lambda	ng/L	1	0%	ND	-	-	-	-	2	100%	1.20	2.50	1.85	1.85	0.919
Permethrin	ng/L	2	100%	5.70	20.9	13.3	13.3	10.8	2	100%	22.0	48.0	35.0	35.0	18.4
Bifenthrin	ng/L	2	50%	ND	8	4	4.0	5.7	2	100%	8.70	18.0	13.4	13.4	6.58

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 Sunnyvale East Channel was two.
All Hardness results in WY 2013 were censored.

(Lent and McKee, 2011) and maximum PCB concentrations (176 ng/L) exceeded the maximum observed in Z4LA (110 ng/L) (Gilbreath et al., 2012). Similarly, the range of mercury concentrations were comparable to those observed in Z4LA while the maximum total mercury concentration in Sunnyvale East Channel (220 ng/L) was greater than sampled in Z4LA (150 ng/L). Nutrient concentrations were also in the same range as measured in 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.

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. Carbaryl and Fipronil (not measured previously by RMP studies) were lower or on the low end relative to 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). Concentrations of Bifenthrin, Cyhalothrin lambda, and Permethrin were within but on the low end of the range observed in Z4LA. Based on these first order comparisons, we see no quality issues with the data.

8.3.1. Sunnyvale East Channel toxicity

Composite water samples were collected in the Sunnyvale East Channel during two storm events in WY 2012 and two storm events in WY 2013. 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* was observed during both WY 2012 and WY 2013 storm events[3]. Although limited use of this species has occurred for the evaluation of toxicity in water, it has consistently been used for assessments of receiving water sediment toxicity. No significant effects were observed for the crustacean *Ceriodaphnia dubia*, the algae *Selenastrum capricornutum* or the fathead minnow during these storms.

8.3.2. Sunnyvale East Channel preliminary loading estimates

Given that the turbidity record in WY 2012 was unreliable due to optical interference from bottom substrate (problem now rectified), and gaps 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 (**Error! Not a valid bookmark self-reference.**). Concentrations of other POCs were estimated using regression equations between the contaminant 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.

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[3] In one of the two samples where significant toxicity was observed, a holding time violation occurred and therefore the results should be considered in the context of this exceedance of measurement quality objectives.

Preliminary monthly loading estimates for Sunnyvale East Channel are presented in Table 23. This table highlights how monthly loads can be dominated by a few large storm events. Relative to discharge, suspended sediment load exerted quite high variability relative to some of the other sampling locations in the study. Although December 2012 only discharged 27% of the total volume for WYs 2012 and 2013 combined, 73% of the suspended sediment load was transported during this month as well as approximately 60% of the PCB and mercury loads. Normalized to total annual discharge, WY 2013 transported 11-fold more sediment than WY 2012, 3-fold the amount of PCBs and almost 4-fold the amount of Hg. Provided the context that both WY 2012 and 2013 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.

Table 22. Regression equations used for loads computations for Sunnyvale East Channel during water year 2012 and 2013. 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/CFS)	Mainly urban	0.7145		0.97	Regression with flow
Suspended Sediment (WY2013) (mg/CFS)	Mainly urban	1.4421		0.67	Regression with flow
Suspended Sediment (WY2013) (mg/NTU)	Mainly urban	0.4913x1.2907		0.75	Regression with turbidity
Total PCBs (ng/CFS)	Mainly urban	0.23	2.7	0.62	Regression with flow
Total Mercury (ng/mg)	Mainly urban	0.13	13	0.93	Regression with estimated SSC
Total Methylmercury (ng/CFS)	Mainly urban	0.0011	0.12	0.77	Regression with flow
Total Organic Carbon (mg/L)	Mainly urban	5.77			Flow weighted mean concentration
Total Phosphorous (mg/mg)	Mainly urban	0.00076	0.2	0.86	Regression with estimated SSC
Nitrate (mg/L)	Mainly urban	0.245			Flow weighted mean concentration
Phosphate (mg/L)	Mainly urban	0.106			Flow weighted mean concentration

8.6. Pulgas Creek Pump Station

8.6.1. Pulgas Creek Pump Station flow

Flow into the Pulgas Creek Pump Station from the southern catchment has not historically been monitored. An ISCO area velocity flow meter situated directly in the incoming pipe was used to measure stage and flow in WY 2013. Total runoff during WY 2013 for the period of record 12/17/12 to 3/15/13 was 0.09 Mm^3. A monthly (or partial monthly for December 2012 and March 2013) rainfall to runoff regression was applied to the missing period of the wet season. Based on this regression estimator method, a coarse estimate total runoff during WY 2013 for the period 10/01/12 to 4/30/13 was 0.21 Mm^3. This estimate will be improved as the monthly rainfall to runoff regression improves in future years with a larger dataset. Since runoff from this watershed is likely to highly correlate with rainfall due to its small drainage area and high imperviousness, but since MAP for the nearby Redwood City NCDC meteorologic gauge (gauge number 047339-4) was 78% of normal, total runoff for WY 2013 at Pulgas Creek was likely below average.

Table 23. Preliminary monthly loads for Sunnyvale East Channel during water years 2012 and 2013.

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	-	-	-	-	-	-	-	-	-	-
	11-Nov	-	-	-	-	-	-	-	-	-	-
	11-Dec	2	0.148	0.282	852	0.492	1.92	0.0175	36.2	15.7	29.6
	12-Jan	37	0.254	13.4	1468	4.98	4.96	0.0502	62.3	27.0	60.7
	12-Feb	22	0.151	1.36	872	0.846	2.10	0.0196	37.0	16.0	31.1
	12-Mar	69	0.260	8.29	1501	3.36	4.38	0.0429	63.7	27.6	58.0
	12-Apr	39	0.260	13.3	1498	4.95	5.01	0.0506	63.6	27.5	61.7
	Wet season total	169	1.07	36.7	6192	14.6	18.4	0.181	263	114	241
2013	12-Oct	13	0.125	7.33	722	0.445	2.53	0.0150	30.7	13.3	30.4
	12-Nov	61	0.456	130	2634	19.1	22.5	0.139	112	48.4	189
	12-Dec	101	0.786	516	4535	50.9	76.1	0.327	193	83.3	546
	13-Jan	8	0.115	2.78	664	0.407	1.82	0.0138	28.2	12.2	25.0
	13-Feb	10	0.102	7.15	591	0.536	2.22	0.0131	25.1	10.9	25.8
	13-Mar	20	0.150	8.80	867	1.51	3.04	0.0227	36.8	15.9	36.5
	13-Apr	6	0.059	0.238	339	0.187	0.780	0.007	14.4	6.24	11.9
	Wet season total	219	1.79	673	10352	73.1	109	0.538	440	190	865

During the very short and incomplete period of record at Pulgas Creek pump station, a large storm series occurred towards the end of December 2012, followed by few and relatively minor storms for the remainder of the record. Flow peaked at 50 cfs on 12/23/12 at 17:04 (Figure 8). 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. However large the peak flows were for nearby creek systems such as San Francisquito Creek, flows in Pulgas Creek Pump Station south may respond differently again due to its very small size and high imperviousness. Pulgas Creek Pump Station south 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 was 0.43 inches per hour and occurred on 12/23/12 at 17:10, concurrent with the peak flow. Relative to the Redwood City NCDC meteorologic gauge and based on the partial duration series, the maximum 1-hour rainfall intensity at Pulgas has approximately a 1-year recurrence interval. Based on this rainfall intensity recurrence, we suggest peak flows in Pulgas Creek Pump Station South watershed were approximately average.

