INTEGRATED MONITORING REPORT

PART B: CREEK STATUS MONITORING

Water Year 2014 through Water Year 2019

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

SAN MATEO COUNTYWIDE
Water Pollution
Prevention Program

March 31, 2020

Preface

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

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

This Integrated Monitoring Report (IMR) Part B: Creek Status Monitoring, Water Year (WY) 2014 – WY 2019 complies with Provision C.8.h.v of the MRP for reporting of all data collected since the previous IMR which was submitted on March 31, 2014. It includes data collected in WY 2014 through WY 2019 (October 1, 2013 through September 30, 2019). Data were collected pursuant to Creek Status Monitoring and Pesticides & Toxicity Monitoring requirements of MRP Provision C.8. Data presented in this report were developed under the direction of the RMC and the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) using probabilistic and targeted monitoring designs as described herein.

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

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

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

List of Acronyms

ACCWP	Alameda Countywide Clean Water Program
AFDM	Ash Free Dry Mass
AFS	American Fisheries Society
ASCI	Algae Stream Condition Index
BASMAA	Bay Area Stormwater Management Agency Association
BMI	Benthic Macroinvertebrate
BMP	Best Management Practices
C/CAG	City/County Association of Governments
CCCWP	Contra Costa Clean Water Program
CDF	Cumulative Distribution Function
CEDEN	California Data Exchange Network
COLD	Cold Freshwater Habitat
CSBP	California Bioassessment Protocol
CSCI	California Stream Condition Index
DF	Detection Frequency
DO	Dissolved Oxygen
DPR	Department of Pesticide Regulation
EMAP	Environmental Monitoring and Assessment Program
FSURMP	Fairfield Suisun Urban Runoff Management Program
GIS	Geographic Information Systems
GM	Geometric Mean
GRTS	Generalized Random Tessellation Stratified
GSI	Green Stormwater Infrastructure
HDI	Human Disturbance Index
IBI	Index of Biological Integrity
IDDE	Illicit Discharge Detection and Elimination
IMR	Integrated Monitoring Report
IPI	Index Physical Habitat Integrity
IPM	Integrated Pest Management
LID	Low Impact Development
MDL	Method Detection Limit
MIGR	Fish Migration
MMI	Multimetric Index
MPC	Monitoring and Pollutants of Concern Committee
MPN	Most Probable Number
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
MUN	Municipal and Domestic Water Supply Beneficial Use
MWAT	Maximum Weekly Average Temperature
MWMT	Maximum Weekly Maximum Temperature
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
O/E	Observed to Expected
PAH	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PEC	Probable Effects Concentrations
PHAB	Physical Habitat Assessments
pMMI	Predictive Multimetric Index
PSA	Perennial Streams Assessment
QAPP	Quality Assurance Project Plan
QAPrP	Quality Assurance Program Plan
QA/QC	Quality Assurance/Quality Control
RARE	Preservation of Rare and Endangered Species

RM	Reporting Module
RMC	Regional Monitoring Coalition
RWB	Reachwide Benthos
RWQC	Recreation Water Quality Criteria
SAFIT	Southwest Association of Freshwater Invertebrate Taxonomists
SCAPE	Stream Classification and Priority Explorer
SCCWRP	Southern California Coastal Water Research Project
SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
SFRWQCB	San Francisco Bay Regional Water Quality Control Board
SMC	Southern California Monitoring Coalition
SMCWPPP	San Mateo County Water Pollution Prevention Program
SOP	Standard Operating Protocol
SPoT	Stream Pollution Trends Program
SPWN	Fish Spawning
SRP	Stormwater Resource Plan
SSID	Stressor/Source Identification
STORMS	Strategy to Optimize Resource Management of Storm Water
SWAMP	Surface Water Ambient Monitoring Program
SWPP	Surface Water Protection Program
TEC	Threshold Effects Concentrations
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
TST	Test of Significant Toxicity
TU	Toxicity Unit
UCMR	Urban Creeks Monitoring Report
USEPA	Environmental Protection Agency
WARM	Warm Freshwater Habitat
WQO	Water Quality Objective
WY	Water Year

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1.0 Introduction

This Integrated Monitoring Report (IMR) Part B: Creek Status Monitoring, Water Year[3] (WY) 2014 through WY 2019 was prepared by the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP or Program). SMCWPPP is a program of the City/County Association of Governments (C/CAG) of San Mateo County. Each incorporated city and town in the county and the County of San Mateo share a common National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities referred to as the Municipal Regional Permit (MRP). The MRP was first adopted by the San Francisco Regional Water Quality Control Board (SFRWQCB or Regional Water Board) on October 14, 2009 as Order R2-2009-0074 (SFRWQCB 2009; referred to as MRP 1.0). On November 19, 2015, the Regional Water Board updated and reissued the MRP as Order R2-2015-0049 (SFRWQCB 2015; referred to as MRP 2.0).

This report fulfills the requirements of Provision C.8.h.v of MRP 2.0 for comprehensively interpreting and reporting all Creek Status and Pesticides & Toxicity monitoring data collected since the previous IMR. As such, this report includes data collected during WY 2014 through WY 2019.[4] The previous IMR included data collected during WY 2012 and WY 2013 (SMCWPPP 2014). Data presented in this report from WY 2014 and WY 2015 were collected pursuant to water quality monitoring requirements in provisions C.8.c (Creek Status Monitoring) of MRP 1.0 and provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) of MRP 2.0.[5] Data presented in this report were submitted electronically to the Regional Water Board by SMCWPPP and may be obtained via the California Environmental Data Exchange Network (CEDEN).

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

- **Section 1.0** – Introduction including overview of the Program goals, background, monitoring approach, and statement of data quality
- **Section 2.0** – Biological condition assessment and stressor analysis at probabilistic sites
- **Section 3.0** – Continuous water quality monitoring (temperature, general water quality)
- **Section 4.0** – Pathogen indicators
- **Section 5.0** – Chlorine monitoring
- **Section 6.0** – Pesticides & Toxicity monitoring
- **Section 7.0** – Conclusions and recommendations
- **Section 8.0** – Summary of stormwater management programs

[3] Most hydrologic monitoring occurs for a period defined as a Water Year, which begins on October 1 and ends on September 30 of the named year. For example, Water Year 2019 (WY 2019) began on October 1, 2018 and concluded on September 30, 2019.

[4] The exception is biological condition data, which are reported for the WY 2012 through WY 2019 period of record.

[5] Monitoring data collected pursuant to other C.8 provisions (e.g., Pollutants of Concern Monitoring, Stressor/Source Identification Monitoring Projects) are reported in other Parts of the SMCWPPP Integrated Monitoring Report (IMR) for WY 2014 through WY 2019.

1.1 Monitoring Goals

Provision C.8.d of MRP 2.0 (and Provision C.8.c of MRP 1.0) requires Permittees to conduct creek status monitoring that is intended to answer the following management questions:

1. ***Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?***
2. ***Are conditions in local receiving water supportive of or likely supportive of beneficial uses?***

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

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

Creek Status and Pesticides & Toxicity monitoring parameters, methods, occurrences, durations and minimum number of sampling sites are described in Provisions C.8.d and C.8.g of the MRP, respectively. The monitoring requirements in the 2015 MRP (MRP 2.0) are similar to the 2009 MRP (MRP 1.0) requirements (which began implementation on October 1, 2011) and build upon earlier monitoring conducted by SMCWPPP. Creek Status and Pesticides & Toxicity monitoring is coordinated through the Bay Area Stormwater Agencies Association (BASMAA) Regional Monitoring Coalition (RMC). Monitoring results are evaluated to determine whether triggers are met, and further investigation is warranted as a potential SSID Project, as described in Provision C.8.e of the MRP. Results of Creek Status and Pesticides & Toxicity Monitoring conducted in Water Years 2012 through 2018 are summarized in this report and were detailed in prior reports (SMCWPPP 2019a, SMCWPPP 2018, SMCWPPP 2017, SMCWPPP 2016, SMCWPPP 2015, SMCWPPP 2014).

1.2 Regional Monitoring Coalition

Provision C.8.a (Compliance Options) of the MRP allows Permittees to address monitoring requirements through a regional collaborative effort, their Stormwater Program, and/or individually. The RMC was formed in early 2010 as a collaboration among a number of the BASMAA members and MRP Permittees (Table 1.1) to develop and implement a regionally coordinated water quality monitoring program to improve stormwater management in the region and address water quality monitoring required by the MRP[6]. Implementation of the RMC's Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012) allows Permittees and

[6] The Regional Water Board issued the first five-year MRP to 76 cities, counties and flood control districts (i.e., Permittees) in the Bay Area on October 14, 2009 (MRP 1.0; SFRWQCB 2009). On November 19, 2015, the Regional Water Board updated and reissued the MRP (MRP 2.0; SFRWQCB 2015). The BASMAA programs supporting MRP Regional Projects include all MRP Permittees as well as the cities of Antioch, Brentwood, and Oakley which are not named as Permittees under the MRP but have voluntarily elected to participate in MRP-related regional activities.

the Regional Water Board to 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 (MPC) Committee.

Table 1.1. Regional Monitoring Coalition participants.

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

The goals of the RMC are to:

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

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

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

The RMC's monitoring strategy for complying with Creek Status Monitoring is described in the RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). The strategy includes regional ambient/probabilistic monitoring and local "targeted" monitoring. The combination of these two components allows each individual RMC participating program to assess the status of beneficial uses in local creeks within its jurisdictional area, while also contributing data to answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks). The 2015 MRP (MRP 2.0) specifically prescribes the probabilistic/targeted approach and most of the other details of the RMC Creek Status and Long-Term Trends Monitoring Plan. Table 1.2 provides a list of which monitoring parameters are included in the probabilistic versus the targeted programs in MRP

2.0. This report includes data collected in San Mateo County under both monitoring components. Data are organized into report sections that reflect the format of monitoring requirements in the MRP.

Table 1.2. Monitoring parameters of MRP 2.0 Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides & Toxicity Monitoring) and associated monitoring component.

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

Notes:
[1] Provision C.8.d.i.(6) allows for up to 20% of sample locations to be selected on a targeted basis.
[2] Provision C.8.d.ii.(2) provides options for probabilistic or targeted site selection. In WY 2012 - 2019, chlorine was measured at probabilistic sites.

1.3 Monitoring and Data Assessment Methods

1.3.1 Monitoring Methods

Water quality data were collected in accordance with California Surface Water Ambient Monitoring Program (SWAMP) comparable methods and procedures described in the BASMAA RMC Standard Operating Procedures (SOPs; BASMAA 2016b) and the associated Quality Assurance Project Plan (QAPP; BASMAA 2016a). These documents are updated as needed to stay current and optimize applicability. Where applicable, monitoring data were collected using methods comparable to those specified by the SWAMP Quality Assurance Program Plan (QAPrP)[7], and were submitted in SWAMP-compatible format to the Regional Water Board. The SOPs were developed using a standard format that describes health and safety cautions and considerations, relevant training, site selection, and sampling methods/procedures, including

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

pre-fieldwork mobilization activities to prepare equipment, sample collection, and de-mobilization activities to preserve and transport samples.

1.3.2 Laboratory Analysis Methods

RMC participants, including SMCWPPP, agreed to use the same laboratories for individual parameters (except pathogen indicators), developed standards for contracting with the labs, and coordinated quality assurance samples. All samples collected by RMC participants that were sent to laboratories for analysis were analyzed and reported per SWAMP-comparable methods as described in the RMC QAPP (BASMAA 2016a). Analytical laboratory methods, reporting limits and holding times for chemical water quality parameters are also described in BASMAA (2016a). Analytical laboratory contractors in WY 2019 included:

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

1.3.3 Data Analysis Methods

Monitoring data generated during WY 2014 through WY 2019 were analyzed and evaluated to identify potential stressors that may be contributing to degraded or impacted biological conditions, including exceedances of water quality objectives (WQOs). Creek Status Monitoring and Pesticides & Toxicity Monitoring data are evaluated with respect to numeric thresholds (i.e., triggers) specified in the MRP (SFRWQCB 2015, SFRWQCB 2009). Sites with monitoring data that do not meet WQOs and/or exceed MRP trigger thresholds require consideration for further evaluation as part of a Stressor/Source Identification project. SSID projects are intended to be oriented toward taking action(s) to alleviate stressors and reduce sources of pollutants. A stepwise process for conducting SSID projects is described in Provision C.8.e.iii of MRP 2.0.

In compliance with Provision C.8.e.i of MRP 2.0, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects that will be maintained throughout the permit term. Follow-up SSID projects are selected from this list.

1.4 Setting

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

The complete list of probabilistic and targeted monitoring sites sampled by SMCWPPP in WY 2019 in compliance with Provisions C.8.d (Creek Status Monitoring) and C.8.g (Pesticides and Toxicity Monitoring) is presented in Table 1.3. Probabilistic station numbers, generated from the RMC Sample Frame, are provided for all bioassessment locations. Targeted stations numbers, based on SWAMP station numbering methods (BASMAA 2016b), are provided for all targeted monitoring sites. Monitoring locations with monitoring parameter(s) from WY 2019 are mapped in Figure 1.1. Monitoring locations from WY 2014 through WY 2018 are mapped in the various parameter-specific sections of this report.

Table 1.3. Sites and parameters monitored in WY 2019 in San Mateo County.

Map ID [1]	Station ID	Bayside or Coastside	Watershed	Creek Name	Land Use	Latitude	Longitude	Probabilistic	Targeted				
								Bioassessment, Nutrients, General WQ	Chlorine	Pesticides & Toxicity	Temp [2]	Contin-uous WQ [3]	Pathogen Indicators
030	202TUN030	Coastal	Tunitas Creek	Tunitas Creek	NU	37.37940	-122.3748	X	X		X	X	
040	202TUN040	Coastal	Tunitas Creek	Tunitas Creek	NU	37.38847	-122.3709	X	X			X	
005	204BEL005	Bayside	Belmont Creek	Belmont Creek	U	37.51778	-122.26914	X	X				
4280	204R04280	Bayside	Belmont Creek	Belmont Creek	U	37.45434	-122.20118	X	X				
4428	204R04428	Bayside	Cordilleras Creek	Cordilleras Creek	U	37.55466	-122.35632	X	X				
4160	204R04160	Bayside	Burlingame Creek	Burlingame Creek	U	37.51480	-122.28340	X	X				
3635	204R03635	Bayside	Atherton Creek	Atherton Creek	U	37.47975	-122.25986	X	X				
4600	204R04600	Bayside	Atherton Creek	Atherton Creek	U	37.43671	-122.21467	X	X				
4056	205R04056	Bayside	San Francisquito Cr	Dry Creek	U	37.43885	-122.26506	X	X				
5044	205R05044	Bayside	San Francisquito Cr	Dry Creek	U	37.42803	-122.25148	X	X				
010	204PUL010	Bayside	Pulgas Creek	Pulgas Creek	U	37.50195	-122.25238			X			
138	202PES138	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27410	-122.28860						X
142	202PES142	Coastside	Pescadero Creek	McCormick Creek	NU	37.27757	-122.28635						X
144	202PES144	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27592	-122.28550						X
150	202PES150	Coastside	Pescadero Creek	Jones Gulch	NU	37.27424	-122.26811						X
154	202PES154	Coastside	Pescadero Creek	Pescadero Creek	NU	37.27446	-122.26798						X
5	202TUN005	Coastside	Tunitas Creek	Tunitas Creek	NU	37.36202	-122.39062				X		
25	202TUN025	Coastside	Tunitas Creek	Tunitas Creek	NU	37.37735	-122.37413				X		
35	202TUN035	Coastside	Tunitas Creek	Tunitas Creek	NU	37.38425	-122.37323				X		
60	202TUN060	Coastside	Tunitas Creek	Tunitas Creek	NU	37.40476	-122.35711				X		

U = urban, NU = non-urban

[1] Map ID applies to Figure 1.1.

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

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

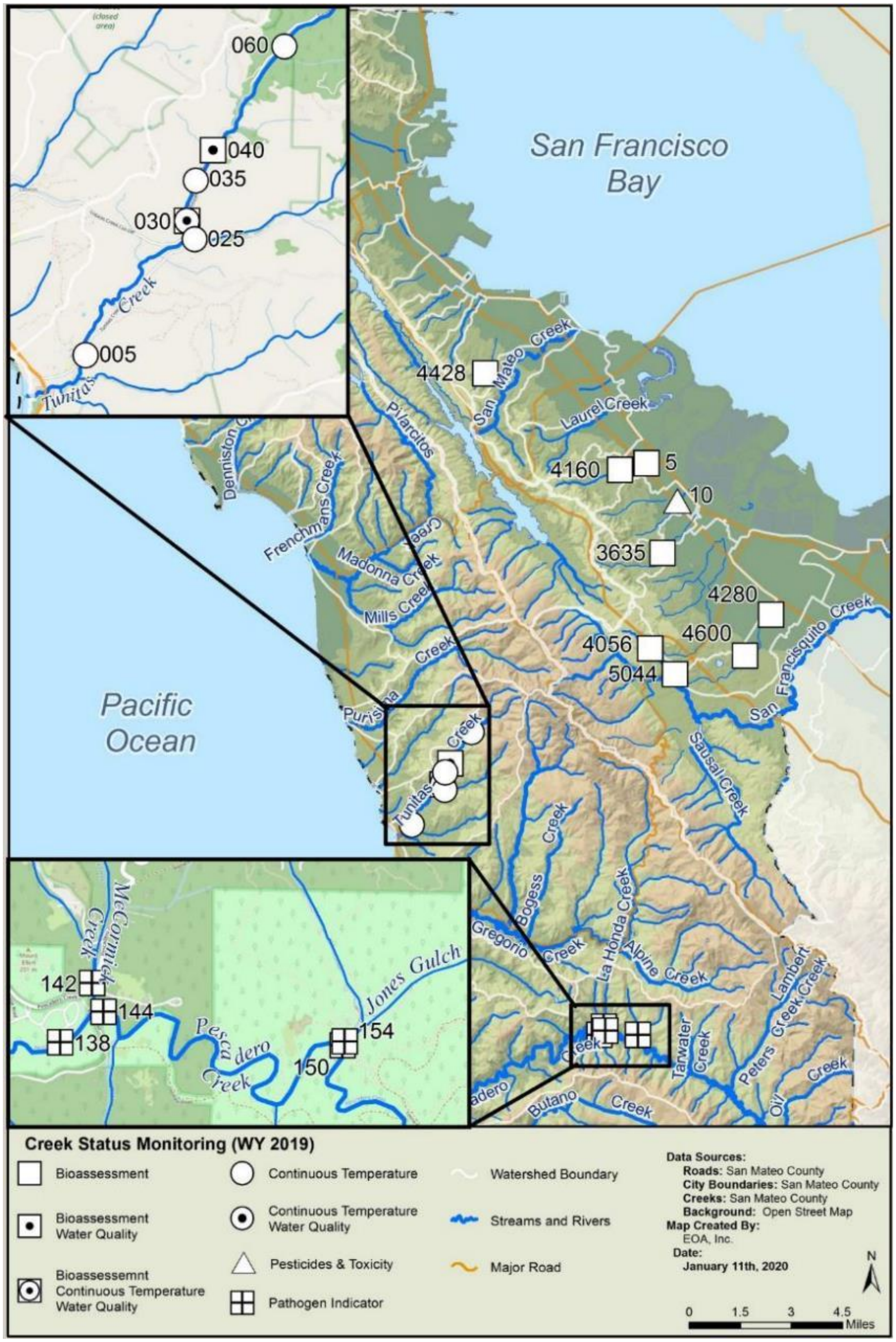

Figure 1.1. Map of SMCWPPP sites monitored in WY 2019.

1.4.1 Designated Beneficial Uses

Beneficial Uses in San Mateo County creeks are designated by the Regional Water Board for specific water bodies and serve as the basis for establishing WQOs designed to protect those uses (SFBRWQCB 2017). All creeks in San Mateo County, except a few coastal creeks, are designated as having warm freshwater habitat (WARM) beneficial uses. Nearly all coastal creeks and a few bayside creeks, such as San Mateo Creek and San Francisquito Creek, are designated as having cold freshwater habitat (COLD) beneficial uses, meaning they generally support trout, anadromous salmon, and/or steelhead fisheries. Dissolved oxygen WQOs are more stringent in creeks with COLD beneficial uses because these species are relatively intolerant to environmental stresses. Virtually all creeks in the region are designated as having water contact recreations (REC-1) beneficial uses such as swimming and wading where ingestion of water is considered reasonably possible. Fecal indicator bacteria WQOs are identified to protect REC-1 beneficial uses. Several coastal creeks, as well as Bear Gulch Creek and Crystal Springs Reservoir in the San Mateo Creek watershed, are designated as having municipal and domestic supply (MUN) beneficial uses, due to the presence of drinking water reservoirs and/or diversions for these purposes. The Basin Plan identifies WQOs for several constituents of concern that apply only to waters with MUN beneficial uses.

1.4.2 Climate

San Mateo County experiences a Mediterranean climate with cool, wet winters and hot, dry summers. The area is characterized by microclimates created by topography, ocean currents, fog exposure, and onshore winds. The wet season typically extends from October through April with local long-term, mean annual precipitation ranging from 20 inches near the Bay to over 40 inches along the highest ridges of the San Mateo Mountain Range (PRISM Climate Group 30-year normals, 1981-2010[8]). Figure 1.2 illustrates the geographic variability of mean annual precipitation in the area. It is important to understand that mean annual precipitation depths are statistically calculated or modeled; actual measured precipitation each year rarely equals the statistical average. Figure 1.3 illustrates the temporal variability in annual precipitation measured at the San Francisco International Airport (SFO) from WY 1946 to WY 2019. This record illustrates that extended periods of drought are common and often punctuated by above average years. Creek Status Monitoring in compliance with the MRP began in WY 2012 which was the first year of a severe statewide drought that persisted through WY 2016. WY 2018 rainfall was below average at SFO, but it was preceded by a wet year in WY 2017.

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

Climate patterns (e.g., extended droughts) and individual weather events (e.g., extreme storms, hot summers) influence biological communities (i.e., vegetation, wildlife) and their surrounding physical habitat and water quality. They should therefore be considered when evaluating the

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

type of data collected by the Creek Status Monitoring Program. For example, periods of drought (rather than individual dry years) can result in changes in riparian and upland vegetation communities. Long drought periods are associated with increased streambed sedimentation, which can persist directly or indirectly for many years, depending on the occurrence and magnitude of flushing flow events. Furthermore, in response to prolonged drought, the relative proportion of pool habitat can increase at the expense of riffle habitat.

It is uncertain what effect these factors have on indices of biotic integrity (IBIs) that are calculated using data collected by the Creek Status Monitoring Program, such as benthic macroinvertebrates or algae. A study evaluating 20 years of bioassessment data collected in northern California showed that, although benthic macroinvertebrate taxa with certain traits may be affected by dry (and wet) years and/or warm (and cool) years, IBIs based on these organisms appear to be resilient (Mazor et al. 2009, Lawrence et al. 2010). However, this study did not specifically examine the impact of longer *periods* of extended drought or heat on IBIs, which would require analysis of a dataset with a much longer period of record. The Herbst Lab at the Sierra Nevada Aquatic Research Laboratory, University of California Santa Barbara recently completed a study exploring how flooding and droughts vary taxa metrics in the Sierra Nevada streams. While species diversity and density remained relatively unchanged during flooding, extreme dry weather conditions significantly impacted benthic macroinvertebrate population structure. These differences were exacerbated with continued exposure to drought (Herbst et al. 2019). Similar changes to the benthic macroinvertebrate community in San Mateo County streams may have occurred during the WY 2012 – WY 2016 drought but have not been evaluated.

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

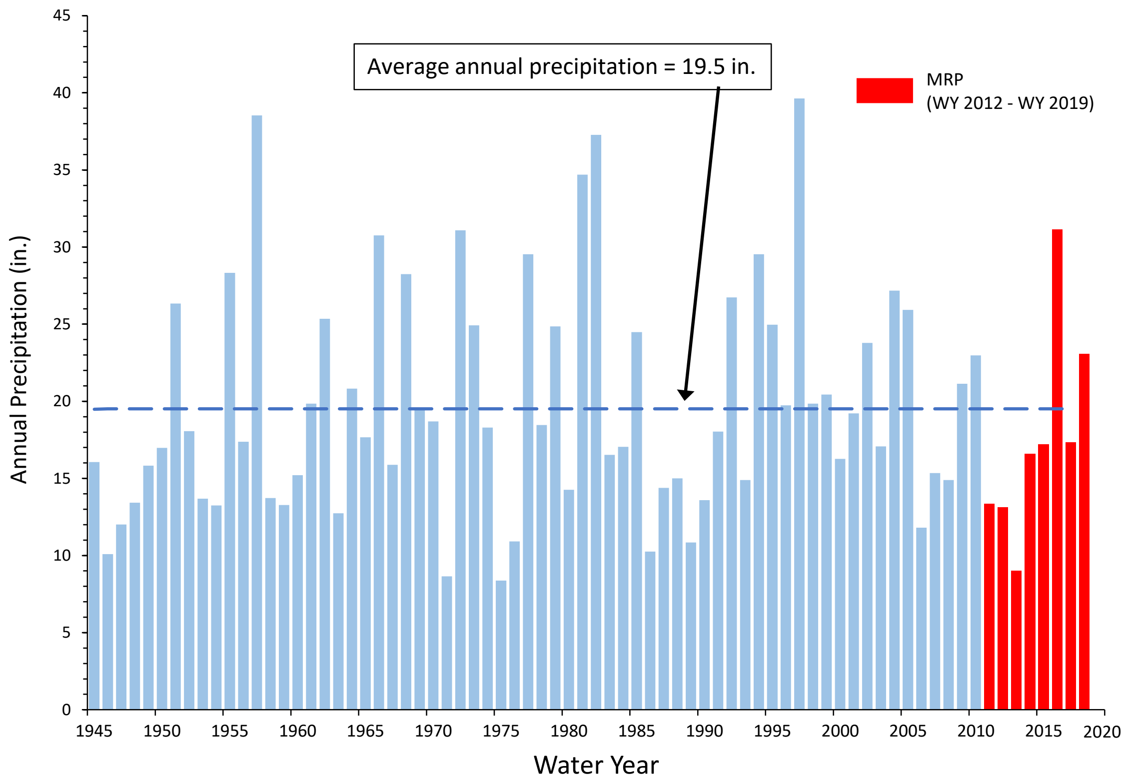

Figure 1.3. Annual rainfall recorded at the San Francisco International Airport, WY 1946 – WY 2019.

1.5 Statement of Data Quality

A comprehensive Quality Assurance/Quality Control (QA/QC) program was implemented by SMCWPPP covering all aspects of the probabilistic and targeted monitoring. In general QA/QC procedures were implemented as specified in the BASMAA RMC QAPP (BASMAA 2016a), which was adapted from the methods detailed by the SWAMP QAPrP[9]. The QAPP was revised twice –in 2014 and again in 2016 – to conform to changes in the MRP reissuance and changes made to the SWAMP QAPrP. The revisions were minor, and overall methods and protocols remain similar. Each year's monitoring data were compared against objectives in the governing QAPP. Monitoring was performed according to protocols specified in the BASMAA RMC SOPs (BASMAA 2016b), which were also revised with the QAPP.

Overall, the results of the QA/QC reviews suggest that the Creek Status Monitoring data generated during WY 2012 – WY 2019 were of sufficient quality for the purposes of this evaluation. Some data were flagged in accordance with QA/QC protocols, but none were rejected. A detailed QA/QC report for WY 2019 data is included as Attachment 1. Detailed QA/QC reports for monitoring data collected during past water years are included with previous reports (SMCWPPP 2019a, SMCWPPP 2018, SMCWPPP 2017, SMCWPPP 2016, SMCWPPP 2015, SMCWPPP 2014).

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

2.0 Biological Condition Assessment

2.1 Introduction

In compliance with Creek Status Monitoring Provisions C.8.c of MRP 1.0 and C.8.d.i of MRP 2.0, SMCWPPP has conducted bioassessment monitoring since WY 2012. Nearly all bioassessment monitoring has been performed at sites selected randomly using the probabilistic monitoring design. The probabilistic monitoring design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its program area (i.e., county jurisdictional area) while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks. The survey design provides an unbiased framework for condition assessment of ambient aquatic life uses within known estimates of precision. The monitoring design was developed to address management questions for RMC participating counties and the overall RMC area:

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

The first question (i.e., *What is the condition of aquatic life in creeks in the RMC?*) is addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. Once a sufficient number of samples have been collected, ambient biological condition can be estimated for streams at a regional (or countywide) scale. Over the past eight years (WY 2012 through WY 2019), SMCWPPP and the Regional Water Board have sampled 90 probabilistic sites in San Mateo County, providing a sufficient sample size to estimate ambient biological condition for urban and non-urban streams countywide. There is still an insufficient number of samples to accurately assess the biological condition of individual watersheds or smaller jurisdictional areas (i.e., cities).[10]

The second question (i.e., *What are major stressors to aquatic life in the RMC area?*) is addressed by evaluation of physical habitat and water chemistry data collected at the probabilistic sites, as potential stressors to biological health. The stressor levels can be

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

compared to biological indicator data through correlation and random forest models. Assessing the extent and relative importance of stressors in predicting biological condition can help prioritize stressors at a regional scale and inform local management decisions.

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

MRP 2.0 allows for up to 20% of bioassessment surveys at targeted sites to address other types of management questions, provided a statistically representative dataset (i.e., 30 samples) has already been collected. Under MRP 2.0, SMCWPPP conducted bioassessment surveys at three targeted sites. Two sites on Tunitas Creek were selected to follow-up on previous monitoring results that suggested lower than expected biological health (202TUN030 and 202TUN040). One site on Belmont Creek provides baseline data in a creek where a multi-benefit project is planned (204BEL005).

This section of the report presents bioassessment results from WY 2019, as well as a comprehensive evaluation of the probabilistic bioassessment data collected in San Mateo County from WY 2012 through WY 2019. In addition, in compliance with Provision C.8.d.i.(8) of MRP 2.0, WY 2019 data are compared to triggers and WQOs identified in the MRP. Sites with results exceeding trigger thresholds are added to the list of candidate SSID projects.

2.2 Methods

2.2.1 Probabilistic Survey Design

The RMC probabilistic design was created using the Generalized Random Tessellation Stratified (GRTS) approach developed by the United States Environmental Protection Agency (USEPA) and Oregon State University (Stevens and Olsen 2004). GRTS offers multiple benefits for coordinating among monitoring entities, including the ability to develop a spatially balanced design that produces statistically representative data with known confidence intervals. The GRTS approach has been implemented in California by several organizations including the statewide Perennial Streams Assessment (PSA) conducted by Surface Water Ambient Monitoring Program (Ode et al. 2011) and the Southern California Stormwater Monitoring Coalition's (SMC) regional monitoring program conducted by municipal stormwater programs in Southern California (SCCWRP 2007).

Sample sites were selected using the GRTS approach from a sample frame consisting of a creek network geographic information system (GIS) data set within the 3,407-square mile RMC area (BASMAA 2012). The sample frame includes non-tidally influenced perennial and non-perennial creeks within five management units representing areas managed by the stormwater programs associated with the RMC (listed in Table 1.1). There is approximately one site for every stream kilometer in the sample frame. The National Hydrography Plus Dataset (1:100,000) was selected as the creek network data layer to provide consistency with both the Statewide PSA and the SMC, and the opportunity for future data coordination with these programs.

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

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

2.2.2 Site Evaluations

Sites identified in the regional sample draw are evaluated by each RMC participant in chronological order using the process described in RMC Standard Operating Procedure FS-12 (BASMAA 2016a) which is consistent with the procedure described by Southern California Coastal Water Research Project (SCCWRP 2012). Each site is evaluated to determine if it meets RMC sampling location criteria (e.g., not tidally influenced, sufficient flow, safe accessibility, landowner permission to access site). Site evaluation information is stored in a database and analyzed to determine the statistical significance of local and regional average ambient conditions calculated from the multi-year dataset.

2.2.3 Field Sampling Methods

Bioassessment survey methods were consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b). In accordance with the RMC QAPP (BASMAA 2016a) bioassessments were planned during the spring index period (approximately April 15 – July 15) with the goal to sample a minimum of 30 days after any significant storm (defined as at least 0.5-inch of rainfall within a 24-hour period). The 30-day grace period allows diatom and soft algae communities to recover from peak flows that may scour benthic algae from the bottom of the stream channel.[12]

Over the eight-year monitoring period, one or two small but significant storms (i.e., 0.5 inches in 24-hour period) typically occurred during the first two weeks of April. Generally, bioassessment sampling was conducted 20-30 days following the storm event to allow recovery time for the algal community. However, due to drought or below average rainfall conditions that characterized the WY 2012 – WY 2016 period, bioassessments at selected sites (i.e., small streams less impacted by storm) were conducted approximately 10 days after the significant storm event to ensure that flow would still be present. During WY 2019, a significant storm occurred late in the season (May 20, 2019), after bioassessment fieldwork had commenced. Bioassessment sampling was paused until June 3, 2019 (approximately two weeks after the storm). All algae data collected prior to the 30-day grace period were flagged.

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

[12] The BASMAA 30-day grace period is more conservative than the 21-day grace period described in the SWAMP SOP (Ode et al. 2016).

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

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

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

2.2.4 Data Analysis

Biological condition indicator data and stressor data for all bioassessment sites surveyed in WY 2012 – WY 2019 were compiled into a master spreadsheet for data analyses. The master spreadsheet is included with this report as Attachment 2. BMI and algae data were analyzed to assess the biological condition (i.e., aquatic life Beneficial Uses) of the sampled reaches using condition index scores. Physical habitat data were used to assess biological condition and were evaluated as potential stressors. Water chemistry data were evaluated as potential stressors to biological health using triggers and WQOs identified in the MRP (see Stressor Variable section below). Data analysis methods for biological indicators and stressors are described below.

2.2.4.1 Biological Indicators

<u>Benthic Macroinvertebrates</u>

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

The California Stream Condition Index (CSCI) is an assessment tool that was developed by the State Water Resources Control Board (State Water Board) to support the development of California's statewide Biological Integrity Plan[13]. The CSCI translates benthic macroinvertebrate data into an overall measure of stream health. The CSCI was developed using a large reference data set that represents the full range of natural conditions in California and site-specific models for predicting biological communities. The CSCI combines two types of indices: 1) taxonomic completeness, as measured by the ratio of observed-to-expected taxa (O/E); and 2) ecological structure and function, measured as a predictive multimetric index (pMMI) that is based on reference conditions. The CSCI score is computed as the average of the sum of the O/E and pMMI.

Odonata cordulegastridae "Spiketail Dragonfly"

Megaloptera corydalidae "Dobsonflies"

Ephemeroptera ephemerellidae "Spiny Crawler Mayflies"

Trichoptera limnephilidae "Northern Caddisflies"

Diptera ceratopogonidae "Biting Midges"

Coleoptera psephenidae "Water Penny Beetle"

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

Figure 2.1. Examples of benthic macroinvertebrates.

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

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

developed by Southern California Coastal Water Research Project (SCCWRP) staff (Mazor et al. 2016).

The State Water Board is continuing to evaluate the performance of CSCI in a regulatory context. In Provision C.8.d of MRP 2.0, the Regional Water Board defines a CSCI score of 0.795 as a trigger threshold for identifying sites with potentially degraded biological condition that may be considered as candidates for a Stressor/Source Identification project.

<u>Benthic Algae</u>

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

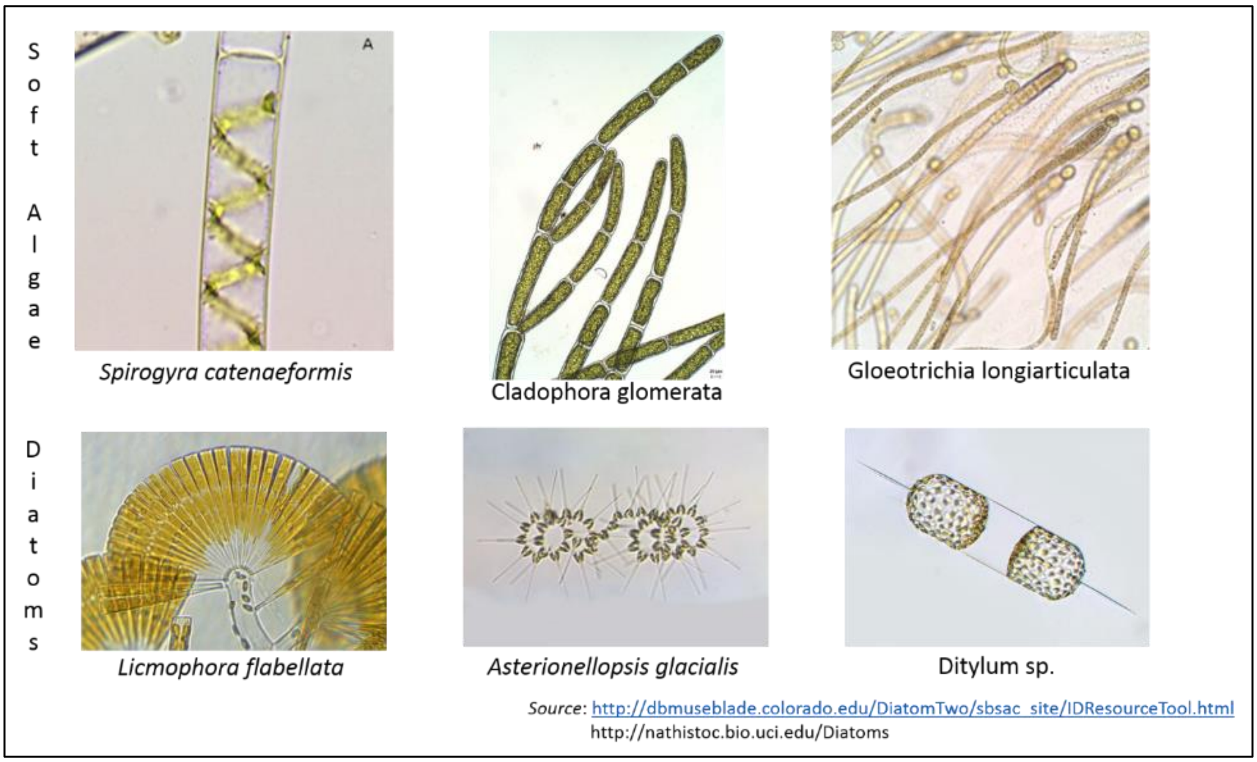

Figure 2.2. Examples of soft algae and diatoms.

The State Water Board and SCCWRP recently developed the draft Algae Stream Condition Index (ASCI) which uses benthic algae data as a measure of biological condition for streams in California (Theroux et al. in prep.). The ASCI includes both predictive[14] and non-predictive multimetric indices (MMI) used to evaluate ecological conditions. There are three versions of the ASCI MMI: an index for diatoms, one for soft-bodied algae and a hybrid index using both assemblages. Using a statewide data set, all three indices were evaluated by the State Water Board for precision, accuracy, responsiveness, and regional bias. The hybrid ASCI was found to be the most sensitive to anthropogenic stressor gradients, emphasizing the value of combining multiple algal assemblages (diatoms and soft bodied algae) to provide a more comprehensive assessment of biological condition (Theroux et al. in prep).

Additional study is needed to determine the best approach to apply the ASCI tools to evaluate bioassessment data. For example, it is not clear if the ASCI should be used as a second line of evidence to understand CSCI scoring results, or if it would be more effective as an independent indicator to evaluate different types of stressors (e.g., nutrients) to which BMIs are not very responsive. The ASCI is currently under review by the Biostimulatory-Biointegrity Policy Science Advisory Panel and the State Water Board.

The algae data collected at 90 bioassessment sites in San Mateo County between 2012 and 2019 were evaluated using the three ASCI MMIs (diatom, soft algae and hybrid). ASCI scores were generated using the beta version reporting module developed by SCCWRP. These scores are considered provisional until the ASCI has been fully evaluated and finalized.

2.2.4.2 Physical Habitat Indicators

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

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

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[14] Predictive indices utilize environmental variables that characterize immutable natural gradients as predictors for biological conditions. A predictive algal O/E model was developed and tested, but ultimately not recommended due to low precision and accuracy. Predictive metrics were used for both diatom and hybrid MMIs, but the soft body algae MMI did not incorporate predictive metrics.

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

2.2.4.3 Biological and Physical Habitat Condition Thresholds

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

A CSCI score below 0.795 is referenced in MRP 2.0 as a threshold indicating a potentially degraded biological community, and thus should be considered for a SSID Project. The MRP threshold is at the division between the “possibly intact” and “likely altered” condition categories described in Mazor (2015). Further investigation is needed to evaluate the applicability of this threshold to sites in highly urban watersheds and/or modified channels that are common throughout the Bay Area.

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

Biological Indicator	Tool	Likely Intact	Possibly Intact	Likely Altered	Very Likely Altered
BMI	CSCI	≥ 0.92	≥ 0.79 to < 0.92	≥ 0.63 to < 0.79	< 0.63
Diatoms	ASCI	≥ 0.92	≥ 0.81 to < 0.92	≥ 0.66 to < 0.81	< 0.66
Soft Algae		≥ 0.92	≥ 0.80 to < 0.92	≥ 0.65 to < 0.80	< 0.65
Hybrid		≥ 0.95	≥ 0.88 to < 0.95	≥ 0.78 to < 0.88	< 0.78
Physical Habitat	IPI	≥ 0.94	≥ 0.84 to < 0.94	≥ 0.71 to < 0.83	< 0.70

2.2.4.4 Stressor Variables

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

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

Table 2.2. Physical habitat metrics used to assess physical habitat data collected at bioassessment sites in San Mateo County, WY 2012 through WY 2019. The five metrics used to calculate IPI scores are also shown.

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

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

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

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

- Conversion of measured total ammonia to the more toxic form of unionized ammonia was calculated to compare with the 0.025 mg/L annual median standard provided in the San Francisco Basin Water Quality Control Plan (Basin Plan) (SFRWQCB 2017). The conversion was based on a formula provided by the American Fisheries Society (AFS; https://fisheries.org/wp-content/uploads/2016/03/Copy-of-pub_ammonia_fwc.xls). The calculation requires total ammonia and field-measured values of pH, temperature, and specific conductance.

- Total nitrogen concentration was calculated by summing nitrate, nitrite, and Total Kjeldahl Nitrogen concentrations.
- The volumetric concentrations (mass/volume) for ash free dry mass and chlorophyll a (as measured by the laboratory) were converted to an area concentration (mass/area). Calculations required using both algae sampling grab size and composite volume.

Another potential stressor is climate. During the first five years of probabilistic sampling (WY 2012 – WY 2016), annual precipitation was lower than average. The drought ended with an above average wet season in WY 2017, followed by an average season in WY 2018 and above average in WY 2019. Comparison of sampling results from wet and dry years will provide useful information to evaluate the impacts of drought on biological integrity of the streams.

2.2.4.5 Trigger Thresholds

In compliance with Provision C.8.h.iii.(4) of MRP 2.0, water chemistry data collected at the bioassessment sites during WY 2019 were compared to MRP trigger thresholds and applicable water quality standards (Table 2.3). Thresholds for pH, specific conductance, dissolved oxygen (DO), and temperature (for waters with COLD Beneficial Use only) are listed in Provision C.8.d.iv of MRP 2.0. Except for temperature and specific conductance, these conform to WQOs in the Basin Plan (SFRWQCB 2017). Of the eleven nutrients analyzed synoptically with bioassessments, WQOs only exist for three: ammonia (unionized form), and chloride and nitrate (for waters with MUN Beneficial Use only).

Table 2.3. MRP trigger thresholds for nutrient and general water quality variables.

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

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

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

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

2.2.4.6 Stressor Assessment

The association of stressors (physical habitat, landscape, chemistry) with biological indicator scores (CSCI and ASCI) was evaluated using eight years (WY 2012 – 2019) of bioassessment data collected in San Mateo County. Spearman's rank correlation analyses and random forest statistical models were applied to the dataset. A summary of these analyses is provided in Section 2.3.2. A technical report detailing the methods and results is provided in Attachment 3.

2.2.4.7 SCAPE Modeling to Assess CSCI Scores

Biological conditions, based on CSCI scores, for the 90 bioassessment sampling locations in San Mateo County were compared to a landscape model developed for streams in California that estimates ranges of likely scores for CSCI scores based on the level of landscape alteration contributing to the sampling reach (Beck et al. 2020). The landscape model was created using data from StreamCat, which is a national dataset that includes attributes characterizing watershed development (Hill at al. 2015).

The predictive model was developed to support management decisions, such as identifying reaches for restoration or enhanced protection based on how observed scores relate to the model expectation. It has been integrated into a publicly available web-based application called the Stream Classification and Priority Explorer (SCAPE). The SCAPE tool can be used to compare measured/calculated CSCI scores with the predictive scores produced by the model (https://sccwrp.shinyapps.io/scape/).

The SCAPE model was obtained from SCCWRP as a GIS shapefile. Stream/channel attributes in the shapefile include stream classifications using three thresholds for CSCI (1^{st}, 10^{th}, and 30^{th} percentile of reference sites) and a prediction interval (ranging from the 10th to the 90th percentiles of the quantile predictions). There are four possible stream classifications in the model: "likely unconstrained", "possibly constrained", "possibly unconstrained" and "likely unconstrained". The model predicts a range of CSCI scores for each stream reach and an expected median score. Observed CSCI scores at a site are compared to the model expectations and characterized as over-scoring, expected or under-scoring. See section 2.4.1 for application of the SCAPE model to CSCI scores at bioassessment sites in San Mateo County.

2.3 Results and Discussion

The results for bioassessment monitoring in WY 2019, as well as the previous eight years (WY 2012 – WY 2019), are presented in the section below.

- **Section 2.3.1** presents results of biological assessments conducted at ten sites in San Mateo County during WY 2019. The bioassessment monitoring conducted at the three targeted sites is described in greater detail.

- **Section 2.3.2** provides an overall summary of biological conditions (CSCI and ASCI scores) and exceedances of stressor thresholds for the 90 bioassessment sites sampled in San Mateo County between WY 2012 and WY 2019. The association between biological conditions and stressor data (land use, water chemistry, physical habitat) for 87 probabilistic sites is evaluated using statistical analyses. The evaluation of bioassessment data is consistent with the approach used in the RMC 5-year Bioassessment Report (BASMAA 2019). A complete description of methods and results for the countywide analysis of bioassessment data is provided in Attachment 3.

- **Section 2.3.3** presents a comparison of historical BMI data (Pre-MRP; WY 2002 – WY 2007) and BMI data collected in compliance with the MRP (WY 2012 – WY 2019), based on CSCI scores, as one approach using existing data sources to evaluate trends in biological conditions. The Program conducted bioassessments in four watersheds in San Mateo County between 2002 and 2007.

- **Section 2.4** provides potential approaches to consider for future monitoring design to address requirements for Provision C.8 of the next MRP (i.e., MRP 3.0) that is currently under development and will likely become effective in WY 2022. One approach would be to conduct targeted monitoring at specific watershed/reaches that have identified water quality problems or reduced biological conditions and high potential to mitigate stressor impacts through management actions. Another approach is to identify healthy stream reaches and focus efforts on protecting those resources.

Conclusions and recommendations for this section are presented in Section 7.0.

2.3.1 Bioassessment Results (WY 2019)

This section documents the biological condition and stressor data collected in WY 2019. In WY 2019, the Program conducted bioassessments at seven probabilistic sites and three targeted sites in San Mateo County[15]. The WY 2019 bioassessment sites are listed in Table 2.4 and mapped in Figure 2.3. The probabilistic sites were derived from the RMC Sample Frame. Two of the targeted sites were selected to follow-up on previous monitoring results that suggested lower than expected biological health. The remaining targeted site provides baseline data in a creek where a multi-benefit project is planned. Targeted monitoring results are provided below in Section 2.3.1.3.

Table 2.4. Bioassessment sampling locations and dates in San Mateo County in WY 2019.

Station Code	Drainage Area	Creek Name	Land Use	Sample Date	Latitude	Longitude	Targeted	Probabilistic
202TUN030	Pacific Ocean	Tunitas Creek	NU	14-May-19	37.37940	-122.37483	x	
202TUN040		Tunitas Creek	NU	14-May-19	37.38840	-122.37090	x	
204BEL005	San Francisco Bay	Belmont Creek	U	13-May-19	37.51770	-122.26910	x	
204R03635		Atherton Creek	U	10-Jun-19	37.51522	-122.28230		x
204R04160		Burlingame Creek	U	15-May-19	37.47890	-122.26126		x
204R04280		Belmont Creek	U	13-May-19	37.55342	-122.35830		x
204R04428		Cordilleras Creek	U	15-May-19	37.45430	-122.20001		x
204R04600		Atherton Creek	U	10-Jun-19	37.43610	-122.21560		x
205R04056		Dry Creek	U	11-Jun-19	37.43903	-122.26530		x
205R05044		Dry Creek	U	11-Jun-19	37.42820	-122.25179		x

Land use: NU = non-urban, U = urban

2.3.1.1 Biological and Physical Habitat Conditions (WY 2019)

Biological condition for the ten sites sampled by SMCWPPP in WY 2019, as represented by CSCI and ASCI (diatom, soft algae, and hybrid) scores, is shown in Table 2.5. Physical habitat condition, as represented by IPI Scores, is shown in Table 2.6. Scores in the two highest condition categories (i.e., above the 10th percentile of reference sites) for each indicator are shown in shaded cells with bold text.

CSCI Scores

The CSCI scores ranged from 0.46 to 0.94 across the ten bioassessment sites sampled in WY 2019 (Table 2.5). Two of ten (20%) of the sites had CSCI scores in the two highest condition categories: “possibly intact” and “likely intact”. These classifications are above the MRP trigger threshold value of 0.795. Both sites were located in Tunitas Creek, which is a relatively undeveloped watershed that drains to the Pacific Ocean (Figure 2.3). See Section 2.3.1.3 for more information on Tunitas Creek bioassessment monitoring.

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[15] MRP 2.0 allows for up to 20% of bioassessment locations (2 sites) to be targeted each year. Prior to WY 2019, targeted sites were not selected for monitoring. During WY 2019, bioassessments were conducted at three targeted sites.

The remaining eight sites had CSCI scores in the “very likely altered” condition category (<0.63). These sites are located in developed (13% - 41% impervious area) watersheds draining to San Francisco Bay. Sites with CSCI scores below 0.795 will be considered as candidates for SSID projects.

Table 2.5. Biological condition scores, presented as CSCI and ASCI (diatom, soft algae and hybrid) for ten sites sampled in San Mateo during WY 2019. Site characteristics related to percent impervious watershed area and channel modification are also presented. Bold shaded values indicate scores in the two highest condition categories for each indicator.

Station Code	Creek	Impervious Watershed Area (%)	Modified Channel	CSCI Score	ASCI Score		
					Diatom	Soft Algae	Hybrid
202TUN030	Tunitas Creek	1%	N	**0.84**	0.79	0.37	0.82
202TUN040	Tunitas Creek	1%	N	**0.94**	0.61	0.54	0.78
204BEL005	Belmont Creek	41%	Y	0.46	0.63	**0.81**	0.67
204R03635	Atherton Creek	24%	Y	0.49	0.35	0.55	0.46
204R04160	Burlingame Creek	37%	N	0.51	0.66	**0.81**	0.72
204R04280	Belmont Creek	39%	N	0.55	0.43	**1.07**	0.86
204R04428	Cordilleras Creek	19%	N	0.60	**0.85**	**0.81**	0.73
204R04600	Atherton Creek	24%	N	0.53	0.57	**1.28**	0.67
205R04056	Dry Creek	14%	N	0.49	0.58	0.37	0.63
205R05044	Dry Creek	13%	N	0.48	0.47	**1.28**	0.51

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

<u>ASCI Scores</u>

The benthic algae taxa identified in the samples collected in San Mateo County were used to calculate scores for the provisional statewide ASCI. Scores for three ASCI indices (diatoms, soft algae and hybrid) are shown in Table 2.5. In general, ASCI scores were lower for the diatom and hybrid indices compared to the soft algae index. Only one site in Cordilleras Creek (204R04428) scored in either of the top two condition categories for either index. In contrast, six of the ten sites had scores in top two condition categories for the soft algae index. There is no MRP trigger for any of the ASCI index scores.

<u>IPI Scores</u>

Physical habitat conditions, as represented by IPI scores, are listed in Table 2.6 along with CSCI scores and hybrid ASCI scores. The top two condition categories for all three indices (i.e., above the 10th percentile of reference sites) are shown in shaded cells with bold text. Six of the ten sites had IPI scores that were in the top two condition categories (> 0.83). Interestingly, IPI scores for the two sites on Tunitas Creek were two condition categories apart, despite their proximity (Figure 2.3). Differences in IPI scores between the two sites appear to be mostly associated with differences in the amount of riparian canopy cover.

The qualitative habitat (PHAB) scores, including individual scores for channelization, epifaunal substrate and sedimentation attributes[16], and total PHAB (sum of the three attributes scores) are also presented in Table 2.6. Total PHAB scores ranged from 16 to 47 (total possible is 60). In contrast to IPI scores, the total PHAB scores were nearly identical for the two sites on Tunitas Creek. Biological condition scores for CSCI and the hybrid ASCI are included in the table for comparison.

Table 2.6. IPI scores for ten probabilistic sites sampled by SMCWPPP in WY 2019. Qualitative PHAB scores are also listed. CSCI and hybrid ASCI scores are provided for comparison.

Station Code	Creek	CSCI Score	ASCI Hybrid	IPI Score	Channel Alteration	Epifaunal Substrate	Sediment Deposition	Total PHAB Score
202TUN030	Tunitas Creek	**0.84**	0.82	**1.09**	19	17	11	47
202TUN040	Tunitas Creek	**0.94**	0.78	0.77	20	17	9	46
204BEL005	Belmont Creek	0.46	0.67	0.63	9	5	4	18
204R03635	Atherton Creek	0.49	0.46	0.49	0	1	15	16
204R04160	Burlingame Creek	0.51	0.72	**0.92**	13	11	6	30
204R04280	Belmont Creek	0.55	0.86	**0.84**	6	8	7	21
204R04428	Cordilleras Creek	0.60	0.73	**0.84**	10	9	6	25
204R04600	Atherton Creek	0.53	0.67	0.40	2	1	16	19
205R04056	Dry Creek	0.49	0.63	**0.92**	15	14	9	38
205R05044	Dry Creek	0.48	0.51	**0.87**	15	10	6	31

Overall Condition

The condition categories for each site based on two of the biological indicators (CSCI and hybrid ASCI) and physical habitat indicator (IPI) are listed in Table 2.6 and mapped in Figure 2.3. There were no WY 2019 sites that received scores in the top two condition categories for all three indicators (CSCI, ASCI, and IPI). Both of the targeted sites on Tunitas Creek had CSCI scores in the top two condition categories (≥ 0.795); however, only one of the sites was in the top two condition categories for the other indices; 202TUN030 had an IPI score in the highest category (Table 2.6, Figure 2.3). The remaining eight WY 2019 bioassessment sites were located in urban watersheds draining to San Francisco Bay and had CSCI and ASCI hybrid scores that were in the lower two condition categories.

[16] Channelization is measure of extent of reach that is armored/modified; Epifaunal substrate is measure of quantity and quality of physical habitat features (substrate, wood) that provides structure for colonization of biological communities; Sedimentation is a measure of the amount of sediment that has accumulated in the reach.

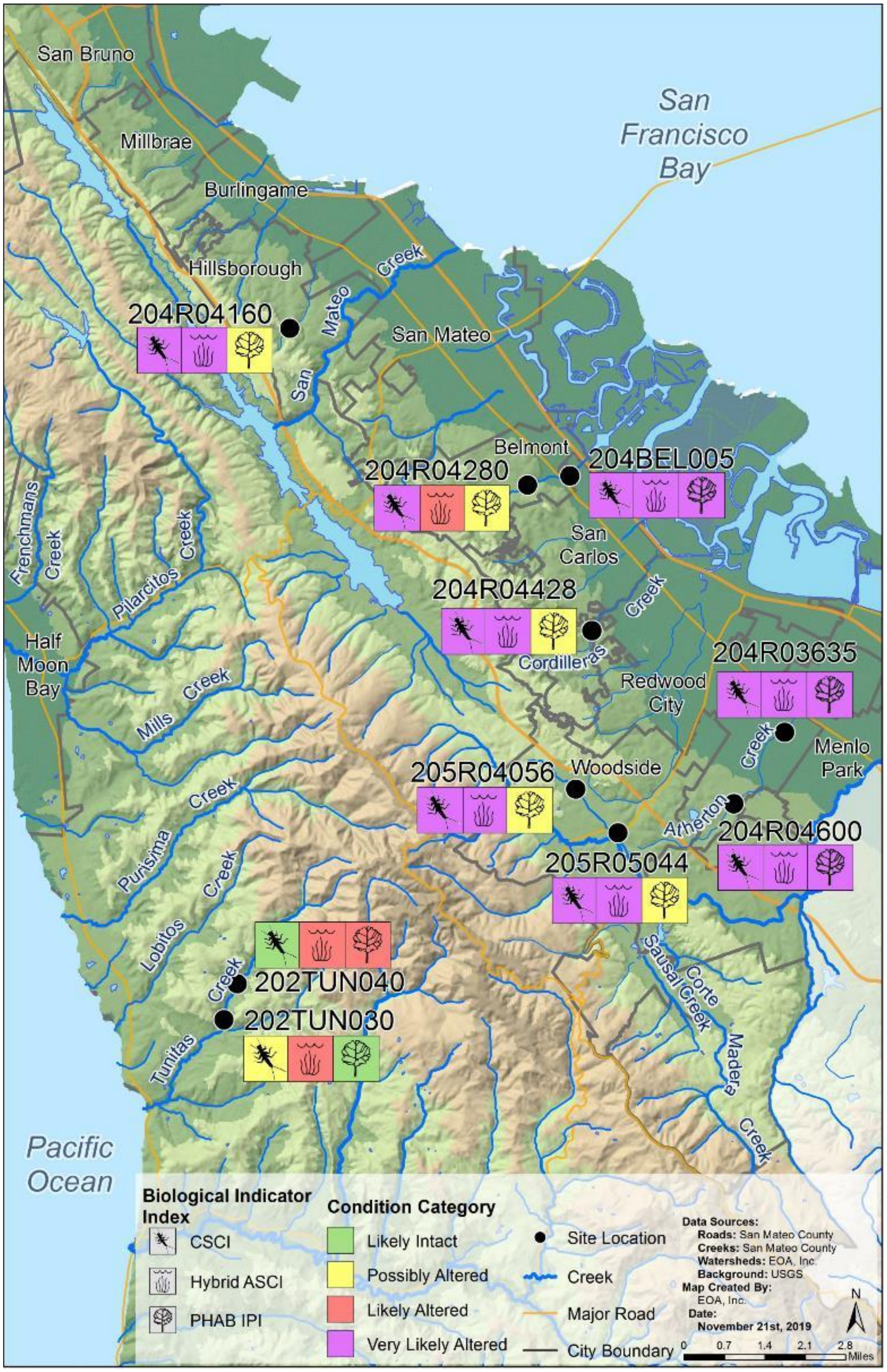

Figure 2.3. Condition category as represented by CSCI, hybrid ASCI and IPI Scores for ten bioassessment sites sampled in San Mateo County in WY 2019.

2.3.1.2 Stressor Assessment (WY 2019)

This section presents results for stressor data collected at the ten bioassessment sites in WY 2019. The comparison of WY 2019 stressor data to associated MRP triggers and/or WQOs is also documented for the purposes of maintaining the list of sites with trigger exceedances for SSID project consideration.

General Water Quality

General water quality measurements sampled at the ten bioassessment sites in WY 2019 are listed in Table 2.7. The MRP trigger threshold for specific conductance was exceeded at site 204R03635 in Atherton Creek. No other triggers or WQOs were exceeded.

Table 2.7. General water quality measurements for ten bioassessment sites in San Mateo County sampled in WY 2019.

Station Code	Creek Name	Temp (C)	DO (mg/L)	pH	Specific Conductance (uS/cm)
202TUN030	Tunitas Creek	12.7	9.8	8.3	756
202TUN040	Tunitas Creek	11.9	10.3	8.3	601
204BEL005	Belmont Creek	16.9	10.7	8.3	1224
204R03635	Atherton Creek	20.4	11.5	8.4	**2113**[a]
204R04160	Burlingame Creek	13.7	7.2	8.2	1160
204R04280	Belmont Creek	13.3	7.7	8.0	1343
204R04428	Cordilleras Creek	14.7	8.2	8.2	918
204R04600	Atherton Creek	17.4	10.1	8.1	2102
205R04056	Dry Creek	17.0	7.1	7.9	799
205R05044	Dry Creek	20.2	6.7	7.9	722

a. The MRP trigger of 2000 µS/cm was exceeded at this site.

Water Chemistry (Nutrients)

Nutrient and conventional analyte concentrations measured in water samples collected at ten bioassessment sites in San Mateo County during WY 2019 are listed in Table 2.8. Water quality objectives were not exceeded for water chemistry parameters.

Total nitrogen concentrations ranged from 0.2 to 1.2 mg/L. The two highest total nitrogen concentrations (1.2 mg/L) were measured at the two sites on Atherton Creek. Total phosphorus concentrations ranged from 0.04 to 0.18 mg/L. The two highest total phosphorus concentrations (0.17 and 0.18 mg/L) were also measured at two sites on Atherton Creek.

Chlorophyll a and ash free dry mass are two indicators of biomass. The highest concentration of chlorophyll a (260 mg/m^2) occurred at the upper elevation site on Tunitas Creek (site 202TUN040). In contrast, the lowest concentration of chlorophyll a (10 mg/m^2) occurred at the lower elevation site on Tunitas Creek (site 202TUN030). Similar discrepancies in chlorophyll a concentrations were observed between the two sites on Atherton Creek.

Table 2.8. Nutrient and conventional constituent concentrations in water samples collected at ten sites in San Mateo County during WY 2019. Water quality objectives were not exceeded. See Table 2.1 for WQO values.

Station Code	Creek	Ammonia as N	Unionized Ammonia (as N)	Chloride	AFDM	Chlorophyll a	Nitrate as N	Nitrite as N	Total Kjeldahl Nitrogen As N	Total Nitrogen	Ortho-phosphate as P	Phosphorus as P	Silica as SiO2
		mg/L	mg/L	mg/L	g/m2	mg/m2	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	WQO:	*NA*	*0.025* [b]	*250* [a]	*NA*	*NA*	*10* [a]	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
202TUN030	Tunitas Creek	0.28	0.010	72	55	10	0.07	0.002 J	0.08 J	0.2	0.04	0.05	22
202TUN040	Tunitas Creek	0.22	0.008	69	143	260	< 0.02	0.001 J	0.14	0.2	0.04	0.04	22
204BEL005	Belmont Creek	0.24	0.013	140	111	53	0.33	0.004 J	0.52	0.9	0.06	0.07	20
204R03635	Atherton Creek	0.11	0.009	220	145	220	0.5	0.005	0.66	1.2	0.15	0.18	24
204R04160	Burlingame Creek	0.15	0.005	60	390	132	0.15	< 0.001	0.69	0.8	0.13	0.16	47
204R04280	Belmont Creek	0.39	0.009	130	41	59	0.33	0.002 J	0.52	0.9	0.04	0.05	20
204R04428	Cordilleras Creek	0.08	0.003	58	83	49	0.18	0.004 J	0.44	0.6	0.04	0.05	20
204R04600	Atherton Creek	0.13	0.004	170	51	10	0.53	0.004 J	0.63	1.2	0.15	0.17	30
205R04056	Dry Creek	0.11	0.003	43	87	51	0.23	0.004 J	0.3	0.5	0.07	0.08	30
205R05044	Dry Creek	0.08	0.003	58	117	37	0.16	0.013	0.47	0.6	0.09	0.11	18
Number of exceedances		NA	0	0	NA	NA	0	NA	NA	NA	NA	NA	NA

NA = Not Applicable

J = The reported result is an estimate.

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

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

2.3.1.3 Targeted Sites (WY 2019)

<u>Tunitas Creek</u>

The Tunitas Creek watershed was targeted for bioassessment in WY 2019 to follow-up on prior CSCI scores that were relatively low for an undeveloped watershed. The SCAPE model (discussed in Section 2.2.4.7) classifies Tunitas Creek as a “possibly unconstrained” channel with CSCI scores expected to range between 0.55 and 1.05 and median expected scores of 0.83 to 1.02. However, in WY 2013, a CSCI score of 0.51 was calculated for a station on the Dry Creek tributary to Tunitas Creek (202R00268) and in WY 2016, a CSCI score of 0.55 was calculated for a station in the upper watershed (202R00488) (Figure 2.4). Both scores are in the *very likely altered* condition category. One hypothesis for this result is that lower than expected scores at site 202R00488 were the result of land uses in the watershed that are not well captured by the SCAPE model (i.e., timber growing/harvesting, ranching, and road crossings). The Tunitas Creek watershed was also targeted in WY 2019 for continuous temperature and water quality monitoring (see Section 3.4.1).

<u>Site Selection</u>

In WY 2019, the Program targeted two sites along the mainstem of Tunitas Creek for bioassessment sampling.

- **202TUN030**. Station 202R00488 was resampled and was given a new station code (202TUN030) to distinguish the results from the probabilistic dataset. It was assumed that the CSCI score from WY 2019 at 202TUN030 would be similar to the CSCI score from WY 2016 at 202R00488 (0.55). This assumption was based on another assumption that there were no changes in land uses between WY 2016 and WY 2019. The BMI communities upon which CSCI scores are based are generally responsive to land use and resilient to year-to-year changes in precipitation.

- **202TUN040**. The second station (202TUN040) was located approximately 0.7 miles upstream of 202TUN030. This location is 0.25 miles downstream of Station 202R00376, which was sampled in WY 2015 and had a CSCI score of 0.92. Station 202TUN040 is also just downstream of Rings Gulch, a relatively small (150-acre) catchment area with cattle ranching land uses. This location was intended to provide higher resolution of the CSCI score gradient along Tunitas Creek and to test whether drainage from Rings Gulch was responsible for low CSCI scores observed in Tunitas Creek at station 202R00488 / 202TUN030.

<u>Results</u>

Biological condition at sites in the Tunitas Creek watershed, as represented by CSCI and ASCI (hybrid) scores, are listed in Table 2.9. Physical habitat conditions, as represented as IPI Scores and Total PHAB Score (channel alteration, epifaunal substrate, and sediment deposition), are also listed in Table 2.9. Scores in the top two condition categories (*likely intact* and *possibly intact*) for each predictive indicator are shown with bold text. See Table 2.1 for condition category thresholds.

Table 2.9. Biological condition presented as CSCI and ASCI (hybrid) scores and Physical Habitat conditions presented as IPI Score and Total PHAB in Tunitas Creek. Bold values indicate scores in the top two condition categories.

Station Code	Year	CSCI Score	ASCI Hybrid	Physical Habitat				
				IPI Score	Channel Alteration (0 – 20)	Epifaunal Substrate (0 – 20)	Sediment Deposition (0 – 20)	Total PHAB Score (0 – 60)
202R00376	2015	**0.92**	0.69	--[1]	18	15	16	49
202TUN040	2019	**0.94**	0.78	0.77	20	17	9	46
202R00488 / 202TUN030	2016	0.55	0.75	**1.04**	20	17	9	46
	2019	**0.84**	0.82	**1.09**	19	17	11	47
202R00268	2013	0.51	**0.99**	--[1]	17	10	7	34

[1] Riparian data required for the calculation of IPI Scores was not collected prior to 2016.

CSCI Scores

The CSCI score in WY 2019 was 0.84 (*possibly intact* condition category), which is within the range predicted by the SCAPE model. This CSCI score is almost 0.3 points higher than CSCI score at same location sampled during WY 2016. The reason for the change in score between the two years is uncertain. There are no known changes in land use. For example, no large developments were constructed during this time period. However, there could have been changes in land management practices on ranches, private forests, and open space areas in the watershed. A large portion of the upper watershed is within the County Timberland Preserve Zone (TPZ; see Figure 2.4). Timber growing and harvesting uses can be permitted in the TPZ area.

Another possible explanation for the change in CSCI scores is a change in drought condition. Water Year 2016, when the score of 0.55 was observed, was the fifth year of an extended dry period that began in WY 2012 and ended with a very wet year in WY 2017. Although the CSCI tool is reported to be resilient to drought conditions (Mazor et al. 2009), it may be more susceptible to wet and dry years in some types of watersheds, such as Tunitas Creek which is perennial with large areas of protected open space, privately-owned redwood forests (TPZ areas), and small ranching operations (Figure 2.4).

These results suggest that there may be year-to-year variability in CSCI scores. Additional bioassessment monitoring over time at this site may provide additional insights into overall variability in conditions and/or changes in stressor levels.

ASCI Scores

A comparison of the ASCI hybrid scores for WY 2016 and WY 2019 at Station 202TUN030 also show variation. Scores for this index increased from 0.75 in WY 2016 to 0.82 in WY 2019.

Physical Habitat Scores

In contrast to CSCI and ASCI scores, there was very little change in any of the physical habitat measures between WY 2016 and WY 2019 at Station 202TUN030. IPI scores in both years were above 0.94 and thus in the *likely intact* condition category. The qualitative habitat (PHAB) scores were also similar between the two years. Channel alteration and epifaunal substrate were both in the optimal range; however, sediment deposition (9 in WY 2016 and 11 in WY 2019) indicated marginal performance.

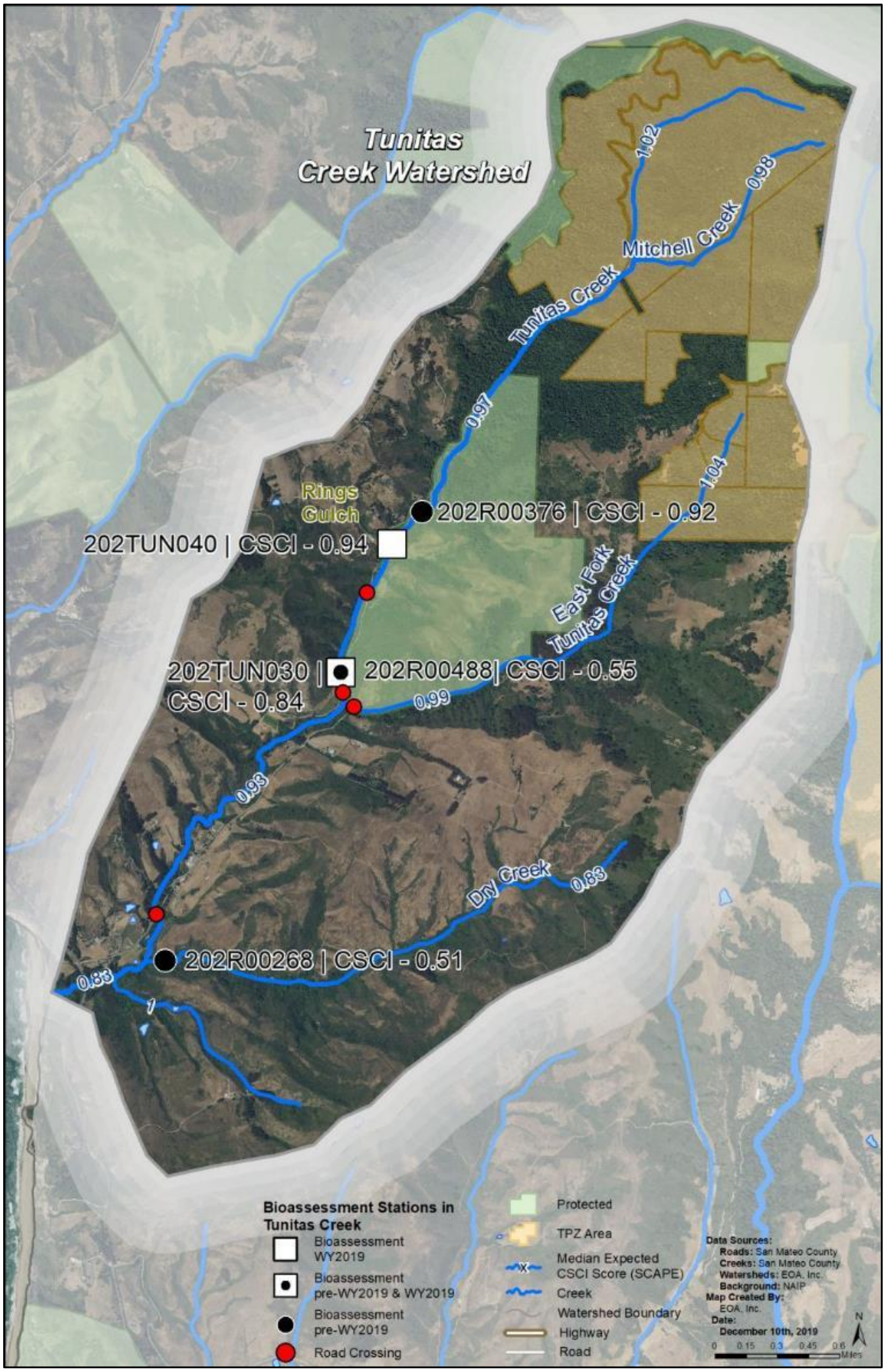

Figure 2.4. Bioassessments stations in the Tunitas Creek Watershed, San Mateo County, WY 2015 – WY 2019.

Belmont Creek

The purpose for conducting targeted bioassessment sampling on Belmont Creek was to establish baseline data on biological and physical habitat conditions prior to potential construction of a flood control project. The San Mateo County Flood and Sea Level Rise Resiliency Agency is coordinating with the Cities of Belmont and San Carlos on the Belmont Creek Watershed Management Plan (Watershed Plan) to address flooding issues in lower Belmont Creek (creek reach between Old County Road and Industrial Road) (Erika Powell, San Mateo County PWD, personal communication, 2019). In addition to flood protection, the Watershed Plan would include measures to reduce impacts to the channel (e.g., prevent erosion in upstream reaches), incorporate green infrastructure and improve water quality.

A flood by-pass channel, just upstream of Old County Road, is one of the alternatives being considered for the Watershed Plan. The targeted sampling location was in the reach that historically floods, just downstream of Old County Road (Figure 2.5). Figure 2.5 shows the sampling location, CSCI score, and additional bioassessment monitoring data collected by SMCWPPP at three probabilistic sites in Belmont Creek from WY 2012 to WY 2019.

Bioassessments were conducted at the targeted monitoring site in Belmont Creek on May 13, 2019 and results are presented in Sections 2.3.1.1 and 2.3.1.2. Additional bioassessment monitoring at the targeted site may occur in the future, following the completion of different components of the Watershed Plan.

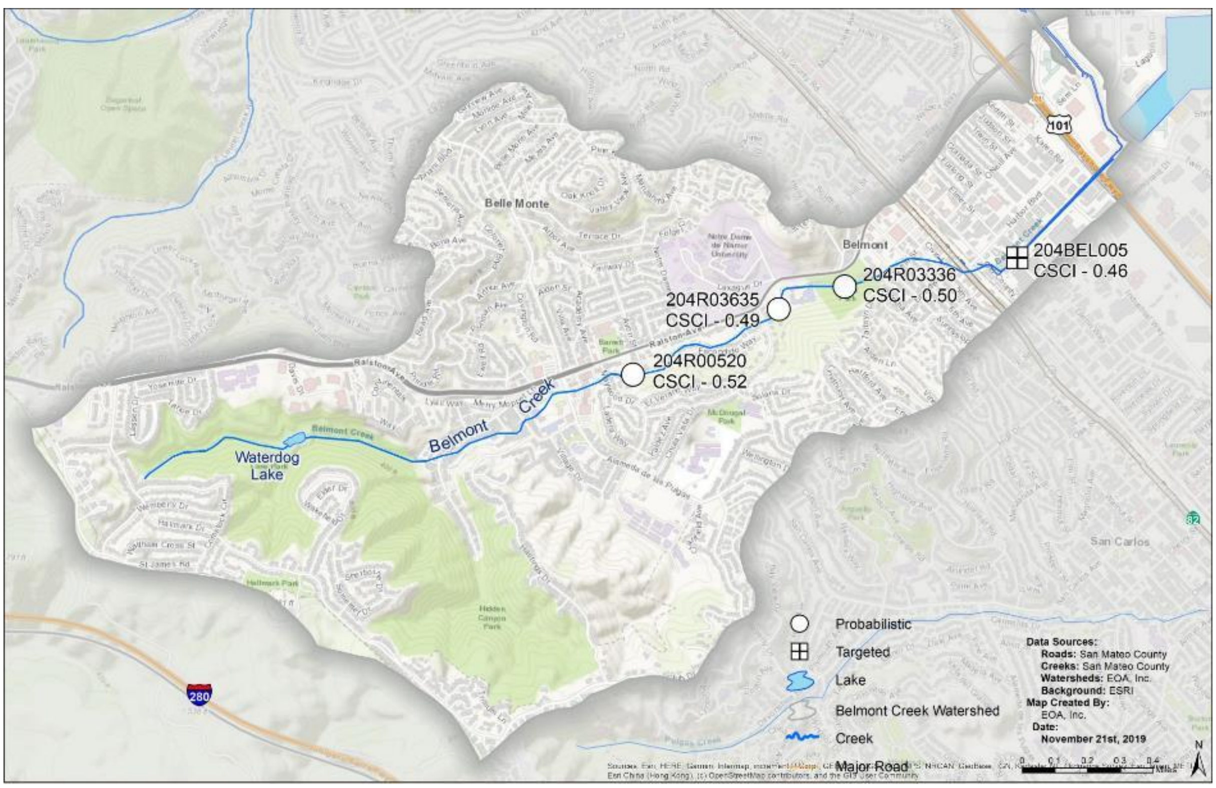

Figure 2.5. Bioassessments stations in the Belmont Creek Watershed, San Mateo County, WY 2012 – WY 2019.

2.3.2 Evaluation of Countywide Bioassessment Results (WY 2012 – WY 2019)

This section addresses the first two bioassessment monitoring management questions presented at the beginning of Section 2.0 by summarizing WY 2012 – WY 2019 biological condition data and comparing condition scores to synoptically-collected stressor data.

The first bioassessment monitoring management question (i.e., *What is the condition of aquatic life in creeks in the RMC?*) is addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. As part of the RMC Bioassessment Monitoring Program, 90 sites were sampled by SMCWPPP (n=80) and SWAMP (n=10) in San Mateo County from WY 2012 to WY 2019. SMCWPPP sampled 65 urban and 15 non-urban sites and SWAMP sampled 10 non-urban sites. All monitoring sites were derived from the RMC sample frame, except for three targeted sites that were sampled during WY 2019.

The bioassessment data collected at probabilistic sites (n=87) were evaluated to assess the current condition of water bodies in the County and to identify stressors that are likely to pose the greatest risk to the health of those streams. The methods used to evaluate bioassessment data are consistent with the approach used to develop the RMC Five-Year Bioassessment Report (BASMAA 2019). A detailed description of the methods and results used for the countywide analysis of bioassessment data is provided in Attachment 3. A summary of the methods and results is presented below.

The overall extent of biological conditions in San Mateo County streams was estimated using cumulative distribution functions (CDFs). CDF sample weights were calculated as the total stream length in the RMC sample frame divided by the stream length evaluated in each land use category (urban and non-urban). The adjusted sample weights were used to estimate the proportion of stream length (average and 95% confidence interval) represented by CSCI and hybrid ASCI scores for all SMCWPPP sites combined, as well as urban and non-urban sites only. All calculations were conducted using the R-package *spsurvey* (Kincaid and Olsen 2016).

The second bioassessment monitoring management question (i.e., *What are major stressors to aquatic life in the RMC area?*) is addressed by evaluation of physical habitat, land use, and water chemistry data collected at the probabilistic sites, as potential stressors to biological health. Potential stressors to biological condition were evaluated using Spearman's rank correlation analysis and random forest statistical models. The stressor variable list consisted of 50 quantitative environmental variables, related to water quality, physical habitat, and land use factors that could potentially influence biological condition scores. In addition, two categorical factors (Land Use and Strata) were used to evaluate condition scores for different types of streams. Watershed drainage location (Pacific Ocean versus San Francisco Bay) was used as the strata to evaluate regional differences in biological conditions.

2.3.2.1 Site Evaluations

A total of 514 randomly selected monitoring sites were sampled in the RMC region between 2012 and 2019. Eighty-seven of these sites (17%) were located in San Mateo County, representing a total stream length of 91.6 km. Sixty-four of the sites in San Mateo County (74%) were from urban streams and channels.

A total of 250 sites were initially evaluated to obtain the 87 sites that were ultimately sampled. This equates to a rejection rate of about 65%, which can largely be attributed to sites corresponding to areas that were not sampleable, e.g. due to lack of flow, lack of creek, tidal influence, or accessibility. As of the beginning of WY 2020, there are 500 sites remaining in the RMC sample draw for San Mateo County. The majority of these sites correspond to the non-urban portion of the County (472 of 500 sites). Assuming a rejection rate of 65%, the sample draw will likely only be sufficient to provide new sites through WY 2020.

2.3.2.2 Countywide Biological Conditions (WY 2012 – WY 2019)

A summary of CSCI and three ASCI index scores from bioassessment sites in San Mateo County sampled between 2012 and 2019 is presented in Table 2.10. A total of 60 of the 90 (67%) bioassessment sites (including three targeted sites) received CSCI scores below the MRP trigger of 0.795, which corresponds to the two lower condition categories *(likely altered* and *very likely altered)* (Table 2.10 and Figure 2.6). Fifty-five of the 60 sites with CSCI scores below 0.795 were in streams classified as urban. As a reminder, urban areas were delineated by combining urban area boundaries and city boundaries defined by the U.S. Census (2000). Non-urban areas were defined as the remainder of the RMC area. Some sites classified as urban fall near the non-urban edge of the city boundaries and have little upstream development.

Table 2.10. Number of sites grouped by land use classification for each condition category for the four biological indicators.

Index[1]	Sites with index score[2]	Land Use	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
CSCI	90	Urban	6	4	8	47
		Non-Urban	13	7	2	3
ASCI-D	90	Urban	7	7	12	39
		Non-Urban	10	7	5	3
ASCI-SB	85	Urban	29	16	5	10
		Non-Urban	15	5	3	2
ASCI-H	85	Urban	1	5	8	47
		Non-Urban	10	3	9	3

[1] Indices: CSCI = California Stream Condition Index; ASCI-D = Diatom Algae Stream Condition Index; ASCI-SB = Soft Bodied Algae Stream Condition Index; ASCI-H = Hybrid Algae Stream Condition Index.

[2] Index scores for ASCI-SB and ASCI-H were not calculated for 5 bioassessment sites due to insufficient soft algae taxa needed to calculate score.

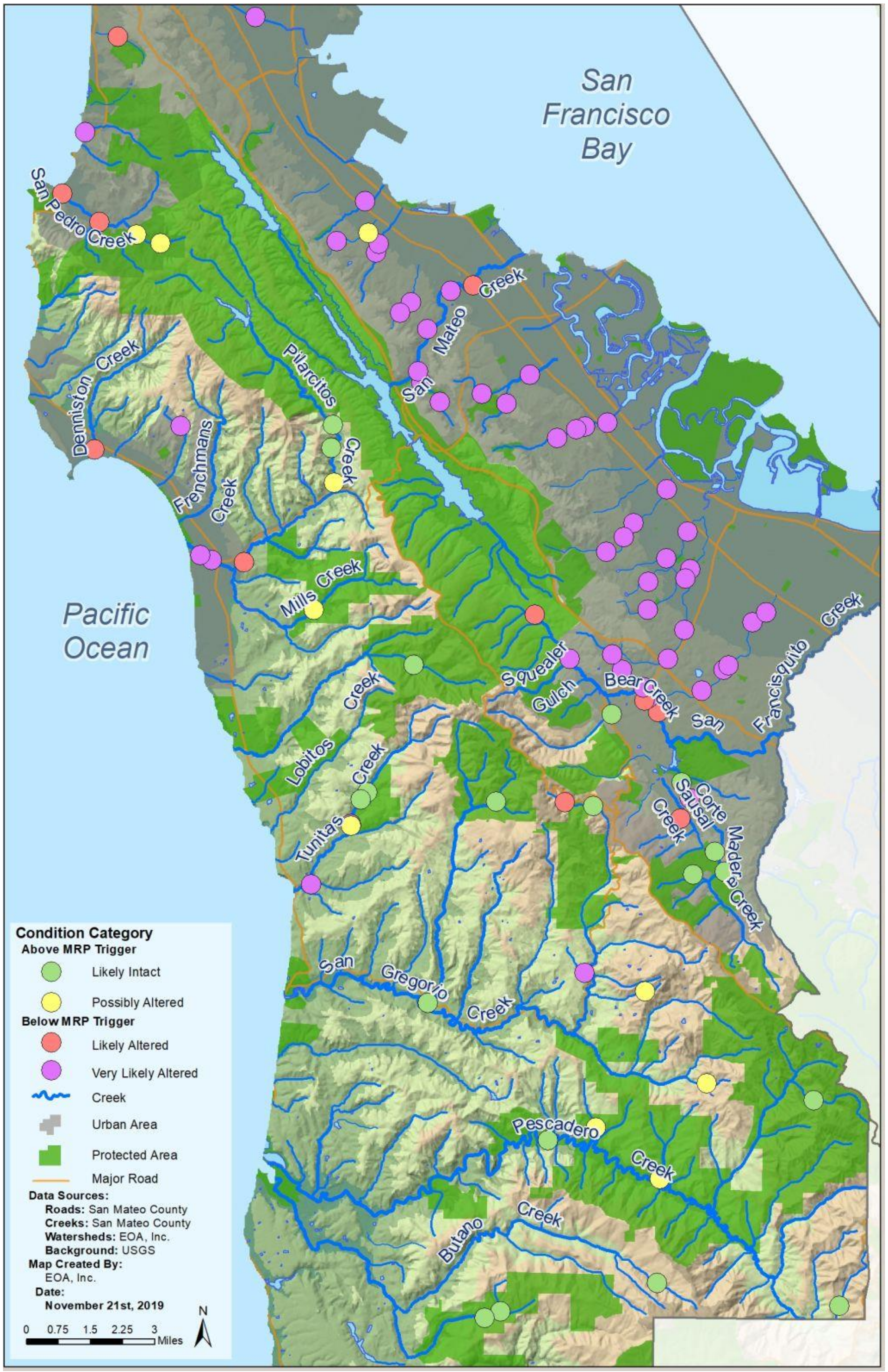

Figure 2.6. Biological conditions categories for CSCI at 90 bioassessment sites in San Mateo County sampled between WY 2012 and WY 2019.

The number of sites receiving scores within the lower two condition categories (*likely altered* and *very likely altered*) for the diatom and hybrid ASCI indices was similar to the CSCI index, with 59 and 67 sites, respectively. The number of sites in the two lower condition categories for the soft-bodied algae ASCI was substantially less (20) than the other three indices (Table 2.10). There were proportionally more urban sites that had ASCI-SB index scores in the two higher condition categories (75%) compared to the other three indices (ranged 10-23%), indicating that the soft-bodied algae index may not respond well to urban disturbance gradients.

Figure 2.7 shows the proportion of scores in each condition category for the four indicators (CSCI, ASCI-D, ASCI-SB, ASCI-H) for two strata: creeks flowing to the Pacific Ocean and creeks flowing to San Francisco Bay. Overall, the proportion of sites with good biological condition (*likely intact*) was higher in creeks draining in the Pacific Ocean compared to sites located in watersheds draining into the San Francisco Bay. Within each of the strata, CSCI, ASCI-D, and ASCI-H indicator scores showed a high degree of similarity. In contrast, the soft-bodied algae index scores (ASCI-SB) had a higher proportion of sites in the highest condition category (*likely intact*). The contrast is particularly evident in creeks flowing to San Francisco Bay. This is consistent with the observation described above that the ASCI-SB may not respond well to urban disturbance gradients, as a greater number of the bayside creek sites are urban.