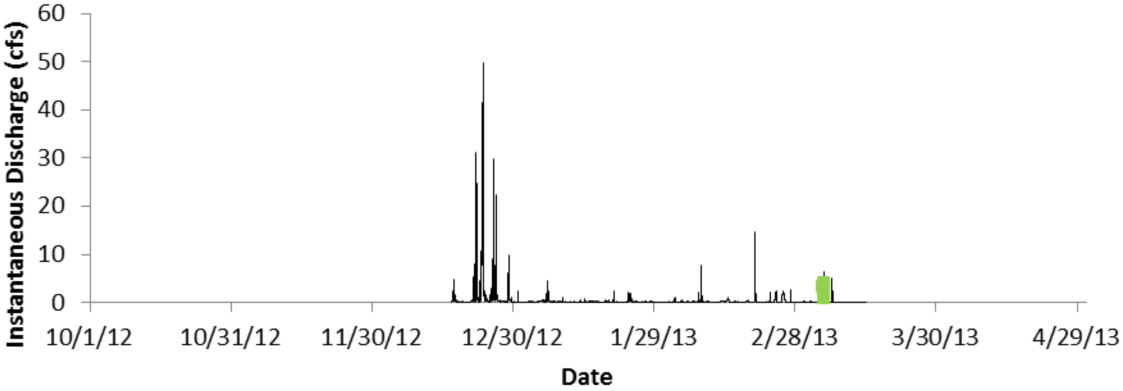

Figure 8. Preliminary flow characteristics at Pulgas Creek Pump Station South during Water Year 2013 with sampling events plotted in green. Pulgas Creek Pump Station turbidity and suspended sediment concentration

8.6.2. Pulgas Creek Pump Station turbidity and suspended sediment concentration

Turbidity in Pulgas Creek Pump Station south watershed generally responded to rainfall events in a similar manner to runoff. During non-storm periods, turbidity 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[4] and did not return to readings below 20 NTU for 18 hours. Storm-associated turbidity peaked at 588 NTU on 1/6/13 during the first storm following the 12/30/12 spike. During all storm events after the 12/30/12 spike, storm maximum turbidities were all greater than maximum turbidities in the large storm series around 12/23/12. Two hypotheses are suggested 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. Future monitoring at Pulgas Creek will help elucidate which of these current hypotheses are more likely and what the typical range of turbidity is for this watershed sampling location as water passes through to the

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[4] 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.

Bay. Despite the turbidity measurements being out of the sensor range during the 12/30/12 spike, at this time we have no evidence to suggest that the DTS-12 instrument utilized at this sampling location (with a range of 0-1600 NTU) will not be sufficient to handle most future storms.

Suspended sediment concentration was computed from the continuous turbidity data and therefore follows the same patterns as turbidity in relation to discharge and the non-storm associated spike on 12/20/12. Suspended sediment concentration peaked at 2693 mg/L during the spike on 12/30/12 at 23:00. Storm-associated suspended sediment concentration peaked at 647 mg/L and occurred in the first subsequent storm event on 1/6/13 at 6:15. These concentration estimates based on the continuous turbidity record are much greater than observed during collection events. The maximum SSC concentration was 110 mg/L measured on 3/6/13 L while the maximum concentration measured during the RMP reconnaissance study (McKee et al., in review) was 60 mg/L. At this time we have chosen to censor the data minimally, however future sampling may indicate that further censorship or reinterpretation is necessary.

8.6.3. Pulgas Creek Pump Station POC concentrations summary (summary statistics)

Summary statistics of pollutant concentrations measured in Pulgas Creek Pump Station South in WY 2013 are presented in Table 24. Except for total methylmercury, in which two dry flow samples were additionally collected, these samples were collected during a single small storm event. Due to the small size of this dataset and relatively low SSC during sample collection, it is likely that samples collected in future years will yield higher concentrations for many pollutants of concern. Therefore, the following statements provide a first order judgment of quality assurance, but are heavily caveated by the currently unrepresentative sample dataset.

For all pollutants sampled with the exception of total methylmercury and total phosphorous, concentrations followed the typical pattern of median < mean. The range of PCB concentrations were 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, reported in Lent and McKee, 2011). Mean total mercury concentrations (10.5 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). Nutrient concentrations were in the same range as measured in in Z4LA, but generally lower than the other watersheds in this study. Although the dataset is possibly unrepresentative of the broader range of concentrations we might see in subsequent years as the dataset grows, we find no reason to suspect data quality issues since the concentration ranges appear reasonable in relation to our conceptual models of water quality for these analytes.

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). Carbaryl and fipronil 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). Concentrations of Cypermethrin were similar to those observed in Z4LA whereas concentrations of Permethrin and Bifenthrin were about 20x and 10x lower, respectively (Gilbreath et al., 2012). In summary, concentrations measured at Pulgas Creek Pump Station South during WY 2013 are in a the typical range of Bay Area urban watersheds, however the dataset is currently very small and is probably unrepresentative of the full range of concentrations for this site.

Table 24. Summary of laboratory measured pollutant concentrations in Pulgas Creek Pump Station during water year 2013.

		Water Year 2012	Water Year 2013						
Analyte Name	Unit	Samples taken (n)	Samples taken (n)	Proportion detected (%)	Min	Max	Median	Mean	Standard Deviation
SSC	mg/L	0	15	100%	4.3	110	24.0	33.3	33.1
∑PCB	ng/L	0	4	100%	15.1	62.7	30.5	34.7	20.1
Total Hg	ng/L	0	6	100%	4.20	23.0	7.45	10.53	6.90
Total MeHg	ng/L	0	6	100%	0.040	0.280	0.215	0.178	0.100
TOC	mg/L	0	4	100%	7.30	17.0	8.35	10.3	4.53
NO3	mg/L	0	4	100%	0.240	0.490	0.350	0.358	0.102
Total P	mg/L	0	4	100%	0.100	0.250	0.125	0.150	0.071
PO4	mg/L	0	4	100%	0.051	0.094	0.059	0.066	0.020
Hardness	mg/L	0	-	-	-	-	-	-	-
Total Cu	µg/L	0	1	100%	-	-	-	30.0	-
Dissolved Cu	µg/L	0	1	100%	-	-	-	20.0	-
Total Se	µg/L	0	1	100%	-	-	-	0.180	-
Dissolved Se	µg/L	0	1	100%	-	-	-	0.170	-
Carbaryl	ng/L	0	1	100%	-	-	-	204	-
Fipronil	ng/L	0	1	0%	ND	-	-	-	-
∑PAH	ng/L	0	4	100%	211	1138	552	614	389
∑PBDE	ng/L	0	4	100%	5.18	89.8	32.5	40.0	39.7
Delta/ Tralo-methrin	ng/L	0	1	0%	ND	-	-	-	-
Cypermethrin	ng/L	0	1	100%	-	-	-	0.9	-
Cyhalothrin lambda	ng/L	0	1	0%	ND	-	-	-	-
Permethrin	ng/L	0	1	100%	-	-	-	2.9	-
Bifenthrin	ng/L	0	1	100%	-	-	-	1.3	-

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 Pump Station was four.
All Hardness results in WY 2013 were censored.

8.6.4. Pulgas Creek Pump Station toxicity

A composite water sample was collected at Pulgas Creek on March 6, 2013. No significant effects were observed on any of the four test organisms.

8.6.5. Pulgas Creek Pump Station preliminary loading estimates

Continuous concentrations of suspended sediment, PCBs, total mercury and methylmercury, and total phosphorous were computed using regression equations of each contaminant with turbidity (Table 25). Similarly, continuous concentrations of TOC and phosphate were computed using regression equations with instantaneous flow. A flow weighted mean concentration (FWMC) was computed for nitrate and the static concentration was applied to the entire record. These equations and FWMC were applied during both storm and baseflow conditions as there was no data to support using a different method for base flow conditions. The monthly (or partial monthly for December 2012 and March 2013) load for each POC was regressed with monthly (or partial monthly) rainfall. The resulting equation was used to estimate the monthly POC load for the non-monitored period of record. This is considered a coarse method of estimation and the resulting loads are shown for uses of preliminary comparison between the six monitored watersheds and should not be considered accurate at this time. As the dataset for this site grows in future monitoring years, these estimates will be recalculated.

Preliminary monthly loading estimates are dominated by the two wet months of WY 2013 (November and December) (Table 26), during which time 65% of the total discharge volume occurred and 67 – 83% of the total load for each POC passed through the system. At this time, all loads estimates should be considered preliminary and data collected in subsequent water years will be used to improve our understanding of rainfall-runoff-pollutant transport processes and used to recalculate and finalize loads for WY 2013.

Table 25. Regression equations used for loads computations for Pulgas Creek Pump Station during water year 2013. 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 (mg/NTU)	Mainly urban	1.102		0.84	Regression with turbidity
Total PCBs (ng/NTU)	Mainly urban	0.73	8.6	0.77	Regression with turbidity
Total Mercury (ng/NTU)	Mainly urban	0.24	3.4	0.94	Regression with turbidity
Total Methylmercury (ng/NTU)	Mainly urban	0.00094	0.2	0.53	Regression with turbidity
Total Organic Carbon (mg/CFS)	Mainly urban	1.8	5.8	0.4	Regression with flow
Total Phosphorous (mg/NTU)	Mainly urban	0.0016	0.081	0.47	Regression with turbidity
Nitrate (mg/L)	Mainly urban	0.34			Flow weighted mean concentration
Phosphate (mg/CFS)	Mainly urban	0.0086	0.045	0.41	Regression with flow

Table 26. Preliminary monthly loads for Pulgas Creek Pump Station during water year 2013.