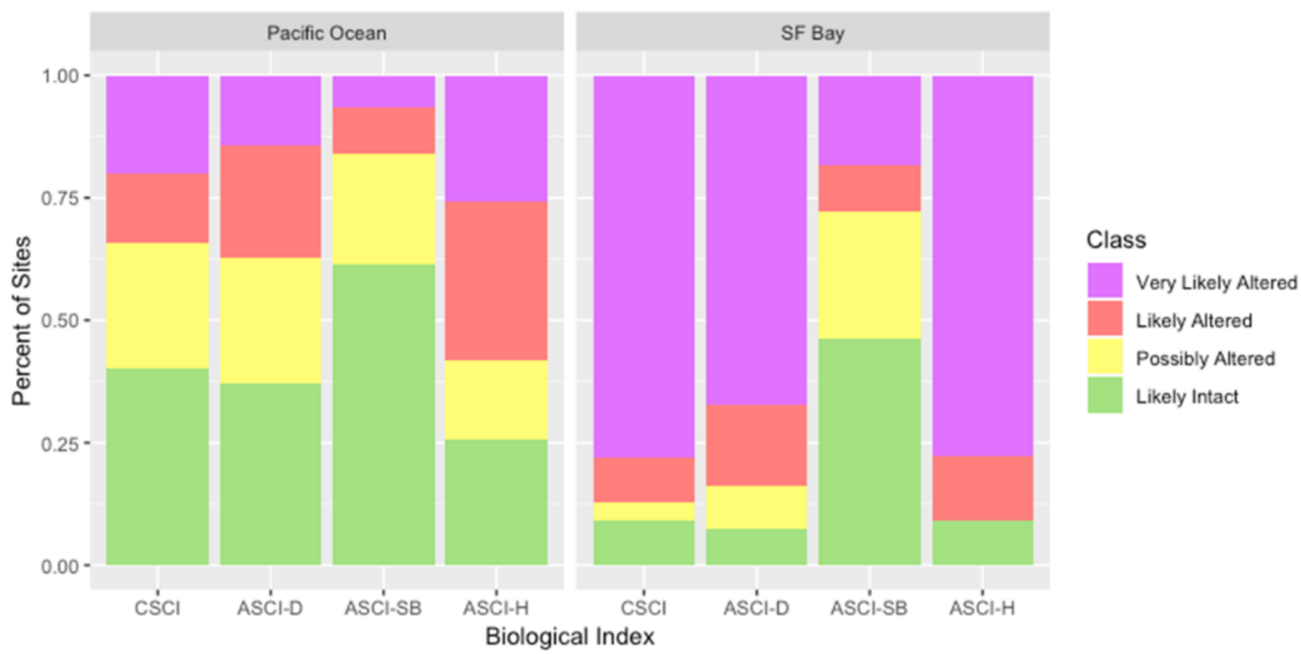

Figure 2.7. All San Mateo County biological condition scores (WY 2012 – WY 2019) grouped by condition category and strata (n=90, including 3 targeted WY 2019 sites)

Figure 2.8 includes four plots showing cumulative distribution functions for the four biological condition indicators (CSCI, ASCI-D, ASCI-SB, and ASCI-H). Each plot shows CDFs for urban sites (n=64) all sites (n=87[17]), and non-urban sites (n=23). The CDFs can be used to determine the probability that a random observation will be less than or equal to a certain value. The dashed lines show the uncertainty around these estimates. For example, there is a 48% probability that a random site in San Mateo County will have a CSCI score below 0.79 (i.e., *likely altered* or *very likely altered*). There is an 86% probability that a random *urban* site in San Mateo County will have a CSCI score below 0.79 and there is a 22% probability that a random *non-urban* site will have a CSCI score below 0.79.

The CDFs for the various indicators are shaped differently illustrating the differences in scores in the San Mateo County dataset. The responsiveness or lack of responsiveness of the indicator to urban land uses is illustrated by the separation of the “urban” line from the “all sites” and “non-urban” lines. The CSCI CDFs have the greatest degree of separation between the urban line and the others; whereas, the ASCI-SB CDFs have the smallest degree of separation. As stated previously, the ASCI-SB may not respond to urban disturbance gradients in San Mateo County streams.

[17] CDFs were developed using only the 87 probabilistic sites.

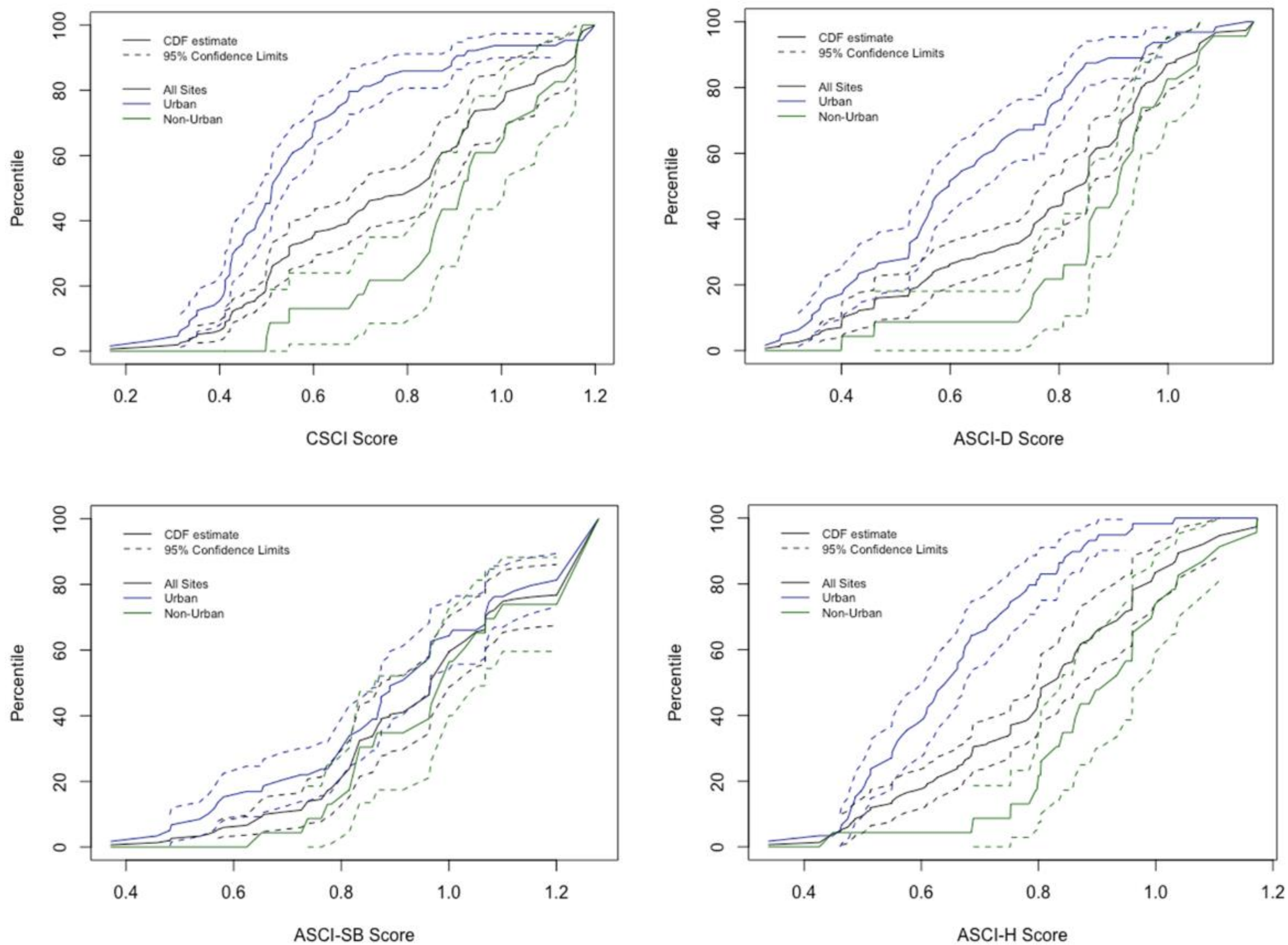

Figure 2.8. Cumulative distribution functions of CSCI, ASCI-D, ASCI-H and ASCI-SB scores in San Mateo County (n = 87)

2.3.2.3 Stressor Association with Biological Conditions (WY 2012 – WY 2019)

To evaluate the association of stressors with biological condition, Spearman's rank correlation analyses and random forest modeling was performed. The correlation was conducted first to prune the list of 50 potential stressor variables. Nineteen of the 50 variables exhibited a statistically significant correlation with at least one of the four biological indices (CSCI, ASCI-D, ASCI-SB, ASCI-H). Many of the correlated variables were representative of land use (i.e., road density, road crossings, impervious and urban area). Three variables were related to water quality (Total Nitrogen, Total Kjeldahl Nitrogen, and temperature); and four variables were representative of physical habitat (filamentous algae cover, channel alteration, epifaunal substrate and combined human disturbance index).

The prioritized list of 19 variables was used in random forest model development for CSCI and ASCI-H. Random forest model results indicated better relationships between stressors and CSCI scores compared to stressors and ASCI-H scores. The random forest models showed that 64% of the variability in CSCI scores could be explained with eight predictor (stressor) variables; whereas, only 43% of the variability ASCI-H scores could be explained with seven predictors.

The CSCI random forest model indicated that land use and physical habitat variables were most influential in predicting biological condition as expressed by CSCI scores (Table 2.11). The ASCI-H random forest model indicated that land use and water quality variables were most influential in predicting biological condition as expressed by ASCI-H scores (Table 2.12). The percent impervious and percent urban in 5k area were top stressor variables for CSCI and ASCI-H, respectively (see Section 2.3.2.4 for more discussion on urban influence on biological conditions).

Table 2.11. Summary statistics for the CSCI random forest model. Ranking of most influential predictor variables are colored according to: physical habitat (green), land use (orange), and water quality (blue).

Stressor Variable	% Increase MSE	Increase Node Purity
Percent Impervious Area in 5km (PctImp_5K)	15.8	0.81
Road Density in 1 km (RdDen_1K)	15.5	0.72
Total Nitrogen (TotalN)	15.2	0.33
Road Density in Watershed (RdDen_W)	15.1	0.43
Percent Impervious Areas of Reach (PctImp)	14.1	0.44
Total Kjeldahl Nitrogen (TKN)	12.1	0.32
Epifaunal Substrate Score	12.1	0.36
Percent Urban in 5 km (PctUrb_5K)	10.9	0.39

Table 2.12. Summary statistics for the ASCI-H random forest model. Ranking of most influential predictor variables are colored according to: land use (orange) and water quality (blue).

Stressor Variable	% Increase MSE	Increase Node Purity
Percent Urban Area in 5 km (PctUrb_5K)	15.5	0.39
Percent Impervious Areas of Reach (PctImp)	14.9	0.22
Road Density in 1 km (RdDen_1K)	13.9	0.34
Road Crossings in 5 km (RdCrs_5K)	11.7	0.23
Temperature (Temp)	11.6	0.28
Road Density in 5 km (RdDen_5K)	11.2	0.28
Total Kjeldahl Nitrogen (TKN)	10.0	0.13

The stressor analysis of biological condition in San Mateo County streams using BMIs (CSCI scores) and algae (ASCI scores) has shown that both types of assemblages correlate with landscape factors, as well as unique sets of water quality and habitat stressors. It should be acknowledged that despite these apparent relationships to stressors, these analyses do not determine causation, particularly as stressors from habitat/landscape factors are often present at the same sites that exhibit water quality impairment.

Comparison of San Mateo Stressor Assessment to RMC Regional Assessment

The analyses of stressor data association for San Mateo bioassessment sites was similar to findings in the RMC Five-Year Bioassessment Report (BASMAA 2019). Regional biological condition, based on CSCI scores, was strongly influenced by physical habitat variables and land use within the vicinity of the site. The percent of the land area within a 5 km radius of a site that is impervious appears to have the largest influence on CSCI scores based on the regional random forest model results. Regional biological condition, based on an algae diatom index, was moderately correlated with water quality variables, and less associated with physical habitat or landscape variables (note: the algae index used for the RMC report was different than the ASCI index used in this report).

However, the RMC report showed that nutrient variables (e.g., nitrate, total nitrogen, orthophosphate, phosphorus) did not correlate strongly with CSCI scores in the Bay Area, nor were nutrients ranked as important variables explaining CSCI scores via the random forest model. These results are in contrast to the San Mateo stressor data analyses, which found that total nitrogen and TKN were significantly correlated to CSCI scores.

2.3.2.4 Biological Conditions in Urban Landscapes

The previous section shows that biological indicator scores appear highly sensitive to urbanization. The correlation and random forest analyses of stressor association with biological conditions indicated that percent impervious area has the greatest influence on both CSCI and ASCI-H scores. The relationship is strongest for sites in the San Francisco Bay strata (Figure 2.9).

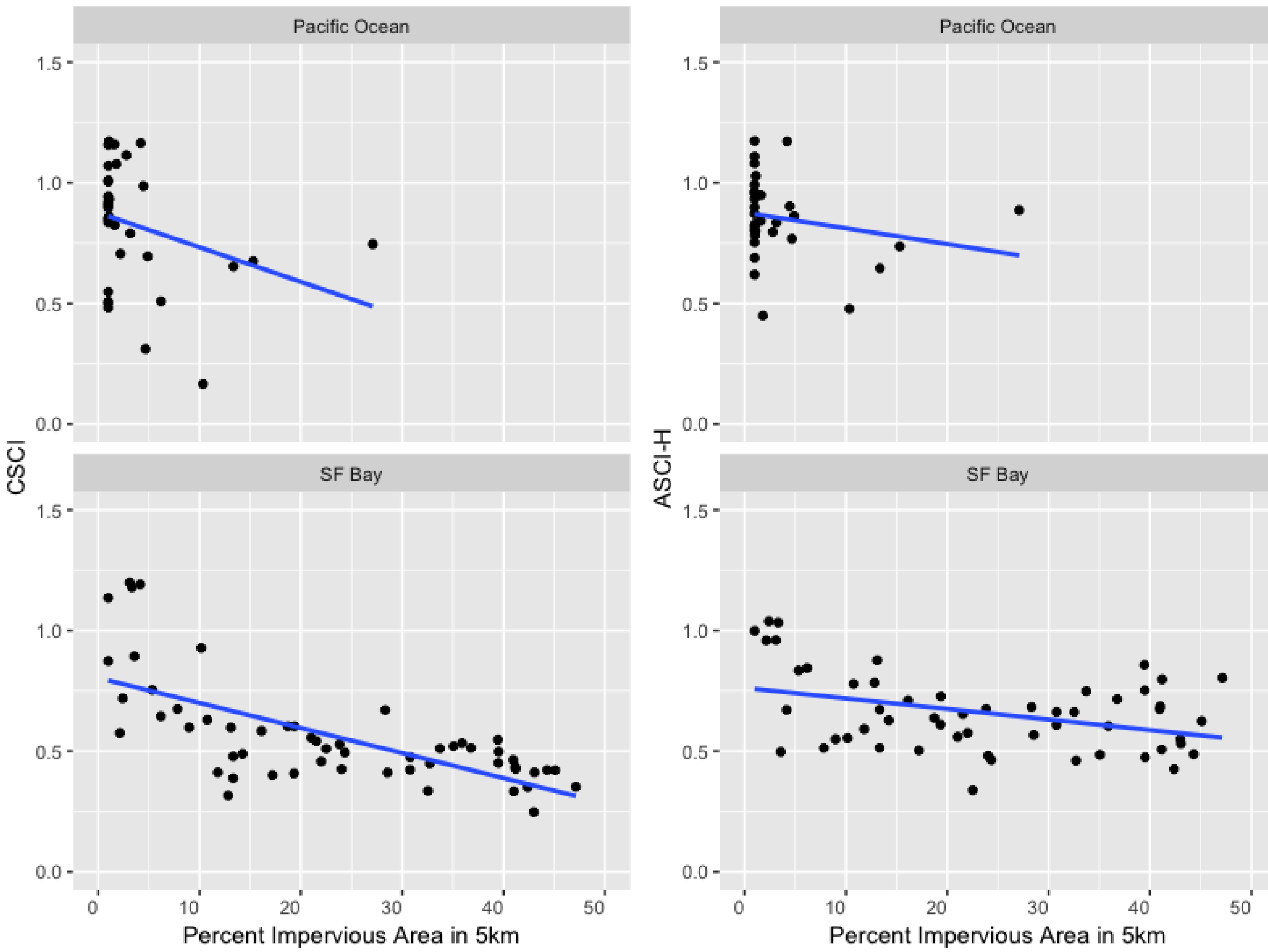

Figure 2.9. Percent Impervious Area in 5 km vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

The distribution of CSCI and ASCI-H scores for the 90 bioassessment sites in San Mateo County, presented as box plots, is shown for three classes of urbanization, represented by percent watershed imperviousness (Figure 2.10). For highly developed watersheds (>10% impervious area), the median CSCI score was below 0.5 and all but three sites were below the MRP trigger (0.795). The variability in CSCI scores was lower at sites in highly developed watersheds, indicating that BMI communities are consistently impacted by stressors associated with urbanization.

Sites with a moderate level of urbanization (3-10%) had a median CSCI score of about 0.75. These sited ranged 0.5 to 1.2 in CSCI scores, indicating a much wider range of stressor impacts associated with urbanization (and other factors). Sites with a low level of urbanization (<3% impervious area) were generally in good biological conditions, with a median CSCI score of about 0.83. However, there were some low scoring sites, indicating non-urban stressors were impacting those sites.

The ASCI hybrid scores showed very similar patterns with regards to three classes of urbanization (Figure 2.10). A wider range in scores at sites in highly developed watersheds may indicate a wider range of responses to urban stressors (i.e., algae may have less sensitivity to habitat modification).

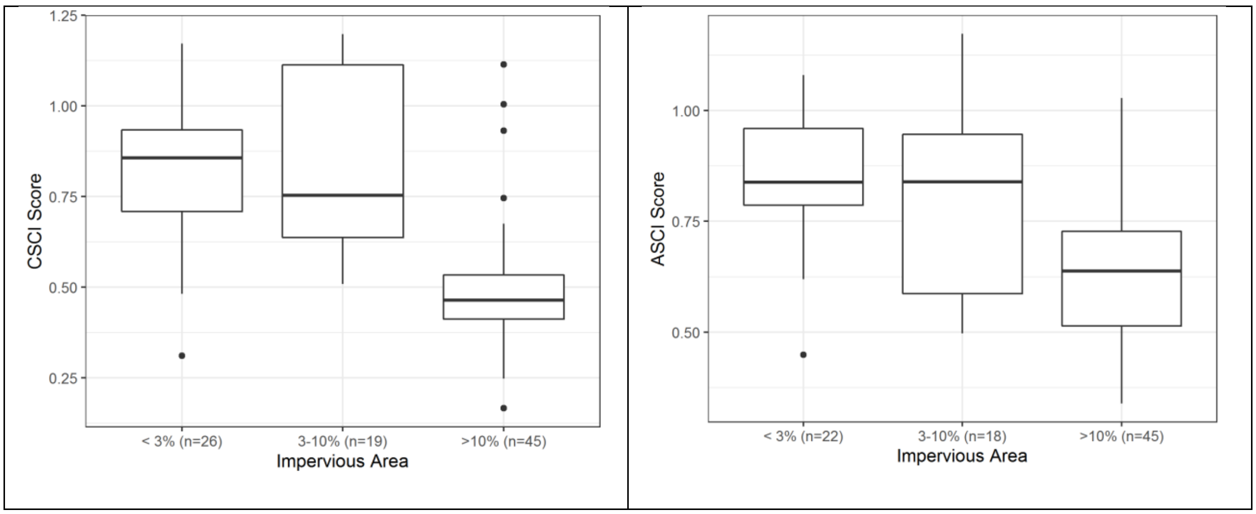

Figure 2.10. Box plots showing the distribution of CSCI and ASCI-H scores for 90 bioassessment sites in San Mateo County, grouped by three classes of percent watershed imperviousness.

2.3.3 Trend Analysis

This section addresses the third bioassessment monitoring management question presented at the beginning of Section 2.0 (i.e., *What are the long-term trends in water quality in creeks over time?*) by assessing the change in biological condition over several years. Changes in biological condition over time can help evaluate the effectiveness of management actions. For example, control measures, such as green stormwater infrastructure (GSI), implemented to disconnect impervious areas, should result in improved stream condition and water quality. Many of these measures are still in the planning phase and it may take decades to see their benefits. Therefore, more than eight years of data will be required to evaluate trends. In the interim, a preliminary trend analysis is presented using probabilistic data and historic data collected prior to adoption of MRP 1.0.

Figure 2.11 shows the distribution of CSCI scores calculated for urban sites for each year of MRP monitoring (WY 2012 – WY 2019). Over the eight-year monitoring period, biological conditions, based on CSCI scores, have been relatively consistent at urban sites (median scores around 0.5), with the exception of a couple of years (WY 2012 and WY 2018) when median CSCI scores ranged from 0.6 to 0.7 (Figure 2.11)

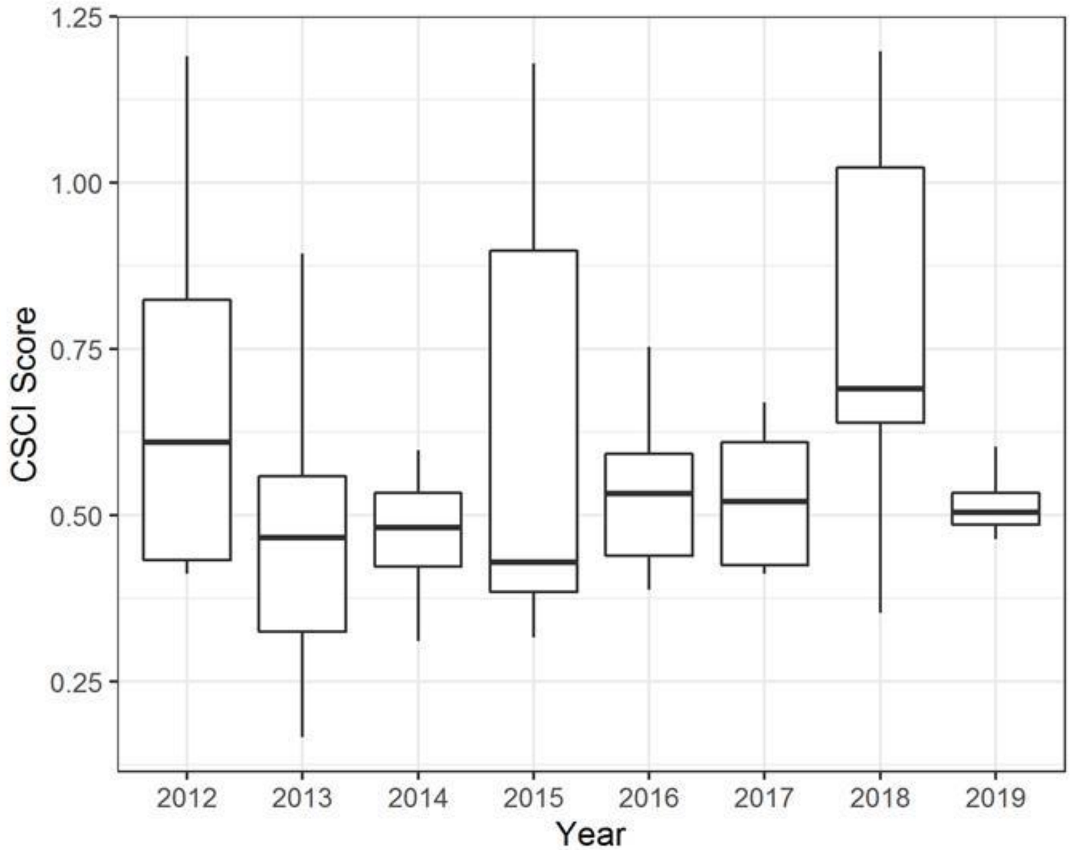

Figure 2.11. Box plots showing the distribution of CSCI scores at urban sites in San Mateo County, WY 2012 – WY 2019.

Comparison of MRP Data to Historic Data

The Program conducted bioassessments in four watersheds between 2002 and 2007 as part of watershed assessment and monitoring requirements in its municipal stormwater NPDES Permit (Pre-MRP). Bioassessments were conducted in San Pedro Creek (2002 and 2003), San Mateo Creek (2004), Cordilleras Creek (2005 and 2006) and Belmont Creek (2006 and 2007). The total number of bioassessment surveys conducted in San Mateo County watersheds during Pre-MRP and MRP time periods is shown in Table 2.13. Watersheds with less than four sampling locations were combined into two groups: "Tributaries to San Francisco Bay" and "Tributaries to Pacific Ocean".

Bioassessment sampling during the Pre-MRP time period was conducted using the California Stream Bioassessment Protocol (CSBP), a different methodology than the SWAMP Bioassessment Reachwide Protocol which was implemented during the MRP. The CSBP was the standardized methodology developed by California Department Fish and Wildlife for bioassessments conducted in streams throughout California. BMI samples collected using the CSBP method have been shown to produce taxonomic metric scores similar to the SWAMP protocol. In addition, the level of taxonomic identification (SAFIT Level 1+) is consistent for samples collected and analyzed during Pre-MRP and MRP, which allows for a consistent and standard approach to calculate CSCI scores.

Table 2.13. Total number of bioassessment surveys conducted by SMCWPPP, grouped by watershed, during MRP and Pre-MRP.

Watershed	Bioassessment Sites	
	MRP	Pre-MRP
Monitoring Period	2012-2019	2002 - 2007
San Francisco Bay		
Atherton Creek	5	0
Belmont Creek	4	5
Cordilleras Creek	4	7
Redwood Creek	8	0
San Francisquito Creek	16	0
San Mateo Creek	6	6
Tributaries to SF Bay	11	0
Pacific Ocean		
Pescadero Creek	8	0
Pilarcitos Creek	6	0
San Gregorio Creek	7	0
San Pedro Creek	4	7
Tributaries to Ocean	6	0
Tunitas Creek	4	0
Total	90	25

Biological conditions based on CSCI scores during the Pre-MRP and MRP time periods were compared for four San Mateo County watersheds. Bioassessment sites were well distributed throughout each watershed for both monitoring periods. The sample time frames were approximately 7-10 years apart. During the Pre-MRP monitoring period, some sites were sampled two consecutive years; average CSCI scores were used for these sites. The distribution of CSCI scores for each watershed, grouped by the Pre-MRP and MRP time periods is shown in Figure 2.12. Median CSCI scores were consistently higher in all four watersheds during the MRP sample period.

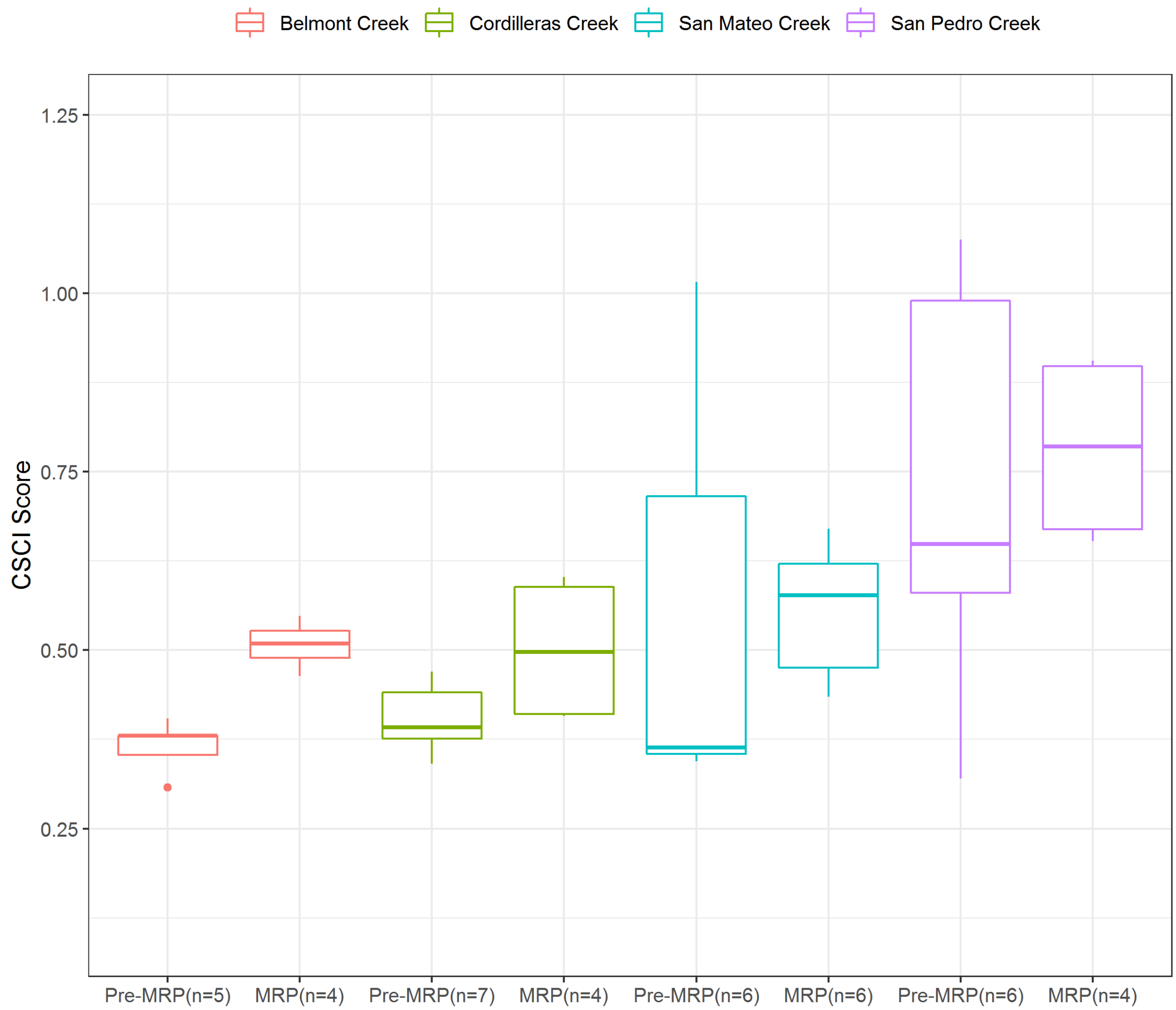

Figure 2.12. Distribution of CSCI scores at sites in four San Mateo County watersheds that were sampled during Pre-MRP and MRP time periods.

A comparison of CSCI scores at individual sites that were sampled during the two sampling periods is shown in Table 2.14. SWAMP Station codes were used for sites sampled during Pre-MRP. The CSCI scores for both sampling events that occurred during Pre-MRP time period are shown. Similar to the overall watershed results previously discussed, the CSCI scores were higher for sampling events that occurred during the MRP time period.

The higher CSCI scores observed at watershed/sites during the MRP time period may be an indication that biological conditions have improved since the Pre-MRP time period. It is important to note that biological condition, based on CSCI scores, can be influenced by many factors, including: timing and magnitude of storm events during sampling index period, variable antecedent conditions (e.g., precipitation, temperature), and changes in management actions (e.g., operations related to water releases from reservoirs or diversions). It is not clear, especially with such a small sample size, what factors might be associated with general trend of improved biological conditions at these watersheds/sites.

Table 2.14. CSCI scores for bioassessments conducted at three San Mateo County sites during two different monitoring periods: Pre-MRP and MRP.

Site Name	Status	Station ID	Sampling Date	CSCI Score
San Pedro Creek at Sanchez Art Center	Pre-MRP	202SPE040	15-May-02	0.65
		202SPE040	27-Apr-03	0.62
	MRP	202R03404	17-May-18	0.65
Belmont Creek at Misty Lane	Pre-MRP	204BEL030	04-May-06	0.33
		204BEL030	04-Apr-07	0.29
	MRP	204R00520	28-May-13	0.52
Cordilleras Creek downstream of El Camino Real	Pre-MRP	204COR010	25-Apr-05	0.35
		204COR010	02-May-06	0.38
	MRP	204R02548	17-May-16	0.41

2.4 Considerations for Future Bioassessment Monitoring

The RMC bioassessment dataset provides a comprehensive survey of stream health throughout the San Francisco Bay Area. The probabilistic design allows for an evaluation of ambient stream conditions using biological indicators and stressor data at regional and countywide scales. These data provide stormwater programs with an understanding of existing stream conditions that can assist in the decision-making process for future management actions, as well as baseline conditions that can be re-evaluated over time to assess trends.

The urban sites for most counties within the RMC sample frame will be exhausted (i.e., either sampled or evaluated) following Creek Status Monitoring during WY 2020. As result, the RMC is currently evaluating options for revising the monitoring design to address the Creek Status Monitoring requirements anticipated under MRP 3.0. One of the options under consideration by the RMC is to implement a targeted monitoring design that would focus on specific watersheds or reaches of interest. A watershed approach would provide stormwater programs more flexibility to evaluate priority areas that stakeholders want to improve, protect, or learn more about. The following objectives could be used to guide the monitoring design:

- Address existing problems (i.e., poor biological conditions, water quality issues) at locations where implementation of potential management actions is practical and feasible.
- Evaluate changes in biological conditions and/or water quality at locations that are likely affected by planned management activities.
- Actively monitor and manage areas that are in good condition.

Examples for each of these approaches are provided in section below:

2.4.1 Investigate Sites with Reduced Biological Conditions

The RMC dataset indicates majority of urban streams are in poor condition. Biological conditions were poor (i.e., lowest two condition categories) at 85% and 90% of the bioassessment sites classified as urban, based on CSCI and ASCI-H scores, respectively. This suggests that stressors associated with urban streams (e.g., poor physical habitat, hydromodification) may create too many constraints to achieve good biological conditions (as defined in the MRP. As a result, stormwater programs may want to focus resources on better understanding the biological conditions of urban sites/reaches that have a higher potential for improved conditions due to management actions.

The SCAPE tool (discussed in Section 2.2.4.7) is an existing channel model that provides a context for evaluating stream health by estimating an expectation of biological condition at a given stream reach relative to landscape constraints. Biological condition, based on CSCI scores, can be compared to the reach expectation. As an example, CSCI scores for 16 sites sampled in San Francisquito Creek watershed over an eight-year period were compared to the range of scores predicted by the landscape model (Figure 2.13). The predicted range of CSCI scores for these sites are fall into two stream classifications: possibly constrained (light red), and possibly unconstrained (light blue). The CSCI scores for bioassessment sites (i.e., Relative Site Score) are represented by either circles or triangles superimposed over the predicted range of CSCI scores estimated by the model. Sites that have CSCI scores higher than model predictions are depicted by an up-pointing triangle symbol (i.e., “over scoring”); sites with CSCI scores lower than model predictions were depicted by an inverted triangle (i.e., under scoring”).

There was one “under scoring site” in San Francisquito Creek watershed. Dry Creek, tributary to Bear Creek, (site 205R01704) was below the predicted range for “possibly constrained” stream segment. A second site on Dry Creek (site 205R02728) was also on the very low end of the predicted range for CSCI scores. These two sites indicate biological conditions that may have impacts beyond what is predicted by the model for the developed landscape. Follow-up monitoring could be implemented at these sites to evaluate stressors impacting conditions.

The over-scoring sites depicted in the figure are examples of bioassessment locations that are in good condition relative to channel constraints associated with development. Sites 205R00088 and site 205R01816 are located in the upper reaches of Corte Madera Creek that have rural land uses. Stormwater program efforts could be made to work with private landowners to implement projects (e.g., bank stabilization) that protect biological conditions at these sites.

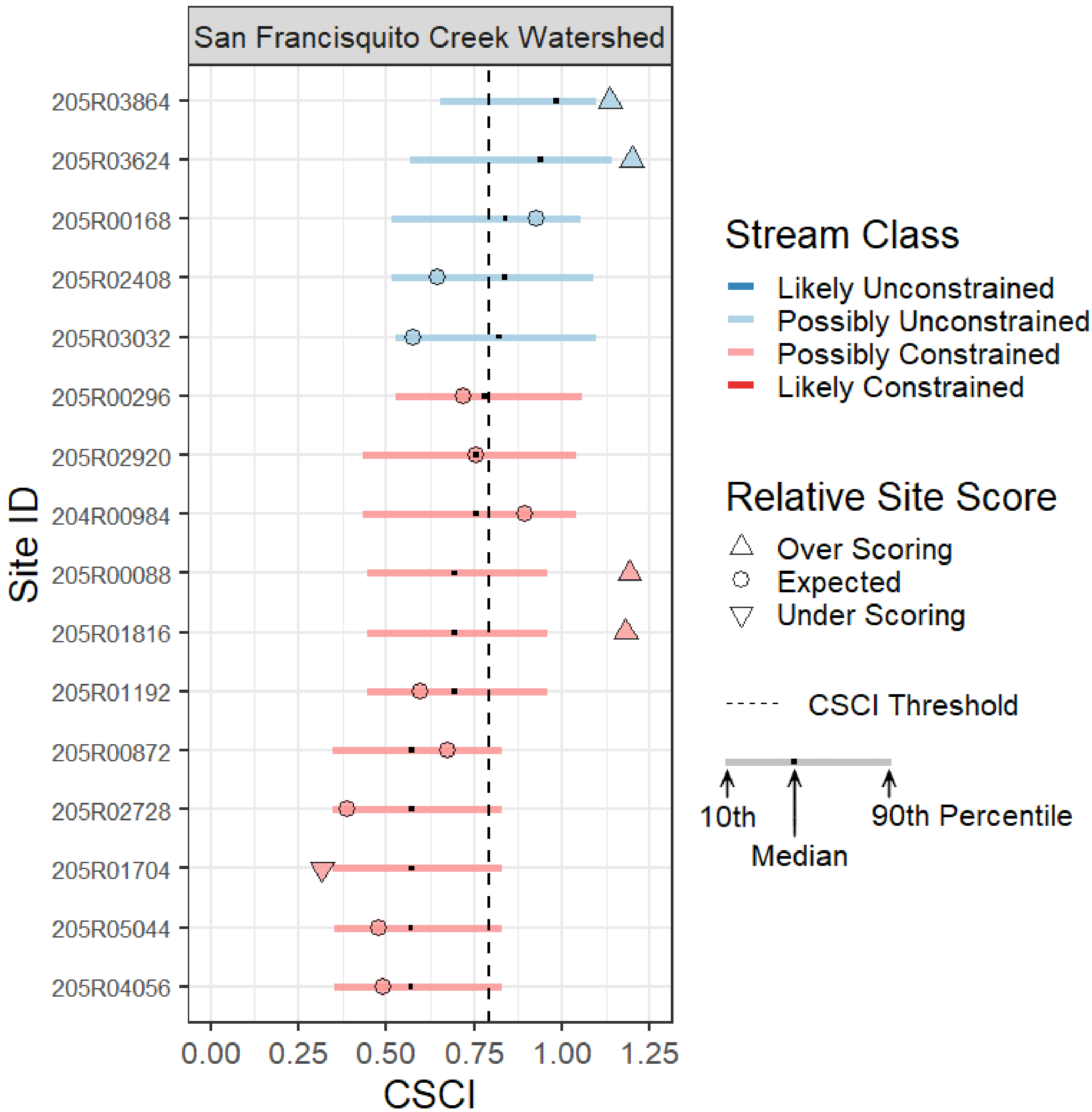

Figure 2.13. Comparison of CSCI scores for 16 sites in the San Francisquito Creek watershed with predicted model of CSCI scores based on developed landscapes (Beck et al. 2020)

2.4.2 Evaluate Sources and Impacts of Potential Stressors

Targeted monitoring design could also focus on site) where bioassessment data exceeded stressor thresholds or WQOs. For example, nutrient concentrations (e.g., total nitrogen, total phosphorus) are potential water quality stressors that can impact biological conditions (Sutula et al 2018). Comparisons of total nitrogen concentrations to CSCI and ASCI-H scores for sites in San Mateo County that drain to San Francisco Bay and the Pacific Ocean are presented in Figure 2.14. This figure illustrates that the association between total nitrogen concentrations and CSCI scores is stronger than the association between total nitrogen and ASCI-H scores.

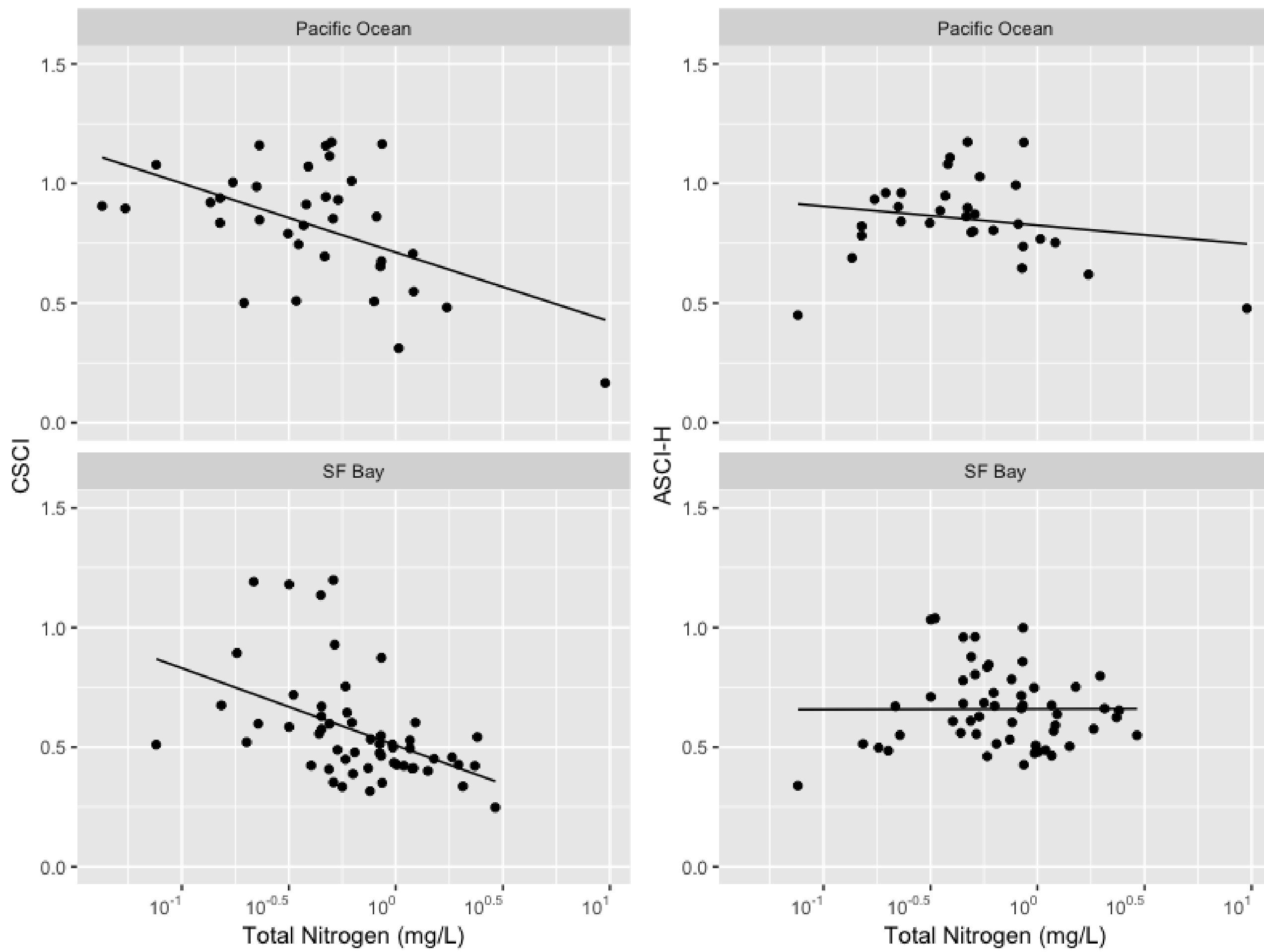

Figure 2.14. Total Nitrogen vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

Follow-up monitoring could be conducted at selected watersheds to evaluate sites with elevated concentrations of nutrients. Total nitrogen concentrations for the 90 bioassessment sites sampled in San Mateo County are shown in Figure 2.15. The highest concentration (< 3.0 mg/L)) occurred in Calera Creek (tributary to the Pacific Ocean). Moderately high concentrations (1.5 – 3.0 mg/L) occurred primarily in San Francisco Bay watersheds, including Atherton, Redwood, Laurel and Colma Creeks. Future monitoring in these watersheds may be directed at identifying sources of nutrients and implementing controls to reduce those concentrations.

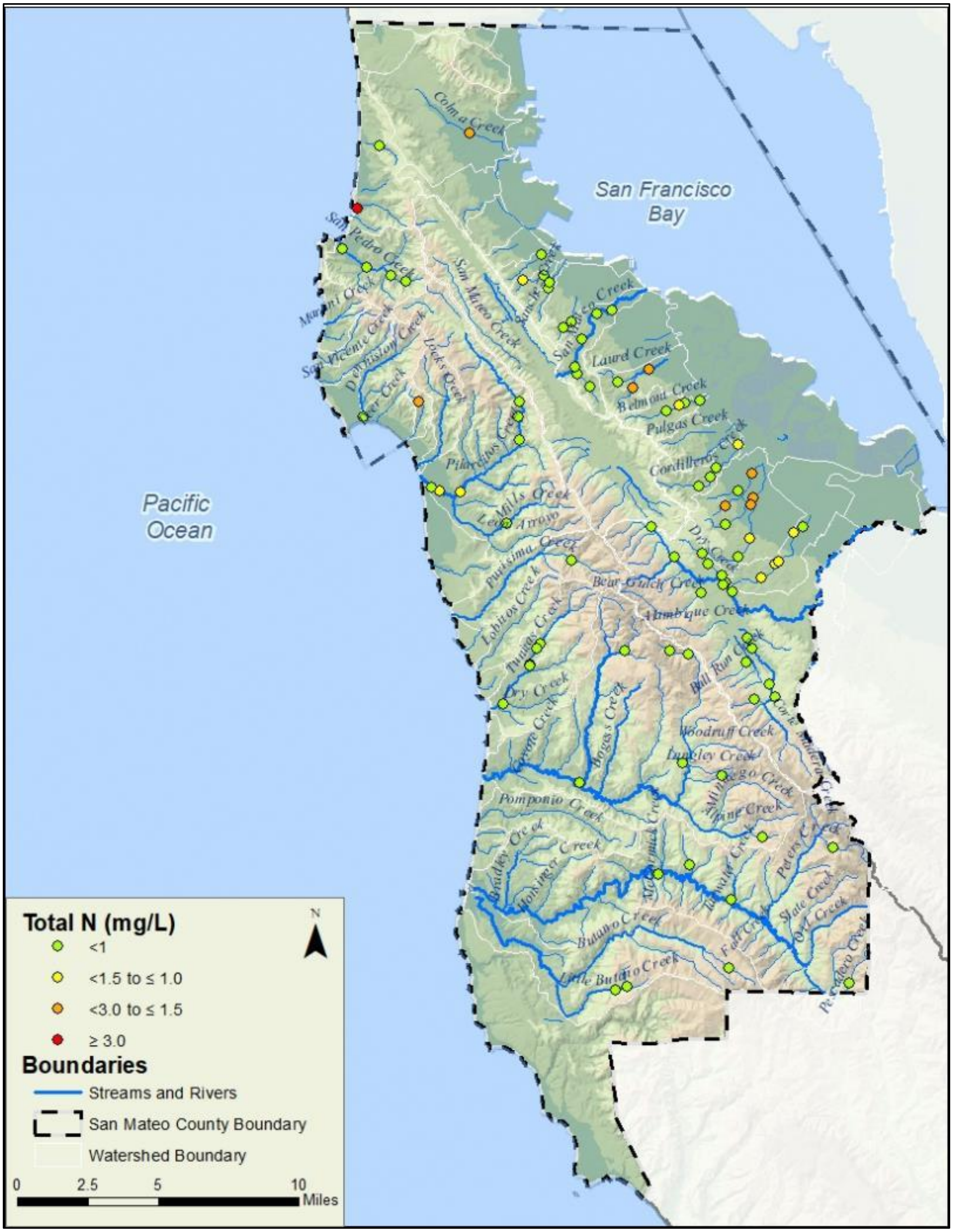

Figure 2.15. Total nitrogen concentrations measured at 90 bioassessment sites in San Mateo County sampled between WY 2012 and WY 2019.

2.4.3 Evaluate Effectiveness of BMP/Restoration Projects

Bioassessment monitoring could be conducted at stream locations that may be impacted by stream restoration or best management practices (BMPs), such as Green Stormwater Infrastructure (GSI) projects. Benthic macroinvertebrate indicators are often used to assess success of stream restoration projects (Rubin et al. 2017). BMIs can be good indicators that show response to changes in physical habitat, as well as water quality. The CSCI score provides an overall measure of biological conditions, however, individual BMI metrics can provide useful information related to presence or absence of specific stressors (e.g., fine sediment).

The RMC dataset may provide information on baseline conditions at locations where projects are currently being planned. Stormwater programs could conduct future bioassessments following construction of restoration or GSI projects to evaluate if conditions have improved. Effectiveness monitoring should be included in all restoration projects as one measure of success.

2.4.4 Evaluate Sites in Good Condition

Many of the bioassessment sites sampled by SMCWPPP and SWAMP are located in publicly protected lands that have limited or no urban development. These lands include State Parks, County Parks, Open Space Districts, and watersheds protected by public utility agencies that provide water supply (e.g., Coastside County Water District). Thirteen of the 90 bioassessment sites sampled in San Mateo County received high biological condition scores for both BMI data (CSCI scores > 0.79) and algae data (ASCI-H scores > 0.88). Nine of the thirteen sites were in publicly protected lands and four sites were located in privately owned land[18]. Site location information and ownership is provided in Table 2.15. Site locations are provided in Figure 2.16.

Stormwater programs should ensure that information and data on high quality sites are made available to park and land managers so that these areas can be managed in a way that protects stream health and water quality. Follow-up monitoring may also be conducted to evaluate whether biological conditions are changing over time. Trends monitoring at minimally disturbed sites may provide useful information related to climate change.

[18] Field crews obtained permission to access private property to conduct bioassessment sampling.

Table 2.15. Location and ownership of bioassessment sites that had scores in the top two condition categories for CSCI and ASCI-H.

Station Code	Creek Name	Watershed	Ownership
202R00312	Mills Creek	Mills Creek	State Park
202R00166	Little Butano Creek	Pescadero Creek	State Park
202R00038	Little Butano Creek	Pescadero Creek	State Park
202R00214	Tarwater Creek	Pescadero Creek	County Park
202R00550	Jones Gulch	Pescadero Creek	County Park
202R00150	Butano Creek	Pescadero Creek	Midpeninsula Regional Open Space District
202R00378	Pescadero Creek	Pescadero Creek	Private
202R00072	Pilarcitos Creek	Pilarcitos Creek	County Water District
202R00440	Purisima Creek	Purisima Creek	Midpeninsula Regional Open Space District
205R03624	Bear Creek	San Francisquito Creek	Private
205R01816	Corte Madera Creek	San Francisquito Creek	Private
202R03880	La Honda Creek	San Gregorio Creek	Midpeninsula Regional Open Space District
202R00280	Tributary to Alpine Creek	San Gregorio Creek	Private

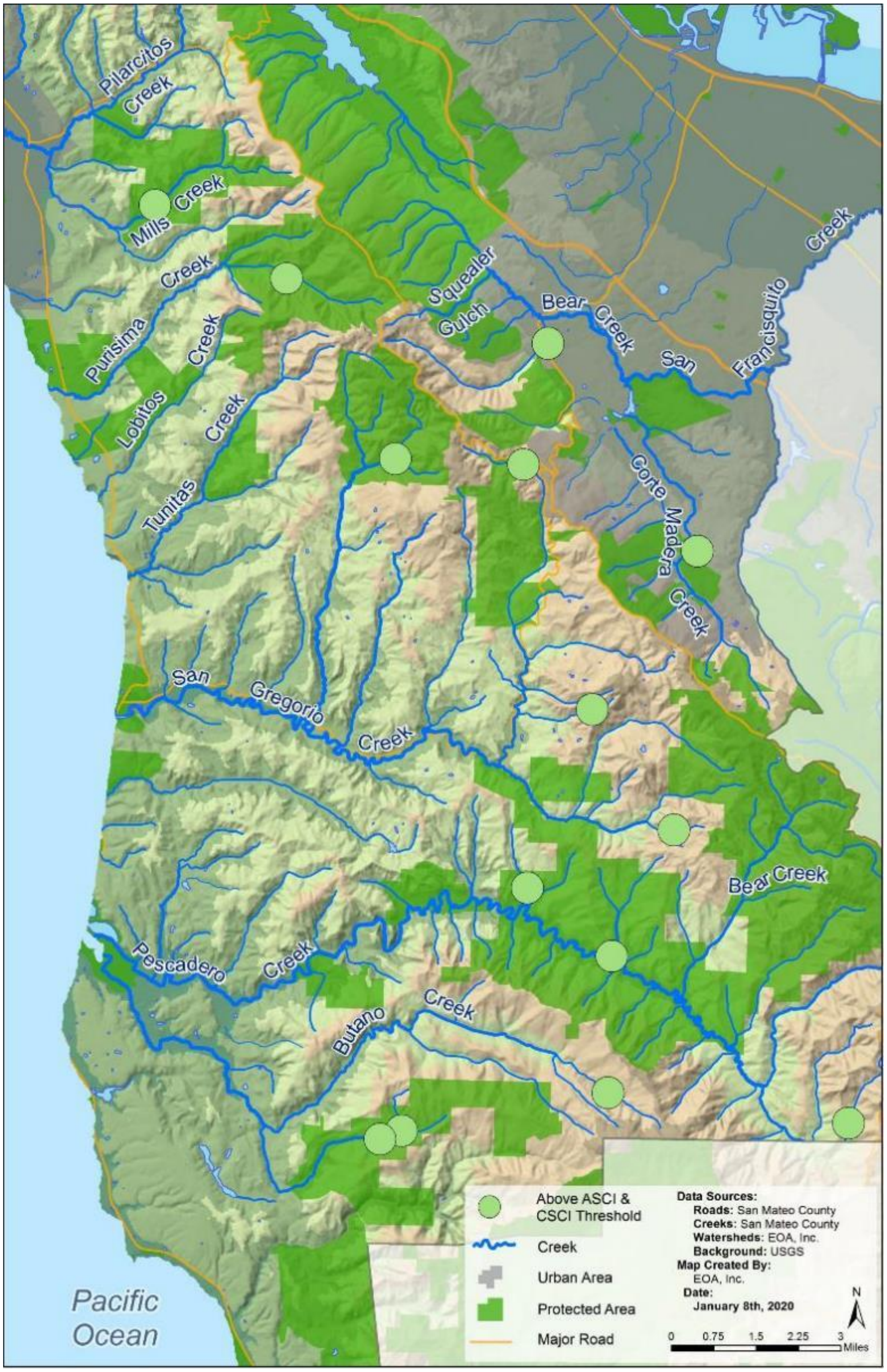

Figure 2.16. Protected areas in San Mateo County and bioassessment sites with scores in the top two condition categories for CSCI and ASCI-H.

3.0 Continuous Water Quality Monitoring

3.1 Introduction

This section describes continuous water temperature and general water quality data that were collected during WY 2014 through WY 2019. These parameters were monitored in compliance with Creek Status Monitoring Provisions C.8.c of MRP 1.0 and C.8.d.iii – iv of MRP 2.0. Monitoring was conducted at selected sites using a targeted design based on the directed principle[19] to address the following management questions:

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

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

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

The sections below summarize methods and results from continuous temperature and water quality monitoring conducted in WY 2014 – WY 2019. Conclusions and recommendations for continuous monitoring are presented in Section 7.0.

3.2 Methods

In compliance with MRP 1.0 and MRP 2.0, temperature was monitored at a minimum of four sites each year and general water quality was monitored at two sites each year. Continuous temperature and water quality data were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (current version is BASMAA 2016a) and associated QAPP (current version is BASMAA 2016b). Data were evaluated with respect to MRP 1.0 Provision C.8.c and MRP 2.0 Provision C.8.d triggers for each parameter.

3.2.1 Continuous Temperature

Digital temperature loggers (Onset HOBO Water Temp Pro V2) were programmed to record data at 60-minute intervals. The loggers were deployed at targeted sites from April through September. Procedures used for calibrating, deploying, programming and downloading data are described in RMC SOP FS-5 (BASMAA 2016a). SMCWPPP typically deploys temperature loggers at more than the minimum number of sites in anticipation of field equipment being stolen or washed downstream.

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[19] 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."

3.2.2 Continuous General Water Quality

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

3.2.3 Data Evaluation

Continuous temperature and water quality data are analyzed and evaluated to identify potential stressors that may be contributing to degraded or impacted biological conditions, including exceedances of WQOs. The relevant trigger criteria for continuous temperature and water quality data are listed in Table 3.1. Sites with continuous monitoring results exceeding the trigger criteria are identified as candidate SSID projects.

Table 3.1. Water Quality Objectives and trigger thresholds used for evaluation of continuous temperature and water quality data.

Monitoring Parameter	Objective/Trigger Threshold	Units	Source
Temperature	Two or more weekly average temperatures exceed the Maximum Weekly Average Temperature (MWAT) threshold of 17.0°C for a Steelhead stream, or 20% of the results at one sampling station exceed the instantaneous maximum of 24°C.	°C	MRP 2.0 Provision C.8.d.iii Sullivan et al. 2000
General Water Quality Parameters	20% of results at each monitoring site exceed one or more established standard or threshold - applies individually to each parameter		
Conductivity	2000	µS/cm	MRP 2.0 Provision C.8.d.iii
Dissolved Oxygen	WARM < 5.0, COLD < 7.0	mg/L	SF Bay Basin Plan Ch. 3, p. 3-4
pH	> 6.5, < 8.5 [1]	pH	SF Bay Basin Plan Ch. 3, p. 3-4
Temperature	Same as Temperature (See Above)		

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

3.3 WY 2014 – WY 2019 Overview

Continuous temperature and water quality monitoring sites were selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns. The same sites were often monitored for multiple years to gain a better understanding of the range of water quality conditions that may occur over time. In some years, continuous monitoring data were used to support or follow-up on SSID investigations. It is important to note that in San Mateo County, there are limited number of urban watersheds that support steelhead populations or other cold-water fish communities.

Figure 3.1 maps the stations where continuous temperature and water quality monitoring was conducted during WY 2014 through WY 2019. For reference, Figure 3.1 shows which creeks are designated in the Basin Plan ~~h~~as having COLD Beneficial Uses. Continuous monitoring stations were focused at stream reaches within the San Mateo Creek Watershed (WY 2014 – WY 2015; water quality sondes only), San Francisquito Creek Watershed (temperature only: WY 2014 – WY 2015; WY 2016: temperature and water quality), San Pedro Creek Watershed (WY 2017 – WY 2018), and Tunitas Creek Watershed (WY 2019).

The sections below summarize monitoring results from WY 2014 – WY 2018. Details are available in the respective UCMRs (SMCWPPP 2015, 2016, 2017, 2018, and 2019a). Results from WY 2019 continuous monitoring are detailed in this IMR in Section 3.4.

3.3.1 San Mateo Creek Watershed (WY 2014 – WY 2015)

Continuous general water quality data (dissolved oxygen, specific conductance, pH, and temperature) were recorded at two locations in the San Mateo Creek Watershed (Figure 3.1). during two two-week deployments in WY 2014 and WY 2015 (four total events) (SMCWPPP 2015 and SCVURPPP 2016). The data were used to support an SSID study investigating low dissolved oxygen concentrations in San Mateo Creek. The sampling stations were located downstream of the juvenile steelhead rearing and spawning habitat that occurs within a two-mile reach of San Mateo Creek below the Crystal Springs Reservoir (Brinkerhoff, SFPUC, personal communication 2013). WY 2015 station locations were located within 0.15 miles upstream of the El Camino Real culvert which functions as a grade control structure within the creek, decreasing upstream channel slope and velocity, and causing fine sediments to accumulate. Although these characteristics have caused low concentrations of dissolved oxygen in prior years, The SSID Project Report, included as Appendix B to the WY 2015 UCMR (SMCWPPP 2016) concluded that previously recorded low dissolved oxygen levels are no longer likely as a result of increased dry season releases from Crystal Springs Reservoir which is owned and operated by the San Francisco Public Utilities Commission (SFPUC). MRP triggers for dissolved oxygen, specific conductivity, pH, and instantaneous maximum temperature were not exceeded in either year of monitoring. The Maximum Weekly Average Temperature (MWAT) trigger of 17°C was exceeded in WY 2015; however, the 17°C threshold is based on streams of the Pacific Northwest and may not be an appropriate trigger for Bay Area streams.

3.3.2 San Francisquito Creek Watershed (WY 2014 – WY 2016)

In WY 2014 – WY 2016, continuous temperature monitoring (hourly) was conducted from April through September at stations in the San Francisquito Creek Watershed. Although the MRP requires a minimum of four temperature stations, six stations were monitored in WY 2014 to mitigate for potential equipment loss. One of the WY 2016 stations (located in upper West Union Creek) was eliminated after WY 2014 due to challenging access and low temperature results in WY 2014 suggesting that the reach was supportive of cold-water aquatic life. Although creeks in the watershed typically cease to have continuous flow through the dry season, all sites were located in pools that have historically remained wet throughout the summer. These pools may provide refuge for cold water fish prior to the onset of wet season flows.

The MRP trigger threshold for instantaneous maximum temperature was not exceeded in any of the three years at any of the targeted temperature stations. However, in WY 2015, one of the stations on Bear Creek (at Sand Hill Road; Station 205BRC010) had an unusual pattern of daily temperature spikes for a portion of the record. The daily spikes would begin at 8:00 AM with a quick temperature increase of 5 to 10 ºC that disappeared from the records by 10:00 AM. The temperature then decreased steadily over the remainder of the day. In very dry years such as WY 2015 when flows are extremely low, it is difficult to determine the cause of the temperature spikes. Possible explanations include: sunshine hitting the instrument, warm overland flows from nearby properties, or temporary diversions from the creek causing water levels to drop below the instrument. As a result of the unexplained spikes, the station was added to the list of candidate SSID studies. WY 2016 temperature monitoring results from the same station did not have any unexplained spikes.

In all three years of monitoring, the MRP MWAT trigger of 17°C was exceeded at one or more station. It was noted in the WY 2016 UCMR that, due to persistent drought conditions, the WY 2014 – WY 2016 monitoring period likely represents a worst-case scenario for summer temperatures (SMCWPPP 2017). Furthermore, alternative data evaluation thresholds, such as the Maximum Weekly Maximum Temperature (MWMT) threshold of 20°C used by the National Marine Fisheries Service (NMFS) in the Central Coast Steelhead Recovery Plan (NMFS 2016) were not exceeded. In compliance with the MRP, stations with MWAT trigger exceedances were added to the list of candidate SSID projects.

In WY 2016, the Bear Creek tributary to San Francisquito Creek was targeted for general water quality monitoring, in part to support exploration of daily temperature spikes observed in WY 2015, but also to evaluate water quality in reaches that have historically supported juvenile steelhead rearing and spawning habitat (Leidy et al. 2005). MRP triggers for specific conductivity, pH, and instantaneous maximum temperature were not exceeded at either station. However, dissolved oxygen concentrations at both stations were below the WQOs for WARM and COLD freshwater habitat during the August 20 – September 5, 2016 deployment. During the dry season, the sampling locations had become isolated pools with just a trickle or no surface flow entering the pool from the upstream channel. These pools would provide the only refugia for juvenile steelhead and other native fishes. Thus, the measured low DO levels would not likely support steelhead, especially if they were cut off from reaches with better habitat and water quality. Both sites were added to the list for potential SSID projects for low DO.

3.3.3 San Pedro Creek Watershed (WY 2017 – WY 2018)

In WY 2017 and WY 2018 the San Pedro Creek Watershed was targeted for continuous temperature and water quality monitoring because it contains the northern-most population of naturally producing steelhead trout (*Oncorhynchus mykiss*) in San Mateo County (Titus et al. 2010). Fish habitat is supported by perennial flow resulting from multiple springs located in the upper watershed. Land uses are mixed, with urban communities in the valleys and along the coast, and undeveloped and public lands in the upper areas of the watershed. Although degradation of physical habitat and the presence of fish barriers such as bridge culverts may threaten the steelhead population in San Pedro Creek, restoration efforts are helping to reestablish and enhance habitat.

The same set of five temperature stations and two water quality stations were monitored in both years. Water temperatures generally increased in the downstream direction (spatial pattern) and increased through the summer (temporal pattern) but remained well below the MRP instantaneous maximum and MWAT triggers. Likewise, general water quality parameters (temperature, pH, dissolved oxygen, and specific conductance) did not exceed MPR trigger thresholds.

Continuous monitoring data were supplemented by other types of Provision C.8 data collected in the San Pedro Creek Watershed. Bioassessments were conducted at a total of four probabilistic monitoring stations from WY 2015 to WY 2018. CSCI scores along the mainstem of San Pedro Creek were in the "likely altered" condition category; whereas CSCI scores farther up in the watershed along the Middle Fork of San Pedro Creek (within County Park land) were in the "possibly intact" and likely intact" stream condition categories. In compliance with Provision C.8.g of MRP 2.0, the mouth of San Pedro Creek was also monitored for dry weather Pesticides and Toxicity monitoring in WY 2017 and wet weather Pesticides and Toxicity monitoring in WY 2018 Although dry weather water samples were significantly toxic to *Pimephales promelas* (fathead minnow) and *Ceriodaphnia dubia* (water flea) and wet weather water samples were significantly toxic to *Pimephales promelas* and *Hyalella azteca* (amphipod), the percent effect of all samples was below the threshold (50%) for additional investigation. Pesticide concentrations in the dry weather sediment samples and wet weather water samples were all very low and the cause of the toxicity is unknown.

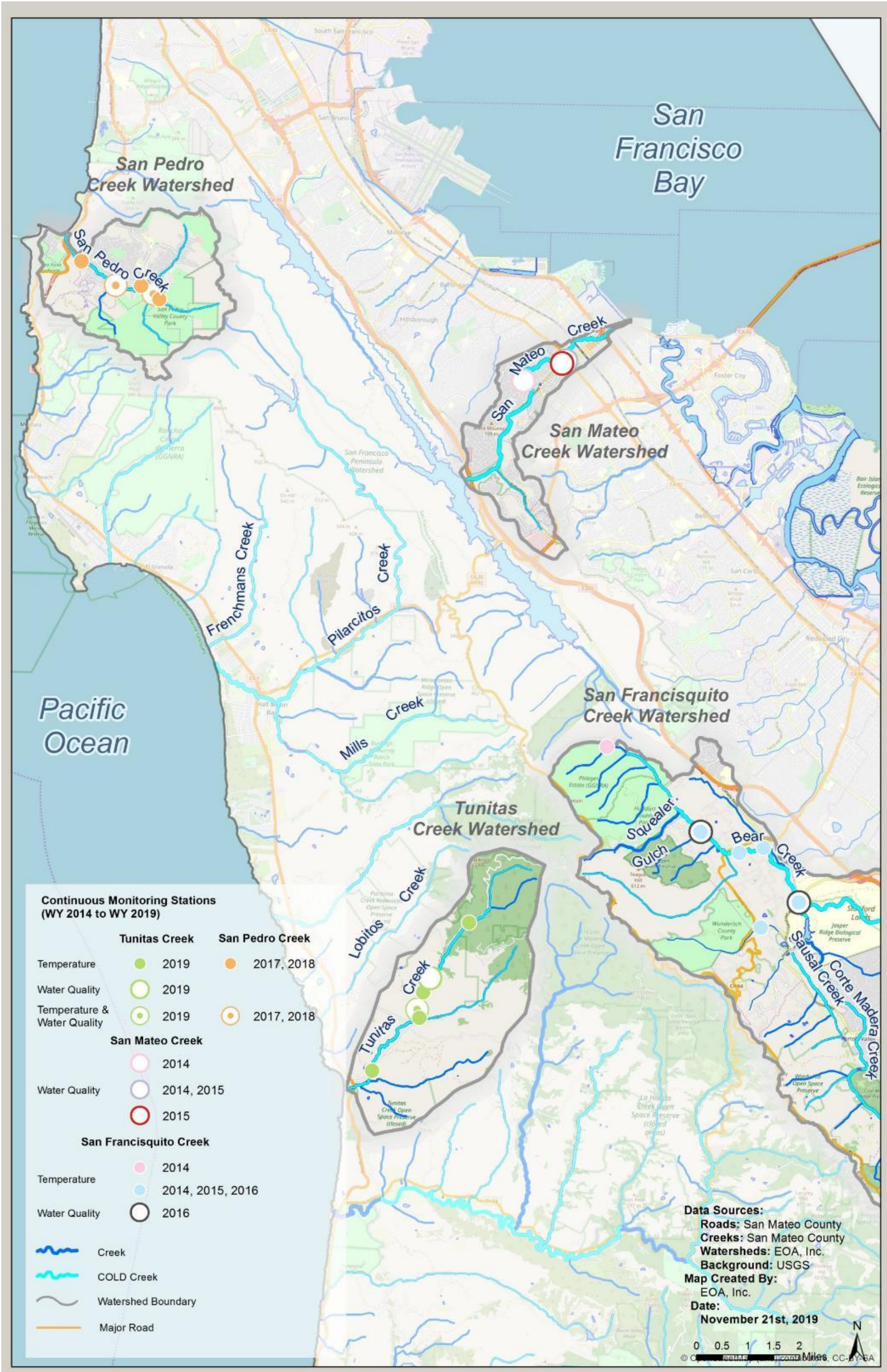

Figure 3.1. Continuous temperature and water quality stations in San Mateo County, WY 2014 – WY 2019.

3.4 WY 2019 Results (Tunitas Creek Watershed)

In WY 2019, continuous (hourly) temperature measurements were recorded from April 3 through September 18, 2019, at five locations in the Tunitas Creek watershed. Continuous (15-minute) general water quality measurements (temperature, dissolved oxygen, pH, specific conductance) were recorded at two stations during two two-week sampling events (Events 1 and 2). Sample Event 1 occurred from May 17 through May 31, 2019. Sample Event 2 occurred from September 5 through September 18, 2019. The two general water quality stations were also targeted for bioassessment surveys in WY 2019. Temperature, general water quality, and bioassessment monitoring stations are illustrated in Figure 3.2.

3.4.1 Tunitas Creek Study Area

The Tunitas Creek watershed was targeted for continuous monitoring in WY 2019 to supplement targeted bioassessment monitoring also conducted in Tunitas Creek in WY 2019. The targeted bioassessment monitoring, discussed in more detail in Section 2.3.1 of this IMR, follows up on prior CSCI scores that were relatively low for an undeveloped watershed.

Tunitas Creek is a coastal stream in western San Mateo County, with a generally undeveloped watershed draining 11.5 square-miles of the Santa Cruz Mountains (MidPeninsula Regional Open Space District 2015) (Figure 3.3). The creek originates in the forested peaks of Kings Mountain, at an elevation of 1,860 feet (570 meters). After flowing southwest 6.6 miles (10.6 km) alongside Tunitas Creek Road, Tunitas Creek drains into the Pacific Ocean. The upper portion of the watershed includes Rings Gulch which is drained by East Fork Tunitas Creek. The lower portion of the watershed contains scattered farms and ranches, and the Dry Creek tributary. Tunitas Creek passes under the Cabrillo Highway and empties into the Pacific Ocean via the Tunitas Creek Beach in Half Moon Bay.

The Basin Plan designates Tunitas Creek as having COLD Beneficial Uses (SFBRWQCB 2017). The watershed historically provided suitable habitat for steelhead trout with “good spawning” habitat in the lower two miles of Tunitas Creek and “excellent” steelhead habitat in the East Fork tributary as identified by the California Department of Fish and Game (DFG) in the 1960s (DFG 1962, DFG 1964). Forty years later, the DFG observed relatively low steelhead populations in the watershed. However, the greatest density of steelhead juveniles was found in the upper reach of Tunitas Creek (Becker et al. 2010, National Marine Fisheries Service 2016).

Riparian species of interest and special concern are also found in the Tunitas Creek watershed. Among the most notable are the California red legged frog (*Rana draytonii*), the San Francisco Garter Snake (*Thamnophis sirtalis tetrataenia*), the California giant salamander (*Dicamptodon* ensatus) and the Santa Cruz black salamander (*Aneides niger*) (California State Coastal Conservancy 2019, MidPeninsula Regional Open Space District 2015).

WY 2019 results for continuous temperature and general water quality, described in the sections below, appear to support COLD Beneficial Uses in Tunitas Creek.

Figure 3.2. Continuous temperature, continuous water quality, and bioassessment stations in the Tunitas Creek Watershed, San Mateo County, WY 2019.

Figure 3.3. Photo of Tunitas Creek approximately 0.15 mile upstream from the convergence with East Fork Tunitas Creek tributary (Photo by SMCWPPP field staff).

3.4.2 WY 2019 Continuous Temperature Results and Discussion

Temperature loggers were deployed at five sites in the Tunitas Creek watershed on April 3, field checked on July 19, and removed on September 18, 2019. Summary statistics for continuous water temperature data collected at the five sites are listed in Table 3.2. None of the recorded temperatures exceeded the instantaneous maximum temperature trigger of 24°C.

Table 3.2 Descriptive statistics for continuous water temperature measured from April 3 through September 18, 2019 at five sites in Tunitas Creek, San Mateo County.

Site ID		202TUN005	202TUN025	202TUN030	202TUN035	202TUN060
		(downstream --- upstream)				
Start Date		4/3/2019	4/3/2019	4/3/2019	4/3/2019	4/3/2019
End Date		9/18/2019	9/18/2019	9/18/2019	9/18/2019	9/18/2019
Temperature (ºC)	Minimum	9.6	8.7	9.1	9.2	9.8
	Median	13.8	13.5	13.7	13.6	13.0
	Mean	13.8	13.4	13.6	13.5	12.9
	Maximum	17.8	16.5	17.9	17.5	15.9
	Max 7-day mean	16.1	15.3	16.2	15.9	14.7
	N (# individual measurements)	4028	4028	4028	4028	4027
# Measurements > 24°C		0	0	0	0	0

Weekly average temperature values calculated for each of the five monitoring sites are listed Table 3.3 and graphed in Figure 3.4. Consistent with MRP requirements, the weekly average temperature was calculated for non-overlapping, seven-day periods. The values across all the sites ranged from lows of 10.9°C to 11.3°C recorded in April or May highs to 14.7°C to 16.2°C recorded in September (Table 3.3). The MWAT trigger was never exceeded at any of the sites.

Table 3.3. Weekly average temperature values for water temperature data collected at five stations monitored in the Tunitas Creek Watershed, WY 2019. The MRP MWAT trigger is 17°C.

Station	202TUN005	202TUN025	202TUN030	202TUN035	202TUN060
Date	Weekly Average Temperature (°C)				
4/3/2019	12.6	12.3	12.3	12.1	11.8
4/10/2019	11.3	11.0	11.1	10.9	11.0
4/17/2019	12.0	11.7	11.7	11.6	11.6
4/24/2019	12.6	12.2	12.3	12.2	11.9
5/1/2019	11.6	11.2	11.3	11.1	10.9
5/8/2019	12.6	12.3	12.3	12.1	11.5
5/15/2019	12.0	11.7	11.7	11.6	11.2
5/22/2019	12.2	12.1	12.0	11.8	11.5
5/29/2019	12.5	12.3	12.3	12.1	11.9
6/5/2019	13.5	13.2	13.5	13.4	13.2
6/12/2019	14.2	13.9	14.0	13.9	13.3
6/19/2019	14.1	13.6	13.8	13.7	13.1
6/26/2019	13.9	13.4	13.6	13.5	12.6
7/3/2019	13.9	13.5	13.6	13.5	12.6
7/10/2019	14.7	14.3	14.6	14.5	13.6
7/17/2019	15.2	14.7	15.0	15.0	13.8
7/24/2019	14.4	14.0	14.3	14.3	13.8
7/31/2019	15.2	14.8	15.1	15.0	13.9
8/7/2019	15.6	15.1	15.4	15.3	14.2
8/14/2019	15.2	14.7	15.1	15.0	14.7
8/21/2019	15.6	14.9	15.5	15.4	14.5
8/28/2019	15.5	14.8	15.4	15.2	14.6
9/4/2019	16.1	15.3	16.2	15.9	14.5
9/11/2019	15.0	14.7	15.3	15.0	14.7
9/18/2019	14.1	14.3	14.3	14.1	14.3
Total Weeks	25	25	25	25	25
MWAT >17	0	0	0	0	0
% Exceed	0%	0%	0%	0%	0%
> MRP Trigger	**No**	**No**	**No**	**No**	**No**

Time series plots of the weekly average temperature values and daily averages are shown for all five sites in Figures 3.4 and 3.5, respectively. Water temperatures increased gradually over the monitoring period, with lowest temperatures measured at the most upstream station (202TUN060) and increasing slightly with decreasing site elevation. A temperature peak recorded at all stations in the early-June record coincided with an historic heat wave caused by unseasonable offshore air flows[20].

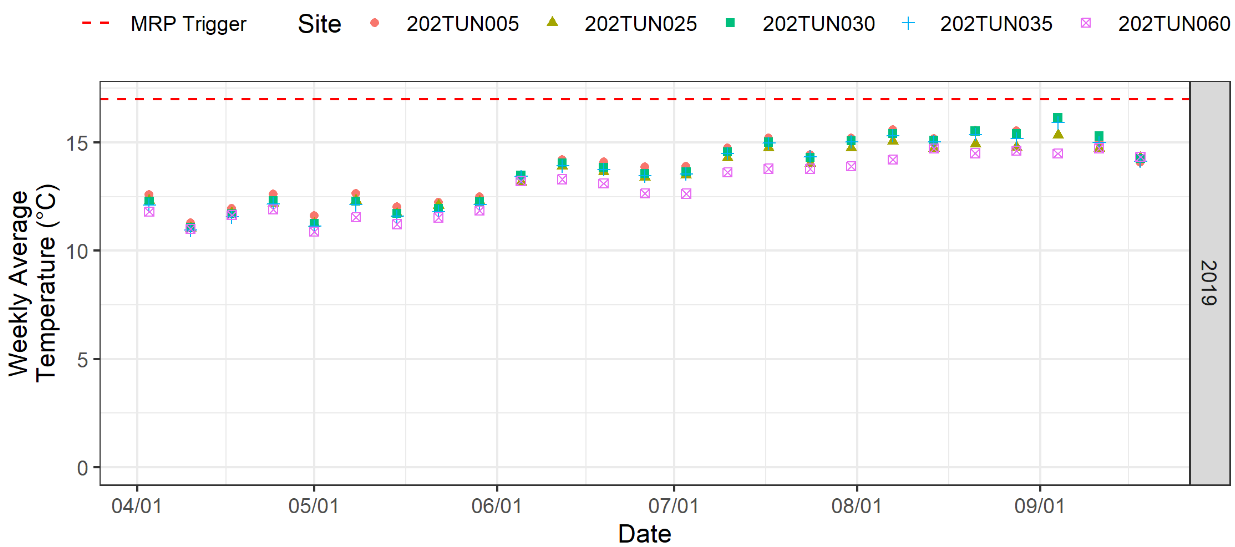

Figure 3.4. Weekly average temperature values calculated for water temperature collected at five sites in Tunitas Creek over 24 weeks of monitoring in WY 2019. The MRP trigger (17°C) is shown for comparison.

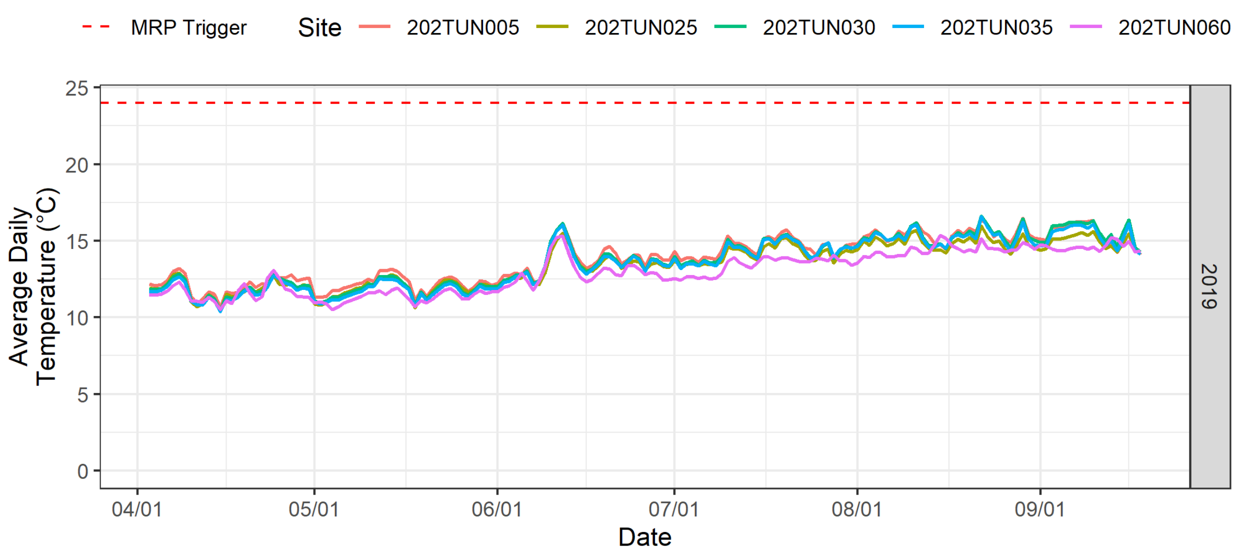

Figure 3.5. Water temperature, shown as daily average, collected between April and September 2019 at five sites in Tunitas Creek, San Mateo County.

[20] https://www.weather.gov/mtr/HeatWave_6_9-11_2019

3.4.3 WY 2019 Continuous General Water Quality Results and Discussion

Summary statistics for general water quality measurements collected at the two stations in Tunitas Creek are listed in Table 3.4. Station locations are mapped in Figure 3.2. For Event 1, sondes were deployed on May 17 and retrieved on May 31, 2019. For Event 2, sondes were deployed on September 5 and retrieved on September 18, 2019. Time series plots of the data for Event 1 and Event 2 are shown in Figures 3.6 and 3.7, respectively. MRP trigger thresholds are shown for reference.

Table 3.4. Descriptive statistics for continuous water temperature, dissolved oxygen, pH, and specific conductance measured at two Tunitas Creek sites in San Mateo County during WY 2019. Data were collected every 15 minutes over a two 2-week time periods during May (Event 1) and September (Event 2).

Parameter	Data Type	202TUN030		202TUN040	
		Event 1 WY19	Event 2 WY19	Event 1 WY19	Event 2 WY19
Temperature (°C)	Minimum	9.8	12.7	10.2	12.9
	Median	11.7	15.7	11.6	15.9
	Mean	11.7	15.6	11.6	15.6
	Maximum	12.9	19.2	12.9	17.6
	% > 24	0%	0%	0%	0%
Dissolved Oxygen (mg/L)	Minimum	10.5	7.9	10.5	6.2
	Median	11.0	9.1	10.8	7.9
	Mean	11.0	9.4	10.9	7.9
	Maximum	11.4	11.1	11.4	8.8
	% < 7	0%	0%	0%	4%
pH	Minimum	7.8	7.4	8.0	7.4
	Median	8.0	7.9	8.2	7.9
	Mean	8.0	7.9	8.2	7.9
	Maximum	8.2	8.5	8.3	8.0
	% < 6.5 or > 8.5	0%	0%	0%	0%
Specific Conductivity (uS/cm)	Minimum	528	1057	478	1122
	Median	594	1075	552	1139
	Mean	608	1079	562	1143
	Maximum	741	1117	697	1170
	% > 2000	0%	0%	0%	0%
Total number of data points (N)		1341	1233	1341	1233

Figure 3.6. Continuous water quality data (temperature, specific conductance, pH, and dissolved oxygen) collected during May 17-31, 2019 (Event 1) at two sites in the Tunitas Creek watershed.

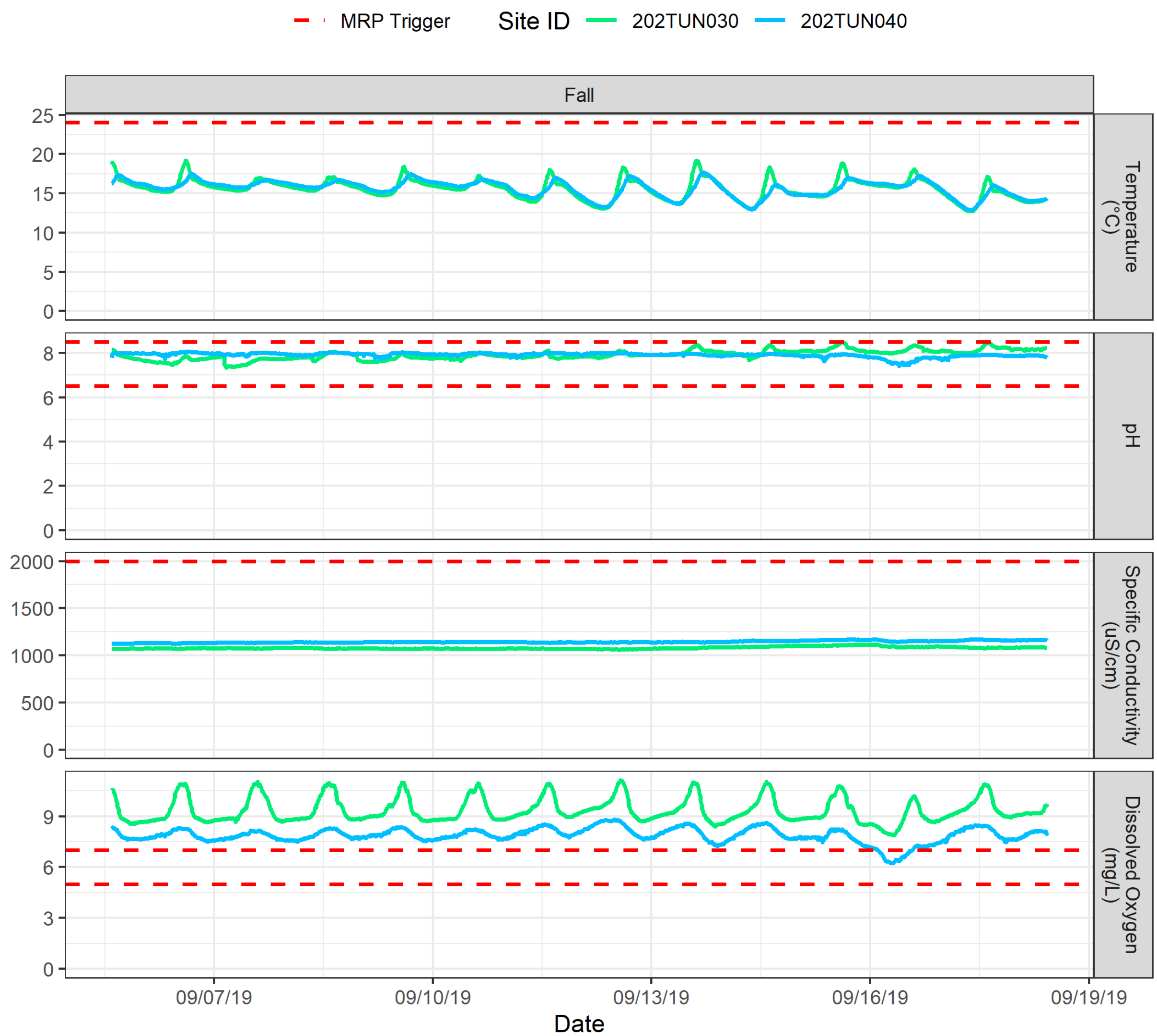

Figure 3.7. Continuous water quality data (temperature, specific conductance, pH, and dissolved oxygen) collected during September 5-18, 2019 (Event 2) at two sites in the Tunitas Creek watershed.

Temperature

Water temperatures recorded by the sondes never exceeded the 24°C MRP trigger threshold for instantaneous maximum temperature at either site for either sampling event (Table 3.4, Figures 3.6 and 3.7). The water temperature data collected by temperature loggers were used to evaluate MWAT (see previous section). As previously stated, the MWAT threshold of 17°C was not exceeded at any of the Tunitas Creek stations (Table 3.3, Figure 3.4).

Specific Conductivity

Specific conductance measurements did not exceed the MRP trigger of 2000 µs/cm during either sampling event. Conductivity was similar at the two stations and was lower during Event 1 compared to Event 2 (Figures 3.6 and 3.7). The increase in specific conductance over the summer may be the result of the increasing importance of higher conductivity groundwater contributions after a long period with little to no precipitation.

pH

During the two sampling events, all pH measurements fell within the Basin Plan WQOs for pH (< 6.5 and/or > 8.5). The pH measurements were similar at both stations and similar during both events.

Dissolved Oxygen

During Event 1, dissolved oxygen (DO) concentrations at both stations were similar in daily patterns and magnitude, remaining well above the Basin Plan WQO for COLD freshwater habitat (7.0 mg/L) (Figure 3.6). Event 2 DO concentrations were lower at both stations compared to Event 1 (Table 3.4). During Event 2, DO was higher at the downstream station (202TUN030) with greater diurnal fluctuations compared to the upstream station (202TUN040) (Figure 3.7) and all recorded concentrations at the downstream station were above the WQO of 7 mg/L. During Event 2, 4% of the recorded DO concentrations at the upstream station (202TUN040) dropped below the WQO of 7 mg/L; however, this did not result in an exceedance of the MRP trigger which would require 20% of the record being below the WQO.