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[a]	25	*0.0165*	*0.779*	*339*	*0.667*	*0.233*	*0.00394*	*6.00*	*1.93*	*2.56*
	12-Nov[a]	121	*0.0548*	*3.28*	*1947*	*2.69*	*0.932*	*0.0135*	*20.5*	*10.4*	*9.67*
	12-Dec[a]	183	*0.0797*	*4.90*	*2992*	*4.00*	*1.39*	*0.0197*	*29.9*	*15.9*	*14.3*
	13-Jan	8	0.0103	0.253	68.8	0.256	0.0908	0.00230	3.49	0.503	1.20
	13-Feb	10	0.0168	0.735	159	0.631	0.220	0.00403	5.70	1.05	2.43
	13-Mar[a]	20	*0.0143*	*0.640*	*249*	*0.555*	*0.194*	*0.00341*	*5.19*	*1.46*	*2.17*
	13-Apr[a]	18	*0.0134*	*0.580*	*211*	*0.506*	*0.177*	*0.00318*	*4.84*	*1.25*	*2.00*
	Wet season total	386	*0.206*	*11.2*	*5967*	*9.30*	*3.23*	*0.0501*	*75.6*	*32.4*	*34.3*

[a] As described in the text, discharge and loads for these months (data italicized) were computed based on monthly or partial monthly regressions between rainfall and discharge/load. These loads are considered coarse estimates and will be updated in future sampling years.

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	Average Lab Blank	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	ug/L	0	0.01-0.01; 0.01	0.02	75.71-75.71; 75.71	1.39-83.55; 42.47	NA	90-116; 102.3
Fipronil	ug/L	0	0-0.01; 0	0.0064	NA	0-141.42; 37.68	NA	45-112.5; 74.4
NH4	mg/L	0.0018	0.01-0.02; 0.01	0	0-9.87; 1.89	0-9.87; 2.43	NA	NA
NO3	mg/L	0	0-0.02; 0.01	0.046	NA	0-4.47; 0.35	NA	105-105; 105
NO2	mg/L	0	0-0; 0	0.013	0-0.73; 0.29	0-4.04; 0.56	NA	89-103.5; 96.5
TKN	mg/L	0	0.07-0.4; 0.23	0.1	0-47.88; 13.65	0-36.35; 14.94	NA	NA
PO4	mg/L	0	0-0.06; 0.01	0.011	0-1.61; 0.9	0-5.29; 1.16	NA	83.5-107; 97.8
Total P	mg/L	0	0.01-0.1; 0.03	0.01	0-2.4; 0.79	0-14.24; 3.86	NA	86-86; 86
SSC	mg/L	470	0.23-6.8; 2.55	3	NA	0-50.63; 13.23	99.8-99.8; 99.8	NA
Benz(a)anthracenes /Chrysenes, C1-	pg/L	102	99-75500; 3661.22	NA	1.01-6.77; 3.96	1.01-27.92; 8.64	NA	NA
Benz(a)anthracenes /Chrysenes, C2-	pg/L	164	118-43100; 2374.97	NA	2.59-16.42; 9.24	0.64-25.76; 9.46	NA	NA
Fluoranthene	pg/L	106	57.9-2580; 481.01	NA	1.26-15.98; 6.48	2.21-33.15; 17.99	NA	NA
Fluoranthene/Pyrenes, C1-	pg/L	430	138-25400; 2277.5	NA	2.63-4.4; 3.3	2.63-24.68; 13.55	NA	NA
Fluorenes, C3-	pg/L	1588	45.1-29400; 1888.57	NA	0.13-5.43; 2.09	0.69-15.99; 8.69	NA	NA
Naphthalenes, C4-	pg/L	2864	95.5-3540; 918.73	NA	2.44-10.96; 6.45	2.44-78.83; 18.97	NA	NA
Phenanthrene/Anthracene, C4-	pg/L	1565	208-27100; 3350.34	NA	0-6.39; 2.27	0.43-23.46; 8.75	NA	NA
Pyrene	pg/L	77.4	57.4-5960; 662.16	NA	0.99-14.38; 5.71	1.59-31.82; 16.25	NA	NA
PBDE 047	pg/L	40.9	0.37-0.87; 0.41	NA	0.39-18.19; 6.09	1.2-13.82; 6.86	NA	NA
PBDE 099	pg/L	43.4	0.47-12.4; 3.19	NA	1.99-9.88; 5.14	1.81-15.1; 7.31	NA	NA
PBDE 209	pg/L	76	12.7-146; 49.83	NA	2.21-42.31; 17.67	1.39-45.22; 19.57	NA	NA
PCB 087	pg/L	0.834	0.18-5.42; 0.87	NA	0-31.19; 13.75	0-31.19; 12.29	NA	NA
PCB 095	pg/L	1.31	0.18-6.23; 1	NA	3.89-37.99; 16.43	0.59-37.99; 14.24	NA	NA
PCB 110	pg/L	1.27	0.18-4.58; 0.74	NA	0.27-25.61; 12.31	0.27-27.4; 12.04	NA	NA
PCB 138	pg/L	2.36	0.25-19.8; 2.26	NA	3.01-25.44; 11.74	0.34-25.44; 9.04	NA	NA
PCB 149	pg/L	1.3	0.26-21.3; 2.45	NA	1.97-31.09; 11.26	1.97-28.66; 10.39	NA	NA
PCB 151	pg/L	0.56	0.18-8.38; 0.75	NA	0.26-29.2; 8.97	0.26-39.81; 10.25	NA	NA
PCB 153	pg/L	2.44	0.22-17.4; 2	NA	1.21-24.37; 10.36	0.59-23.88; 9.57	NA	NA
PCB 174	pg/L	0.039	0.2-4; 0.78	NA	0.25-36.32; 6.22	0.25-37.01; 7.79	NA	NA
PCB 180	pg/L	0.91	0.18-4.52; 0.68	NA	0.43-29.54; 6.15	0.43-23.7; 8.7	NA	NA
Bifenthrin	pg/L	274	1500-5520; 2830	NA	NA	4.8-34.98; 16.11	NA	NA
Cypermethrin	pg/L	0	968-5290; 2694.53	NA	NA	27.58-27.58; 27.58	NA	NA
Delta/Tralomethrin	pg/L	243	185-862; 353.6	NA	NA	22.99-32.44; 27.71	NA	NA
Total Cu	ug/L	0	0.04-0.42; 0.16	0.55	0.2-2.68; 0.88	0.2-10.56; 3.31	104.2-104.2; 104.2	100-100.6; 100.3
Dissolved Cu	ug/L	0	0.04-0.42; 0.12	0.5	NA	3.01-27.52;	104.2-104.2;	100-100.6; 100.3

Analyte	**Unit**	**Average Lab Blank**	**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)**
						10.41	104.2	
Total Hg	ug/L	0	0-0; 0	0.0005	2.12-2.12; 2.12	1.07-31.06; 8.59	98.5-98.5; 98.5	100-100.8; 100.4
Total MeHg	ng/L	0.006	0.01-0.02; 0.02	0.033	0.97-5.87; 3.35	0-37.52; 6.34	NA	74.2-90.4; 85.4
Total Se	ug/L	0.006	0.02-0.06; 0.04	0.086	0-2.4; 0.79	0-14.24; 3.86	103.4-103.4; 103.4	86.5-90.3; 88.4
Dissolved Se	ug/L	0	0.02-0.06; 0.04	0.15	6.18-6.18; 6.18	0-8.59; 4.72	103.4-103.4; 103.4	86.5-90.3; 88.4
TOC	ug/L	0	0.3-0.35; 0.32	462	NA	NA	NA	NA

Table A2: Field blank data from all sites.

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Carbaryl	ug/L	0.01	0.02	ND	ND	ND
Fipronil	ug/L	0.000875	0.004	ND	ND	ND
Fipronil Desulfinyl	ug/L	0.000625	0.0028	ND	ND	ND
Fipronil Sulfide	ug/L	0.000625	0.0028	ND	ND	ND
Fipronil Sulfone	ug/L	0.000875	0.004	ND	ND	ND
NH4	mg/L	0.01	-	0.01	0.01	0.01
NO3	mg/L	0.0164	0.041	ND	0.039	0.0078
NO2	mg/L	0.001142	0.01	ND	0.025	0.005
TKN	mg/L	0.18	0.1	ND	ND	ND
PO4	mg/L	0.006	0.01	ND	ND	ND
Total P	mg/L	0.0076	0.01	ND	0.018	0.0052
SSC	pg/L	653	-	ND	ND	ND
Acenaphthene	pg/L	147	-	ND	ND	ND
Acenaphthylene	pg/L	119.5	-	ND	ND	ND
Anthracene	pg/L	230	-	ND	ND	ND
Benz(a)anthracene	pg/L	68.5	-	ND	ND	ND
Benz(a)anthracenes/Chrysenes, C1-	pg/L	31	-	69.5	109	89.25
Benz(a)anthracenes/Chrysenes, C2-	pg/L	63.05	-	171	393	282
Benz(a)anthracenes/Chrysenes, C3-	pg/L	64.9	-	149	389	269
Benz(a)anthracenes/Chrysenes, C4-	pg/L	66.35	-	449	1030	739.5
Benzo(a)pyrene	pg/L	199	-	ND	ND	ND
Benzo(b)fluoranthene	pg/L	82.05	-	ND	ND	ND
Benzo(e)pyrene	pg/L	182.5	-	ND	ND	ND
Benzo(g,h,i)perylene	pg/L	123.9	-	ND	ND	ND
Benzo(k)fluoranthene	pg/L	110	-	ND	ND	ND
Chrysene	pg/L	72.3	-	ND	86.5	43.25
Dibenz(a,h)anthracene	pg/L	119	-	ND	ND	ND
Dibenzothiophene	pg/L	78.6	-	ND	ND	ND
Dibenzothiophenes, C1-	pg/L	63.85	-	ND	ND	ND

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
Dibenzothiophenes, C2-	pg/L	62.9	-	278	582	430
Dibenzothiophenes, C3-	pg/L	48.95	-	576	771	673.5
Dimethylnaphthalene, 2,6-	pg/L	422	-	ND	ND	ND
Fluoranthene	pg/L	45.15	-	238	343	290.5
Fluoranthene/Pyrenes, C1-	pg/L	90.05	-	82.8	716	399.4
Fluorene	pg/L	207.5	-	ND	ND	ND
Fluorenes, C2-	pg/L	139.15	-	2080	2730	2405
Fluorenes, C3-	pg/L	133.5	-	2950	4130	3540
Indeno(1,2,3-c,d)pyrene	pg/L	43.1	-	ND	ND	ND
Methylnaphthalene, 2-	pg/L	479.5	-	ND	677	338.5
Methylphenanthrene, 1-	pg/L	210.7	-	ND	89.5	44.75
Naphthalene	pg/L	207	-	2330	21200	11765
Naphthalenes, C1-	pg/L	129	-	ND	1120	560
Naphthalenes, C3-	pg/L	298.5	-	941	3940	2440.5
Perylene	pg/L	213.5	-	ND	ND	ND
Phenanthrene	pg/L	101.6	-	469	608	538.5
Phenanthrene/Anthracene, C1-	pg/L	210.7	-	ND	335	167.5
Phenanthrene/Anthracene, C2-	pg/L	82.95	-	423	843	633
Pyrene	pg/L	43.25	-	179	229	204
Trimethylnaphthalene, 2,3,5-	pg/L	154.5	-	ND	189	94.5
PBDE 007	pg/L	0.3775	-	ND	1.64	0.82
PBDE 008	pg/L	0.3775	-	ND	1.3	0.65
PBDE 010	pg/L	0.527	-	ND	ND	ND
PBDE 011	pg/L	-	-	-	-	-
PBDE 012	pg/L	0.3775	-	ND	0.793	0.3965
PBDE 013	pg/L	-	-	-	-	-
PBDE 015	pg/L	0.3775	-	ND	4.16	2.08
PBDE 017	pg/L	0.3905	-	ND	23.6	11.8
PBDE 025	pg/L	-	-	-	-	-
PBDE 028	pg/L	0.3775	-	0.811	29	14.9055
PBDE 030	pg/L	0.4105	-	ND	ND	ND
PBDE 032	pg/L	0.3775	-	ND	ND	ND
PBDE 033	pg/L	-	-	-	-	-
PBDE 035	pg/L	1.7285	-	ND	ND	ND
PBDE 047	pg/L	0.3775	-	26.4	1040	533.2
PBDE 049	pg/L	0.3775	-	0.845	86.3	43.5725
PBDE 051	pg/L	0.3775	-	ND	8.65	4.325
PBDE 066	pg/L	0.3775	-	ND	49.4	24.7
PBDE 071	pg/L	0.3775	-	ND	14.3	7.15
PBDE 075	pg/L	1.6885	-	ND	ND	ND
PBDE 077	pg/L	0.529	-	ND	ND	ND

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PBDE 079	pg/L	0.3775	-	ND	ND	ND
PBDE 085	pg/L	0.8735	-	1.49	57.8	29.645
PBDE 099	pg/L	0.6535	-	29.9	1200	614.95
PBDE 100	pg/L	0.505	-	6.47	281	143.735
PBDE 105	pg/L	1.0985	-	ND	ND	ND
PBDE 116	pg/L	1.557	-	ND	11.3	5.65
PBDE 119	pg/L	0.9635	-	ND	6.86	3.43
PBDE 120	pg/L	-	-	-	-	-
PBDE 126	pg/L	0.619	-	ND	1.21	0.605
PBDE 128	pg/L	9.519	-	ND	ND	ND
PBDE 140	pg/L	0.5205	-	ND	6.77	3.385
PBDE 153	pg/L	0.4765	-	3.34	135	69.17
PBDE 155	pg/L	0.382	-	ND	9.43	4.715
PBDE 166	pg/L	-	-	-	-	-
PBDE 181	pg/L	2.3685	-	ND	ND	ND
PBDE 183	pg/L	1.715	-	ND	43.7	21.85
PBDE 190	pg/L	6.1835	-	ND	ND	ND
PBDE 197	pg/L	4.52	-	2.36	97.3	49.83
PBDE 203	pg/L	4.9135	-	5.08	123	64.04
PBDE 204	pg/L	-	-	-	-	-
PBDE 205	pg/L	8.683	-	ND	ND	ND
PBDE 206	pg/L	24.92	-	ND	1400	700
PBDE 207	pg/L	2.2935	-	75.6	2330	1202.8
PBDE 208	pg/L	25.115	-	ND	1690	845
PBDE 209	pg/L	9.99	-	1240	22900	12070
PCB 008	pg/L	1.4536	-	ND	1.33	0.4176
PCB 018	pg/L	0.5882	-	ND	1.37	0.748
PCB 020	pg/L	-	-	-	-	-
PCB 021	pg/L	-	-	-	-	-
PCB 028	pg/L	0.2558	-	1.58	2.43	2.05
PCB 030	pg/L	-	-	-	-	-
PCB 031	pg/L	0.4338	-	ND	1.61	1.082
PCB 033	pg/L	0.2446	-	0.617	0.915	0.7782
PCB 044	pg/L	0.7	-	ND	2.94	1.85
PCB 047	pg/L	-	-	-	-	-
PCB 049	pg/L	0.2668	-	0.782	2.07	1.1386
PCB 052	pg/L	0.734	-	ND	2.65	2.06
PCB 056	pg/L	0.3356	-	0.408	0.909	0.6332
PCB 060	pg/L	0.3888	-	ND	1.3	0.3304
PCB 061	pg/L	-	-	-	-	-
PCB 065	pg/L	-	-	-	-	-

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 066	pg/L	0.4328	-	ND	4.87	1.5982
PCB 069	pg/L	-	-	-	-	-
PCB 070	pg/L	0.317	-	2.33	5.91	3.478
PCB 074	pg/L	-	-	-	-	-
PCB 076	pg/L	-	-	-	-	-
PCB 083	pg/L	-	-	-	-	-
PCB 086	pg/L	-	-	-	-	-
PCB 087	pg/L	0.3138	-	2.53	3.74	2.962
PCB 090	pg/L	-	-	-	-	-
PCB 093	pg/L	-	-	-	-	-
PCB 095	pg/L	0.354	-	2.76	4.39	3.568
PCB 097	pg/L	-	-	-	-	-
PCB 098	pg/L	-	-	-	-	-
PCB 099	pg/L	0.3666	-	1.39	2.4	1.952
PCB 100	pg/L	-	-	-	-	-
PCB 101	pg/L	0.3208	-	3.14	3.92	3.422
PCB 102	pg/L	-	-	-	-	-
PCB 105	pg/L	0.7304	-	ND	2.16	1.048
PCB 108	pg/L	-	-	-	-	-
PCB 110	pg/L	0.2704	-	3.43	6.53	4.968
PCB 113	pg/L	-	-	-	-	-
PCB 115	pg/L	-	-	-	-	-
PCB 118	pg/L	0.355	-	1.72	3.74	2.778
PCB 119	pg/L	-	-	-	-	-
PCB 125	pg/L	-	-	-	-	-
PCB 128	pg/L	0.401	-	0.28	1.27	0.7448
PCB 129	pg/L	-	-	-	-	-
PCB 132	pg/L	0.4912	-	0.846	2.72	1.6392
PCB 135	pg/L	-	-	-	-	-
PCB 138	pg/L	0.3996	-	1.76	5.37	3.33
PCB 141	pg/L	0.4506	-	ND	0.78	0.2378
PCB 147	pg/L	-	-	-	-	-
PCB 149	pg/L	0.4212	-	1.63	3.64	2.39
PCB 151	pg/L	0.3766	-	ND	1.65	0.978
PCB 153	pg/L	0.355	-	1.19	3.08	1.826
PCB 154	pg/L	-	-	-	-	-
PCB 156	pg/L	0.409	-	ND	0.581	0.2076
PCB 157	pg/L	-	-	-	-	-
PCB 158	pg/L	0.3134	-	ND	0.602	0.1204
PCB 160	pg/L	-	-	-	-	-
PCB 163	pg/L	-	-	-	-	-