The cause of the decrease in DO from Event 1 to Event 2 is likely due to increases in water temperatures during Event 2. Warmer water has less capacity to absorb oxygen. The cause of the differences in DO between the two stations during Event 2 is unknown. It may be related to differences in land use within the catchment areas and/or it may be related to differences in physical habitat at the two stations. The downstream station (202TUN030) is in a deep canyon with a thick riparian canopy blocking sunlight; whereas, the upper station (202TUN040) has more exposure to sunlight. DO during Event 2 may also have been responding to small algae bloom/decomposition associated with warm weather. Above average air temperatures were recorded on September 13, 2019 at Half Moon Bay (reaching 81˚F, or 15 ˚F warmer than the historical average high temperature for that time of year) (AccuWeather 2019).

4.0 Pathogen Indicator Monitoring

4.1 Introduction

This section describes the results of pathogen indicator monitoring that was conducted during WY 2014 through WY 2019 in compliance with Creek Status Monitoring Provisions C.8.c of MRP 1.0 and C.8.d.v of MRP 2.0. Monitoring was conducted at selected sites using a targeted design based on the directed principle to address the following management question(s):

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

2. *What are the pathogen indicator concentrations in catchment areas that drain to creek or ocean sites where there is potential for water contact recreation to occur?*

These management questions are addressed primarily through the evaluation of data with respect to trigger thresholds identified in the MRP and WQOs adopted by the State Water Board. Sites where exceedances occur may indicate potential impacts to water contact recreation (REC-1) or other beneficial uses and are considered as candidates for future Stressor Source Identification projects.

In compliance with MPR 1.0 and 2.0, five samples were collected each year for a cumulative total of 30 samples for the WY 2014 through WY 2019 IMR reporting period. The sections below summarize methods and results from pathogen indicator monitoring conducted during WY 2014 through WY 2019. Conclusion and recommendations for this section are presented in Section 7.0.

4.2 Methods

4.2.1 Sample Collection

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

4.2.2 Data Evaluation

During MRP 1.0 (WY 2014 and WY 2015) *E. coli* and fecal coliform were monitored as pathogen indicators. During MRP 2.0 (WY 2016 – WY 2019), *E. coli* and enterococcus were monitored as pathogen indicators. Pathogen indicator data were evaluated with respect to trigger thresholds identified in the MRP and WQOs adopted by the State Water Board on August 7, 2018 and approved by the USEPA on March 22, 2019. Pathogen indicator trigger thresholds and WQOs are listed in Table 4.1.

The MRP triggers and adopted WQOs are both based on the 2012 USEPA recommended recreational water quality criteria (RWQC). The 2012 RWQC offer two sets of numeric concentration thresholds for *E. coli* and enterococci designed to protect all types of water contact recreation in freshwaters where immersion and ingestion are likely. The two sets of criteria are based on estimated rates of gastrointestinal illness (estimated illness rate of 36 per 1,000 recreators and estimated illness rate of 32 per 1,000 recreators). MPR 2.0 specified the illness rate of 36/1000 as a trigger threshold; whereas, the State Water Board adopted the more conservative set of criteria based on the illness rate of 32/1000. The 2012 RWQC consist of both a geometric mean (GM) and a Statistical Threshold Value (STV). The GM criteria are applied when there are at least five samples distributed over a six-week period. The STV criteria should not be exceeded by more than 10 percent of the samples taken in a month, and therefore approximate a single sample maximum. Because pathogen indicator samples collected in compliance with the MRP are not repeated, results are compared to the STV criteria. Also, in this evaluation, the Most Probable Number (MPN) of bacteria colonies given by the analytical method is compared directly with the Colony Forming Units (CFU) of the USEPA recommendations.

The 2012 USEPA RWQC do not recommend using fecal coliform as a pathogen indicator. Therefore, fecal coliform data collected during MRP 1.0 were compared to WQOs listed in the Basin Plan (2017).

Table 4.1. Bacteriological trigger thresholds and WQOs for water contact recreation in freshwater.

Pathogen Indicator	State Water Board WQO (Estimated Illness Rate 32/1,000)		MRP 2.0 Trigger Threshold (Estimated Illness Rate 36/1,000)		Basin Plan WQO	
	GM	STV	GM	STV	GM	STV
Fecal Coliform (MPN/100 mL)	NA	NA	NA	NA	200	400
E. coli (cfu/100 mL)	100	320	125	410	NA	NA
Enterococci (cfu/100 mL)	30	110	35	130	NA	NA

4.3 Study Area

Pathogen indicator monitoring sites have been selected to inform bacteria SSID investigations and follow-up on anecdotal reports of high bacteria in creeks where water contact recreation (REC-1) is likely. Figure 4.1 includes an overview of San Mateo County showing where pathogen indicator monitoring has been conducted from WY 2014 – WY 2019. Inset maps in Figure 4.1 show details of the three targeted areas that are described in the sections below.

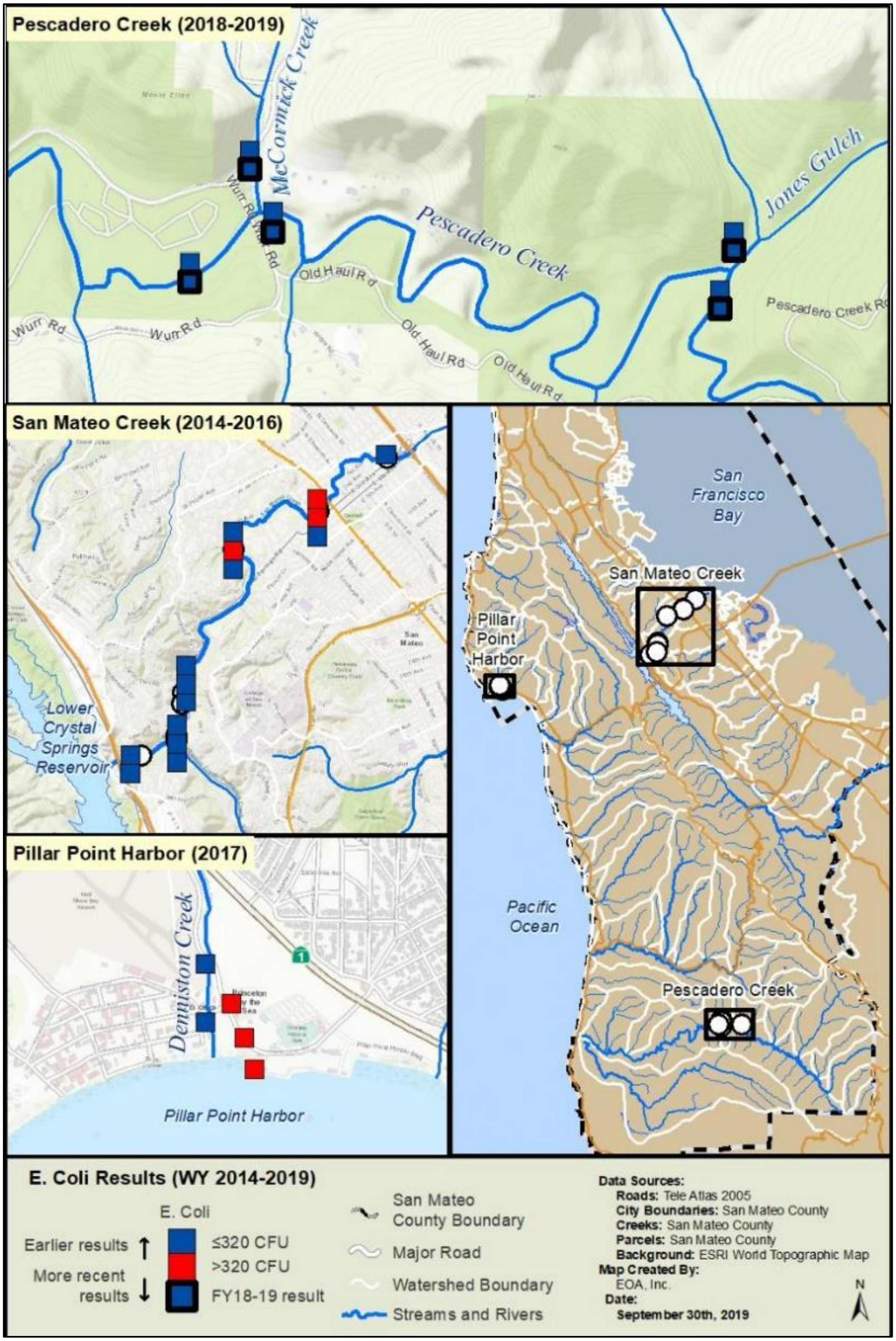

Figure 4.1. Pathogen indicator monitoring sites in WY 2014- WY 2019, San Mateo County. Exceedances of *E. coli* WQOs are shown in red.

4.3.1 WY 2018 – WY 2019: Pescadero Creek Watershed

In WY 2019, pathogen indicator samples were collected during one sampling event (August 1, 2019) from five sites chosen in coordination with San Mateo County Parks (Figure 4.1). The sample stations for WY 2019 were the same sample stations that were monitored for pathogen indicators in WY 2018. Repeat sampling can provide information (albeit limited) on variability at the sites. All sites were located in the Pescadero Creek watershed in the vicinity of Memorial County Park. Two sites were located on tributaries to Pescadero Creek: Jones Gulch (202PES150) and McCormick Creek (202PES142). Three sites were located on the main stem of Pescadero Creek upstream and downstream of the confluences with the two sampled tributaries. The sites were selected in coordination with San Mateo County Parks staff to characterize geographic patterns of pathogen indicator densities within the Pescadero Creek watershed.

Results of WY 2018 and WY 2019 pathogen indicator monitoring in the Pescadero Creek watershed are described in Section 4.4.

4.3.2 WY 2017: Pillar Point Harbor Watershed

In WY 2017, pathogen indicator samples were collected during one sampling event (August 28, 2017) from five sites in the Pillar Point Harbor watershed. Two of the sites were located on Denniston Creek, upstream and downstream of an MS4 outfall, and the MS4 draining to Denniston Creek was sampled. Two samples were collected from the MS4 in the “Capistrano Catchment”, a 15-acre area with no creeks that is drained entirely by the MS4 and discharges directly to one of the beaches along Pillar Point Harbor. Monitoring results were used to develop a Stressor Source Identification work plan that was implemented in WY 2018 and WY 2019. The Final Pillar Point Harbor Watershed Pathogen Indicator SSID Project Report is included as an appendix to Part C (SSID Status Report) this IMR.

The SSID project included microbial source tracking (MST) techniques such as development of a geodatabase to map potential bacteria sources and analysis of samples for human and dog genetic markers. Results of the SSID study showed that *E. coli* densities were highly variable and did not follow predictable seasonal patterns. Furthermore, an overall lack of human and dog markers suggests that bacteria sources may not be associated with anthropogenic sources that can be easier to control than wildlife sources and that are more likely to impact REC-1 beneficial uses. See Part C of this IMR (SSID Status Report) for more information.

4.3.3 WY 2014 – WY 2016: San Mateo Creek Watershed

San Mateo Creek and its tributary, Polhemus Creek, were targeted for MRP required pathogen indicator monitoring in WY 2014 through WY 2016. Results were used to support monitoring conducted as part of the San Mateo Creek Pathogen Indicator SSID Project. The SSID project followed up on SWAMP monitoring in the watershed that identified exceedances of *E. coli* WQOs in 2003 and MRP monitoring that confirmed *E. coli* exceedances in 2012. The SSID Project investigated the magnitude, seasonal variability, and predominant sources of pathogen indicators in the watershed using MST approaches consisting of both field and desktop methods. *E. coli* results followed predictable seasonal and spatial patterns, with higher densities observed during wet season monitoring events and at stations lower in the watershed. Genetic marker analyses suggested year-round human sources in lower reaches of San Mateo Creek and dog sources during wet weather. The San Mateo Creek Pathogen Indicator SSID Final Project Report, submitted with the WY 2015 UCMR, recommended that local municipalities work together to increase public education and outreach targeting pet waste cleanup. In addition, planned improvements to the sanitary sewer conveyance system in response to a Cease and Desist Order are anticipated to improve water quality by reducing leakage. There were no exceedances of the *E. coli* WQO observed in follow-up monitoring conducted in WY 2016, suggesting that the control actions had a beneficial impact on water quality in San Mateo Creek.

4.4 Results and Discussion

Pathogen indicator (*E. coli* and enterococci) densities measured in grab samples collected from the Pescadero Creek watershed in WY 2018 on July 27, 2018 and WY 2019 on August 1, 2019 are listed in Table 4.2. Stations are mapped in Figure 4.1. There were no measurements that exceeded the MRP 2.0 trigger threshold or State Water Board WQO for *E. coli* in either year. Two samples exceeded the criteria for enterococci in WY 2018 but not in WY 2019. The WY 2018 enterococci trigger exceedances were observed in McCormick Creek (202PES142) and Pescadero Creek at Memorial Park downstream of the McCormick confluence (202PES138). It appears likely that McCormick Creek discharges were affecting water quality in Pescadero Creek on July 27, 2018 but not on August 1, 2019. This high year to year variability in pathogen indicator density is consistent with findings reported by the USEPA – indicator density can fluctuate on both short (hourly) and long temporal scales in river and stream sites (USEPA 2010). Potential sources of pathogen indicators in the Pescadero Creek watershed include, but are not limited to, pet waste, wildlife, bacterial growth within the creek bed and conveyance systems, and leaking public and private sewer lines or onsite wastewater treatment systems.

Table 4.2. Enterococci and *E. coli* levels measured in San Mateo County during WY 2018 and WY 2019 (August 1, 2019).

Site ID	Site Name	Enterococci *(MPN/100ml)* WY 2018	Enterococci *(MPN/100ml)* WY 2019	*E. Coli* *(MPN/100ml)* WY 2018	*E. Coli* *(MPN/100ml)* WY 2019
202PES154	Pescadero Creek Upstream of Jones Gulch	43	16	30	13
202PES150	Jones Gulch Upstream of Confluence	36	35	ND	31
202PES144	Pescadero Creek Upstream of McCormick Creek	42	12	19	26
202PES142	McCormick Creek Upstream of Confluence	**816**	82	153	57
202PES138	Pescadero Creek at Memorial Park	**435**	23	14	29
WQO (based on 32 per 1000 recreators)		110		320	
MRP 2.0 Trigger (36 per 1000 recreators)		130		410	

All monitoring data collected between WY 2014 and WY 2019 were compared to the MRP trigger thresholds and State Water Board WQOs. The results for *E. coli* during this period of record are shown in Figure 4.1 with samples exceeding the WQO of 320 cfu/100 mL shown in red. There were three exceedances in WY 2017 at MS4 stations in the Pillar Point Harbor watershed. The data were used to support an SSID study investigation that was completed in WY 2019. There were three exceedances in two years (WY 2014 and WY 2015) in San Mateo Creek at two of the more urbanized sites on the creek.

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

5.0 Chlorine Monitoring

5.1 Introduction

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

From WY 2012 through WY 2019, in compliance with Provision C.8.c of MRP 1.0 and Provision C.8.d.ii of MRP 2.0, and to assess whether chlorine in receiving waters is present at concentrations potentially toxic to aquatic life, SMCWPPP field staff measured total and free chlorine residual in creeks where bioassessments were conducted. Total chlorine residual is comprised of "combined" chlorine and free chlorine and should always be greater than or equal to the free chlorine residual. Combined chlorine is chlorine that has reacted with ammonia or organic nitrogen to form chloramines, while free chlorine is chlorine that remains unbound. Both can be toxic to aquatic life, but chlorine dissipates into the atmosphere more quickly than chloramine.

5.2 Methods

In accordance with the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), field testing for free chlorine and total chlorine residual was conducted at ten sites each year concurrent with spring bioassessment sampling. From WY 2012 through WY 2018, all sites were selected using the probabilistic design described in Section 2.0. In WY 2019, three of the ten sites were selected on a targeted basis to address bioassessment management questions. Probabilistic and targeted site selection methods are described in Section 2.0.

Field testing for free chlorine and total chlorine residual conformed to methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016b), which are comparable to those specified in the SWAMP QAPP. Per SOP FS-3 (BASMAA 2016b), water samples were collected and analyzed for free and total chlorine using a Pocket Colorimeter™ II and DPD Powder Pillows, which has a manufacturer reported method detection limit of 0.02 mg/L. If concentrations exceeded the MRP trigger, the site was immediately resampled. The MRP 1.0 trigger criterion, implemented in WY 2012 through WY 2015, was 0.08 mg/L. The MRP 2.0 trigger criterion, implemented in WY 2016 through WY 2019, was 0.1 mg/L. If the resample also exceeds the trigger, the site is added to the list of candidate SSID projects. Provision C.8.d.ii(4) of MRP 2.0 also specifies that "Permittees report the observation to the appropriate Permittee central contact point for illicit discharges so that the illicit discharge staff can investigate and abate the associated discharge in accordance with its Provision C.5.e – Spill and Dumping Complaint Response Program."

5.3 Results and Discussion

The section below summarizes results from chlorine monitoring conducted during WY 2012 through WY 2018 and details results from WY 2019. Conclusion and recommendations are presented in Section 7.0.

In WY 2019, SMCWPPP monitored ten sites for free chlorine and total chlorine residual. The measurements were compared to the MRP 2.0 trigger threshold of 0.1 mg/L. Results are listed in Table 5.1. The trigger threshold for total chlorine residual was exceeded in the initial sample and the immediate resample at one station (204R04160), Burlingame Creek in the Town of Hillsborough. The field crew noted a pipe discharging a trickle of water to the creek just upstream of the sampling site. The 4-inch PVC pipe was unburied suggesting that it was a temporary and private installation, not part of the MS4. The exceedance and the presence of the pipe were immediately reported to the Hillsborough illicit discharge contact.

In WY 2019, at one station (202R03624), the free chlorine result (0.09 mg/L) was greater than the total residual chlorine result (0.06 mg/L). Inverted results such as this have been occasionally noted throughout the WY 2012 – WY 2019 monitoring program. Potential causes for these inverted results include matrix interferences, colorimeter user error, and concentrations near the detection limit. According to Hach, the supplier of the equipment and reagents, the free chlorine could have false positive results due to a pH exceedance of 7.6 and/or an alkalinity exceedance of 250 mg/L. The pH was measured concurrently with the chlorine sample, but alkalinity was not measured. The pH measured concurrently with chlorine at station 202R03624 exceeded 7.6, which may have resulted in a false positive for the free chlorine measurement. It is unlikely that the higher free chlorine readings were caused by user error. The field crew is well trained and aware of potential problems with this testing method, such as wait times between adding reagents and taking the readings and separating the free chlorine and total residual chlorine samples. The cause of the inverted free chlorine and total chlorine residual results (compared to expected) is unknown. However, it should be noted that colorimetric field instruments are generally not considered capable of providing accurate measurements of free chlorine and total chlorine residual below 0.13 mg/L, regardless of the method detection limit provided by the manufacturer. For this reason, the Statewide General Permit for drinking Water Discharges (Order WQ 2014-0194-DWQ) uses 0.1 mg/L as a reporting limit for field measurements of total chlorine residual.

Table 5.1. Summary of SMCWPPP chlorine testing results compared to MRP trigger of 0.1 mg/L, WY 2019.

Station Code	Date	Creek	Free Chlorine (mg/L)[1,2]	Total Chlorine Residual (mg/L)[1,2]	Exceeds Trigger Threshold (0.1 mg/L)[2]
202TUN030	05/14/19	Tunitas Creek	<0.02	<0.02	No
202TUN040	05/14/19	Tunitas Creek	<0.02	<0.02	No
204BEL005	05/13/19	Belmont Creek	<0.02	<0.02	No
204R03635	06/10/19	Atherton Creek	0.01	0.06	No
204R04160	05/19/19	Burlingame Creek	<0.02	0.1 / 0.2	Yes
204R04280	05/13/19	Belmont Creek	<0.02	<0.02	No
204R04428	05/15/19	Cordilleras Creek	0.1	0.1	No
204R04600	06/10/19	Atherton Creek	0.03	0.04	No
205R04056	06/11/19	Dry Creek	0.03	0.03	No
205R05044	06/11/19	Dry Creek	0.09	0.06	No

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

A total of 80 stations have been monitored by SMCWPPP for free chlorine and total chlorine residual between WY 2012 and WY 2019 in compliance with MRP 1.0 and MRP 2.0. Occasional exceedances were recorded throughout the years and addressed by the appropriate follow-up process. Figure 5.1 maps of all the samples stations with their associated results. Each sample station has two symbols; free chlorine in the left square and total chlorine residual on the right. Larger symbols are used to represent WY 2019 results. The results exceeding the MRP 2.0 trigger threshold of 0.1 mg/L are shown in red. The results exceeding the MRP 1.0 trigger threshold of 0.08 mg/L (but below the MRP 2.0 trigger) are shown in orange. All results equal to or below 0.08 mg/L are shown in green. Since WY 2012 there have been 11 stations with exceedances of either the free chlorine (9 exceedances) or total chlorine (6 exceedances) residual trigger. Trigger exceedances tend to occur in high order streams that flow through populated areas. The values range from non-detectable levels of chlorine to 0.58 mg/L. The two highest results occurred on Redwood Creek in WY 2017.

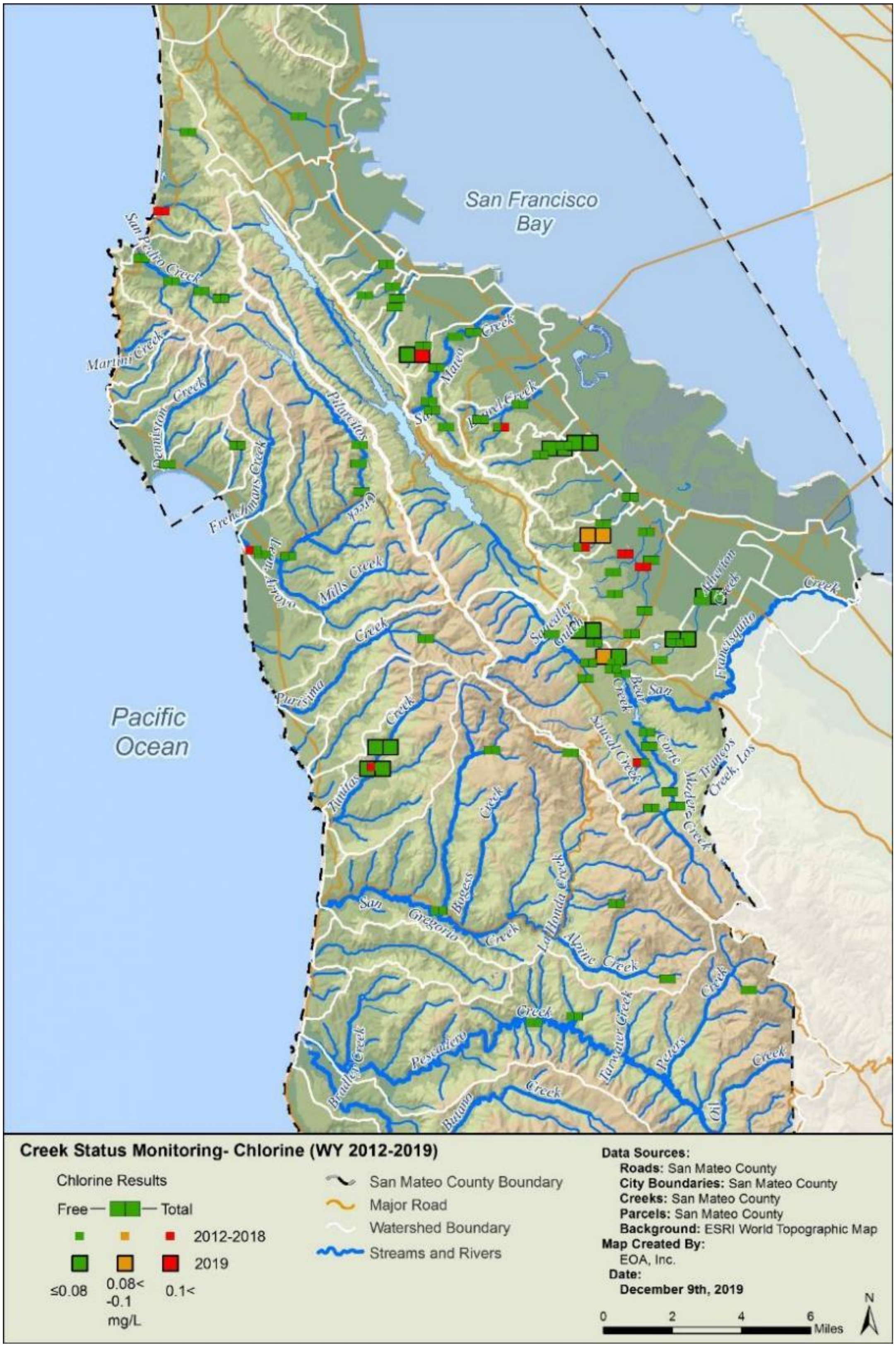

Figure 5.1 Chlorine sample stations and results WY 2012 – WY 2019 in San Mateo County.

6.0 Toxicity and Sediment Chemistry Monitoring

6.1 Introduction

This section describes the results of toxicity testing, sediment chemistry monitoring, and water column pesticides monitoring, collectively referred to as pesticides and toxicity monitoring, conducted during WY 2014 through WY 2019 in compliance with Provisions C.8.c of MRP 1.0 and C.8.g of MRP 2.0. The following discussion uses the pesticides and toxicity monitoring results and data from projects external to the RMC, to inform management efforts for San Mateo County urban creeks with respect to achievement of WQOs and support of beneficial uses.

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

Wet and dry weather monitoring of pesticides and toxicity in urban creeks was required during both the MRP 1.0 and MRP 2.0 permit terms. However, there were slight differences between the two permit terms with regard to the required number of samples, toxicity test organisms, and chemical constituents.

Dry Weather

In WY 2014 and WY 2015, Provision C.8.c of MRP 1.0 required that two sites be sampled for pesticides and toxicity each year during the dry weather period. SMCWPPP selected these two sites from the list of ten probabilistic sites where bioassessment was conducted during the same WY. MRP 1.0 dry weather monitoring included:

- Toxicity testing in water using four species: *Ceriodaphnia dubia* (chronic survival and reproduction), *Pimephales promelas* (larval survival and growth), *Selenastrum capricornutum* (growth), and *Hyalella azteca* (survival).
- Toxicity testing in sediment using one species: *Hyalella azteca* (survival)[21].
- Sediment chemistry analysis for pyrethroids, chlordane, dieldrin, endrin, heptachlor epoxide, lindane, dichlorodiphenyltrichloroethanes (DDT), metals, polycyclic aromatic hydrocarbons (PAHs), total organic carbon (TOC), and sediment grain size.

In WY 2016 through WY 2019, Provision C.8.g of MRP 2.0 required SMCWPPP to sample one site each year during the dry season for pesticides and toxicity. The permit provides examples of possible monitoring location types, including sites with suspected or past toxicity results,

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[21] Although the chronic (growth) endpoint for *Hyalella azteca* was not required by the MRP, it was provided by the laboratory and reported in the UCMRs.

existing bioassessment sites, or creek restoration sites. MRP 2.0, dry weather monitoring includes:

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

Wet Weather

In WY 2014 and WY 2015, MRP 1.0 required wet weather toxicity testing at the same two sites where dry season toxicity and sediment chemistry monitoring was conducted. The wet weather toxicity monitoring was based on the same four species as was used in the dry season monitoring. No wet weather water chemistry monitoring for pesticides or other potential pollutants was required during MRP 1.0.

Provision C.8.g.iii.(3) of MRP 2.0, covering WY 2016 through WY 2019, requires a collective total of ten wet weather toxicity and water chemistry samples if the wet weather monitoring is conducted by the RMC on behalf of all Permittees. MRP 2.0 states that the monitoring locations should be representative of urban watersheds (i.e., at the bottom of watersheds). At the RMC Monitoring Workgroup meeting on January 25, 2016, RMC members agreed to collaborate on implementation of the wet weather monitoring requirements. MRP 2.0 wet weather monitoring requirements include collection of water column samples during storm events for toxicity testing using the same five organisms required for dry weather testing and analysis of pyrethroids, fipronil, imidacloprid, and indoxacarb[22]. All ten wet weather samples were collected in WY 2018 during a single storm event on January 8, 2018. SCVURPPP and ACCWP each collected three samples, and SMCWPPP and CCCWP each collected two samples.

6.2 Methods

6.2.1 Site Selection

In WY 2014 and WY 2015, under MRP 1.0, the two annual pesticides and toxicity monitoring sites were selected from the list of ten probabilistic sites where bioassessment surveys were conducted. See Section 2.2 of this report for a description of the probabilistic survey design. Sites were identified based on the likelihood that they would be safe to access during storm events and that fine depositional sediments would be present during the dry season.

In WY 2016 through WY 2019, under MRP 2.0, sites were selected to represent mixed-land use in urban watersheds not already being monitored for toxicity or pesticides by other programs, such as the SWAMP Stream Pollution Trends (SPoT) program. A different watershed was targeted each year with the goal of eventually developing a geographically diverse dataset.

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

Specific monitoring locations within the identified creeks were based on the likelihood that they would contain fine depositional sediments during the dry season and would be safe to access during wet weather sampling, if relevant. During WY 2019, Pulgas Creek in the City of San Carlos (see Figure 6.1) was selected for monitoring.

In WY 2018, in compliance with Provision C.8.g.iii of MRP 2.0, water toxicity and pesticides samples were collected from two sites during wet weather: San Pedro Creek in the City of Pacifica and Cordilleras Creek near the City of San Carlos. San Pedro Creek was selected because it was monitored for dry weather pesticides and toxicity in WY 2017. Cordilleras Creek was selected because it was targeted for dry weather monitoring in WY 2018. The goal was to compare dry and wet weather monitoring results.

All stations monitored by SMCWPPP for wet and dry weather pesticides and toxicity during WY 2014 through WY 2019 are mapped in Figure 6.1. The SPoT station on San Mateo Creek is also mapped.

6.2.2 Sample Collection

Water and sediment samples for pesticides and toxicity monitoring were collected in accordance with SWAMP-comparable methods and procedures described in the BASMAA RMC SOPs (BASMAA 2016a) and the associated QAPP (BASMAA 2016b). Before sampling, field personnel conduct a qualitative assessment of the proposed sampling site to identify appropriate sampling locations. This is particularly necessary for sediment sampling, which requires the presence of fine-sediment depositional areas that can support at least five sub-sites within a 100-meter reach.

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

Sediment samples were collected after any water samples were collected. Sediment samples were collected from the top 2 cm at each sub-site beginning at the downstream-most location and continuing upstream. Field staff walk in an upstream direction, carefully avoiding disturbance of sediment at collection sub-sites. Sediment samples were placed in a compositing container, thoroughly homogenized, and then aliquoted into separate jars for chemical or toxicological analysis using standard clean sampling techniques (see SOP FS-6, BASMAA 2016a).

Samples were submitted to respective laboratories under RMC SOP FS-9 Chain of Custody procedures and field data sheets were reviewed per SOP FS-13 (BASMAA 2016a).

Figure 6.1 Pesticide and toxicity sampling locations in San Mateo County during WY 2014 through WY 2019.

6.2.3 Data Evaluation

Water and Sediment Toxicity

Toxicity data evaluation required by MRP 1.0 and MRP 2.0 involves first assessing whether the samples are toxic to the test organisms relative to the laboratory control treatment via statistical comparison. MRP 2.0 specifies using the Test of Significant Toxicity (TST) statistical approach to compare the sample to the laboratory control. For samples with toxicity (i.e., those that "failed" the TST), the Percent Effect is evaluated. The Percent Effect compares sample endpoints (survival, reproduction, growth) to the laboratory control endpoints. Both the statistical comparison (e.g., TST) and the comparison of the sample results to the laboratory control (e.g., Percent Effect) are determined by the laboratory.

For WY 2014 and WY 2015 data, Table 8.1 of MRP 1.0 identified toxicity results of less than 50% of the laboratory control as requiring follow-up action for water toxicity tests. For sediment toxicity tests in these years, MRP 1.0 Table H-1 identified toxicity results of greater than 20% less than the control as requiring follow-up action.

For WY 2016 through WY 2019 data, Provision C.8.g of MRP 2.0 identified toxicity results reported as "fail" via the TST approach and a Percent Effect of ≥ 50% as requiring follow-up action for water and sediment tests.

MRP 2.0 (WY 2016 – WY 2019) requires that the site is resampled if any toxicity test result exceeds the threshold. MRP 1.0 (WY 2014 and WY 2015) required resampling for water toxicity tests only, not sediment tests. If both the initial and follow-up sample exceed the threshold, the site is added to the list of candidate SSID projects.

Sediment Chemistry

Sediment chemistry results were evaluated using three criteria: Probable Effects Concentration (PEC) quotients, Threshold Effects Concentration (TEC) quotients and Toxicity Unit (TU) equivalents. PEC and TEC quotients are calculated as the ratio of the measured concentration to the respective PEC and TEC values from MacDonald et al. (2000). TU equivalents are calculated for individual pyrethroid pesticide results based on available LC50[23,] values from the literature. Because organic carbon mitigates the toxicity of pyrethroid pesticides and the LC50 values are derived on the basis of TOC-normalized concentrations, the pyrethroid concentrations as reported by the lab were divided by the measured TOC concentration at each site, and the TOC-normalized concentrations were then used to compute TU equivalents for each pyrethroid.

Under MRP 1.0 (WY 2014 and WY 2015), sites were added to the list of candidate SSID projects if three or more TEC quotients were ≥ 1.0, if the site had a mean PEC quotient ≥ 0.5, or if the sum of TU equivalents for all measured pyrethroids was ≥ 1.0.

MRP 2.0 requires that all sites where a PEC or TEC quotient is ≥ 1.0 are added to the list of candidate SSID projects. MRP 2.0 does not require consideration of pyrethroid, fipronil, or carbaryl[24] sediment chemistry data for follow-up SSID projects, perhaps because pyrethroids

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

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

are ubiquitous in the urban environment and little is known about fipronil and carbaryl distribution.

Evaluation of sediment chemistry data and calculation of PEC/TEC quotients and TU equivalents is based in several assumptions and considerations, including:

- For PAHs in sediment, the laboratory reports concentrations for 24 individual PAHs; whereas, PECs and TECs are listed in MacDonald et al. (2000) for total PAHs. Total PAH concentrations were calculated by summing the concentrations of 24 individual PAHs.
- Concentrations equal to one-half of the respective laboratory method detection limits were substituted for non-detect data so that calculations and statistics could be computed. Therefore, some of the TEC and PEC quotients and TU equivalents may be artificially elevated (and contribute to trigger exceedances) due to the method used to account for non-detect data.
- The TECs for bedded sediments are very conservative values that do not consider site specific background conditions and are therefore not very useful in identifying real water quality concerns in receiving waters in San Mateo County. All sites in the County are likely to have at least one TEC quotient equal to or greater than 1.0. This is due to high levels of naturally occurring chromium and nickel in geologic formations (i.e., serpentine) and soils that contribute to TEC and PEC quotients.

Water Chemistry

Provision C.8.g.iv of MRP 2.0 requires that chemical pollutant data from water and sediment monitoring be compared to the corresponding WQOs in the Basin Plan for each analyte sampled. If concentrations in the samples exceed their WQOs, then the site at which the exceedances were observed will be added to the list of candidate SSID projects. However, the Basin Plan does not contain numeric WQOs for the chemical analytes encompassed within the wet weather pesticide monitoring.

Water chemistry analysis was not part of pesticides and toxicity monitoring under MRP 1.0.

6.3 Results and Discussion

In WY 2014 and WY 2015, a total of four sites (two sites per year) were monitored for water and sediment toxicity and sediment chemistry during the wet and dry seasons. In WY 2014, sites in the Laurel Creek and Pilarcitos Creek watersheds were selected for monitoring. In WY 2015, sites in the Laurel Creek and Atherton Creek watersheds were selected for monitoring. The monitoring sites were selected from a list of locations where bioassessment surveys had been conducted. The results of these monitoring efforts were compared to MRP 1.0 trigger thresholds.

WY 2016 through WY 2019 dry weather water and sediment toxicity and sediment chemistry monitoring was conducted to satisfy the requirements specified in MRP 2.0. Dry weather monitoring took place at one site per year and was located in varying watersheds throughout San Mateo County to shed light on spatial variations in water quality present within the County. The monitored sites from WYs 2016, 2017, 2018, and 2019 were located in Laurel Creek, San Pedro Creek, Cordilleras Creek, and Pulgas Creek, respectively. In WY 2018, wet weather toxicity and water chemistry monitoring was conducted in San Pedro Creek and Cordilleras Creek to satisfy Provision C.8.g.iii of MRP 2.0.

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

6.3.1 Toxicity

WY 2019 Results

Details of the WY 2019 toxicity tests are listed in Table 6.1. Based on the WY 2019 toxicity test results, it is not necessary to add Pulgas Creek to the list of potential SSID projects. The sediment sample was not toxic to either of the test organisms. The water sample was significantly toxic to one of the five test organisms (*C. dubia* reproduction*);* however, the Percent Effect did not exceed the 50% threshold for follow-up. The cause of the water toxicity is unknown. Consistent with MRP requirements, no water chemistry samples were collected with the toxicity samples. The sediment chemistry, described in more detail in Section 6.3.2, suggests that copper and zinc may be slightly elevated in the Pulgas Creek watershed and could have caused toxicity to this test orgasms that is sensitive to a broad range of aquatic contaminants. Pyrethroids were also elevated in the sediment sample; however, no sediment toxicity to *H. azteca* which was observed is a test organism known to be sensitive to pyrethroid pesticides.

Table 6.1. Summary of SMCWPPP dry weather water and sediment toxicity results, Pulgas Creek, WY 2019.

Site	Organism	Test Type	Unit	Results		% Effect	TST Value	Follow up needed (TST "Fail" and ≥50%)
				Lab Control	Organism Test			
204PUL010 Pulgas Creek July 23, 2019	**Water**							
	Ceriodaphnia dubia	Survival	%	100	100	0%	NA[1]	No
		Reproduction	Num/Rep	32	25.6	20.0%	Fail	No
	Pimephales promelas	Survival	%	100	87.5	12.9%	Pass	No
		Growth	mg/ind	0.767	0.73	4.73%	Pass	No
	Chironomus dilutus	Survival	%	100	97.5	13%	Pass	No
	Hyalella azteca	Survival	%	100	100	0.00%	Pass	No
	Selenastrum capricornutum	Growth	cells/ml	3560000	8000000	-125%	Pass	No
	Sediment							
	Chironomus dilutus	Survival	%	80	80	0.00%	Pass	No
	Hyalella azteca	Survival	%	97.5	90	7.69%	Pass	No

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

WY 2014 – WY 2019 Summary

Toxicity results for the IMR reporting period, WY 2014 through WY 2019, are summarized in Table 6.2. Details of the WY 2014 to WY 2018 toxicity tests can be found in the Urban Creeks Monitoring Reports for each year (SMCWPPP 2019a, SMCWPPP 2018, SMCWPPP 2017, SMCWPPP 2016, SMCWPPP 2015).

During WY 2014 through WY 2019, there were three toxicity tests with sample results having toxicity relative to the laboratory control *and* a Percent Effect exceeding the MRP trigger threshold (see Section 6.2.3 for an explanation of MRP 1.0 and 2.0 triggers). All three of these tests with trigger exceedances were conducted in WY 2014 and WY 2015 for the growth (chronic) endpoint of *H. azteca*, a test that was not required by the MRP but was reported by the analytical laboratory. With one exception, where the Percent Effect was below the MRP trigger threshold, the associated tests for the survival (acute) endpoint did not cause toxicity to *H. azteca. H. azteca* is known to be sensitive to pyrethroid pesticides and these pesticides are commonly detected in urban creek sediment samples throughout San Mateo County. Long-term monitoring of San Mateo Creek by the SPoT program suggests that pyrethroid concentrations in sediment have decreased since 2011/2012 (SMCWPPP 2019b), which may explain why MRP 2.0 sediment samples were not toxic to *H. azteca*.

There were 18 test results that had significant toxicity, but with a Percent Effect that did not exceed the MRP trigger thresholds. A majority of these toxicity results were found in water samples and were associated with either *C. dubia* reproduction (six samples), a chronic toxicity endpoint, or *H. azteca* survival (six samples), an acute toxicity endpoint. Five of the six water samples with toxicity to *H. azteca* were collected during wet season sampling events suggesting that stormwater runoff is affecting *H. azteca*. The water samples with toxicity to *C. dubia* were more evenly dispersed between wet and dry season sampling events.

Table 6.2. Toxicity test result summary, WY 2014 – WY 2019, SMCWPPP. The Percent Effect is indicated for test results with toxicity relative to the lab control. Test results with toxicity exceeding the MRP 1.0 and MRP 2.0 trigger thresholds are shaded.

Station ID	Creek	Date	Season	Sediment			Water						
				C. dilutus [2]	*H. azteca*		*C. dubia*		*P. promelas*		*C. dilutus* [2]	*H. azteca*	*S. capricornutum*
				Survival	Survival	Growth [2]	Survival	Reproduction	Survival	Growth	Survival	Survival	Growth
MRP 1.0													
204R01288	Laurel Cr	2/8/2014	Wet	--	--	--	No	No	No	No	--	**Yes** (16%)	No
204R01288	Laurel Cr	6/4/2014	Dry	--	**Yes** (18%)	**Yes** (50%)	No	No	No	No	--	No	No
204R01308	Pilarcitos Cr	2/8/2014	Wet	--	--	--	No	No	No	No	--	No	No
204R01308	Pilarcitos Cr	6/4/2014	Dry	--	No	**Yes** (43%)	No	**Yes** (33%) [1]	No	No	--	No	No
204R01448	Atherton Cr	2/6/2015	Wet	--	--	--	No	**Yes** (30%)	No	No	--	**Yes** (24%)	No
204R01448	Atherton Cr	7/7/2015	Dry	--	No	No	No	No	No	No	--	No	No
204R02056	Laurel Cr	2/6/2015	Wet	--	--	--	No	**Yes** (22%)	No	No	--	**Yes** (45%)	No
204R02056	Laurel C	7/7/2015	Dry	--	No	**Yes** (31%)	No	No	No	No	--	No	No
MRP 2.0													
205LAU010	Laurel Cr	7/11/2016	Dry	**Yes** (14%)	No	--	No	**Yes** (31%)	No	No	**Yes** (10%)	**Yes** (29%)	No
202SPE005	San Pedro Cr	7/13/2017	Dry	No	No	--	No	**Yes** (46%)	**Yes** (18%)	No	No	No	No
202SPE005	San Pedro Cr	1/20/2018	Wet	--	--	--	No	No	No	**Yes** (23%)	No	**Yes** (16%)	No
204COR010	Cordilleras Cr	7/17/2018	Dry	No	No	--	No	No	No	No	**Yes** (11%)	No	No
204COR010	Cordilleras Cr	1/18/2018	Wet	--	--	--	No	No	No	No	No	**Yes** (20%)	No
204PUL010	Pulgas Cr	7/23/2019	Dry	No	No	--	No	**Yes** (20%)	No	No	No	No	No

Notes:
1 - The test response in one of the replicates for this test treatment was determined to be a statistical outlier; the results reported above are for the analysis of the data excluding the outlier.
2 - *Chironomus dilutus* testing was not required by MRP 1.0. *Hyalella azteca* growth was not required by either permit but is included here when reported by the lab.

6.3.2 Sediment Chemistry

Sediment chemistry results are evaluated as potential stressors based on TEC quotients and PEC quotients according to trigger thresholds listed in MRP 1.0 and MRP 2.0 (see Section 6.2.3). Evaluation of TU equivalents was required under MRP 1.0 and, although not required under MRP 2.0, used to inform stormwater management.

WY 2019 Results

Table 6.3 lists concentrations and TEC quotients for sediment chemistry constituents (metals and total PAHs) collected in WY 2019 from Pulgas Creek. TEC quotients are calculated as the measured concentration divided by the highly conservative TEC value, per MacDonald et al. (2000)[25]. TECs are extremely conservative and are intended to identify concentrations below which harmful effects on sediment-dwelling organisms are unlikely to be observed. The site on Pulgas Creek exceeded the trigger threshold from MRP 2.0 of having at least one result with a TEC quotient ≥ 1.0 and will therefore be added to the list of potential SSID projects. Two of the exceedances were for copper and zinc, while the other was for nickel. Exceedances for chromium and nickel are expected in watersheds draining hillsides underlain by serpentine formations. The reasons for the copper and zinc exceedances are unknown; however, these metals are commonly found in runoff from roads and other urban uses. The 2,200-acre Pulgas Creek watershed is almost entirely urban (84%) with an impervious surface area of 48%.