AnalyteName	Unit	Average MDL	RL	Minimum Field Blank	Maximum Field Blank	Average Field Blank
PCB 166	pg/L	-	-	-	-	-
PCB 168	pg/L	-	-	-	-	-
PCB 170	pg/L	0.3922	-	ND	1.09	0.5358
PCB 174	pg/L	0.4822	-	ND	0.58	0.2824
PCB 177	pg/L	0.3628	-	ND	0.645	0.1854
PCB 180	pg/L	0.6086	-	ND	1.66	0.4408
PCB 183	pg/L	0.4356	-	ND	0.24	0.048
PCB 185	pg/L	-	-	-	-	-
PCB 187	pg/L	0.3644	-	ND	1.31	0.3662
PCB 193	pg/L	-	-	-	-	-
PCB 194	pg/L	0.3704	-	ND	ND	ND
PCB 195	pg/L	0.3968	-	ND	ND	ND
PCB 201	pg/L	0.295	-	ND	ND	ND
PCB 203	pg/L	0.3798	-	ND	ND	ND
Allethrin	pg/L	2790	-	ND	ND	ND
Bifenthrin	pg/L	949	-	ND	ND	ND
Cyfluthrin, total	pg/L	7020	-	ND	ND	ND
Cyhalothrin,lambda, total	pg/L	748	-	ND	ND	ND
Cypermethrin, total	pg/L	997	-	ND	ND	ND
Delta/Tralomethrin	pg/L	539	-	ND	ND	ND
Esfenvalerate/Fenvalerate, total	pg/L	845	-	ND	ND	ND
Fenpropathrin	pg/L	1770	-	ND	ND	ND
Permethrin, total	pg/L	287	-	ND	ND	ND
Phenothrin	pg/L	525	-	ND	ND	ND
Prallethrin	pg/L	7020	-	ND	ND	ND
Resmethrin	pg/L	653	-	ND	ND	ND
Calcium	ug/L	6.32	31.6	ND	ND	ND
Total Cu	ug/L	0.063	0.4013	ND	1.13	0.365
Dissolved Cu	ug/L	0.063	0.4013	ND	0.681	0.17025
Magnesium	pg/L	43.1	-	ND	ND	ND
Total Hg	ug/L	0.000198	0.0004	ND	0.0044	0.00092
Total MeHg	ng/L	0.018571429	0.0314	ND	0.021	0.003
Dissolved Se	ug/L	0.051	0.093	ND	ND	ND
Total Se	ug/L	0.051	0.093	ND	ND	ND
Total Hardness (calc)	mg/L	0.02	0.09	ND	ND	ND
TOC	mg/L	-	-	-	-	-

Table A3: Average RSD of field and lab duplicates at each site.

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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	-	-	-	-	-	-	83.5%	75.7%	-	-	1.4%	-
Fipronil	79.5%	-	-	-	9.2%	-	10.9%	-	-	-	-	-
Fipronil Desulfinyl	10.9%	-	0.0%	-	15.5%	-	-	-	-	-	-	-
Fipronil Sulfide	0.0%	-	-	-	-	-	-	-	-	-	-	-
Fipronil Sulfone	0.0%	-	-	-	4.9%	-	-	-	-	-	-	-
NH4	3.1%	0.0%	1.8%	1.5%	4.0%	4.9%	0.0%	0.0%	3.3%	-	-	-
NO3	0.0%	0.0%	0.0%	0.0%	1.1%	-	0.0%	0.0%	0.0%	-	0.0%	-
NO2	1.0%	0.7%	0.0%	0.0%	1.0%	-	0.0%	0.0%	0.0%	-	0.0%	-
TKN	10.2%	3.4%	-	-	14.5%	23.9%	12.0%	-	31.4%	-	-	-
PO4	0.3%	0.8%	0.9%	0.9%	0.3%	-	1.5%	1.1%	0.0%	-	4.7%	-
Total P	7.1%	0.0%	0.0%	0.0%	3.0%	2.4%	0.0%	0.0%	2.9%	-	-	-
SSC	12.3%	-	11.9%	-	11.5%	-	8.6%	-	19.6%	-	19.9%	-
Acenaphthene	20.1%	-	-	-	-	-	10.0%	0.4%	1.5%	1.5%	-	-
Acenaphthylene	10.7%	-	-	-	-	-	31.8%	18.1%	5.5%	5.5%	-	-
Anthracene	14.2%	-	24.6%	9.4%	43.4%	-	39.1%	23.4%	5.7%	5.7%	-	-
Benz(a)anthracene	15.3%	-	-	-	-	-	-	-	-	-	-	-
Benz(a)anthracenes/Chrysenes, C1-	5.7%	-	6.9%	4.1%	2.9%	-	17.3%	6.8%	1.0%	1.0%	-	-
Benz(a)anthracenes/Chrysenes, C2-	4.3%	-	7.5%	8.7%	6.0%	-	19.0%	16.4%	2.6%	2.6%	-	-
Benz(a)anthracenes/Chrysenes, C3-	23.6%	-	6.3%	6.9%	11.1%	-	40.2%	8.9%	0.7%	0.7%	-	-
Benz(a)anthracenes/Chrysenes, C4-	5.9%	-	25.2%	20.6%	10.6%	-	16.7%	7.0%	0.3%	0.3%	-	-
Benzo(a)pyrene	16.7%	-	19.5%	7.0%	20.8%	-	23.6%	6.5%	1.1%	1.1%	-	-
Benzo(b)fluoranthene	9.3%	-	10.2%	2.7%	26.6%	-	17.5%	5.2%	4.7%	4.7%	-	-
Benzo(e)pyrene	13.5%	-	7.0%	4.4%	9.9%	-	28.4%	5.9%	0.9%	0.9%	-	-
Benzo(g,h,i)perylene	16.6%	-	8.8%	0.0%	4.6%	-	14.2%	5.3%	4.5%	4.5%	-	-
Benzo(k)fluoranthene	36.4%	-	20.6%	1.8%	-	-	33.0%	2.8%	2.0%	2.0%	-	-
Chrysene	8.4%	-	11.6%	1.3%	9.5%	-	19.0%	7.5%	2.2%	2.2%	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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
Dibenz(a,h)anthracene	39.9%	-	31.9%	9.9%	-	-	-	-	2.1%	2.1%	-	-
Dibenzothiophene	-	-	8.5%	2.1%	-	-	15.9%	13.0%	-	-	-	-
Dibenzothiophenes, C1-	8.9%	-	6.3%	1.7%	5.1%	-	24.6%	2.9%	2.5%	2.5%	-	-
Dibenzothiophenes, C2-	4.5%	-	3.8%	0.7%	10.2%	-	12.2%	2.9%	6.1%	6.1%	-	-
Dibenzothiophenes, C3-	4.8%	-	7.3%	2.1%	8.0%	-	14.7%	0.8%	0.5%	0.5%	-	-
Dimethylnaphthalene, 2,6-	22.2%	-	4.7%	1.6%	0.4%	-	12.2%	13.8%	7.1%	7.1%	-	-
Fluoranthene	16.0%	-	16.3%	1.3%	33.2%	-	17.2%	16.0%	2.2%	2.2%	-	-
Fluoranthene/Pyrenes, C1-	16.3%	-	10.5%	4.4%	8.7%	-	17.4%	2.9%	2.6%	2.6%	-	-
Fluorene	15.3%	-	-	-	-	-	15.8%	9.1%	3.7%	3.7%	-	-
Fluorenes, C2-	14.0%	-	7.3%	8.9%	0.8%	-	9.4%	1.2%	1.8%	1.8%	-	-
Fluorenes, C3-	7.0%	-	8.6%	5.4%	9.0%	-	12.3%	0.1%	0.7%	0.7%	-	-
Indeno(1,2,3-c,d)pyrene	21.9%	-	14.5%	0.4%	14.9%	-	18.1%	5.3%	8.9%	8.9%	-	-
Methylnaphthalene, 2-	9.3%	-	3.3%	1.1%	2.1%	-	10.6%	6.3%	3.4%	3.4%	-	-
Methylphenanthrene, 1-	16.7%	-	12.7%	13.6%	11.6%	-	14.6%	10.7%	0.0%	0.0%	-	-
Naphthalene	10.3%	-	7.6%	1.5%	3.2%	-	2.1%	3.8%	0.5%	0.5%	-	-
Naphthalenes, C1-	14.5%	-	-	-	0.5%	-	7.5%	5.7%	3.4%	3.4%	-	-
Naphthalenes, C3-	17.2%	-	1.3%	1.9%	0.6%	-	8.9%	11.2%	8.5%	8.5%	-	-
Perylene	17.6%	-	20.8%	4.2%	5.0%	-	25.6%	8.6%	-	-	-	-
Phenanthrene	5.8%	-	33.9%	6.1%	29.0%	-	21.3%	26.5%	1.6%	1.6%	-	-
Phenanthrene/Anthracene, C1-	28.7%	-	12.0%	2.1%	13.7%	-	13.0%	0.2%	2.5%	2.5%	-	-
Phenanthrene/Anthracene, C2-	15.6%	-	6.0%	8.4%	7.1%	-	12.9%	8.1%	3.9%	3.9%	-	-
Pyrene	16.7%	-	13.4%	1.0%	19.5%	-	19.2%	14.4%	1.7%	1.7%	-	-
Trimethylnaphthalene, 2,3,5-	22.1%	-	3.6%	0.3%	2.3%	-	17.6%	9.0%	-	-	-	-
PBDE 007	-	-	-	-	-	-	-	11.2%	15.4%	15.6%	2.0%	2.0%
PBDE 008	8.3%	4.7%	-	-	-	-	-	-	56.9%	65.0%	6.5%	6.5%
PBDE 010	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 011	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 012	-	-	-	-	-	-	-	11.7%	68.7%	73.4%	9.5%	9.5%
PBDE 013	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 015	11.7%	9.5%	-	-	-	-	3.2%	4.3%	13.8%	15.4%	7.5%	7.5%
PBDE 017	5.9%	12.7%	7.6%	-	-	-	-	-	9.1%	5.0%	12.9%	12.9%
PBDE 025	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 028	4.5%	7.0%	0.9%	-	-	-	15.6%	20.7%	5.8%	2.0%	14.9%	14.9%
PBDE 030	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 032	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 033	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 035	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 047	2.9%	1.2%	5.9%	-	-	-	13.8%	18.2%	12.0%	0.4%	4.6%	4.6%
PBDE 049	5.0%	0.7%	1.7%	-	-	-	10.2%	8.6%	5.7%	0.7%	12.4%	12.4%
PBDE 051	5.7%	5.7%	-	-	-	-	-	-	16.2%	7.8%	15.3%	15.3%
PBDE 066	2.3%	0.5%	1.0%	-	-	-	13.8%	14.1%	6.2%	1.7%	8.4%	8.4%
PBDE 071	1.9%	1.9%	-	-	-	-	-	-	-	-	32.7%	32.7%
PBDE 075	0.7%	0.7%	9.8%	-	-	-	-	-	-	-	22.0%	22.0%
PBDE 077	15.8%	15.8%	-	-	-	-	-	-	-	-	-	-
PBDE 079	16.4%	16.4%	-	-	-	-	-	-	11.3%	13.2%	-	-
PBDE 085	6.3%	5.2%	5.7%	-	-	-	4.6%	5.7%	19.6%	2.4%	2.9%	2.9%
PBDE 099	4.8%	3.9%	6.2%	-	-	-	8.1%	9.9%	15.1%	2.0%	4.8%	4.8%
PBDE 100	2.8%	0.3%	6.5%	-	-	-	9.2%	11.7%	14.6%	0.0%	6.0%	6.0%
PBDE 105	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 116	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 119	6.8%	6.3%	-	-	-	-	-	21.0%	34.7%	13.6%	-	-
PBDE 120	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 126	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 128	-	-	-	-	-	-	-	-	-	-	-	-