Table 6.4 lists concentrations and PEC quotients for sediment chemistry constituents (metals and total PAHs) collected in WY 2019 from Pulgas Creek. PECs are intended to identify concentrations above which toxicity to benthic-dwelling organisms are predicted to be probable. No PEC quotients were greater than 1.0.

Table 6.3. Threshold Effect Concentration (TEC) quotients for WY 2019 sediment chemistry constituents. Bolded and shaded values indicate TEC quotient ≥ 1.0.

	TEC	204PUL010	
		Pulgas Creek	
Metals (mg/kg DW)		**Concentration**	**Quotient**
Arsenic	9.79	3.6	0.37
Cadmium	0.99	0.16	0.16
Chromium	43.4	37	0.9
Copper	31.6	33.6	**1.06**
Lead	35.8	19	0.53
Nickel	22.7	34	**1.5**
Zinc	121	130	**1.07**
PAHs (ug/kg DW)			
Total PAHs	1610	334.2	0.21 [a]

a. Total calculated using 1/2 MDLs for some individual PAHs.

[25] MacDonald et al. (2000) does not provide TEC or PEC values for pyrethroids, fipronil, or carbaryl. Pesticides are compared to LC50 values in Table 6.5.

Table 6.4. Probable Effect Concentration (PEC) quotients for WY 2019 sediment chemistry constituents. Bolded and shaded values indicate PEC quotient ≥ 1.0.

	PEC	204PUL010 Pulgas Creek	
Metals (mg/kg DW)		**Concentration**	**Quotient**
Arsenic	33.0	3.6	0.11
Cadmium	4.98	0.16	0.03
Chromium	111	37	0.33
Copper	149	33.6	0.23
Lead	128	19	0.15
Nickel	48.6	34	0.7
Zinc	459	130	0.28
PAHs (ug/kg DW)			
Total PAHs	22,800	334.2	0.02 [a]

a. Total calculated using ½ MDLs for some individual PAHs.

Table 6.5 lists the concentrations of pesticides measured in sediment samples taken in WY 2019, TOC-normalized concentrations, and TU equivalents for the pesticides for which there are published LC50 values in the literature. Many of the pesticides measured were below method detection limits (MDLs) and TU equivalents were calculated using ½ the MDL concentration. The highest TU equivalent was for bifenthrin (0.56) which is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the California Department of Pesticide Regulation (DPR) Surface Water Protection Program Monitoring (SWPP) (Ensminger 2017). The sum-of-pyrethroids TU equivalent is 1.2 which exceeds the MRP 1.0 trigger threshold. With the exception of fipronil sulfone, all other pesticides were below the MDL; therefore, the TU equivalents calculated using ½ the MDL are not very informative.

Table 6.5. Pesticide concentrations and calculated toxicity unit (TU) equivalents, WY 2019.

			204PUL010 Pulgas Creek			
	Unit	**LC50**	**Concentration**		**Normalized to TOC**	**TU Equivalent**
Total Organic Carbon	%	NA	1.2		NA	NA
Pyrethroid						
Bifenthrin	µg/g dw	0.52	0.0035		0.29	0.56
Cyfluthrin, total	µg/g dw	1.08	0.0009	b	0.07	0.07
Cypermethrin, total	µg/g dw	0.38	0.0003	a	0.02	0.06
Deltamethrin/Tralomethrin	µg/g dw	0.79	0.004		0.33	0.42
Esfenvalerate/Fenvalerate, total	µg/g dw	1.54	0.0003	a	0.03	0.02
Cyhalothrin, Total lambda-	µg/g dw	0.45	0.0002	a	0.01	0.02
Permethrin, Total	µg/g dw	10.83	0.0028		0.23	0.02
			Sum of TU Equivalents			**1.2**
Other MRP Pesticides of Concern						
Carbaryl	mg/Kg	NA	0.01	a, c	0.8	NA
Fipronil	ng/g dw	306	0.26	a	21.3	0.07
Fipronil Desulfinyl	ng/g dw	NA c	0.26	a	21.3	NA
Fipronil Sulfide	ng/g dw	435	0.26	a	21.3	0.05
Fipronil Sulfone	ng/g dw	158	0.62	b	51.7	0.33

a. Concentration was below the method detection limit (MDL). TU equivalents calculated using 1/2 MDL.
b. TU equivalents calculated from concentration below the reporting limit but above the MDL (J-flagged).
c. Sources: Amweg et al. 2005 and Maund et al. 2002 for pyrethroids; Maul et al. for fipronil compounds
d. No available LC50 value for Carbaryl or Fipronil Desulfinyl.

In compliance with the MRP, a grain size analysis was conducted on the sediment sample (Table 6.6). The sample was 5.5% fines (i.e., 1.5% clay and 4.0% silt).

Table 6.6. Summary of grain size for site 204PUL010 in San Mateo County, WY 2019.

Grain Size (%)		204PUL010 Pulgas Creek
Clay	<0.0039 mm	1.5%
Silt	0.0039 to <0.0625 mm	4.0%
Sand	V. Fine 0.0625 to <0.125 mm	6.2%
	Fine 0.125 to <0.25 mm	23.3%
	Medium 0.25 to <0.5 mm	32.1%
	Coarse 0.5 to <1.0 mm	19.2%
	V. Coarse 1.0 to <2.0 mm	13.7%
Granule	2.0 to <4.0 mm	9.3%
Pebble	Small 4 to <8 mm	6.6%
	Medium 8 to <16 mm	3.3%
	Large 16 to <32 mm	0%
	V. Large 32 to <64 mm	0%

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

WY 2014 – WY 2019 Summary

Between WY 2014 and WY 2019, there were no PEC quotients calculated for the SMCWPPP sediment chemistry dataset that were ≥ 1.0 for analytes other than chromium and nickel. Chromium and nickel are excluded from this PEC/TEC analysis because they are contributed primarily by serpentine formations present in the watersheds where monitoring occurred. Excluding chromium and nickel, there were four samples with TEC quotients ≥ 1.0; the more conservative of the two evaluation criteria. The constituents and locations with TEC quotients ≥ 1.0 included:

- Legacy insecticide DDT compounds, which were monitored under MRP 1.0 but not under MRP 2.0, and exceeded the TEC in Laurel Creek WY 2014 and WY 2015 and in Atherton Creek in WY 2015;
- Individual PAHs, pyrene and chlordane, in Atherton Creek in WY 2015 and chlordane in Laurel Creek in WY 2015; and
- Copper and zinc in Pulgas Creek in WY 2019.

Table 6.7 lists TU equivalents for pesticides with LC50s available in the literature and concentrations for pesticides without LC50s for sediment samples collected in WY 2014 – WY 2019. The sum-of-pyrethroids TU equivalents ranged from 0.08 (San Pedro Creek in WY 2017) to 7.9 (station 204R01288 on Laurel Creek in WY 2014). The Laurel Creek sediment sample with the high pyrethroid TU equivalent was collected from a location relatively high in the watershed (Figure 6.1). Subsequent sampling at stations near the bottom of the Laurel Creek watershed in WY 2015 and WY 2016 had lower TU equivalents of 0.07 and 2.6, respectively. All three of these Laurel Creek sediment samples also had sediment toxicity (Table 6.2). The WY 2014 and WY 2015 samples had chronic (growth) toxicity to the pyrethroid-sensitive test organism, *H. azteca,* with Percent Effects exceeding the MRP 1.0 trigger threshold. The WY 2016 Laurel Creek sample was not toxic to *H. azteca* but was toxic to *C. dilutus* with a Percent Effect that did not exceed the MRP 2.0 trigger threshold. Four samples had sum-of-pyrethroid TU equivalents that exceeded the MRP 1.0 trigger threshold of 1.0: Pilarcitos Creek in WY 2014, Laurel Creek in WY 2014 and WY 2015, and Pulgas Creek in WY 2019.

Sampling for fipronil and carbaryl pesticides began in WY 2016 with adoption of MRP 2.0 and the fipronil degradates were added in WY 2017. Carbaryl has not been detected in any of the sediment samples (Table 6.7). Fipronil and/or fipronil sulfone were detected in San Pedro Creek and Pulgas Creek at TOC normalized concentrations below the LC50.

Table 6.7. TU equivalent summary for San Mateo County sediment samples, WY 2014 – WY 2019.

Analyte			Pyrethroids								Other MRP Pesticides of Concern				
			Bifenthrin	Cyfluthrin	Cypermethrin	Deltamethrin	Esfenvalerate	Lambda-cyhalothrin	Permethrin	**Sum Pyrethroids**	Carbaryl	Fipronil	Fipronil desulfinyl	Fipronil sulfide	Fipronil sulfone
LC50 [c]			0.52 µg/g dw	1.08 µg/g dw	0.38 µg/g dw	0.79 µg/g dw	1.54 µg/g dw	0.45 µg/g dw	10.83 µg/g dw	-	NA [d]	306 ng/g dw	NA [d]	435 ng/g dw	158 ng/g dw
Station ID	**Creek**	**Date**													
MRP 1.0															
202R01308	Pilarcitos	6/4/2014	1.06	0.24	<MDL	0.22 [b]	<MDL	<MDL	0.15	**1.9** [a]	-	-	-	-	-
204R01288	Laurel	6/4/2014	5.19	1.02	0.58	0.66	<MDL	<MDL	0.32	**7.9** [a]	-	-	-	-	-
204R01448	Atherton	7/7/2015	0.56	0.06	<MDL	<MDL	<MDL	<MDL	0.03	**0.7** [a]	-	-	-	-	-
204R02056	Laurel	7/7/2015	0.51	0.07	<MDL	<MDL	<MDL	<MDL	<MDL	**0.7** [a]	-	-	-	-	-
MRP 2.0															
204LAU010	Laurel	7/11/2016	1.37	0.36	0.23 [b]	0.51	<MDL	0.09 [b]	0.05	**2.6** [a]	<MDL	<MDL	-	-	-
202SPE005	San Pedro	7/13/2017	0.04	<MDL	<MDL	<MDL	<MDL	<MDL	0.001 [b]	**0.08** [a]	<MDL	0.02 [b]	<MDL	<MDL	0.08 [b]
204COR010	Cordilleras	7/17/2018	0.25 [b]	<MDL	<MDL	0.10 [b]	<MDL	<MDL	0.08 [b]	**0.52** [a]	<MDL	<MDL	<MDL	<MDL	<MDL
204PUL010	Pulgas	7/23/2019	0.56	0.07 [b]	<MDL	0.42	<MDL	<MDL	0.02	**1.2** [a]	<MDL	<MDL	<MDL	<MDL	0.33 [b]

a. TU equivalent calculated using 1/2 MDL and total calculated using 1/2 MDLs for some individual pyrethroids.
b. TU equivalents calculated from concentration below the reporting limit (J-flagged).
c. Sources: Amweg et al. 2005 and Maund et al. 2002 for pyrethroids; Maul et al. 2008 for fipronil compounds
d. No available LC50 value for Carbaryl or Fipronil Desulfinyl.

6.3.3 Pesticides in Water

During WY 2018, wet weather water samples were collected for pesticide analysis at two sites in San Mateo County (San Pedro Creek and Cordilleras Creek) to fulfill Provision C.8.g.iii.(3) of MRP 2.0. Results were reported in the WY 2018 UCMR (SMCWPPP 2019a). The concentrations of most pesticides analyzed were below the MDL, meaning that these analytes were reported as non-detects. The neonicotinoid, imidacloprid was found at detectable levels at one of the two sites (Cordilleras Creek). Additionally, detectable levels of fipronil and its degradation products were found at both sites.

There are no WQOs specified in the San Francisco Bay Basin Plan for the water column pesticide analytes. As a result, no WQO or MRP trigger threshold exceedance analysis was performed on wet weather pesticide data.

6.3.4 Additional Pesticide Monitoring Efforts

Throughout the monitoring period associated with the sampling results described in this report, several additional programs external to SMCWPPP and the RMC conducted similar pesticides and toxicity studies within California. These studies provide valuable data for comparison against RMC findings to view regional water quality in a broader spatial and temporal context, ultimately providing more accurate and complete answers to the management questions set forth by the MRP.

DPR SWPPP Monitoring

Mentioned previously in this document, the DPR SWPP is one of the largest pesticide monitoring and management efforts currently being undertaken in California. Pesticide studies conducted by the DPR SWPP evaluate the frequency of pesticide detections at any concentration and make use of USEPA aquatic benchmarks for many pesticide compounds. DPR provides web access to a number of their monitoring reports which contain detailed analyses of USEPA aquatic benchmark exceedance rates. DPR also maintains the Surface Water Database (SURF) to provide public access to quantitative pesticide data from a wide array of surface water monitoring studies. This database could be queried in the future to allow for the leverage of DPR monitoring data in more complex analyses of MRP pesticide data.

In WY 2017, DPR conducted two studies in Northern and Southern California that involved pesticides and toxicity monitoring at urban sites in Alameda, Contra Costa, Placer, Sacramento, Santa Clara (Guadalupe River – see Figure 6.1), Los Angeles, Orange, and San Diego Counties. Both water and sediment samples were collected and analyzed for a wide range of pesticide compounds. In both the Northern and Southern California studies, bifenthrin and fipronil were found to be among the most frequently detected pesticides. Additionally, pyrethroid concentrations were found to be above their USEPA minimum benchmarks for toxicity to aquatic life for the majority of samples with the exception of cyfluthrin. The studies also state that the detection frequencies of most pyrethroids have remained consistent over recent years. (Budd 2018 and Ensminger 2017)

In WY 2018, DPR again conducted two urban monitoring studies in Northern and Southern California that targeted watersheds in the same counties sampled during WY 2017 and involved the collection of water and sediment samples. Similar to WY 2017, bifenthrin was among the most frequently detected insecticides in water samples from both the Northern and Southern California WY 2018 studies. In the Northern California study, bifenthrin was the most frequently detected insecticide and second most frequently detected compound in water samples with a detection frequency (DF) of 76%. In the Southern California study, bifenthrin was the most frequently detected pyrethroid insecticide and the fifth most frequently detected compound in water samples with a DF of 72%. Fipronil and its degradates were also detected at high rates in water samples from the Northern and Southern California studies. While fipronil itself only had a DF of 48% in the Northern California study, fipronil and its degradates collectively had a DF of 72%. Out of these compounds, fipronil sulfone was found at the highest rate with a DF of 70%. Fipronil was also found at a high rate during the Southern California study with a DF of 76%. Its degradates were also found in a large portion of samples, with fipronil sulfone again being the most found with a DF of 67%. Sediment samples from Northern and Southern California were collected and analyzed for bifenthrin and eight other pyrethroids, but concentrations of fipronil and its degradates were not measured. In both studies, bifenthrin was detected in all samples and was also responsible for the greatest magnitude of TUs. (Budd 2019 and Ensminger 2019)

Findings from the WY 2017 and WY 2018 DPR studies generally corroborate the results garnered from SMCWPPP pesticides monitoring. In particular, bifenthrin has been the most frequently detected pesticide in samples collected by SMCWPPP from WYs 2014 through 2019 and responsible for the high-magnitude TU equivalents. Similarly, fipronil and/or its degradates were found at detectable levels in 50% of SMCWPPP sediment samples.

SPoT Monitoring Program

The SPoT Monitoring Program conducts annual dry season monitoring (subject to funding constraints) of sediments collected from a statewide network of large rivers. The goal of the SPoT Program is to investigate long-term trends in water quality. Sites are targeted in bottom-of-the-watershed locations with slow water flow and appropriate micromorphology to allow deposition and accumulation of sediments, including a station near the mouth of San Mateo Creek (Figure 6.1). In most years, sediments are analyzed for toxicity, pesticides, metals, PCBs, mercury, and organic pollutants (Phillips et al. 2014). The most recent technical report prepared by SPoT program staff was published in 2016 and describes seven-year trends from the initiation of the program in 2008 through 2014 (Phillips et al. 2016). An update to the report is anticipated in the near future.

Toxicity testing was conducted by SPoT in San Mateo County using *H. azteca* as the indicator organism and the TST statistical approach, similar to a subset of the toxicity testing completed by SMCWPPP. SPoT samples were characterized as highly toxic if the percent survival was lower than the threshold of 38.6% survival identified as the lower limit survival rate threshold for high toxicity (Anderson et al. 2011). SPoT reported that *H. azteca* toxicity responses have been consistent over the seven-year monitoring period with toxic and highly toxic samples accounting for an average of 18.6% of the samples tested (Phillips et al. 2014). This average aligns relatively closely with the total amount of toxicity exceedances attributed to *H. azteca* survival found during SMCWPPP monitoring from WY 2014 through WY 2019, which was 12.5%. The SPoT study also calculated five-year rolling averages of toxicity results from 2008 to 2012 and again from 2010 to 2014 to resolve temporal trends in the data. It was found that while the total number of sites exhibiting no toxicity increased from the first averaging period to the second, the number of sites exhibiting moderate to high toxicity also increased during this time (Phillips et al. 2014).

During SPoT sediment chemistry monitoring, the average total pyrethroid concentrations were shown to have doubled from 2010 to 2013. The SPoT analysis identified urban monitoring sites as the exclusive cause of the increase in average pyrethroid concentrations, as pyrethroid concentrations in agricultural and other land use areas remained consistently low throughout the entirety of the monitoring period. The study identified bifenthrin as the primary driver of the increase in average pyrethroid concentrations with a DF of 73% throughout the extent of the monitoring period (Phillips et al. 2014). These findings contrast with the results of the most recent SMCWPPP monitoring period, which have not shown a measurable increase in pyrethroid-related water quality impairment. Additionally, results from SPoT testing for fipronil at urban sites in 2013 and 2014 showed that the DF of fipronil and its degradates in addition to their average and maximum concentrations increased between the two years.

7.0 Conclusions and Recommendations

This section includes conclusions and recommendations from the review of WY 2014 through WY 2019 Creek Status and Pesticides & Toxicity Monitoring data that were presented in the preceding chapters. In addition, it evaluates probabilistic bioassessment data collected in San Mateo County from WY 2012 through WY 2019.

In WY 2019, in compliance with Provisions C.8.d and C.8.g of MRP 2.0 and the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012), SMCWPPP continued to implement a two-component monitoring design that was initiated in WY 2012. The strategy includes a regional ambient/probabilistic bioassessment monitoring component and a component based on local targeted monitoring for general water quality parameters and pesticides/toxicity. The combination of these monitoring designs allows each individual RMC participating program (including SMCWPPP) to assess the status of Beneficial Uses in local creeks within its jurisdictional area, while also contributing data to eventually answer management questions at the regional scale (e.g., differences between aquatic life condition in urban and non-urban creeks).

Conclusions from Creek Status and Pesticides/Toxicity Monitoring conducted during WY 2014 through WY 2019 (WY 2012 through WY 2019 for bioassessment) in San Mateo County are based on the management questions from the MRP presented in Section 1.0 of this report:

1) *Are water quality objectives, both numeric and narrative, being met in local receiving waters, including creeks, rivers, and tributaries?*
2) *Are conditions in local receiving water supportive of or likely supportive of beneficial uses?*

The first management question was addressed primarily through the evaluation of probabilistic and targeted monitoring data with respect to WQOs and triggers defined in the MRP. A summary of trigger exceedances observed for each WY 2019 site is presented in Table 7.2. Trigger exceedances from WY 2014 through WY 2018 are summarized in this IMR, described in prior annual monitoring reports (SMCWPPP 2019a, SMCWPPP 2018, SMCWPPP 2017, SMCWPPP 2016, SMCWPPP 2015), and listed in Attachment 4. In compliance with Provision C.8.e.i of MRP 2.0, SMCWPPP coordinates with the RMC to maintain a comprehensive list of all monitoring results from the region (since WY 2016) exceeding trigger thresholds. Sites where triggers are exceeded may indicate potential impacts to aquatic life or other beneficial uses and are considered for future evaluation via Stressor/Source Identification projects.

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

All monitoring and data validation were conducted using methods consistent with the BASMAA RMC QAPP (BASMAA 2016a) and SOPs (BASMAA 2016b). Recommendations for future monitoring are described in Section 7.3.

7.1 Conclusions

7.1.1 Biological Condition Assessment

In WY 2012 through WY 2019, bioassessment monitoring was conducted in compliance with Provisions C.8.c of MRP 1.0 and C.8.d.i of MRP 2.0. Nearly all bioassessment monitoring (87 of 90 sites) was performed at sites selected randomly using the regional probabilistic monitoring design. The probabilistic monitoring design allows each individual RMC participating program to objectively assess stream ecosystem conditions within its jurisdictional area while contributing data to answer regional management questions about water quality and beneficial use condition in San Francisco Bay Area creeks. The monitoring design was developed to address the following management questions from the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012):

1. *What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?*
2. *What are major stressors to aquatic life in the RMC area?*
3. *What are the long-term trends in water quality in creeks over time?*

The first question (i.e., *What is the condition of aquatic life in creeks in the RMC area; are water quality objectives met and are beneficial uses supported?*) was addressed by assessing indicators of aquatic biological health at probabilistic sampling locations. Over the past eight years (WY 2012 through WY 2019), SMCWPPP and the Regional Water Board have sampled 87 probabilistic sites in San Mateo County, providing a sufficient sample size to estimate ambient biological condition for urban streams countywide within known estimates of precision. Stream condition was assessed using three different types of indices/tools: the BMI-based CSCI, the draft benthic algae-based ASCI (diatom, soft algae, and hybrid), and the physical habitat-based IPI. Of these three, the CSCI is the only tool with an MRP trigger threshold for follow-up SSID consideration.

The second question (i.e., *What are major stressors to aquatic life in the RMC area?*) was addressed by the evaluation of physical habitat and water chemistry data collected at the probabilistic sites, as potential stressors to biological health. Assessing the extent and relative risk of stressors can help prioritize stressors and inform local management decisions. The stressor levels were compared to biological indicator data (i.e., CSCI and ASCI scores) through correlation and random forest models. The methods were consistent with the approach used in the RMC Five-Year Bioassessment Report (BASMAA 2019) which analyzed the first five years (WY 2012 – WY 2016) of regional bioassessment data. Results from SMCWPPP's assessment are compared to the regional assessment. A detailed description of the methods and results for the countywide analysis of bioassessment data is provided in Attachment 3.

The third question (i.e., *What are the long-term trends in water quality in creeks over time?*) was addressed by assessing the change in biological condition over several years. Changes in biological condition over time can help evaluate the effectiveness of management actions.

7.1.1.1 Bioassessment Data (WY 2019)

In WY 2019, ten sites were sampled for benthic macroinvertebrates, benthic algae, and nutrients. Physical habitat was also assessed at each of the ten stations, and general water quality parameters were measured using a pre-calibrated multi-parameter field probe. Seven of the ten sites were randomly selected using the probabilistic monitoring design and three were targeted. Two of the targeted sites were in Tunitas Creek and were selected to follow-up on previous CSCI scores that were lower than expected. The third targeted site, in Belmont Creek, was selected to provide baseline data in a creek where a multi-benefit project is planned.

CSCI scores and water quality data were compared to applicable WQOs and triggers identified in the MRP. Sites with results that exceed WQOs and triggers are considered as candidates for SSID projects, consistent with Provision C.8.e of MRP 2.0.

- All seven of the probabilistic sites and the site in Belmont had CSCI scores below the MRP trigger threshold of 0.795. These eight sites were all classified as urban and were located in creeks that drain to San Francisco Bay.
- One site on Atherton Creek had a specific conductance level that exceeded the MRP trigger threshold. Other nutrient or general water quality parameters were not measured at concentrations exceeding WQOs or MPR trigger thresholds.

Tunitas Creek

With redwood forest dominated headwaters, the Tunitas Creek watershed is relatively undeveloped and drains to the Pacific Ocean. In WY 2016, the CSCI score from a site in Tunitas Creek was 0.55, which is in the lowest stream condition category (*very likely altered*). Targeted monitoring at the same site in WY 2019 resulted in a CSCI score of 0.84, which is in the second highest condition category (*possibly intact*) and above the MRP trigger threshold. It is unknown why the CSCI score increased in WY 2019, when there were no known changes in land use or land management. It is possible that the CSCI tool produces results that are more variable than expected under changing weather conditions. Water Year 2016 was the fifth year in a row with below average rainfall; whereas, WY 2019 had above average rainfall and was within two years of the very wet year of WY 2017.

7.1.1.2 Countywide Bioassessment Data (WY 2012 – WY 2019)

The bioassessment data collected at probabilistic sites from WY 2012 to WY 2019 (n=87) were evaluated to assess the current condition of streams in the County and to identify stressors that are likely to pose the greatest risk to stream health. The methods used to evaluate bioassessment data were consistent with the approach used to develop the RMC Five-Year Bioassessment Report (BASMAA 2019).

Biological Condition Assessment

Four biological indicators (CSCI and ASCI-D, ASCI-SB, ASCI-H) were used to assess stream conditions. Results of the analysis indicate that much of the stream length in San Mateo County is in poor biological condition. Aquatic life uses may not be fully supported at most sites sampled by SMCWPPP. These findings should be interpreted with the understanding that the survey focused on urban streams. Approximately 65% of the samples (60 of 90) were collected at urban sites. Although the low non-urban sample size precludes making any definitive comparisons, bioassessment scores at non-urban sites were generally higher than scores at urban sites:

- A total of 60 of the 90 (67%) bioassessment sites (including three targeted sites) received CSCI scores that were below the MRP trigger (0.795), corresponding to the two lower condition categories *(likely altered* and *very likely altered)*. Fifty-five of the 60 low scoring sites were classified as urban. The proportion of sites with good biological conditions was much higher in watersheds draining to the Pacific Ocean compared to sites located in watersheds draining to San Francisco Bay.

- Cumulative frequency functions (CDFs) for CSCI scores indicate there is a 48% probability that a random site in San Mateo County will have a CSCI score below 0.79 (i.e., *likely altered* or *very likely altered*). There is an 86% probability that a random *urban* site in San Mateo County will have a CSCI score below 0.79 and there is a 22% probability that a random *non-urban* site will have a CSCI score below 0.79.

- Biological conditions based on algae data (ASCI) differ from the conditions based on BMI data (CSCI). The ASCI-H tool applies diatom and soft bodied algae data, the ASCI-D tool applies diatom data, and the ASCI-SB tool applies soft bodied algae data. Table 7.1 summarizes the percent of sites in each condition category for each of the four indices. The percent of sites in each category based on ASCI-D and ASCI-H were similar in magnitude to the CSCI results. The ASCI-SB scores do not appear to be associated with the urban disturbance gradient. A higher percent of sites was in the *likely intact* condition category based on ASCI-SB scores, and a lower percent was in the *very likely altered* category.

Table 7.1. Percent of sites in San Mateo County in each condition category, WY 2012 – WY 2019.

Index [1]	Sites with index score [2]	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Benthic Macroinvertebrates (BMI)					
CSCI	90	21%	12%	11%	56%
Benthic Algae					
ASCI-D	90	19%	16%	19%	47%
ASCI-SB	85	52%	25%	9%	14%
ASCI-H	85	13%	9%	20%	59%

[1] Indices: CSCI = California Stream Condition Index; ASCI-D = Diatom Algae Stream Condition Index; ASCI-SB = Soft Bodied Algae Stream Condition Index; ASCI-H = Hybrid Algae Stream Condition Index.
[2] Index scores for ASCI-SB and ASCI-H were not calculated for 5 bioassessment sites due to insufficient soft algae taxa.

<u>Stressor Assessment</u>

The association between biological indicators (CSCI and ASCI-H) and stressor data was evaluated in the using Spearman's rank correlation and random forest models. The results indicate that each of the biological indicators respond to different types of stressors:

- The random forest model of CSCI scores indicates that landscape, habitat, and water-quality stressors, specifically road density, impervious area, and total nitrogen were the best predictors of biological condition. The random forest model of ASCI-H scores indicates habitat and water-quality stressors, specifically temperature, channel alteration, and combined human disturbance (HDI) were the best predictors of biological condition.

- In the Spearman's rank correlation analysis, nutrients (Total Nitrogen and Total Kjeldahl Nitrogen) correlated better with CSCI scores from sites on creeks flowing to San Francisco Bay than sites on creeks flowing to the Pacific Ocean. Nutrient stressors (Total Kjeldahl Nitrogen and Total Nitrogen) also ranked as important variables in the random forest models.

- Results of the San Mateo County stressor assessment differ from the RMC regional assessment. Although both San Mateo County and regional CSCI scores are strongly influenced by imperviousness in the contributing area, the regional assessment did not identify nutrients as important predictors of CSCI scores (BASMAA 2019).

It should be noted that despite these apparent relationships to stressors, these analyses do not determine causation, particularly as stressors from habitat/landscape factors are often present at the same sites that exhibit water quality impairment.

7.1.1.3 Trend Assessment

Based on a review of the probabilistic data collected in San Mateo County, it appears that analysis of long-term trends using the probabilistic dataset will require more than eight years of monitoring. For example, annual median CSCI scores at urban sites were similar during all years of MRP monitoring (WY 2012 – WY 2019).

Comparison of the probabilistic dataset with targeted data collected prior to adoption of the MRP (i.e., WY 2002 to WY 2007) allows for a semi-quantitative trends assessment. SMCWPPP conducted bioassessments in four San Mateo County watersheds between 2002 and 2007 as part of watershed assessment and monitoring requirements in its municipal stormwater NPDES Permit (Pre-MRP). Biological conditions, based on CSCI scores, during Pre-MRP and MRP time periods were compared for all sites within each watershed. Median CSCI scores were consistently higher for sampling events occurring during the MRP. Likewise, comparison of data from three individual sites that were monitored during each of the time periods shows higher CSCI scores for the MRP time period.

7.1.2 Continuous Monitoring for Temperature and General Water Quality

Continuous monitoring of water temperature and general water quality in WY 2012 through WY 2019 was conducted in compliance with Provisions C.8.c of MRP 1.0 and C.8.d.iii – iv of MRP 2.0. Hourly temperature measurements were recorded at a minimum of four sites each year from April through September. Continuous (15-minute) general water quality measurements (pH, DO, specific conductance, temperature) were recorded at two sites each year during two 2-week periods in spring (Event 1) and summer (Event 2). Monitoring was conducted to address the following management questions from the BASMAA RMC Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012):

1. *What is the spatial and temporal variability in water quality conditions during the spring and summer season?*

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

Monitoring sites were selected based on the presence of significant fish and wildlife resources as well as historical and/or recent indications of water quality concerns. The same sites were often monitored for multiple years to gain a better understanding of the range of water quality conditions that may occur over time. In some years, continuous monitoring data were used to support or follow-up on SSID investigations. The results from continuous monitoring of water temperature and general water quality in San Mateo County in WY 2014 through WY 2019 may be summarized as follows:

- The San Mateo Creek watershed, which supports steelhead rearing and spawning habitat, was targeted for general water quality monitoring in WY 2014 and WY 2015. Data were used to support an SSID study investigating low dissolved oxygen concentrations. The study confirmed that historic low dissolved oxygen concentrations were likely caused by low dry season flows which no longer occurred as a result of increased dry season releases from the Crystal Springs Reservoir. However, the MRP MWAT trigger of 17°C was exceeded in WY 2015.

- The San Francisquito Creek watershed was targeted for temperature monitoring in WY 2014 through WY 2016, which represents a worst-case scenario for summer temperatures due to persistent drought conditions. Creeks in the watershed typically cease to have continuous flow through the dry season, even during non-drought years. Therefore, all sites were located in pools that have historically remained wet throughout the summer and likely provide refuge for cold water fish. In all three years of monitoring, the MRP MWAT trigger of 17°C was exceeded at one or more station.

- The Bear Creek tributary to San Francisquito Creek was targeted for general water quality monitoring in WY 2016 to evaluate water quality in reaches that have historically supported juvenile steelhead rearing and spawning habitat. Both stations had become isolated pools by the summer monitoring event but would not have provided good refuge for cold water fish due to low dissolved oxygen concentrations that were below WQOs for WARM and COLD freshwater habitat.

- The San Pedro Creek watershed, which contains the northern-most population of naturally producing steelhead trout in San Mateo County, was targeted for temperature and general water quality monitoring in WY 2017 and WY 2018. No WQOs or MRP trigger thresholds were exceeded in either year.

- The Tunitas Creek watershed, which currently supports steelhead populations, was targeted for temperature and general water quality monitoring in WY 2019 to supplement targeted bioassessment monitoring also conducted in Tunitas Creek. As described above, in WY 2016 the CSCI score for a site on Tunitas Creek was in the *very likely altered* condition category, an unexpectedly low score considering the low level of urban development in the watershed. In WY 2019, the CSCI score was much higher, in the *possibly intact* category. In addition, no WQOs or MPR trigger thresholds were exceeded in the continuous monitoring dataset.

Overall, continuous monitoring results typically reveal that temperature and specific conductivity increase in the downstream direction which is also characterized by increasing urbanization in San Mateo County watersheds. In addition, the MRP MWAT trigger threshold of 17°C is often exceeded. These exceedances result in sites being placed on the list of candidate SSID projects, but are usually explained by lack of continuous flow in the late summer. Other locations where the MWAT trigger is exceeded are in reaches that cold water fish travel through rather than reside.

7.1.3 Pathogen Indicator Monitoring

From WY 2014 through WY 2019, in compliance with Provisions C.8.c of MRP 1.0 and C.8.d.v of MRP 2.0, SMCWPPP collected five grab samples per year for pathogen indicator bacteria analysis. Monitoring was conducted in three areas at sites selected to inform bacteria SSID investigations and/or follow-up on reports of potential high bacteria in creeks where water contact recreation (REC-1) is likely (e.g., by San Mateo County Parks staff). The overall goal of pathogen indicator monitoring is to assess whether WQOs are being met, i.e., supportive of REC-1 Beneficial Uses. The results from pathogen indicator monitoring in San Mateo County in WY 2014 through WY 2019 may be summarized as follows:

- The San Mateo Creek watershed was targeted in WY 2014 through WY 2016 to support and follow-up on the San Mateo Creek Pathogen Indicator SSID Project (SMCWPPP 2016). The study found that *E. coli* followed predictable seasonal and spatial patterns, with higher densities observed during wet season monitoring events and at stations lower in the watershed. There were no exceedances of the *E. coli* WQO in WY 2016 samples, suggesting that the control actions had a beneficial impact on water quality in San Mateo Creek.

- Creek and MS4 stations were sampled in WY 2017 to support the Pillar Point Harbor Watershed Pathogen Indicator SSID Project. Results of the SSID study showed that *E. coli* densities were highly variable and did not follow predictable seasonal patterns. The Final Project report is included as an appendix to Part C (SSID Status Report) of this IMR.

- The Pescadero Creek watershed, in the vicinity of Memorial County Park, was targeted in WY 2018 and WY 2019 to characterize geographic patterns of pathogen indicator densities in the area. Two of the WY 2018 grab samples exceeded the enterococci WQO and the pattern suggested a bacterial source in the McCormick Creek tributary. In WY 2019, the McCormick Creek station had the highest bacteria densities of the monitored stations but no WQOs were exceeded.

Overall, pathogen indicator monitoring results from San Mateo County are highly variable and sometimes exceed WQOs. It is important to recognize that pathogen indicators do not directly represent actual pathogen concentrations and do not distinguish among sources of bacteria. Sources of pathogen indicator bacteria include homeless encampments, wildlife, livestock, pets, leaking septic systems/sanitary sewers, and regrowth of bacteria in the environment. Bacteria from human sources are more likely to be associated with human health risks during water contact recreation. As a result, the comparison of pathogen indicator results to WQOs may not be appropriate and should be interpreted cautiously.

7.1.4 Chlorine Monitoring

From WY 2012 through WY 2019, in compliance with Provision C.8.c of MRP 1.0 and Provision C.8.d.ii of MRP 2.0, SMCWPPP collected field measurements of total and free chlorine residual in creeks where bioassessments were conducted.

While chlorine residual has generally not been a concern in San Mateo County creeks, WY 2019 and prior monitoring results suggest there are occasional trigger exceedances of free chlorine and/or total chlorine residual in the County. Trigger exceedances may be the result of one-time potable water discharges, and it is generally challenging to determine the source of elevated chlorine from such episodic discharges. Furthermore, chlorine in surface waters can dissipate from volatilization and reaction with sediment and organic matter. In WY 2019, there was one exceedance of the MRP trigger for chlorine (0.1 mg/L). Over the past eight years of monitoring (WY 2012 – WY 2019), there have been a total of 11 sites with chlorine trigger exceedances (including the one site in WY 2019).

7.1.5 Pesticides and Toxicity Monitoring

Toxicity testing, sediment chemistry monitoring, and water column pesticides monitoring, collectively referred to as pesticides and toxicity monitoring, was conducted during WY 2014 through WY 2019 in compliance with Provisions C.8.c of MRP 1.0 and C.8.g of MRP 2.0. There were slight differences between the two permit terms regarding the required number of samples, toxicity test organisms, chemical constituents, and MRP triggers.

Data Evaluation Summary

There are five toxicity test species for water samples and two test species for sediment samples. The test organism *H. azteca*, required for water and sediment is known to be sensitive to pyrethroid pesticides. The test organism *C. dilutus*, added in MRP 2.0, is known to be sensitive to neonicotinoids. A two-tiered approach is applied to assess toxicity. First, organism responses from ambient samples are compared to responses from appropriate laboratory control samples using a statistical comparison. This is followed by a comparison to a “threshold value” or “Percent Effect” that indicates the magnitude of the difference in response. The MRP 2.0 trigger threshold is 50 Percent Effect in the initial sample and a second, follow-up sample for both water and sediment toxicity tests. The MRP 1.0 trigger threshold was 20 Percent Effect in sediment samples with no follow-up required and 50 Percent Effect in the initial and follow-up water samples.

Sediment chemistry data for metals, PAHs, and legacy pesticides (MRP 1.0 only) are compared to Threshold Effect Concentrations (TECs) and Probably Effect Concentrations (PECs) published by MacDonald et al. (2000). Most samples in San Mateo County have chromium and nickel concentrations that exceed the TEC and PEC. These metals are naturally occurring in the serpentine formations that underly mountains and hills in the region. Sediment chemistry data for pyrethroid and fipronil (MRP 2.0 only) pesticides are compared to TOC-normalized LC50s, calculated at Toxicity Unit equivalents. There are no WQOs for the suite of monitored constituents for comparison to water chemistry data.

Under MRP 1.0 (WY 2014 and WY 2015), pesticides and toxicity monitoring stations were selected from the list of bioassessment stations surveyed those years. Under MRP 2.0 (WY 2016 – WY 2019), bottom-of-the-watershed stations in different creeks were monitored each year with the goal of eventually developing a geographically diverse dataset.

WY 2019 Results

In WY 2019, SMCWPPP conducted dry weather pesticides and toxicity monitoring at one station on Pulgas Creek in the City of San Carlos. Statistically significant toxicity to *C. dubia* was observed in the water sample collected from Pulgas Creek. However, the magnitude of the toxic effects in the samples compared to laboratory controls did not exceed MRP trigger criteria of 50 Percent Effect. The cause of the observed toxicity is unknown; however, sediment concentrations of copper and zinc were slightly elevated (i.e., exceeded the PEC) and could have caused toxicity to this test orgasm that is sensitive to a broad range of aquatic contaminants.

Pesticide concentrations in the WY 2019 Pulgas Creek sediment sample were all very low, most below the MDL, and TU equivalents were calculated using ½ the MDL concentration. The exceptions were bifenthrin (with a TU equivalent of 0.56), deltamethrin/tralomethrin (with a TU equivalent of 0.42), and fipronil sulfone (with a TU equivalent of 0.33). Bifenthrin is considered to be the leading cause of pyrethroid-related toxicity in urban areas (Ruby 2013) and the most-commonly detected insecticide monitored by the California DPR SWPP (Ensminger 2017).

<u>WY 2018 Wet Weather Monitoring</u>

During WY 2018, wet weather water samples were collected for pesticide analysis at two sites in San Mateo County (San Pedro Creek and Cordilleras Creek) to fulfill Provision C.8.g.iii.(3) of MRP 2.0, in coordination with the RMC partners. Results were reported in the WY 2018 UCMR (SMCWPPP 2019a). The concentrations of most pesticides analyzed were below the MDL. However, the neonicotinoid, imidacloprid was found at detectable levels at one of the two sites (Cordilleras Creek). Additionally, detectable levels of fipronil and its degradation products were found at both sites.

<u>WY 2014 – WY 2019 Data Summary</u>

Toxicity and chemistry data from WY 2014 through WY 2019 were reviewed for overall findings and evidence of trends. There were 18 test results that had significant toxicity, but with a Percent Effect that did not exceed the MRP trigger thresholds. A majority of these toxicity results were found in water samples and were associated with either *C. dubia* reproduction (six samples), a chronic toxicity endpoint, or *H. azteca* survival (six samples), an acute toxicity endpoint. Five of the six water samples with toxicity to *H. azteca* were collected during wet season sampling events suggesting that stormwater runoff is affecting *H. azteca*. The water samples with toxicity to *C. dubia* were more evenly divided between wet and dry season sampling events.

Between WY 2014 and WY 2019, there were no PEC quotients calculated for the SMCWPPP sediment chemistry dataset that were ≥ 1.0 for analytes other than chromium and nickel. Excluding these naturally occurring metals, there were four samples with TEC quotients ≥ 1.0, the more conservative of the two evaluation criteria. These included legacy insecticide DDT compounds in Laurel Creek and Atherton Creek, individual PAHs in Laurel Creek and Atherton Creek, and copper and zinc in Pulgas Creek in WY 2019. Overall, detection frequencies for bifenthrin and fipronil were on par with results from the DPR Northern California study (Ensminger 2019) and *H. azteca* toxicity responses were similar to SPoT monitoring in San Mateo Creek (Phillips et al. 2014).

The pesticides and toxicity data collected from WYs 2014 through 2019 provide a reference to inform management decisions regarding water quality improvement in San Mateo County watersheds and guide the planning of future monitoring in the area.

7.2 Trigger Assessment

The MRP requires analysis of the monitoring data to identify candidate sites for SSID projects. Trigger thresholds against which to compare the data are provided for most monitoring parameters in the MRP and are described in the foregoing sections of this report. Stream condition was assessed based on CSCI scores that were calculated using BMI data. Nutrient data were evaluated using applicable water quality standards from the Basin Plan (SFRWQCB 2017). Water and sediment chemistry and toxicity data were evaluated using numeric trigger thresholds specified in the MRP. In compliance with Provision C.8.e.i of the MRP, all monitoring results exceeding trigger thresholds are added to a list of candidate SSID projects that will be maintained throughout the permit term. Follow-up SSID projects will be selected from this list. Table 7.2 lists candidate SSID projects based on WY 2019 Creek Status and Pesticides/Toxicity monitoring data. Trigger and WQO exceedances from WY 2014 through WY 2018 were reported in the respective UCMRs (SMCWPPP 2015, 2016, 2017, 2018, and 2019a) and are summarized in the tables included in Attachment 4.

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

Table 7.2. Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2019. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Bioassessment [1]	Nutrients [2]	Chlorine [3]	Water Toxicity [4]	Sediment Toxicity [4]	Sediment Chemistry [5]	Continuous Temperature [6]	Dissolved Oxygen [7]	pH [8]	Specific Conductance [9]	Pathogen Indicators [10]
202TUN030	Tunitas Creek	No	No	No	--	--	--	No	No	No	No	--
202TUN040	Tunitas Creek	No	No	No	--	--	--	No	No	No	No	--
204BEL005	Belmont Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R04280	Belmont Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R04428	Cordilleras Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R04160	Burlingame Creek	Yes	No	Yes	--	--	--	--	--	--	--	--
204R03635	Atherton Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R04600	Atherton Creek	Yes	No	No	--	--	--	--	--	--	--	--
205R04056	Dry Creek	Yes	No	No	--	--	--	--	--	--	--	--
205R05044	Dry Creek	Yes	No	No	--	--	--	--	--	--	--	--
204PUL010	Pulgas Creek	--	--	--	No	No	Yes	--	--	--	--	--
202PES138	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	No
202PES142	McCormick Creek	--	--	--	--	--	--	--	--	--	--	No
202PES144	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	No
202PES150	Jones Gulch	--	--	--	--	--	--	--	--	--	--	No
202PES154	Pescadero Creek	--	--	--	--	--	--	--	--	--	--	No
202TUN005	Tunitas Creek	--	--	--	--	--	--	No	--	--	--	--
202TUN025	Tunitas Creek	--	--	--	--	--	--	No	--	--	--	--
202TUN035	Tunitas Creek	--	--	--	--	--	--	No	--	--	--	--
202TUN060	Tunitas Creek	--	--	--	--	--	--	No	--	--	--	--

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

7.3 Recommendations

The recommendations presented in this section are directed towards the next iteration of the MRP (MRP 3.0) that is currently under development and will likely become effective in WY 2022. In WY 2020 and WY 2021, SMCWPPP will continue to coordinate with RMC partners on implementation of monitoring requirements in Provisions C.8.d and C.8.g of MRP 2.0.

The following recommendations are based on findings from six years (WY 2014 through WY 2019) of Creek Status and Pesticides and Toxicity monitoring conducted by SMCWPPP, as well as reflections on other monitoring, data analysis, and policy development projects being conducted in the region and statewide.

7.3.1 Biological Condition Assessment

The Program is currently working with RMC partners and Regional Water Board staff to evaluate options for revising the Biological Condition Assessment monitoring design to address Creek Status Monitoring requirements anticipated under MRP 3.0. One of the options under consideration is a targeted monitoring design that would focus on specific watersheds or reaches of interest. A watershed approach would provide stormwater programs more flexibility to evaluate priority areas that stakeholders want to improve, protect, or study. This approach was developed in response to the following findings:

- Baseline ambient conditions in San Mateo County urban creeks are described within known estimates of precision using probabilistic data generated through MRP 1.0 and MRP 2.0 monitoring and assessment tools such as the CSCI and ASCI. Continuing to build the dataset at a countywide scale is unlikely to provide additional benefit to local stormwater management programs.
- The probabilistic sample draw will likely only be sufficient to provide new sites through WY 2020. A re-design of the sample draw could provide more sites and address some of the lessons learned about the current sample draw; however, this effort would only be warranted if ambient probabilistic monitoring is desired.
- Stakeholders, such as municipal stormwater programs, land managers, creek groups, and other interested individuals and organizations have expressed that the probabilistic monitoring data results do not adequately provide information needed to identify and address site-specific water quality problems. They prefer for the Program to conduct monitoring activities in creeks of high interest.

The following objectives could be used to guide future monitoring design:

- Conduct monitoring within watersheds or subwatersheds of interest. Watershed(s) could be selected based on known water quality concerns, existing aquatic and riparian resources, planned management activities, or stakeholder interest. Monitoring could be used to develop a high-resolution longitudinal profile of CSCI scores and potential stressors with the goal of identifying sources of stressors and implementing control actions. In addition to bioassessment surveys, monitoring could include creek walks using established protocols and desktop watershed mapping.
- Re-assess sites that have lower or higher biological condition than expected. Use the SCAPE model (discussed in Section 2.2.4.7) to prioritize sites for follow-up assessment. The SCAPE model that provides a context for evaluating stream health by estimating an

expectation of biological condition along a given stream reach relative to landscape constraints. Biological condition, based on CSCI scores, can be compared to the reach expectation.

- Evaluate the effectiveness of BMPs or restoration projects. Conduct annual or biannual monitoring in creek reaches where biological condition and/or water quality are likely to be improved by planned management actions such as GSI implementation, flood control projects, and creek restoration. Baseline data generated through MRP 2.0, MRP 1.0, and Pre-MRP monitoring can be used for comparison.
- Actively monitor and manage stream segments where monitoring data have indicated good water quality and biological condition.

7.3.2 Continuous Monitoring for Temperature and General Water Quality

Continuous monitoring for temperature and general water quality has been an effective tool in supporting SSID studies and evaluating cold water habitat. The Program recommends continued implementation of this approach in MRP 3.0.

7.3.3 Pathogen Indicator Monitoring

Pathogen indicator monitoring is a relatively small part of the overall Creek Status and Pesticides & Toxicity monitoring program. Nonetheless, the Program recommends discontinuing this monitoring in MRP 3.0. This recommendation is based on several factors:

- Wildlife, a likely source of pathogen indicator bacteria in creeks, tend to congregate in urban creek corridors. It would be difficult and undesirable to restrict their use of creeks. Furthermore, bacteria from wildlife sources do not generally pose a risk to REC-1 Beneficial Uses.

- Homeless encampments are another common source of bacteria in receiving waters. Although this human source of bacteria does pose a risk to REC-1 Beneficial Uses, control options are challenging and generally not within the scope of stormwater management programs. The issue of homelessness is being dealt with through a patchwork of public and private programs aimed at housing people, preventing homelessness, law enforcement, and other measures.[26]

- Bacteria densities in freshwater creeks are highly variable and single grab samples are not very useful in identifying problems or making decisions about stormwater management.

Monitoring efforts for pathogen indicators should instead be used to support bacteria Total Maximum Daily Load (TMDL) action plans such as the San Pedro Creek and Pacifica State Beach Bacteria TMDL which is implemented through Provision C.14 of MRP 2.0.

[26] https://calmatters.org/explainers/californias-homelessness-crisis-explained/

7.3.4 Chlorine Monitoring

Although chlorine monitoring can be an important tool in investigating fish kills, continued reconnaissance chlorine monitoring is not recommended in the next MRP. Based on the chlorine data from WY 2012 – WY 2019, little value is added to the Creek Status Monitoring program by this monitoring.

- The sources of chlorine detected through Creek Status Monitoring are generally transient and challenging to trace.
- Discharges of drinking water are the most likely source of free chlorine and total chlorine residual. These discharges are already addressed by MRP Provisions C.5 (IDDE) and C.15 (Exempted and Conditionally Exempted Discharges) and the NPDES General Permit for Drinking Water Systems (Order WQ 2014-0194-DWQ).
- Available field equipment does not provide reliable results below 0.13 mg/L, a concentration higher than the MRP trigger resulting in uncertainty of exceedances. False positives can result in wasted efforts trying to track down non-existent sources.

7.3.5 Pesticides and Toxicity Monitoring

The Strategy to Optimize Resource Management of Storm Water (STORMS), adopted by the State Water Board in January 2016, is developing a statewide framework for urban pesticides reduction (Urban Pesticides Amendments). The primary goal of the statewide Urban Pesticides Amendments is to improve collaboration among regulators, leading to better management of pesticides in urban runoff. The Urban Pesticides Amendments will also organize coordinated pesticides and toxicity monitoring and data sharing. The Urban Pesticides Amendments team is proposing a statewide monitoring program that will substitute for pesticides and toxicity monitoring requirements in MS4 permits, such as the MRP. The goal is to generate useful data at minimal cost and standardize information at the statewide level. The Draft Amendments will likely be released for public review in early 2021 with adoption anticipated in mid-2021. Currently, the mechanism for implementing the statewide monitoring program is uncertain.

The Program recommends no changes to the current Provision C.8.g Pesticides and Toxicity monitoring requirements until the statewide monitoring program is in place.

8.0 Summary of Stormwater Management Programs by San Mateo County Permittees

The Creek Status and Pesticides and Toxicity Monitoring programs (consistent with MRP Provisions C.8.d and C.8.g of MRP 2.0, respectively) focus on assessing the water quality condition of urban creeks in San Mateo County and identifying stressors and sources of impacts observed.

This Integrated Creek Status Monitoring Report presents a comprehensive review of bioassessment and stressor data collected in WY 2012 through WY 2019. Data suggest that most urban streams have *likely altered* or *very likely altered* populations of aquatic life indicators (e.g., benthic macroinvertebrates). These poor stream conditions are likely the result of long-term changes in stream hydrology, channel geomorphology, in-stream habitat complexity, and other modifications to the watershed and riparian areas associated with the urban development that has occurred over the past 50 plus years. Additionally, episodic or site-specific increases in temperature (particularly in lower creek reaches or reaches directly below reservoirs) may not be optimal for aquatic life in some local creeks.

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

- In compliance with Provision C.3 of MRP 2.0, new and redevelopment projects in the Bay Area are now designed to more effectively reduce water quality and hydromodification impacts associated with urban development. Low impact development (LID) methods, such as rainwater harvesting and use, infiltration and biotreatment are required as part of development and redevelopment projects. In addition, Green Infrastructure planning is now part of all municipal projects. These LID measures are expected to reduce the impacts of urban runoff and associated impervious surfaces on stream health.
- In compliance with Provision C.7 of MRP 2.0, SMCWPPP and the San Mateo County Permittees are implementing stormwater outreach activities. Some of SMCWPPP's recent accomplishments include a County campaign to reduce littering of cigarette butts, Coastal Cleanup Day events, increased social media presence, participation in the Our Water Our World (OWOW) program, publication of newsletters, launching of a countywide school outreach program that asked students to submit proposal to green up their school campus, a K-12 teacher fellowship program for developing units related to stormwater pollution prevention, and a countywide rain barrel rebate program. The overarching goal of these actions is to reduce stormwater pollution by educating and motivating residents.
- In compliance with MRP Provision C.9, Permittees are implementing pesticide toxicity control programs that focus on source control and pollution prevention measures. The control measures include the implementation of integrated pest management (IPM) policies/ordinances, public education and outreach programs, pesticide disposal programs, supporting the adoption of formal State pesticide registration procedures, and sustainable landscaping requirements for new and redevelopment projects. These efforts will eventually be supplemented by the statewide Urban Pesticides Amendments which will seek to manage pesticide usage via state and federal pesticide regulatory

authorities such as DPR and USEPA. The anticipated result is a reduction in pyrethroids and other pesticides in urban stormwater runoff and a reduction in the magnitude and extent of toxicity in local creeks.

- Trash loadings to local creeks have been reduced through implementation of new control measures in compliance with Provision C.10 of MRP 2.0 and other efforts by Permittees to reduce the impacts of illegal dumping directly into waterways. These actions include the installation and maintenance of trash capture systems, the adoption of ordinances to reduce the impacts of litter prone items, enhanced institutional controls such as street sweeping, and the on-going removal and control of direct dumping. MRP 2.0 establishes a mandatory trash load reduction schedule, minimum areas to be treated by full trash capture systems, and requires development and implementation of receiving water monitoring programs for trash.
- In compliance with Provisions C.2 (Municipal Operations), C.4 (Industrial and Commercial Site Controls), C.5 (Illicit Discharge Detection and Elimination), and C.6 (Construction Site Controls) of MRP 2.0, Permittees continue to implement Best Management Practices (BMPs) that are designed to prevent non-stormwater discharges during dry weather and reduce the exposure of stormwater runoff to contaminants during rainfall events.
- In compliance with Provision C.13 of MRP 2.0, copper in stormwater runoff is reduced through implementation of controls such as architectural and site design requirements, prohibition of discharges from water features treated with copper, and industrial facility inspections.
- Mercury and polychlorinated biphenyls (PCBs) in stormwater runoff are being reduced through implementation of the respective TMDL water quality restoration plans. In compliance with Provisions C.11 (mercury) and C.12 (PCBs) of MRP 2.0, the Countywide Program will continue to identify sources of these pollutants and will implement control actions designed to achieve load reduction goals. Monitoring activities conducted in WY 2014 through WY 2019 that specifically target mercury and PCBs are described in the Integrated Pollutants of Concern Monitoring Data Report that is included as Part D of this IMR.

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

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

9.0 References

Ackerly, D., Jones, A., Stacey, M., Riordan, B. 2018. San Francisco Bay Area Summary Report. California's Fourth Climate Change Assessment. Publication number: CCCA4-SUM-2018-005.

Amweg, E.L., Weston, D.P., and Ureda, N.M. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. Environmental Toxicology and Chemistry: 24(4): 966-972.

Anderson, B.S., Hunt, J.W., Markewicz, D., Larsen, K., 2011. Toxicity in California Waters, Surface Water Ambient Monitoring Program. California Water Resources Control Board. Sacramento, CA.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition (RMC). 2016a. Creek Status and Pesticides & Toxicity Monitoring Quality Assurance Project Plan, Final Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program, and Armand Ruby Consulting on behalf of the Contra Costa Clean Water Program. 83 pp plus appendices.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition (RMC). 2016b. Creek Status and Pesticides & Toxicity Monitoring Standard Operating Procedures, Final Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program, and Armand Ruby Consulting on behalf of the Contra Costa Clean Water Program. 190 pp.

Bay Area Stormwater Management Agency Association (BASMAA). 2012. Regional Monitoring Coalition Final Creek Status and Long-Term Trends Monitoring Plan. Prepared By EOA, Inc. Oakland, CA. 23 pp.

Beck, M., Mazor, R., Johnson, S., Wisenbaker, K., Westfall, J., Ode, P., Hill, R., Loflen, C., Sutula, M., and Stein, E. 2019. Prioritizing management goals for stream biological integrity within the developed landscape context. Freshwater Science 38.4: 883-898.

Becker, G., Smetak, K., and Asbury, D. 2010. Southern Steelhead Resources Evaluation: Identifying Promising Locations for Steelhead Restoration in Watersheds South of the Golden Gate. Center for Ecosystem Management and Restoration. Oakland, CA.

Budd, R. 2018. Urban Monitoring in Southern California watersheds FY 2016-2017. Prepared by California Department of Pesticide Regulation Environmental Monitoring Branch.

Budd, R. 2019. Urban Monitoring in Southern California watersheds FY 2017/2018. Prepared by California Department of Pesticide Regulation Environmental Monitoring Branch.

California Department of Fish and Game (DFG). 1962. Tunitas Creek Stream Survey, April 18, 1962. Report by R.N. Hinton.

California Department of Fish and Game (DFG). 1964. East Fork Tunitas Creek Stream Survey, July 28, 1964. Report by R.M. Greene and W.W. Quinn.

California State Coastal Conservancy. 2019. Tunitas Creek Beach Acquisition and Planning. San Francisco Bay Area Conservancy Program Project No.17-101-01. Recommendation by Walecka, H. and Duff, T.

Ensminger, M. 2017. Ambient Monitoring in Urban Areas in Northern California for FY 2016-2017. Prepared by California Department of Pesticide Regulation Environmental Monitoring Branch.

Ensminger, M. 2019. Ambient and Mitigation Monitoring in Urban Areas in Northern California FY 2017/2018. Prepared by California Department of Pesticide Regulation Environmental Monitoring Branch.

Fetscher, A.E, L. Busse, and P.R. Ode. 2009. Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 002. (Updated May 2010)

Herbst, D.B., Cooper, S.D., Medhurst, R.B., Wiseman, S.W., and Hunsaker, C.T. 2019. Drought ecohydrology alters the structure and function of benthic invertebrate communities in mountain streams. Freshwater Biology 2019;00:1-17. https://doi.org/10.1111/fwb.13270

Hill R.A, M.H. Weber, S.G. Leibowitz, A.R. Olsen, D.J. Thornbrugh. 2015. The Stream-Catchment (StreamCat) Dataset: A database of watershed metrics for the conterminous United States. Journal of the American Water Resources Association. Volume 52. Issue 1. Pages 120-128.

Kaufmann, P.R., Levine, P., Robison, E.G., Seeliger, C., and Peck, D.V. 1999. Quantifying Physical Habitat in Streams. EPA.620/R-99/003.

Kincaid, T.M. and A.R. Olsen. 2017. spsurvey: Spatial survey design and analysis. R package version 3.4

Lawrence, J.E., Lunde, K.B., Mazor, R.D., Beche, L.A., McElravy, E.P., and Resh, V.H. 2010. Long-term macroinvertebrate responses to climate change: implications for biological assessment Mediterranean-climate streams. Journal of the North Americal Benthological Society, 29(4):1424-1440.

Leidy, R.A., G.S. Becker, B.N. Harvey. 2005. Historical distribution and current status of steelhead/rainbow trout *(Oncorhynchus mykiss)* in streams of the San Francisco Estuary, California. Center for Ecosystem Management and Restoration, Oakland, CA.

MacDonald, D.D., C.G. Ingersoll, T.A. Berger. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Arch. Environ. Contam. Toxicol. 39, 20-31.

Maul, J.D., Brennan, A.A., Harwood, A.D., and Lydy, M.J. 2008. Effect of sediment-associated pyrethroids, fipronil, and metabolites on *Chironomus tentans* growth rate, body mass, condition index, immobilization, and survival. Environ. Toxicol. Chem. 27 (12): 2582–2590.

Maund, S.J., Hamer, M.J., Lane, M.C., Farrelly, C., Rapley, J.H., Goggin, U.M., Gentle, W.E. 2002. Partitioning, bioavailability, and toxicity of the pyrethroid insecticide cypermethrin in sediments. Environmental Toxicology and Chemistry: 21 (1): 9-15.

Mazor, R., Ode, P.R., Rehn, A.C., Engeln, M., Boyle, T., Fintel, E., Verbrugge, S., and Yang, C. 2016. The California Stream Condition Index (CSCI): Interim instructions for calculating scores using GIS and R. SWAMP-SOP-2015-0004. Revision Date: August 5, 2016.

Mazor, R.D. 2015. Bioassessment of Perennial Streams in Southern California: A Report on the First Five Years of the Stormwater Monitoring Coalition's Regional Stream Survey. Prepared by Raphael D. Mazor, Southern California Coastal water Research Project. Technical Report 844. May 2015.

Mazor, R.D., A. Rehn, P.R. Ode, M. Engeln, K. Schiff, E. Stein, D. Gillett, D. Herbst, C.P. Hawkins. In review. Bioassessment in complex environments: Designing an index for consistent meaning in different settings.

Mazor, R.D., Purcell, A.H., and Resh, V.H. 2009. Long-term variability in bioassessments: a twenty-year study from two northern California streams. Environmental Management 43:129-1286.

Midpeninsula Regional Open Space District. 2015. Biodiversity of the Midpeninsula Regional Open Space District Appendix C-1. Prepared by McGraw, J.

National Marine Fisheries Service (NMFS). 2016. Coastal Multispecies Recovery Plan Vol IV, Central California Coast Steelhead: Santa Cruz Mountains Diversity Stratum. National Marine Fisheries Service, West Coast Region, Santa Rosa, California.

Ode, P.R. 2007. Standard Operating Procedures for Collection Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.

Ode, P.R., Fetscher, A.E., and Busse, L.B. 2016. Standard Operating Procedures (SOP) for the Collection of Field Data for Bioassessments of California Wadeable Streams: Benthic Macroinvertebrates, Algae, and Physical Habitat. SWAMP-SOP-SB-2016-0001.

Ode, P.R., T.M. Kincaid, T. Fleming and A.C. Rehn. 2011. Ecological Condition Assessments of California's Perennial Wadeable Streams: Highlights from the Surface Water Ambient Monitoring Program's Perennial Streams Assessment (PSA) (2000-2007). A Collaboration between the State Water Resources Control Board's Non-Point Source Pollution Control Program (NPS Program), Surface Water Ambient Monitoring Program (SWAMP), California Department of Fish and Game Aquatic Bioassessment Laboratory, and the U.S. Environmental Protection Agency.

Phillips, B.M., Anderson, B.S., Siegler, K., Voorhees, J., Tadesse, D., Weber, L., Breuer, R. 2014. Trends in Chemical Contamination, Toxicity and Land Use in California Watersheds: Stream Pollution Trends (SPoT) Monitoring Program. Third Report – Five-Year Trends 2008-2012. California State Water Resources Control Board, Sacramento, CA.

Phillips, B.M., Anderson, B.S., Siegler, K., Voorhees, J., Tadesse, D., Weber, L., Breuer, R. 2016. Spatial and Temporal Trends in Chemical Contamination and Toxicity Relative to Land Use in California Watersheds: Stream Pollution Trends (SPoT) Monitoring Program. Fourth Report – Seven-Year Trends 2008-2014. California State Water Resources Control Board, Sacramento, CA.

Rehn, A.C., R.D. Mazor and P.R. Ode. 2018. An index to measure the quality of physical habitat in California wadeable streams. SWAMP Technical Memorandum SWAMP-TM-2018-0005.

Rehn, A.C., R.D. Mazor, P.R. Ode. 2015. The California Stream Condition Index (CSCI): A New Statewide Biological Scoring Tool for Assessing the Health of Freshwater streams. SWAMP-TM-2015-0002. September 2015.

Rubin, Z., G.M. Kondolf, and B. Rios-Touma. 2017. Evaluating Stream Restoration Projects: What do we learn from monitoring? Water 2017, 9, 174.

Ruby, A. 2013. Review of pyrethroid, fipronil and toxicity monitoring data from California urban watersheds. Prepared for the California Stormwater Quality Association (CASQA) by Armand Ruby Consulting. 22 p + appendices.

San Francisco Regional Water Quality Control Board (SFRWQCB). 2009. Municipal Regional Stormwater NPDES Permit. Order R2-2009-0074, NPDES Permit No. CAS612008. 125 pp plus appendices.

San Francisco Regional Water Quality Control Board (SFRWQCB). 2017. Water Quality Control Plan (Basin Plan) for the San Francisco Bay Region. Updated to reflect amendments adopted up through May 4, 2017. http://www.waterboards.ca.gov/sanfranciscobay/basin_planning.shtml.

San Francisco Regional Water Quality Control Board (SFRWQCB). 2015. Municipal Regional Stormwater NPDES Permit. Order R2-2015-0049, NPDES Permit No. CAS612008. 152 pp plus appendices.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2014. Part A of the Integrated Monitoring Report. Water Quality Monitoring. Water Years 2012 and 2013 (October 2011 – September 2013). March 15, 2014.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2015. Urban Creeks Monitoring Report, Water Quality Monitoring Water Year 2014. March 15, 2015.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2016. Urban Creeks Monitoring Report, Water Quality Monitoring Water Year 2015. March 31, 2016.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2017. Urban Creeks Monitoring Report, Water Quality Monitoring Water Year 2016. March 31, 2017.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2018. Urban Creeks Monitoring Report, Water Quality Monitoring Water Year 2017. March 31, 2018.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2019a. Urban Creeks Monitoring Report, Water Quality Monitoring Water Year 2018. March 31, 2019.

San Mateo Countywide Water Pollution Prevention Program (SMCWPPP). 2019b. Pesticide Source Control Actions Effectiveness Evaluation. September 30, 2019.

Southern California Coastal Water Research Project (SCCWRP). 2007. Regional Monitoring of Southern California's Coastal Watersheds. Stormwater Monitoring Coalition Bioassessment Working Group. Technical Report 539.

Southern California Coastal Water Research Project (SCCWRP). 2012. Guide to evaluation data management for the SMC bioassessment program. 11 pp.

Stancheva, R., L. Busse, P. Kociolek, and R. Sheath. 2015. Standard Operating Procedures for Laboratory Processing, Identification, and Enumeration of Stream Algae. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 0003.

Stevens, D.L.Jr., and A.R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. Journal of the American Statistical Association 99(465):262-278.

Sullivan, K., Martin, D.J., Cardwell, R.D., Toll, J.E., and 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.

Sutula, M.A., Mazor, R.D., Theroux, S., In Prep. Scientific Bases for Assessment, Prevention, and Management of Biostimulatory Impacts in California Wadeable Streams (Technical Report No. 1048). 2018. Southern California Coastal Water Research Project, Costa Mesa, CA

Theroux, S., Mazor, R., Beck, M., Ode, P., Sutula, M. and Stein, E. (in preparation.) A Non-Predictive Algal Index for Complex Environments. Prepared for: Ecological Indicators.

Titus, R. G., D. C. Erman, and W. M. Snider. 2010. History and status of steelhead in California.

USEPA. 2010. Sampling and Consideration of Variability (Temporal and Spatial) for Monitoring of Recreational Waters. EPA-823-R-10-005. December 2010.

USEPA. 2012. Recreational Water Quality Criteria. Office of Water 820-F-12-058. A Non-Predictive Algal Index for Complex Environments.

USEPA. 2016-2017. Aquatic Life Benchmarks and Ecological Risk Assessments for Registered Pesticides. https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-and-ecological-risk

Woodard, M.E., Slusark, J., and Ode, P. 2012. Standard Operating Procedures for Laboratory Processing and Identification of Benthic Macroinvertebrates in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 003.

ATTACHMENTS

Attachment 1

QA/QC Report

Quality Assurance/Quality Control Report

Creek Status and Pesticides & Toxicity Monitoring, Water Year 2019

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SAN MATEO COUNTYWIDE
Water Pollution Prevention Program

March 31, 2020

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LIST OF ACRONYMS

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

1. INTRODUCTION

In Water Year 2019 (WY 2019; October 1, 2018 through September 30, 2019), the San Mateo County Water Pollution Prevention Program (SMCWPPP) conducted Creek Status Monitoring in compliance with Provision C.8.d and Pesticide & Toxicity Monitoring in compliance with Provision C.8.g of the National Pollutant Discharge Elimination System (NPDES) stormwater permit for Bay Area municipalities, referred to as the Municipal Regional Permit (MRP). The monitoring strategy includes regional ambient/probabilistic monitoring and local “targeted” monitoring as described in the Bay Area Stormwater Management Agencies Association (BASMAA) Regional Monitoring Coalition (RMC) Creek Status and Long-Term Trends Monitoring Plan (BASMAA 2012). SMCWPPP implemented a comprehensive data quality assurance and quality control (QA/QC) program, covering all aspects of the probabilistic and targeted monitoring. QA/QC for data collected was performed according to procedures detailed in the BASMAA RMC Quality Assurance Project Plan (QAPP) (BASMAA 2016a) and the BASMAA RMC Standard Operating Procedures (SOP; BASMAA 2016b), SOP FS-13 (Standard Operating Procedures for QA/QC Data Review). The BASMAA RMC QAPP and SOP are based on the QA program developed by the California Surface Water Ambient Monitoring Program (SWAMP 2017).

Based on the QA/QC review, no WY 2019 data were rejected, and some data were flagged. Overall, WY 2019 data met QA/QC objectives. Details are provided in the sections below.

1.1. DATA TYPES EVALUATED

During creek status monitoring (MRP Provision C.8.d), several data types were collected and evaluated for quality assurance and quality control. These data types include the following:

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

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

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

1.2. LABORATORIES

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

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

- BioAsessment Services (benthic macroinvertebrate (BMI) identification)
- Jon Lee Consulting (BMI identification Quality Control)
- EcoAnalysts, Inc. (algae identification)

1.3. QA/QC ATTRIBUTES

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

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

1.3.1. Representativeness

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

1.3.2. Comparability

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

1.3.3. Completeness

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

1.3.4. Sensitivity

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

1.3.5. Accuracy

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

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

1.3.6. Precision

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

1.3.7. Contamination

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

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

2. METHODS

2.1. REPRESENTATIVENESS

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

2.2. COMPARABILITY

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

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

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

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

2.3. COMPLETENESS

2.3.1. Data Collection

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

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

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

2.3.2. Field Sheets

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

2.3.3. Laboratory Results

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

2.4. Sensitivity

2.4.1. Biological Data

Benthic macroinvertebrates were identified to SAFIT STE Level I, with the additional effort of identifying chironomids (midges) to subfamily/tribe instead of family (Chironomidae).

2.4.2. Chemical Analysis

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

2.5. Accuracy

2.5.1. Biological Data

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

2.5.2. Chemical Analysis

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

For reference materials, percent recovery was calculated as:

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

Where: MV = the measured value
EV = the expected (reference) value

For matrix spikes, percent recovery was calculated as:

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

Where: MV = the measured value of the spiked sample
NV = the native, unspiked result
SV = the spike concentration added

2.5.3. Water Quality Data Collection

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

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

2.6. PRECISION

2.6.1. Field Duplicates

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

The RMC QAPP requires collection and analysis of duplicate sediment chemistry and toxicity samples at a rate of 5% of total samples collected for the project. Responsibility for the collection of the field duplicate rotates each year amongst Alameda County Clean Water Program (ACCWP), Contra Costa Clean Water Program (CCCWP), Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), and SMCWPPP.

The sediment sample and field duplicate were collected together using the Sediment Scoop Method described in the RMC SOP, homogenized, and then distributed to two separate containers. For sediment chemistry field duplicates, the RPD was calculated for each analyte and compared to the MQOs (RPD < 25%) set by Tables 26-7 through 26-11 in Appendix A of the RMC QAPP. For sediment and water toxicity field duplicates, the RPD of the batch mean was calculated and compared to the recommended acceptable RPD (< 20%) set by Tables 26-12 and 26-13 in Appendix A. If the RPD of the field duplicates did not meet the MQO, the results were flagged.

The RPD is calculated as:

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

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

No field duplicate is required for pathogen indicators.

2.6.2. Chemical Analysis

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

2.7. CONTAMINATION

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

3. RESULTS

3.1. Overall Project Representativeness

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

3.2. Overall Project Comparability

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

3.3. Bioassessments and Physical Habitat Assessments

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

3.3.1. Completeness

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

3.3.2. Sensitivity

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

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

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

3.3.3. Accuracy

The BMI sample that was submitted to an independent QC taxonomic laboratory had one instance of a lower taxonomic resolution discrepancy, however these discrepancies are not considered to be misidentifications according to the individual error rate MQO. One minor counting error was also found. The QC laboratory calculated sorting and taxonomic identification metrics, which were compared to the measurement quality objectives in Table 27-1 in Appendix B of the RMC QAPP. All MQOs were met. A comparison of the metrics with the MQOs is shown in Table 1. A copy of the QC laboratory report is available upon request.

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

Table 1. Quality control metrics for taxonomic identification of benthic macroinvertebrates collected in San Mateo County in WY 2019 compared to measurement quality objectives.

Quality Control Metric	MQO	Error Rate	Exceeds MQO?
Recount Accuracy	> 95%	99.84%	No
Taxa ID	≤ 10%	0%	No
Individual ID	≤ 10%	0%	No
Low Taxonomic Resolution Individual	≤ 10%	3.70%	No
Low Taxonomic Resolution Count	≤ 10%	0.16%	No
High Taxonomic Resolution Individual	≤ 10%	0.16%	No
High Taxonomic Resolution Count	≤ 10%	3.70%	No

3.3.4. Precision

Field blind duplicate chlorophyll a and ash free dry mass samples were collected at one site in WY 2019 and were sent to the laboratory for analysis.

Duplicate field samples do not provide a valid estimate of precision in the sampling and are of little use to assessing precision, because there is no reasonable expectation that duplicates will produce identical data. Nonetheless, the RPD of the chlorophyll a and ash free dry mass duplicate results were calculated and compared to the MQO (< 25%) for conventional analytes in water (Table 26-1 in Appendix B of the RMC QAPP). Due to the nature of chlorophyll a and ash free dry mass collection, the RPDs for both parameters are expected to exceed the MQO. The field duplicate results and their RPDs are shown in Table 2. As expected, exceedances were observed for both analytes.

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

Table 2. Field duplicate water chemistry results for sites 205R04056, collected on June 11, 2019

Analyte	Units	205R04056 June 11, 2019			
		Original Result	Duplicate Result	RPD	Exceeds MQO (>25%)[a]
Chlorophyll a	**mg/m^2**	640	910	35%	Yes
Ash Free Dry Mass	**g/m^2**	1090	1760	47%	Yes

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

Laboratory duplicates were also collected for chlorophyll a and ash free dry mass samples. The RPD for ash free dry mass was found to be above the MQO limit, and the corresponding samples were flagged.

3.3.5. Contamination

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

3.4. FIELD MEASUREMENTS

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

3.4.1. Completeness

Temperature, dissolved oxygen, pH, specific conductivity, free and total chlorine residual were collected at all 10 bioassessment sites for a 100% completeness rate.

3.4.2. Sensitivity

Free and total chlorine residual were measured using a HACH Pocket Colorimeter™ II, which uses the DPD method. For this method, the estimated detection limit for the low range measurements (0.02-2.00 mg/L) was 0.02 mg/L. There is, however, no established reporting limit. Colorimetric field instruments are generally not considered capable of providing accurate measurements of free chlorine and total chlorine residual below 0.13 mg/L (Missouri Department of Natural Resources 2004), due to analytical noise, regardless of the method detection limit provided by the manufacturer. For this reason, the Statewide General Permit for drinking Water Discharges (SWRCB 2014) and other recently issued NPDES permits, use 0.1 mg/L as a reporting limit for field measurements of total chlorine residual.

SMCWPPP also uses this threshold as a reporting limit for MRP chlorine residual monitoring. All measurements between 0.02 and 0.1 mg/L have been flagged as "detected, not quantified". The adopted SMCWPPP reporting limit is still much lower than the target reporting limit of 0.5 mg/L listed in the RMC QAPP for free and total chlorine residual.

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

3.4.3. Accuracy

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

Free chlorine was measured to be higher than total chlorine at one of the ten sites sampled in WY 2019. In past years, free chlorine has also occasionally been measured as higher than total chlorine. Theoretically, the free chlorine measurement should always be less than or equal to the total chlorine measurement, as the total chlorine concentration in water encompasses the free chlorine concentration in addition to any other chlorine species. The reason for free chlorine concentrations exceeding total chlorine concentrations at a sample site has not been definitively established. Potential causes for these inverted results include matrix interferences, colorimeter user error, and uncertainty associated with low concentrations below the reporting limit. According to Hach, the manufacturer of the equipment and reagents, the free chlorine could have false positive results due to a pH exceedance of 7.6 and/or an alkalinity exceedance of 250 mg/L. It is unlikely that the higher free chlorine readings were caused by user error. The field crew is well trained and aware of potential problems with this testing method, such as wait times between adding reagents and taking the readings and separating the free chlorine and total residual chlorine samples. When free chlorine was observed to be higher than total chlorine at a sample site, the free chlorine measurement was retaken with a new water sample and recorded on the field form. It was deemed unnecessary to flag free chlorine measurements that were higher than total chlorine measurements.

3.4.4. Precision

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

3.5. Water Chemistry

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

3.5.1. Completeness

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

3.5.2. Sensitivity

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

The reporting limit (0.05 mg/L) and method detection limit (0.02 mg/L) for nitrate samples were higher than the target reporting limit (0.01 mg/L). As a result, the nitrate concentration at one site was measured to be below the method detection limit but may have been quantified if the detection and reporting limit. SMCWPPP has discussed the reporting limits with Caltest, and due the methodology, lower limits cannot currently be achieved. Target and actual reporting limits are shown in Table 3.

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

Analyte	Target RL mg/L	Actual RL mg/L
Ammonia	0.02	0.02
Chloride	0.25	1-50
Total Kjeldahl Nitrogen	0.5	0.1
Nitrate	0.01	0.05
Nitrite	0.01	0.005
Orthophosphate	0.01	0.01-0.05
Silica	1	0.1-1
Phosphorus	0.01	0.01

3.5.3. Accuracy

The RMC QAPP lists a target range of 90-110% for nutrient laboratory control samples (LCS), and 80-120% for nutrient matrix spike and matrix spike duplicates (MS/MSD). For other conventional analytes (i.e., silica and chloride), both the LCS and MS/MSD MQO for recovery is 80-120%.

Recoveries on most LCS and MS/MSD samples were within the MQO target range. An LCS collected for silica exceeded the MQO range listed in the RMC QAPP, and six MS/MSD PRs collected for silica exceeded the MQO range. The QA samples affected eight sites, whose results have been assigned the appropriate SWAMP flag. Though the data were flagged, none of the analytical data were rejected due to accuracy.

The target PR ranges on laboratory reports differed from the RMC QAPP PR for several LCS and MS/MSD samples. As a result, some QA samples that exceeded RMC MQOs were flagged, but not by the laboratory and vice versa.

3.5.4. Precision

The RPD for all laboratory control sample and MS/MSD pairs were consistently below the MQO target of < 25%. Please note that the laboratory used a lower threshold of 20% for all analytes. However, all RPDs were much lower than 20% and no samples were flagged by the laboratory or the QA officer for exceeding the RPD MQO.

Water chemistry field duplicates were collected at one site in San Mateo County and were compared against the original samples. For WY 2019, the Total Kjeldahl Nitrogen and ammonia duplicate samples exceeded the RPD MQO. In past years of sampling, Total Kjeldahl Nitrogen has been common among the analytes that exceed the field duplicate RPD MQOs. Field crews will continue to make an effort in subsequent years to collect the original and duplicate samples in an identical fashion.

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

Table 4. Field duplicate water chemistry results for site 205R04056, collected on June 11, 2019. Data in highlighted rows exceed measurement quality objectives in RMC QAPP.

Analyte Name	Fraction Name	Unit	Original Result	Duplicate Result	RPD	Exceeds MQO (>25%)[a]
Ammonia as N	Total	mg/L	0.11	0.078	34%	Yes
Chloride	None	mg/L	38	38	0%	No
Nitrate as N	None	mg/L	0.06	ND	N/A	N/A
Nitrite as N	None	mg/L	J 0.004	J 0.004	N/A	N/A
Nitrogen, Total Kjeldahl	None	mg/L	0.3	0.47	44%	Yes
Orthophosphate as P	Dissolved	mg/L	0.068	0.067	2%	No
Phosphorus as P	Total	mg/L	0.076	0.076	0%	No
Silica as SiO2	Total	mg/L	30	30	0%	No

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

3.5.5. Contamination

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

3.6. PATHOGEN INDICATORS

Pathogen indicator samples were collected by SMCWPPP staff and were analyzed by Alpha Analytical Laboratories, Inc for *E. coli* and enterococcus. Samples were collected on August 1, 2019.

3.6.1. Completeness

All five required/planned pathogen indicator samples were collected for a 100% completeness rate. However, the samples taken at site 202PES150 and 202PES154 were not analyzed within the eight-hour hold time specified by the RMC QAPPP. The sample from site 202PES150 was analyzed 70 minutes after the eight-hour hold time limit, and the sample from site 202PES154 was analyzed 60 minutes after the limit. These hold time limit exceedances are not expected to have affected the integrity of the sample results. As a result, these were flagged but not rejected.

3.6.2. Sensitivity

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

3.6.3. Accuracy

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

3.6.4. Precision

The RMC QAPP requires one laboratory duplicate to be run per 10 samples or per analytical batch, whichever is more frequent. However, determining precision for pathogen indicators requires 15 duplicate sets. Due to the small number of samples collected for this project, there were not enough laboratory duplicates to determine precision. In WY 2019, only one laboratory duplicate was run and is not sufficient to determine precision.

The RMC QAPP does not require a field duplicate to be collected for pathogen indicators. However, one field duplicate was collected in WY 2019 by the field crew for a different project. The RPD for *E. coli* was 0% and 113% for enterococcus. Since there is no requirement for pathogen field duplicates, there is no corresponding MQO, and the precision could not be assessed. See Table 5 for the field duplicate results.

Table 5. Lab and field duplicate pathogen results collected on August 1, 2019.

Duplicate Type	Analyte	Original Result (MPN/100mL)	Duplicate Result (MPN/100mL)	RPD
Lab Duplicate	E. coli	29.4	27.9	NA
Lab Duplicate	Enterococcus	23.1	16.0	NA
Field Duplicate	E. coli	7.5	7.5	0%
Field Duplicate	Enterococcus	14.8	4.1	113%

3.6.5. Contamination

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

3.7. Continuous Water Quality

Continuous water quality measurements were recorded at two sites during the spring (May 2019), concurrent with bioassessments, and again in the summer (September 2019) in compliance with the MRP. Temperature, pH, dissolved oxygen, and specific conductivity were recorded once every 15 minutes for approximately two-weeks using a multi-parameter water quality sonde (YSI 6600-V2).

3.7.1. Completeness

The MRP requires one to two-week deployments, and both deployments exceeded the one week minimum. The first deployment lasted 14 days, while the second deployment lasted 13 days. All sondes collected data for 100% of the planned deployments, and no data were rejected. However, the pH sensor for the sonde deployed at site 202TUN030 failed the post-calibration drift check during the summer deployment. These data were flagged but not rejected.

3.7.2. Sensitivity

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

3.7.3. Accuracy

The SMCWPPP staff conduct pre- and post-deployment sonde calibrations for the two sondes used during monitoring events and calculate the drift during the deployments. During the second monitoring event, the sonde deployed at 202TUN030 exceeded both the pH 7 and pH 10 MQOs. The pH results at this site were subsequently flagged for this deployment, but not rejected. A summary of the drift measurements is shown in Table 6.

Table 6. Drift measurements for two continuous water quality monitoring events in San Mateo County urban creeks during WY 2019. Bold and highlighted values exceeded measurement quality objectives.

Parameter	Measurement Quality Objectives	202TUN030		202TUN040	
		Event 1	Event 2	Event 1	Event 2
Dissolved Oxygen (mg/l)	± 0.5 mg/L or 10%	0.13	0.05	-0.09	0.07
pH 7.0	± 0.2	0.08	0.20	0.04	-0.04
pH 10.0	± 0.2	-0.10	0.43	0.06	-0.01
Specific Conductance (uS/cm)	± 10%	-3.9%	-0.2%	-0.6%	-0.1%

3.7.4. Precision

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

3.8. Continuous Temperature Monitoring

Continuous temperature monitoring was conducted from April through September 2019 at five sites in San Mateo County. Onset HOBO Water Temperature data loggers recorded one measurement per hour.

3.8.1. Completeness

The MRP requires SMCWPPP to monitor four stream reaches for temperature each year but anticipating the potential for a HOBO temperature logger to be lost during such a long deployment, SMCWPPP deployed one extra temperature logger for a total of five loggers. In the middle of the deployment, SMCWPPP staff checked the loggers to ensure that they were still present and recording. If a logger was missing during the mid-deployment field check, it would be replaced with a new logger. During the field check, staff also downloaded the existing data and redeployed the other loggers. All temperature loggers were recovered at the end of the deployment, resulting in a completion rate of over 100%.

3.8.2. Sensitivity

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

3.8.3. Accuracy

A pre-deployment accuracy check was run on the temperature loggers in March 2019. None of the loggers exceeded the 0.2 ºC mean difference threshold for either the room temperature bath or the 0.2 ºC mean difference for the ice bath. The loggers were subsequently deployed, and no flagging of the data was necessary.

3.8.4. Precision

There are no precision protocols for continuous temperature monitoring.

3.9. SEDIMENT CHEMISTRY

The dry season sediment chemistry sample was collected by Kinnetic Laboratories, Inc (KLI) concurrently with the dry season toxicity sample on July 23, 2019. Inorganic and synthetic organic compounds were analyzed by Caltest and grain size distribution was analyzed by Soil Control Laboratories, a subcontractor laboratory. Caltest conducted all QA/QC requirements as specified in the RMC QAPP and reported their findings to the RMC. Key sediment chemistry MQOs are listed in RMC QAPP Tables 26-9 through 26-11. Sediment chemistry data were flagged when necessary, but none were rejected

3.9.1. Completeness

The MRP requires a sediment chemistry sample to be collected at one location each year. In WY 2019, SMCWPPP collected the sediment chemistry sample at 204PUL010. The laboratories analyzed samples within the one year holding time for analytes in sediment, set by the RMC SOP, and reported 100% of the required analytes.

3.9.2. Sensitivity

A comparison of target and actual reporting limits for those parameters is shown in Table 7. For sediment chemistry analysis conducted in WY 2019, laboratory reporting limits were higher than RMC QAPP target reporting limits for 29 analytes. Since reporting limits for a sample are dependent on the percent solids of that sample, it is likely that the amount of solids in the sample resulted in these exceedances.

Table 7. Comparison of target and actual reporting limits for sediment analytes where reporting limits exceeded target limits. Sediment samples were collected in San Mateo County creeks in WY 2019.

Analyte	Target RL	Actual RL	Unit
Arsenic	0.3	0.51	mg/Kg
Cadmium	0.01	0.08	mg/Kg
Chromium	0.1	1	mg/Kg
Copper	0.01	0.41	mg/Kg
Lead	0.01	0.08	mg/Kg
Nickel	0.02	0.08	mg/Kg
Zinc	0.1	0.81	mg/Kg
Benzo(a)pyrene	20	36	ng/g
Benzo(b)fluoranthene	20	36	ng/g
Benzo(e)pyrene	20	36	ng/g
Benzo(g,h,i)perylene	20	36	ng/g
Benzo(k)fluoranthene	20	36	ng/g
Chrysene	20	36	ng/g
Dibenz(a,h)anthracene	20	36	ng/g
Indeno(1,2,3-c,d)pyrene	20	36	ng/g
Perylene	20	36	ng/g
Bifenthrin	0.33	1.3	ng/g
Cyfluthrin	0.33	1.3	ng/g
Total Lambda-cyhalothrin	0.33	1.3	ng/g
Total Cypermethrin	0.33	1.3	ng/g
Total Deltamethrin	0.33	1.3	ng/g
Total Esfenvalerate/Fenvalerate	0.33	1.3	ng/g
Permethrin	0.33	1.3	ng/g
Carbaryl	30	31	ng/g
Fipronil	0.33	1.3	ng/g
Fipronil Desulfinyl	0.33	1.3	ng/g
Fipronil Sulfide	0.33	1.3	ng/g
Fipronil Sulfone	0.33	1.3	ng/g
Total Organic Carbon	0.01	0.05	% dw

3.9.3. Accuracy

Inorganic Analytes

No QA samples exceeded the QAPP MQO for LCS percent recovery (PR) for inorganic analytes (75-125%), but the MS samples for arsenic and lead exceeded the PR MQO. These samples were flagged but not rejected.