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 140	-	-	-	-	-	-	12.1%	12.5%	10.0%	1.6%	9.8%	9.8%
PBDE 153	6.9%	6.6%	5.5%	-	-	-	6.2%	7.1%	12.5%	1.4%	3.5%	3.5%
PBDE 155	8.1%	12.5%	-	-	-	-	6.4%	7.8%	15.2%	1.0%	6.0%	6.0%
PBDE 166	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 181	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 183	21.3%	1.5%	-	-	-	-	27.4%	32.6%	17.6%	11.2%	11.0%	11.0%
PBDE 190	-	-	-	-	-	-	-	-	-	-	1.7%	1.7%
PBDE 197	42.2%	12.3%	15.8%	-	-	-	-	-	-	-	1.7%	1.7%
PBDE 203	26.6%	17.6%	-	-	-	-	-	3.3%	33.4%	21.4%	4.6%	4.6%
PBDE 204	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 205	-	-	-	-	-	-	-	-	-	-	-	-
PBDE 206	9.0%	23.9%	8.8%	-	-	-	6.1%	7.6%	34.1%	17.3%	37.3%	37.3%
PBDE 207	12.8%	25.5%	5.8%	-	-	-	2.0%	2.1%	34.9%	24.4%	28.2%	28.2%
PBDE 208	17.6%	23.7%	13.0%	-	-	-	3.5%	4.1%	36.6%	25.3%	30.5%	30.5%
PBDE 209	22.5%	19.4%	2.2%	-	-	-	2.1%	2.2%	35.6%	6.7%	42.3%	42.3%
PCB 008	15.5%	10.4%	13.6%	13.6%	20.0%	-	5.0%	0.3%	6.8%	3.1%	10.4%	11.9%
PCB 018	13.9%	4.1%	10.0%	10.0%	15.9%	-	4.2%	0.7%	12.3%	5.2%	6.5%	6.5%
PCB 020	-	-	-	-	-	-	-	-	-	-	-	-
PCB 021	-	-	-	-	-	-	-	-	-	-	-	-
PCB 028	10.8%	12.5%	5.9%	7.5%	4.7%	-	3.8%	1.2%	10.9%	3.6%	8.8%	5.4%
PCB 030	-	-	-	-	-	-	-	-	-	-	-	-
PCB 031	11.1%	9.1%	5.1%	7.5%	8.5%	-	4.7%	0.7%	11.3%	2.7%	7.1%	0.8%
PCB 033	13.8%	7.2%	6.4%	8.2%	13.2%	-	3.1%	0.4%	11.3%	7.0%	10.4%	0.4%
PCB 044	4.9%	9.9%	6.6%	10.0%	2.9%	-	6.5%	13.3%	13.0%	8.6%	9.0%	0.2%
PCB 047	-	-	-	-	-	-	-	-	-	-	-	-
PCB 049	6.6%	9.6%	5.6%	8.5%	5.5%	-	5.1%	13.6%	14.3%	12.8%	10.0%	2.0%
PCB 052	8.0%	13.8%	7.6%	10.4%	9.9%	-	7.0%	14.4%	19.2%	22.6%	11.9%	6.6%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 056	6.4%	5.1%	13.7%	7.3%	2.2%	-	5.5%	12.0%	7.2%	1.6%	11.9%	3.8%
PCB 060	6.1%	4.3%	16.9%	7.8%	2.0%	-	6.1%	13.6%	3.1%	3.1%	11.8%	3.2%
PCB 061	-	-	-	-	-	-	-	-	-	-	-	-
PCB 065	-	-	-	-	-	-	-	-	-	-	-	-
PCB 066	7.0%	8.0%	7.5%	8.9%	1.5%	-	8.2%	15.0%	2.3%	1.9%	11.5%	1.6%
PCB 069	-	-	-	-	-	-	-	-	-	-	-	-
PCB 070	8.9%	11.1%	7.8%	10.7%	2.2%	-	6.4%	15.5%	5.2%	9.9%	12.8%	5.5%
PCB 074	-	-	-	-	-	-	-	-	-	-	-	-
PCB 076	-	-	-	-	-	-	-	-	-	-	-	-
PCB 083	-	-	-	-	-	-	-	-	-	-	-	-
PCB 086	-	-	-	-	-	-	-	-	-	-	-	-
PCB 087	11.3%	10.2%	8.7%	9.9%	16.3%	-	6.3%	17.6%	17.3%	22.4%	16.7%	23.2%
PCB 090	-	-	-	-	-	-	-	-	-	-	-	-
PCB 093	-	-	-	-	-	-	-	-	-	-	-	-
PCB 095	13.9%	14.3%	6.2%	7.5%	18.2%	-	11.5%	18.8%	19.8%	29.8%	16.8%	27.1%
PCB 097	-	-	-	-	-	-	-	-	-	-	-	-
PCB 098	-	-	-	-	-	-	-	-	-	-	-	-
PCB 099	11.9%	10.9%	7.6%	7.4%	15.0%	-	8.1%	18.7%	19.6%	24.7%	18.5%	28.6%
PCB 100	-	-	-	-	-	-	-	-	-	-	-	-
PCB 101	10.8%	9.0%	7.6%	8.4%	19.9%	-	13.0%	18.6%	18.0%	23.9%	16.8%	33.0%
PCB 102	-	-	-	-	-	-	-	-	-	-	-	-
PCB 105	7.7%	7.9%	8.5%	11.0%	13.4%	-	7.7%	19.2%	8.1%	17.8%	18.6%	22.5%
PCB 108	-	-	-	-	-	-	-	-	-	-	-	-
PCB 110	10.7%	9.1%	6.9%	6.1%	16.3%	-	8.4%	18.2%	15.9%	20.9%	17.2%	23.3%
PCB 113	-	-	-	-	-	-	-	-	-	-	-	-
PCB 115	-	-	-	-	-	-	-	-	-	-	-	-
PCB 118	8.5%	8.6%	8.6%	8.7%	15.0%	-	8.1%	20.8%	9.2%	21.2%	17.2%	27.9%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 119	-	-	-	-	-	-	-	-	-	-	-	-
PCB 125	-	-	-	-	-	-	-	-	-	-	-	-
PCB 128	7.6%	8.3%	5.5%	4.2%	29.2%	-	10.0%	26.9%	9.6%	15.0%	7.9%	7.7%
PCB 129	-	-	-	-	-	-	-	-	-	-	-	-
PCB 132	10.5%	9.2%	8.2%	4.7%	18.5%	-	11.8%	25.8%	6.5%	14.2%	7.4%	11.4%
PCB 135	-	-	-	-	-	-	-	-	-	-	-	-
PCB 138	8.5%	11.0%	7.6%	4.5%	12.4%	-	12.1%	25.2%	4.2%	10.8%	10.7%	16.8%
PCB 141	10.3%	10.3%	8.4%	3.5%	14.8%	-	14.0%	22.9%	4.6%	6.7%	12.8%	15.9%
PCB 147	-	-	-	-	-	-	-	-	-	-	-	-
PCB 149	10.2%	7.6%	8.7%	5.0%	13.5%	-	15.7%	31.1%	4.8%	10.4%	9.6%	19.3%
PCB 151	9.1%	4.9%	8.4%	5.2%	9.0%	-	25.9%	29.2%	2.8%	5.9%	7.3%	15.6%
PCB 153	8.3%	8.3%	9.7%	4.2%	12.6%	-	14.4%	24.4%	5.1%	7.6%	9.2%	19.8%
PCB 154	-	-	-	-	-	-	-	-	-	-	-	-
PCB 156	9.1%	9.9%	6.3%	3.1%	16.1%	-	10.0%	25.1%	11.2%	18.6%	8.0%	13.2%
PCB 157	-	-	-	-	-	-	-	-	-	-	-	-
PCB 158	9.9%	11.0%	6.5%	3.8%	16.7%	-	11.1%	24.8%	6.9%	13.8%	11.5%	16.7%
PCB 160	-	-	-	-	-	-	-	-	-	-	-	-
PCB 163	-	-	-	-	-	-	-	-	-	-	-	-
PCB 166	-	-	-	-	-	-	-	-	-	-	-	-
PCB 168	-	-	-	-	-	-	-	-	-	-	-	-
PCB 170	6.9%	4.7%	5.4%	1.4%	11.3%	-	13.2%	24.7%	8.5%	1.0%	6.8%	7.7%
PCB 174	4.9%	1.7%	5.6%	2.2%	11.5%	-	21.8%	36.3%	1.4%	1.3%	5.1%	7.2%
PCB 177	4.2%	3.7%	6.1%	3.4%	18.9%	-	22.1%	-	4.6%	4.6%	4.8%	6.0%
PCB 180	9.2%	1.7%	6.2%	3.0%	5.0%	-	15.4%	29.5%	8.1%	4.4%	7.0%	8.9%
PCB 183	3.6%	3.3%	6.6%	4.6%	16.7%	-	20.0%	31.6%	2.5%	5.5%	6.2%	11.3%
PCB 185	-	-	-	-	-	-	-	-	-	-	-	-
PCB 187	3.0%	3.8%	6.2%	3.9%	6.4%	-	23.8%	34.9%	3.1%	2.7%	6.0%	10.5%

Analyte	San Leandro		Sunnyvale Channel		Lower Marsh Creek		Guadalupe River		Richmond Pump Station		Pulgas Creek Pump Station	
	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 193	-	-	-	-	-	-	-	-	-	-	-	-
PCB 194	7.9%	3.3%	6.1%	5.6%	14.4%	-	16.1%	38.7%	12.4%	13.5%	5.9%	8.2%
PCB 195	4.7%	2.0%	7.1%	3.4%	29.7%	-	15.3%	26.9%	14.8%	14.1%	4.4%	3.8%
PCB 201	11.0%	2.4%	4.0%	1.1%	10.1%	-	24.4%	-	10.3%	5.6%	4.9%	8.2%
PCB 203	9.2%	6.7%	6.7%	5.4%	14.3%	-	18.2%	44.1%	10.7%	14.4%	6.0%	12.9%
Allethrin	-	-	-	-	-	-	-	-	-	-	-	-
Bifenthrin	35.0%	-	-	-	8.5%	-	4.8%	-	9.7%	-	-	-
Cyfluthrin, total	-	-	-	-	-	-	-	-	4.3%	-	-	-
Cyhalothrin,lambda, total	-	-	-	-	-	-	-	-	-	-	-	-
Cypermethrin, total	-	-	-	-	27.6%	-	-	-	1.6%	-	-	-
Delta/Tralomethrin	-	-	-	-	32.4%	-	23.0%	-	1.6%	-	-	-
Esfenvalerate/Fenvalerate, total	-	-	-	-	-	-	-	-	24.4%	-	-	-
Fenpropathrin	-	-	-	-	-	-	-	-	-	-	-	-
Permethrin, total	12.9%	-	2.4%	-	10.6%	-	2.1%	-	5.2%	-	-	-
Phenothrin	-	-	-	-	-	-	-	-	0.4%	0.4%	-	-
Prallethrin	-	-	-	-	-	-	-	-	0.0%	-	-	-
Resmethrin	-	-	-	-	-	-	-	-	1.7%	1.7%	-	-
Calcium	0.5%	0.4%	-	-	0.5%	0.5%	1.0%	1.0%	1.3%	1.3%	-	-
Total Cu	1.5%	1.1%	0.2%	0.2%	7.3%	0.8%	-	-	-	-	-	-
Dissolved Cu	9.8%	-	-	-	27.5%	-	-	-	3.0%	-	-	-
Magnesium	0.8%	0.6%	0.3%	0.3%	0.5%	0.5%	1.3%	1.3%	8.9%	8.9%	-	-
Total Hg	13.8%	2.1%	11.5%	-	5.7%	-	5.8%	-	-	-	10.1%	-
Total MeHg	14.4%	4.1%	3.1%	-	3.3%	-	6.1%	2.6%	-	-	0.0%	-
Dissolved Se	3.7%	6.2%	-	-	8.6%	-	-	-	5.2%	-	-	-
Total Se	14.0%	10.1%	-	-	6.4%	1.5%	1.4%	1.4%	-	-	-	-
Total Hardness (calc)	0.4%	-	-	-	-	-	-	-	-	-	-	-
TOC	1.3%	-	-	-	3.8%	-	-	-	15.7%	-	-	-

Memorandum

To: Arleen Feng, ACCWP

From: Paul Salop, AMS

Date: 3/6/2014

Re: Identification of Method Uncertainties Inherent in MRP Sediment Quality Assessment Framework

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As part of the Integrated Monitoring Report (IMR) reporting process, stormwater management Programs are performing cursory assessments of sediment quality at a predetermined number of probabilistic sites sampled during WY2012 and WY2013. For each Program, dry season chemistry and toxicity samples are collected synoptically and analyzed for select sediment chemistry and toxicity parameters (at locations where springtime bioassessments were also conducted). The results are then analyzed through an assessment framework identified in MRP Attachment H (SFWQCB 2009), with sites categorized based upon results within each of the sediment triad categories. For the purposes of this evaluation, the spring bioassessment results are not included in the memorandum as the focus is solely on chemistry and toxicity assessments.

Sediment Triad Approach

There are multiple assessment frameworks that have been identified for use in developing sediment quality guidelines (EPA 1992). Use of a sediment triad approach by the MRP Programs for assessing sediment quality is intended to integrate information from several lines of evidence (LOEs) in order to inform assessments of sediment quality. As more fully discussed in SAB (1990), the main limitation associated with this approach is that it is impossible to establish causal relationships between contaminant concentrations and observed effects. Without confirmatory analysis (e.g., Toxicity Identification Evaluation), there is no method for linking specific chemical concentrations to toxicological or biological outcomes.

MRP Assessment Framework Components

The MRP assessments of sediment chemistry rely in large part upon comparisons against identified sediment effect concentrations (SECs), using the following threshold values:

- Threshold Effects Concentration (TEC) - analyte-specific concentrations below which adverse effects are not expected to occur. Used for assessing sediment chemistry parameters trace elements, PAHs, and organochlorine pesticides.
- Probable Effects Concentration (PEC) - analyte-specific concentrations above which adverse effects are expected to occur “more often than not.” Used for assessing sediment chemistry

parameters trace elements, PAHs, and organochlorine pesticides.
- Toxicity Unit (TU) – Comparison of the measured concentration of an analyte to the concentration at which half of a given test population is killed over a given period (LC50). Used for assessing sediment chemistry parameters pyrethroid pesticides.

Assessments of sediment toxicity are performed using a single test species, *Hyalella azteca*, with both survival and growth endpoints. It should be noted that MRP Attachment H defines toxicity only in relation to survival (and not growth) endpoint, and requires a certain magnitude of mortality beyond laboratory identifications of statistically significant difference from control (SFRWQCB 2009).

MRP Assessment Framework, Uncertainties

An in-depth review of MRP assessment methodology, as well as development of alternative assessment techniques, is beyond the scope of this review. The purpose of this memorandum is simply to identify areas of potential uncertainty associated with the MRP assessment framework to assist with interpretation of the sediment triad data. Specific areas of potential uncertainty are discussed below.

Bioavailability

A key part of the MRP assessment framework is based upon interpretation of contaminant concentration data relative to consensus-based SECs. As stated previously, chemical concentrations do not by themselves indicate a linkage to potential biological effects. While chemical concentrations may exceed particular thresholds, the contaminants themselves may not exist in bioavailable forms, which would limit their observable effects in biota and potential usefulness of sediment quality guidelines (MacDonald 2000a).

Limitations of LOEs

Although data collection and analysis associated with implementation of RMC monitoring requires extensive time and financial resources, the metrics used to conduct sediment quality assessments can examine neither the full spectrum of potential stressors present nor all effects potentially occurring. Using multiple lines of evidence to assess sediment quality is advantageous over use of a single line. However, these assessments are still subject to the limitations of each particular LOE used.

In assessing the analytical chemistry LOE using MRP-proposed metrics, SECs have only been generated for a subset of the overall constituent list. Therefore, the contribution of analytes for which metrics have not been established to potential adverse effects is unknown. Similarly, effects that may be related to non-measured contaminants or synergistic effects of the contaminant mixtures present in the sediment are unknown as well.

Multiple uncertainties have been identified with use of toxicity testing for sediment quality assessment. Numbering among these concerns are the concepts that field manipulation of sediments during collection may affect their testing, that certain test organisms are more sensitive to particular stressors than others (leading to potential disagreements in results depending on test species used), and that test species employed may or may not be ecologically relevant (e.g., Ingersoll and MacDonald, 2003).

For sediment toxicity testing, RMC Creek Status Monitoring makes use of a single test species, *H. azteca*, which is widespread in freshwater environments in the Bay Area and beyond. In assessing the issue of ecological relevance, *H. azteca* were identified in springtime bioassessments at twenty-one of forty sites (53%), and four of six triad sites (67%) monitored by ACCWP. It should also be noted that multiple toxicity test species were used in a variety of studies in development of SECs that informed consensus TEC and PEC calculations of MacDonald (2000), not just *H. azteca*.

Spatial variability

RMC sediment sampling methodology (BASMAA 2012) incorporates techniques to ensure collections are generated as composites of sediments present over a specific, but relatively short, creek segment. Sediments are known to be highly heterogeneous, which can often show up in analytical chemistry results of replicate samples collected at a single location from a single composite.[1] Use of a single, localized sampling event to draw conclusions about the upstream area therefore introduces uncertainty related to how representative the sample may be.

Relevance of effects thresholds

As more than a decade has passed since MacDonald (2000) was published, and the papers referenced therein to development of consensus-based guidelines predate the compilation by several years each, it was desired to assess whether or not more recent publications have proposed alternative SECs to those used in the original evaluation. A quick survey of NOAA (2008), suggested that for the analytes reviewed by MacDonald (2000), there have been no observable modifications made to effects level criteria on which the guidelines were based.

Analysis of RMC-generated data through MRP framework

While MacDonald (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 2000).

Additionally, when performing comparisons of analytical data against MacDonald (2000) SECs, it should be kept in mind that the predictive ability of the thresholds was assumed acceptable if the prediction was correct 75% of the time. For the twelve samples collected by the four Programs collaborating on the BASMAA IMR Part A Reporting Task of Regional Benefit, a single sample exceeded the mean PEC criterion of 0.5; significant toxicity was reported associated with this sample (Table 1). For the one sample that had more than three analytes exceed associated PECs, statistically significant toxicity was not reported (Table 1).[2]

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[1] As an example, for samples for which two detectable concentrations were available, relative percent differences reported associated with blind field duplicate samples collected for ACCWP in WY2013 ranged from 4% to 42% for trace elements; 4% to 77% for PAHs, 9% to 40% for OC pesticides, and 8% to 11% for pyrethroids.

[2] Using MRP Attachment H definition.

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). Half of the twelve samples analyzed by the four collaborating Programs in WY2012 and WY2013 fell within this range (Table 1). This uncertainty can potentially be seen in the RMC results where a sample with a pyrethroid TU of 1.0 was associated with a toxic sample, and one with a TU of 2.9 was not (Table 1).

Table 1. Representative MRP Dry Season Sediment Toxicity Results in Comparison to Potential Sediment Quality Assessment Thresholds. Shaded rows indicate samples meeting MRP trigger for sediment toxicity (interpreted as more than 20% less survival than control). Bold entries indicate results above MRP Table H-1 thresholds.

Dry Season Sediment Samples			**Toxicity relative to the Lab Control treatment?**		**# of TEC Quotients >1**	**Mean PEC Quotient**	**# PEC Quotients>1**	**Pyrethroid TUs**
Program	**Site**	**Sample Date**	**Survival**	**Growth**				
ACCWP	204R00047	7/25/12	Yes	N/A*	12	0.31	**4**	**2.2**
ACCWP	204R00084	7/25/12	No	No	5	0.13	0	0.6
ACCWP	204R00100	7/25/12	No	No	4	0.14	1	**2.9**
ACCWP	204R00327	7/9/13	No	No	13	0.29	1	0.3
ACCWP	204R00447	7/9/13	No	Yes	6	0.22	2	**1.4**
ACCWP	205R00686	7/9/13	No	Yes	1	0.08	0	0.4
CCCWP	207R00011	7/25/12	Yes	N/A*	10	0.14	0	**2.2**
CCCWP	544R00025	7/25/12	Yes	N/A*	11	**0.51**	1	**3.6**
CCCWP	207R00271	7/9/13	Yes	N/A*	0	0.04	0	**10.5**
CCCWP	544R00281	7/9/13	Yes	N/A*	4	0.13	1	**1.0**
FSURMP	207R00236	7/11/13	Yes	N/A*	4	0.12	1	**5.3**
Vallejo	207R05524	7/18/13	No	Yes	5	0.13	0	0.2

* Per EPA guidance, samples with a significant reduction in survival are not evaluated for chronic endpoints (i.e., growth).

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