Synthetic Organic Compounds

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

None of the LCS PRs exceeded the RMC MQO range. However, the MS/MSD PRs exceeded the RMC MQO range for seven PAHs in addition to fipronil, fipronil desulfinyl, fipronil sulfide, and fipronil sulfide. The PAH MS/MSD samples that exceeded the PR MQO include benzo(a)pyrene, benzo(g,h,i)perylene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, perylene, and pyrene.

3.9.4. Precision

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

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

Field Duplicates
A sediment sample field duplicate was collected in Contra Costa County on July 23, 2019 and evaluated for precision. The field duplicate sample and corresponding RPDs are shown in Table 8. Because of the variability in reporting limits, values less than the RL were not evaluated for RPD. The measured concentrations of a majority of analytes from the original and duplicate samples were below the method detection limit and therefore reported as “ND”. As a result, the RPDs were non-calculable. All calculable RPDs were below the MQO limits. Analytes that exceeded the MQO of RPD < 25% were medium sand (0.25 to <0.5 mm); total cyfluthrin; total lambda-cyhalothrin; deltamethrin/tralomethrin.

Given the inherent variability associated with sediment sample field duplicates, the number of analytes with RPDs outside of the MQO limits is acceptable. The method used to collect sediment field duplicates provides more insight to laboratory precision than precision of field methods; however, the results do suggest that field methods are precise.

Table 9. Sediment chemistry duplicate field results for site 544MSH045, collected on July 23, 2019 in Contra Costa County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

	Analyte	Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
Grain Size Distribution	Clay: <0.0039 mm	%	25.14	23.22	7.9%	No
	Silt: 0.0039 to <0.0625 mm	%	60.97	60.13	1.4%	No
	Sand: V. Fine 0.0625 to <0.125 mm	%	7.36	8.39	13.1%	No
	Sand: Fine 0.125 to <0.25 mm	%	3.4	4.19	20.8%	No
	Sand: Medium 0.25 to <0.5 mm	%	1.54	2.37	42.5%	Yes
	Sand: Coarse 0.5 to <1.0 mm	%	0.8	1	22.2%	No
	Sand: V. Coarse 1.0 to <2.0 mm	%	0.8	0.7	13.3%	No
	Granule: 2.0 to <4.0 mm	%	0.38	0.36	5.4%	No
	Pebble: Small 4 to <8 mm	%	0.09	ND	N/A	N/A
	Pebble: Medium 8 to <16 mm	%	1.68	ND	N/A	N/A
	Pebble: Large 16 to <32 mm	%	ND	ND	N/A	N/A
	Pebble: V. Large 32 to <64 mm	%	ND	ND	N/A	N/A
Metals	Arsenic	mg/Kg dw	6.4	6.1	4.8%	No
	Cadmium	mg/Kg dw	0.14	0.17	19.4%	No
	Chromium	mg/Kg dw	31	32	3.2%	No
	Copper	mg/Kg dw	34	34	0%	No
	Lead	mg/Kg dw	9.3	10	7.3%	No
	Nickel	mg/Kg dw	43	45	4.5%	No
	Zinc	mg/Kg dw	130	140	7.4%	No
Pyrethroids (MQO <35%)	Bifenthrin	ng/g dw	18	17	5.7%	No
	Cyfluthrin	ng/g dw	2.5	1.7	38.1%	Yes
	Lambda-Cyhalothrin	ng/g dw	1	1.3	26.1%	No
	Cypermethrin	ng/g dw	ND	ND	N/A	ND
	Deltamethrin/Tralomethrin	ng/g dw	6.8	4.8	34.5%	No
	Esfenvalerate/Fenvalerate	ng/g dw	ND	ND	N/A	N/A
	Permethrin	ng/g dw	0.77	0.83	7.5%	No
	Total Organic Carbon	%	2.6	2.4	8.0%	No
	Carbaryl	mg/Kg dw	ND	ND	N/A	N/A
Fipronil	Fipronil	ng/g dw	ND	ND	N/A	N/A
	Fipronil Desulfinyl	ng/g dw	ND	ND	N/A	N/A
	Fipronil Sulfide	ng/g dw	ND	ND	N/A	N/A
	Fipronil Sulfone	ng/g dw	ND	ND	N/A	N/A
Polycyclic Aromatic Hydrocarbons	Acenaphthene	ng/g dw	ND	ND	N/A	N/A
	Acenaphthylene	ng/g dw	ND	ND	N/A	N/A
	Anthracene	ng/g dw	ND	ND	N/A	N/A
	Benz(a)anthracene	ng/g dw	ND	ND	N/A	N/A
	Benzo(a)pyrene	ng/g dw	ND	ND	N/A	N/A
	Benzo(b)fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Benzo(e)pyrene	ng/g dw	ND	ND	N/A	N/A
	Benzo(g,h,i)perylene	ng/g dw	ND	ND	N/A	N/A
	Benzo(k)fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Biphenyl	ng/g dw	ND	ND	N/A	N/A
	Chrysene	ng/g dw	ND	ND	N/A	N/A

Table 9. Sediment chemistry duplicate field results for site 544MSH045, collected on July 23, 2019 in Contra Costa County. Data in highlighted rows exceed monitoring quality objectives in RMC QAPP.

Analyte		Unit	Original	Duplicate	RPD	Exceeds MQO? (<25%)[a]
	Dibenz(a,h)anthracene	ng/g dw	ND	ND	N/A	N/A
	Dibenzothiophene	ng/g dw	ND	ND	N/A	N/A
	Dimethylnaphthalene, 2,6-	ng/g dw	11	11	0%	No
	Fluoranthene	ng/g dw	ND	ND	N/A	N/A
	Fluorene	ng/g dw	ND	ND	N/A	N/A
	Indeno(1,2,3-c,d)pyrene	ng/g dw	ND	ND	N/A	N/A
	Methylnaphthalene, 1-	ng/g dw	ND	ND	N/A	N/A
	Methylnaphthalene, 2-	ng/g dw	ND	ND	N/A	N/A
	Methylphenanthrene, 1-	ng/g dw	ND	ND	N/A	N/A
	Naphthalene	ng/g dw	ND	ND	N/A	N/A
	Perylene	ng/g dw	ND	ND	N/A	N/A
	Phenanthrene	ng/g dw	ND	ND	N/A	N/A
	Pyrene	ng/g dw	ND	ND	N/A	N/A

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

<u>Laboratory Duplicates</u>

Laboratory duplicates were collected and analyzed for grain sizes and total organic carbon. All RPDs were below the MQO limits except for medium (8 to <16 mm) pebbles in addition to granules (2.0 to <4.0 mm). As a result, the associated samples were flagged.

3.9.5. Contamination

All instrument (lab) blanks had concentrations below the reporting limit, and no data were flagged or rejected.

3.10. Toxicity Testing

Dry season water and sediment toxicity samples were collected by KLI concurrently with dry season sediment chemistry samples at one San Mateo County site on July 23, 2019. All toxicity tests were performed by Pacific EcoRisk. The water samples were analyzed for toxicity to five organisms (*Selenastrum capricornutum, Ceriodaphnia dubia, Pimephales promelas, Hyalella azteca, and Chironomus dilutus*) and the sediment samples were analyzed for toxicity to *Hyalella azteca* and *Chironomus dilutus.*

3.10.1. Completeness

The MRP requires the collection of dry season water and sediment toxicity samples at one site per year in San Mateo County. Pacific EcoRisk tested the required organisms for toxicity, and 100% of results were reported.

3.10.2. Sensitivity and Accuracy

Internal laboratory procedures that align with the RMC QAPP, including water and sediment quality testing and reference toxicant testing, were performed and submitted to SMCWPPP. The laboratory data QC checks found that all conditions and responses were acceptable. A copy of the laboratory QC report is available upon request.

3.10.3. Precision

Field duplicates for sediment toxicity were not taken during the dry weather sampling. This oversight was the result of a misunderstanding of the conflict between the 2016 version of the RMC QAPP (V3.0) and the SWAMP requirements for toxicity sample field duplicates that were revised in 2018. As such, 2019 RMC toxicity data are SWAMP comparable, but were flagged with the “VQCP” qualifier to indicate a discrepancy with the RMC QAPP. The RMC QAPP has been updated to reflect the recent revisions to the SWAMP MQOs.

3.10.4. Contamination

There are no QA/QC procedures for contamination of toxicity samples, but staff followed applicable RMC SOPs to limit possible contamination of samples.

4. CONCLUSIONS

Sample collection and analysis followed MRP and RMC QAPP requirements and data that exceeded measurement quality objectives were flagged. However, no data were rejected.

5. REFERENCES

Bay Area Stormwater Management Agency Association (BASMAA). 2012. Regional Monitoring Coalition Final Creek Status and Long-Term Trends Monitoring Plan. Prepared By EOA, Inc. Oakland, CA. 23 pp.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition. 2016a. Creek Status Monitoring Program Quality Assurance Project Plan, Final Draft Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program, and Armand Ruby Consulting on behalf of the Contra Costa Clean Water Program. 128 pp.

Bay Area Stormwater Management Agency Association (BASMAA) Regional Monitoring Coalition. 2016b. Creek Status Monitoring Program Standard Operating Procedures Version 3. Prepared for BASMAA by EOA, Inc. on behalf of the Santa Clara Urban Runoff Pollution Prevention Program and the San Mateo Countywide Water Pollution Prevention Program, Applied Marine Sciences on behalf of the Alameda Countywide Clean Water Program, and Armand Ruby Consulting on behalf of the Contra Costa Clean Water Program. 192 pp.

Missouri Department of Natural Resources. 2004. Water Pollution Control Permit Manual, Appendix T: Total Chlorine Residual Study. 2 pp.

State Water Resources Control Board (SWRCB). 2014. Statewide National Pollutant Discharge Elimination System (NPDES) Permit for Drinking Water System Discharges to Waters of the United States. Order WQ 2014-0194-DWQ. General Oder No. CAG140001. 111 pp.

Surface Water Ambient Monitoring Program (SWAMP). 2017. SWAMP Quality Assurance Program Plan. May. 140 pp.

Attachment 2

SMCWPPP Bioassessment Data, WY 2012 – WY 2019

Attachment 2: Eight years of bioassessment data (WY 2012- WY 2019) used for analyses in the Integrated Monitoring Report

Site Information						Water Quality						Water Chemistry (nutrients)																		Biological and Physical Habitat Indicator Scores					Physical Habitat									Land Use Variables		
Station Code	Creek Name	Latitude	Longitude	Land Use	Sample Date	Dissolved Oxygen (mg/L)	Spec Conductance (uS/cm)	Temperature (Deg C)	pH	Chloride (mg/L)	Silica (mg/L)	Ash Free Dry Mass (g/m2)	Chlorophyll a (mg/m2)	QA Flag	Ammonia (mg/L)	QA Flag	UIA (ug/L)	Nitrate as N (mg/L)	QA Flag	Nitrite as N (mg/L)	QA Flag	TKN as N (mg/L)	QA Flag	Ortho Phosphate as P (mg/L)	QA Flag	Total Phosphorus as P (mg/L)	QA Flag	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	CSCI	ASCI_D	ASCI_SB	ASCI_H	IPI	Channel Alteration	Epifaunal Substrate	Sediment Deposition	Human Disturbance Index	Evenness Flow Habitat	% Substrate <2 mm	Shannon Diversity Habitat	Sum Riparian Cover	Shannon Diversity Substrate	% Impervious (wat)	% Urban (wat)	Road Density (wat)
202R00072	Pilarcitos Creek	37.51509	-122.38599	NU	5/29/12	11.3	202	11.61	6.01	17	16	50	12	DNQ	0.06	DNQ	0.0	0.33	=	-0.002	ND	0.14	=	0.01	DNQ	0.02	=	0.5	0.02	0.94	0.94	0.90	0.74	NR	20	16	14	0.47	0.75	30	1.6	NR	1.5	1%	0%	0.3
202R00087	Milagra Creek	37.64487	-122.48103	U	5/30/12	10.5	510	10.97	7.63	69	25	17	-6	ND	-0.04	ND	0.2	0.19	=	-0.002	ND	0.16	=	0.03	=	0.03	=	0.4	0.03	0.75	0.68	0.89	1.20	NR	19	13	10	1.5	0.67	14	1.6	NR	1.7	27%	43%	7.7
204R00180	Sanchez Creek	37.57358	-122.36900	U	5/30/12	9.0	555	15.85	7.61	47	20	79	8	DNQ	-0.04	ND	0.2	0.44	=	-0.002	ND	0.4	=	0.11	=	0.13	=	0.8	0.13	0.47	0.79	0.66	0.76	NR	3	3	8	4.96	0.56	14	1.8	NR	1.4	31%	68%	7.2
204R00200	Polhemus Creek	37.52355	-122.34064	U	5/31/12	9.3	1090	14.06	7.84	85	23	231	-50	ND	0.07	DNQ	1.0	0.43	=	0.002	DNQ	0.55	=	0.12	=	0.17	=	1.0	0.17	0.43	0.55	0.51	1.00	NR	16	7	13	2.14	0.61	12	1.7	NR	1.7	41%	66%	8.9
205R00168	Corte Madera Creek	37.39619	-122.23464	U	6/4/12	9.4	664	14.96	7.86	41	21	38	-5	ND	0.10	DNQ	1.7	0.14	=	0.008	DNQ	0.37	=	0.18	=	0.17	=	0.5	0.17	0.93	0.52	0.55	0.91	NR	20	11	12	1.68	0.8	40	1.8	NR	1.4	7%	27%	3.2
205R00088	Corte Madera Creek	37.37287	-122.22002	U	6/4/12	10.2	618	13.76	7	33	21	138	7	DNQ	0.12	=	0.3	0.06	DNQ	-0.002	ND	0.16	=	0.31	=	0.08	=	0.2	0.08	1.19	0.65	0.67	0.56	NR	19	15	15	2.58	0.99	24	1.8	NR	1.5	4%	11%	2.5
202R00024	Woodhams Creek	37.32503	-122.24861	NU	6/6/12	9.7	835	10.8	8.09	13	34	235	-21	ND	0.11	=	2.4	0.06	DNQ	0.003	DNQ	0.45	=	0.16	=	0.20	=	0.5	0.20	0.85	0.75	0.87	0.96	NR	20	12	15	0.21	0.31	16	1.7	NR	1.9	1%	0%	0.0
204R00232	Arroyo Ojo De Agua	37.46381	-122.25059	U	6/12/12	9.6	928	15.19	7.91	30	68	103	-6	ND	-0.04	ND	0.4	1.50	=	-0.002	ND	0.46	=	0.10	=	0.11	=	2.0	0.11	0.43	0.83	0.80	0.48	NR	19	14	15	3.08	0.94	23	1.6	NR	1.8	41%	88%	10.3
204R00244	Trib to Arroyo Ojo De Agua	37.47191	-122.24306	U	6/12/12	10.7	1117	23.76	8.22	53	19	122		=	0.06	DNQ	3.8	0.16	=	0.002	DNQ	0.58	=	0.08	=	0.11	=	0.7	0.11	0.41	0.37	0.53	0.46	NR	0	1	17	3.93	0	3	0.3	NR	1.0	43%	96%	12.1
202R00104	La Honda Creek	37.38878	-122.284299	NU	6/13/12	7.1	238	12	7.24	21	NR	57	9	=	0.11	=	0.4	0.28	=	0.001	ND	0.188	=	0.09	=	0.06	=	0.5	0.06	0.70	1.00	0.86	0.83	NR	15	8	4	0.52	0.68	49	1.7	NR	1.7	5%	7%	2.3
202R00284	Denniston Creek	37.50515	-122.48723	U	6/15/12	10.7	265	12.5	6.81	27	23	56	-6	ND	0.13	=	0.2	0.16	=	0.004	DNQ	0.15	=	0.03	=	0.05	=	0.3	0.05	0.79	0.96	0.83	1.08	NR	15	6	2	2.83	0.8	55	1.5	NR	1.3	3%	3%	1.0
202R00166	Little Butano Creek	37.213634	-122.314113	NU	6/25/12	10.1	235	12.15	7.72	17	NR	31	9	=	0.46	=	5.0	0.24	=	0.001	ND	0.235	=	0.10	=	0.05	=	0.5	0.05	1.16	0.99	1.17	0.97	NR	19	15	8	0	0.45	28	1.6	NR	1.7	8%	0%	1.2
202R00038	Little Butano Creek	37.215901	-122.307277	NU	6/26/12	10.2	230	12.84	7.67	15	NR	17	9	=	0.15	=	1.5	0.20	=	0.001	ND	0.19	=	0.09	=	0.04	=	0.4	0.04	1.07	1.06	1.11	0.77	NR	19	15	12	0	0.97	16	1.9	NR	1.6	6%	0%	1.4
205R00296	West Union Creek	37.45211	-122.29852	NU	5/6/13	5.6	475	12.26	6.73	41	NR	31	3	=	0.04	DNQ	0.0	0.00	ND	0.001	ND	0.331	=	0.00	ND	0.01	=	0.3	0.01	0.72	0.77	1.04	1.28	NR	18	8	4	0.91	0.56	59	1.4	NR	1.5	2%	2%	0.3
204R00436	Easton Creek	37.58017	-122.37242	U	5/20/13	8.1	661	20.62	7.12	72	25	78	115	=	-0.04	ND	0.1	0.29	=	0.003	DNQ	0.57	=	0.07	=	0.08	=	0.9	0.08	0.35	0.57	0.43	0.69	NR	0	6	7	4.36	0.51	17	1.4	NR	1.4	42%	98%	11.7
204R00884	Easton Creek	37.57729	-122.38584	U	5/20/13	9.2	945	12.96	7.39	70	19	57	115	=	-0.04	ND	0.1	0.34	=	-0.002	ND	0.75	=	0.14	=	0.16	=	1.1	0.16	0.42	0.33	0.49	0.62	NR	8	11	19	4.33	0.37	2	1.6	NR	1.6	44%	98%	12.2
202R00908	Calera Creek	37.61230	-122.49411	U	5/21/13	8.6	697	21.56	7.51	130	9	243	84	=	0.09	DNQ	1.1	8.10	=	0.018	DNQ	1.4	=	3.00	=	3.00	=	9.5	3.00	0.17	0.60	0.48	0.87	NR	18	11	6	1.15	0.99	50	1.0	NR	1.5	10%	15%	2.9
204R00807	Colma Creek	37.65251	-122.42241	U	5/21/13	13.6	1386	14.24	7.75	110	25	364	25	=	-0.04	ND	0.2	2.40	=	0.037	=	0.48	=	0.01	DNQ	0.02	=	2.9	0.02	0.25	0.42	0.55	0.58	NR	0	0	13	4.99	0.69	2	0.0	NR	0.0	45%	62%	10.6
202R00280	Tributary to Alpine Creek	37.29444	-122.22163	NU	5/22/13	11.1	703	9.75	7.59	15	30	160	152	=	-0.04	ND	0.1	0.16	=	-0.002	ND	-0.14	ND	0.38	=	0.40	=	0.2	0.40	0.85	0.85	0.96	1.00	NR	20	19	14	0	0.64	13	0.8	NR	1.8	1%	0%	1.2
202R00248	San Gregorio Creek	37.31983	-122.34070	NU	5/23/13	10.4	886	11.65	7.6	56	27	228	10	=	-0.04	ND	0.1	-0.01	ND	-0.002	ND	-0.14	ND	0.15	=	0.16	=	0.1	0.16	1.08	0.40	0.45	0.65	NR	18	16	13	1.69	0.91	28	1.3	NR	1.5	2%	3%	1.7
205R00872	Bear Gulch Creek	37.41986	-122.24529	U	5/27/13	9.4	683	13.86	7.85	56	17	136	17	=	-0.04	ND	0.3	0.08	=	-0.002	ND	-0.14	ND	0.03	=	0.04	=	0.2	0.04	0.67	0.71	0.51	0.89	NR	14	12	10	2.41	0.78	29	1.7	NR	1.8	6%	25%	2.4
205R00984	Bear Gulch Creek	37.58017	-122.37242	U	5/27/13	8.1	661	20.62	7.12	36	17	245	36	=	0.08	DNQ	0.4	0.11	=	-0.002	ND	-0.14	ND	0.03	=	0.05	=	0.2	0.05	0.89	0.46	0.50	0.66	NR	0	6	7	1.18	0.63	27	1.5	NR	1.5	4%	12%	1.4
204R00680	Redwood Creek	37.43783	-122.24151	U	5/28/13	8.2	1595	16.41	7.74	100	45	481	36	=	-0.04	ND	0.3	-0.01	ND	-0.002	ND	-0.14	ND	0.07	=	0.09	=	0.1	0.09	0.51	0.35	0.34	1.01	NR	7	6	9	2.31	0.39	35	1.5	NR	1.6	23%	81%	8.4
204R00520	Belmont Creek	37.51221	-122.29034	U	5/28/13	8.4	1041	15.06	7.1	130	18	135	41	=	0.06	DNQ	0.2	0.13	=	-0.002	ND	-0.14	ND	0.04	=	0.05	=	0.2	0.05	0.52	0.53	0.48	0.87	NR	6	11	10	3.36	0.75	17	1.5	NR	1.7	35%	62%	8.5
202R00150	Butano Creek	37.22664	-122.2412	NU	6/4/13	10.1	333	11.68	7.95	15	NR	42	7	=	0.015	ND	NR	0.00	ND	0.001	ND	0.172	=	0.00	ND	0.01	DNQ	0.2	0.01	1.00	0.91	0.93	1.00	NR	20	19	18	0	0.63	29	1.4	NR	1.9	11%	0%	1.5
202R00268	Dry Creek	37.35917	-122.39124	NU	6/5/13	9.2	1035	11.91	7.65	132	NR	34	22	=	0.015	ND	NR	0.25	=	0.001	ND	0.543	=	0.03	=	0.05	=	0.8	0.05	0.51	0.87	0.99	0.83	NR	17	10	7	0	0.37	30	1.8	NR	1.5	1%	0%	0.7
202R00214	Tarwater Creek	37.26166	-122.24082	NU	6/6/13	9.3	1540	12.34	7.88	286	NR	18	10	=	0.015	ND	NR	0.11	=	0.001	ND	0.267	=	0.31	=	0.36	=	0.4	0.36	0.91	1.08	1.08	0.83	NR	19	18	17	1.12	0.46	23	1.7	NR	1.9	1%	0%	1.5
204R01460	Sanchez Creek	37.57670	-122.36803	U	4/28/14	9.2	88	13.52	7.49	57	21	62	39	=	-0.04	ND	0.1	0.18	=	-0.005	ND	0.22	=	0.08	=	0.08	=	0.4	0.08	0.42	0.29	0.61	0.97	NR	11	8	7	2.25	0.42	14	1.8	NR	1.8	31%	69%	7.2
204R01204	Burlingame Creek	37.55699	-122.35379	U	4/28/14	8.6	79	11.19	7.87	59	33	31	56	ND	0.06	DNQ	0.8	0.23	=	-0.005	ND	0.53	=	0.21	=	0.21	=	0.8	0.21	0.53	0.54	0.60	0.85	NR	18	15	14	2.4	0.53	27	1.7	NR	1.6	36%	94%	10.3
204R01012	Cordilleras Creek	37.47381	-122.26848	U	4/29/14	96.7	872	16.02	7.9	67	15	27	3	=	-0.04	ND	0.4	-0.01	ND	-0.005	ND	0.31	=	0.05	=	0.06	=	0.3	0.06	0.58	0.83	0.71	0.89	NR	18	6	4	2.36	0.46	18	1.7	NR	1.6	16%	36%	5.0
204R01288	Laurel Creek	37.52342	-122.31235	U	4/29/14	7.9	729	11.54	7.55	81	18	29	38	=	1.20	=	8.0	0.33	=	0.029	DNQ	1.7	=	0.14	=	0.17	=	2.1	0.17	0.34	0.75	0.66	0.87	NR	18	7	6	2.36	0.36	16	1.4	NR	1.7	33%	62%	10.6
204R01256	Arroyo Ojo de Agua	37.45444	-122.25038	U	5/6/14	9.1	988	14.34	7.92	32	67	88	32	=	-0.04	ND	0.4	0.43	=	0.005	DNQ	0.53	=	0.31	=	0.12	=	1.0	0.12	0.51	0.81	0.75	1.07	NR	16	17	15	1.66	0.72	17	1.8	NR	1.7	34%	79%	9.6
204R01268	Redwood Creek	37.46835	-122.23270	U	5/6/14	14.9	851	23.93	9.46	52	19	255	240	=	0.12	=	68.8	0.12	=	0.010	DNQ	1.7	=	0.27	=	0.32	=	1.8	0.32	0.46	0.55	0.58	0.48	NR	0	0	5	4.76	0.11	8	0.3	NR	0.7	22%	81%	8.0
202R00312	Mills Creek	37.452328	-122.392423	NU	5/7/14	9.5	761	11.9	8.32	56	23	98	11	=	0.02	DNQ	0.8	0.08	=	0.003	DNQ	0.286	=	0.20	=	0.21	=	0.4	0.21	0.82	0.86	0.95	1.10	NR	19	15	14	0.14	0.38	28	1.6	NR	1.5	2%	3%	0.7
202R00328	Pilarcitos Creek	37.50722	-122.38654	NU	5/7/14	10.4	298	10.82	7.54	20	14	670	30	=	-0.04	ND	0.1	0.27	=	-0.005	ND	0.35	=	0.02	=	0.02	=	0.6	0.02	1.01	0.95	0.80	1.00	NR	19	14	3	0.97	0.62	35	1.4	NR	1.4	1%	0%	0.4
202R01308	Pilarcitos Creek	37.46831	-122.43627	U	5/7/14	9.4	300	14.23	7.39	33	18	70	4	=	-0.04	ND	0.1	0.59	=	-0.005	ND	0.44	=	0.10	=	0.10	=	1.0	0.10	0.31	0.89	0.77	0.97	NR	14	5	3	2	0.78	60	1.7	NR	1.3	3%	3%	0.9
202R00972	Arroyo de en Medio	37.51374	-122.45084	U	5/8/14	10.5	251	11.41	7.56	36	28	170	17	=	0.23	=	1.6	0.53	=	-0.005	ND	1.2	=	0.03	=	0.10	=	1.7	0.10	0.48	0.26	0.62	0.97	NR	20	16	10	0	0.6	67	1.2	NR	1.1	1%	0%	2.0
202R00376	Tunitas Creek	37.390839	-122.368261	NU	5/12/14	10.7	1189	12.1	8.15	195	20	106	16	=	0.015	ND	NR	0.03	=	0.012	ND	0.104	=	0.07	=	0.06	=	0.1	0.06	0.92	0.81	0.69	1.05	NR	18	15	16	0.85	0.47	34	1.6	NR	1.6	1%	0%	1.6
205R01192	Corte Madera Creek	37.39096	-122.23115	U	5/13/14	7.9	897	13.05	7.23	58	21	134	10	=	-0.04	ND	0.1	-0.01	ND	-0.005	ND	0.22	=	0.06	=	0.06	=	0.2	0.06	0.60	0.40	0.55	0.83	NR	11	9	6	2.87	0.44	39	1.6	NR	1.5	7%	26%	3.2
205R01704	Dry Creek	37.43389	-122.26094	U	4/22/15	9.5	875	11.8	7.98	42	24	342	18	=	0.12	=	2.2	-0.01	ND	-0.005	ND	0.75	=	0.12	=	0.10	=	0.8	0.10	0.32	0.64	0.78	1.28	NR	12	9	7	1.88	0.56	22	1.9	NR	1.8	13%	61%	6.3
204R01448	Atherton Creek	37.43459	-122.21776	U	4/22/15	12.4	2801	16.4	8.42	250	23	59	101	=	0.15	=	9.3	0.31	=	-0.005	ND	1.1	=	0.10	=	0.12	=	1.4	0.12	0.40	0.32	0.50	0.86	NR	2	1	9	2.36	0.26	10	0.7	NR	1.2	17%	48%	5.4
202R00378	Pescadero Creek	37.21994	-122.16385	NU	4/23/15	10.0	830	10.8	8.16	55	29	69	-3	ND	0.14	=	3.5	-0.01	ND	-0.005	ND	0.53	=	0.13	=	0.14	=	0.5	0.14	0.93	1.05	1.03	1.28	NR	18	15	8	0.23	0.73	32	1.7	NR	1.9	17%	0%	0.5
205R01816	Corte Madera Creek	37.36615	-122.21570	U	4/30/15	10.8	928	11.7	8.21	40	19	24	6	=	0.04	DNQ	1.3	-0.01	ND	-0.005	ND	0.31	=	0.07	=	0.07	=	0.3	0.07	1.18	0.69	1.03	1.28	NR	14	15	16	2.48	1	13	1.8	NR	1.6	3%	8%	2.4
202R01612	MF San Pedro Cr	37.57810	-122.47139	U	5/11/15	10.6	398	11.7	8.11	23	16	96	30	=	0.35	=	8.7	0.02	DNQ	-0.005	ND	-0.07	ND	0.02	=	0.02	=	0.1	0.02	0.90	0.81	NA	NA	NR	18	18	8	0.47	0.74	18	1.8	NR	1.5	1%	0%	0.6
202R01356	MF San Pedro Cr	37.57524	-122.46105	U	5/11/15	10.5	458	11.1	7.81	27	17	50	11	=	0.23	=	2.7	-0.01	ND	-0.005	ND	-0.07	ND	0.01	=	0.01	=	0.0	0.01	0.91	1.14	NA	NA	NR	20	17	13	0.15	0.48	9	1.4	NR	1.6	1%	0%	0.9
204R02056	Laurel Creek	37.53342	-122.30243	U	5/12/15	9.2	1129	13.2	8.3	120	16	22	11	=	-0.08	ND	1.6	0.67	=	0.010	DNQ	0.83	=	0.09	=	0.10	=	1.5	0.10	0.45	0.54	0.75	1.28	NR	7	5	6	4.14	0.37	17	1.8	NR	1.4	39%	74%	11.7
204R02248	Laurel Creek	37.52659	-122.32286	U	5/12/15	6.7	1179	12.2	7.72	91	19	206	34	=	-0.04	ND	0.2	0.16	=	-0.005	ND	0.4	=	0.06	=	0.07	=	0.6	0.07	0.33	0.62	0.69	1.28	NR	14	10	8	3.76	0.47	10	1.9	NR	1.8	41%	72%	13.0
202R00440	Purisima Creek	37.43417	-122.34959	NU	5/13/15	10.7	665	10.7	8.45	26	20	11	45	=	0.04	DNQ	2.1	0.11	=	-0.005	ND	0.75	=	0.12	=	0.06	=	0.9	0.06	1.16	0.85	1.17	1.28	NR	18	18	10	1.22	0.51	17	1.4	NR	1.8	4%	11%	2.7
204R01972	Cordilleras Creek	37.48375	-122.25730	U	5/13/15	10.1	1115	12.2	8.22	86	13	45	4	=	-0.04	ND	0.6	-0.01	ND	-0.005	ND	0.48	=	0.06	=	0.16	=	0.5	0.16	0.41	0.53	0.61	0.81	NR	9	11	10	4.04	0.78	9	1.5	NR	1.6	19%	45%	5.5
202R00408	Langley Creek	37.33100	-122.27439	NU	5/27/15	8.6	893	11.6	7.32	42	33	49	14	=	0.07	=	0.3	0.01	DNQ	-0.002	ND	0.189	=	0.13	=	0.12	=	0.2	0.12	0.50	0.91	0.96	1.03	NR	18	11	14	0.27	0.61	17	2.0	NR	1.4	1%	0%	1.7
202R00506	Peters Creek	37.28940	-122.17619	NU	5/9/16	10.5	412	11.2	8.19	86	22	28	5	=	0.06	=	1.7	-0.02	ND	0.001	DNQ	0.48	=	0.05	=	0.04	=	0.5	0.04	1.11	0.92	0.80	1.28	1.06	20	18	16	0.27	0.66	14	0.7	200	1.9	19%	3%	2.6
202R00488	Tunitas Creek	37.38001	-122.37482	NU	5/10/16	10.3	8	12.1	8.25	45	22	39	-3	ND	0.03	=	1.0	0.95	=	0.002	DNQ	0.26	=	0.05	=	0.05	=	1.2	0.05	0.55	0.46	0.75	1.07	0.68	18	16	6	1.13	0.5	35	1.8	187	1.9	1%	0%	1.6
202R02332	Pilarcitos Creek	37.47000	-122.44116	U	5/10/16	10.3	570	12.7	7.89	16	23	112	11	=	0.03	=	0.5	0.03	DNQ	0.001	DNQ	0.31	=	0.08	=	0.09	=	0.3	0.09	0.51	0.78	NA	NA	1.04	15	5	2	2.46	0.05	60	1.7	138	1.1	3%	4%	1.0
204R02228	San Mateo Creek	37.56114	-122.33698	U	5/11/16	10.7	309	15.5	8.08	20	10	99	26	=	0.05	=	1.5	0.04	DNQ	0.002	DNQ	0.4	=	0.02	=	0.02	=	0.4	0.02	0.56	0.56	0.56	1.15	0.91	11	7	5	2.67	0.76	35	1.6	137	1.5	9%	14%	2.8
204R02504	Polhemus Creek	37.53015	-122.34871	U	5/11/16	11.0	1077	13	8.02	79	21	148	189	=	0.03	=	0.7	-0.02	ND	0.002	DNQ	0.57	=	0.08	=	0.08	=	0.6	0.08	0.45	0.43	0.46	0.96	0.88	7	15	8	2.76	0.27	14	1.5	137	1.8	33%	54%	6.9
205R02728	Dry Creek	37.42452	-122.24954	U	5/12/16	8.8	9	14.3	8.18	45	18	54	27	=	0.06	=	2.2	0.23	=	0.001	DNQ	0.4	=	0.03	=	0.14	=	0.6	0.14	0.39	0.36	0.67	0.96	0.98	19	12	8	1.82	0.29	30	1.8	140	1.8	13%	64%	6.4
205R02920	Bear Gulch Creek	37.42376	-122.25112	U	5/12/16	10.3	585	16.1	7.97	69	18	42	72	=	0.05	=	1.1	-0.02	ND	0.002	DNQ	0.57	=	0.08	=	0.10	=	0.6	0.10	0.75	0.61	0.83	1.07	0.94	19	11	7	1.1	0.46	22	1.9	131	1.8	5%	16%	1.5

Site Information						Water Quality						Water Chemistry (nutrients)																		Biological and Physical Habitat Indicator Scores					Physical Habitat									Land Use Variables		
Station Code	Creek Name	Latitude	Longitude	Land Use	Sample Date	Dissolved Oxygen (mg/L)	Spec Conductance (uS/cm)	Temperature (Deg C)	pH	Chloride (mg/L)	Silica (mg/L)	Ash Free Dry Mass (g/m2)	Chlorophyll a (mg/m2)	QA Flag	Ammonia (mg/L)	QA Flag	UIA (ug/L)	Nitrate as N (mg/L)	QA Flag	Nitrite as N (mg/L)	QA Flag	TKN as N (mg/L)	QA Flag	Ortho Phosphate as P (mg/L)	QA Flag	Total Phosphorus as P (mg/L)	QA Flag	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	CSCI	ASCI_D	ASCI_SB	ASCI_H	IPI	Channel Alteration	Epifaunal Substrate	Sediment Deposition	Human Disturbance Index	Evenness Flow Habitat	% Substrate <2 mm	Shannon Diversity Habitat	Sum Riparian Cover	Shannon Diversity Substrate	% Impervious (wat)	% Urban (wat)	Road Density (wat)
205R03032	West Union Creek	37.43720	-122.28319	U	5/16/16	10.0	532	12.9	7.77	44	15	64	3	=	0.03	=	0.3	-0.02	ND	-0.001	ND	0.44	=	-0.01	ND	-0.01	ND	0.5	0.00	0.58	0.84	0.96	1.28	0.97	15	16	9	1.9	0.37	21	1.9	137	1.7	2%	3%	0.5
204R02548	Cordilleras Creek	37.49544	-122.24336	U	5/17/16	7.8	976	18.1	8.01	75	17	48	64	=	0.02	DNQ	0.6	0.22	=	0.001	DNQ	0.97	=	0.11	=	0.12	=	1.2	0.12	0.41	0.60	0.57	1.07	0.89	12	7	6	4.22	0.05	17	1.4	89	1.4	28%	60%	7.8
205R02408	Bull Run Creek	37.38400	-122.23499	U	5/17/16	10.1	1106	12.9	8.25	66	19	263	6	=	0.02	DNQ	0.7	0.06	=	-0.001	ND	0.53	=	0.09	=	0.09	=	0.6	0.09	0.64	0.69	0.84	1.28	0.65	19	14	4	1.78	0.76	22	0.9	125	1.7	6%	29%	4.9
204R03496	Redwood Creek	37.44775	-122.23470	U	5/22/17	9.3	922	15.61	8.07	54	33	84	24	=	0.09	=	2.7	0.37	=	0.034	=	0.83	=	0.14	=	0.15	=	1.2	0.15	0.60	0.56	0.64	1.12	0.06	12	8	8	3.72	0.61	59	1.5	143	1.5	19%	79%	7.6
204R02472	Redwood Creek	37.46516	-122.23462	U	5/22/17	13.1	945	26.2	8.86	58	30	179	292	=	0.09	=	24.5	0.47	=	0.032	=	1.9	=	0.18	=	0.23	=	2.4	0.23	0.54	0.40	0.65	0.73	0.85	0	1	15	4.36	0	30	0.1	26	0.5	22%	81%	8.0
204R03240	Atherton Creek	37.42732	-122.22682	U	5/23/17	7.2	5322	14.4	7.87	440	19	546	20	=	0.03	=	0.5	-0.02	ND	0.002	DNQ	1.2	=	0.05	=	0.06	=	1.2	0.06	0.41	0.52	0.59	1.28	0.34	12	8	12	3.3	0.34	78	1.8	138	1.2	12%	30%	3.7
204R02611	Atherton Creek	37.45083	-122.20592	U	5/23/17	13.9	2626	20.55	8.55	230	14	297	203	=	0.04	=	4.2	-0.02	ND	-0.001	ND	1	=	0.01	DNQ	0.01	=	1.0	0.01	0.43	0.29	0.48	0.57	0.74	0	0	18	3.96	0	6	0.6	119	0.5	24%	70%	7.1
202R00552	Lawrence Creek	37.38846	-122.31340	NU	5/24/17	10.4	443	11.9	8.21	32	20	276	5	=	0.02	DNQ	0.5	-0.02	ND	-0.001	ND	0.22	=	0.01	=	0.02	=	0.2	0.02	1.16	0.95	0.84	1.28	0.81	20	17	6	0	0.72	50	1.6	93	1.7	2%	1%	0.4
204R03316	Arroyo Ojo De Agua	37.48119	-122.23427	U	5/24/17	9.2	778	21.8	8.55	54	59	158	193	=	0.05	=	6.1	1.80	=	0.011	=	0.53	=	0.01	=	0.11	=	2.3	0.11	0.42	0.36	0.62	0.54	0.18	0	0	18	5.51	0	14	0.7	23	0.7	45%	93%	12.2
204R03336	Belmont Creek	37.51628	-122.27867	U	5/25/17	8.2	1324	14.6	7.76	160	22	57	8	=	0.02	DNQ	0.2	0.31	=	-0.001	ND	0.66	=	0.05	=	0.05	=	1.0	0.05	0.50	0.57	0.47	1.28	0.72	14	9	7	3.15	0.48	37	1.5	86	1.5	40%	73%	9.1
202R00550	Jones Gulch	37.27880	-122.26832	NU	5/30/17	10.1	519	11.69	7.96	46	50	206	-4	ND	0.05	=	1.7	0.23	=	0.006	=	0.62	=	0.32	=	0.34	=	0.9	0.34	0.87	0.94	1.00	1.28	1.03	20	15	8	0.23	0.62	40	1.7	158	1.8	1%	0%	2.1
204R03252	San Mateo Creek	37.56313	-122.32754	U	5/31/17	10.0	336	15.82	8.07	24	11	163	10	=	0.05	=	1.6	0.05	DNQ	0.004	DNQ	0.4	=	0.01	=	0.03	=	0.5	0.03	0.67	0.80	0.68	1.07	0.87	11	6	4	4.58	0.85	33	1.3	120	1.3	8%	13%	2.7
204R03272	San Mateo Creek	37.53385	-122.35018	U	5/31/17	9.6	249	14.71	7.92	24	11	48	40	=	0.05	=	1.6	0.05	DNQ	0.003	DNQ	0.4	=	0.01	DNQ	0.02	=	0.4	0.02	0.63	0.97	0.78	0.87	0.83	14	13	9	2.69	0.75	46	1.6	107	1.6	7%	8%	2.2
202R00614	Pescadero Creek	37.27410	-122.28860	NU	5/14/18	10.5	644	13.7	7.95	38	23	63	39	=	0.05	=	0.9	0.06	=	0.001	DNQ	0.44	=	0.10	=	-0.01	ND	0.5	0.00	1.17	1.16	0.80	0.87	1.04	14	13	13	1.72	0.64	19	1.9	105	1.6	1%	0%	1.4
202R03656	Pilarcitos Creek	37.46781	-122.42269	U	5/15/18	10.3	379	12.8	7.66	33	18	40	-3	ND	0.05	=	0.4	0.85	=	0.003	DNQ	0.35	=	0.04	=	0.08	=	1.2	0.08	0.71	0.82	NA	NA	0.8	14	4	3	3.12	0.54	65	1.5	96	1.2	2%	1%	0.7
202R00584	Pilarcitos Creek	37.49547	-122.38512	NU	5/15/18	9.5	321	13.3	7.54	16	16	114	9	=	0.03	=	0.2	0.46	=	0.003	DNQ	0.35	=	0.02	=	0.08	=	0.8	0.08	0.86	0.75	0.83	0.81	0.7	12	15	10	2.67	0.74	42	1.6	45	1.7	1%	0%	0.4
204R03508	Mills Creek	37.59105	-122.37406	U	5/16/18	10.0	664	13.2	7.88	51	23	24	54	=	0.07	=	0.6	0.11	=	0.001	DNQ	0.4	=	0.01	=	0.03	=	0.5	0.03	0.35	0.78	0.80	0.81	0.62	6	7	14	5.34	0	17	0.9	59	1.4	47%	91%	11.8
204R03528	San Mateo Creek	37.54808	-122.34661	U	5/16/18	10.7	244	13.2	7.77	16	6	72	31	=	0.07	=	0.9	0.14	=	0.001	DNQ	0.35	=	-0.01	ND	-0.01	ND	0.5	0.00	0.60	0.96	0.88	0.78	0.92	16	14	7	2.26	0.75	44	1.8	71	1.5	7%	10%	2.4
202R03404	San Pedro Creek	37.58203	-122.48719	U	5/17/18	10.0	459	13.5	7.92	26	20	119	27	=	0.07	=	0.8	0.49	=	0.007	=	0.35	=	0.02	=	-0.01	ND	0.8	0.00	0.65	0.73	0.65	0.96	1	15	16	6	2.47	0.82	29	1.7	94	1.7	13%	23%	2.8
202R03916	San Pedro Creek	37.59144	-122.50333	U	5/17/18	10.1	456	14.1	8.07	28	19	159	25	=	0.07	=	2.0	0.50	=	0.006	=	0.35	=	0.03	=	-0.01	ND	0.9	0.00	0.68	1.01	0.74	0.81	1.06	17	9	10	2.5	0.63	32	1.6	102	1.5	15%	26%	3.5
205R03624	Bear Creek	37.41883	-122.26498	U	5/21/18	10.5	562	12.7	8.22	17	18	53	26	=	0.07	=	1.1	0.16	=	-0.001	ND	0.35	=	0.09	=	0.10	=	0.5	0.10	1.20	1.01	0.96	1.28	1.21	11	15	12	4.33	0.99	22	1.6	157	1.6	3%	6%	1.1
205R03864	Hamms Gulch	37.36498	-122.22906	U	5/22/18	10.4	694	10.9	7.83	33	21	92	-3	ND	0.77	=	9.3	0.10	=	-0.001	ND	0.35	=	0.02	=	0.09	=	0.4	0.09	1.14	0.78	NA	NA	1.15	20	15	11	0	0.94	27	1.4	145	1.7	1%	0%	0.9
202R03880	La Honda Creek	37.38759	-122.27219	U	5/22/18	12.5	497	10.7	8.19	22	16	39	24	=	0.77	=	21.0	0.09	=	-0.001	ND	0.13	=	0.02	=	0.01	=	0.2	0.01	0.99	1.09	0.90	0.96	1.16	18	17	9	0.6	0.99	32	1.5	234	1.5	4%	10%	2.4
204R04280	Belmont Creek	37.55342	-122.35830	U	5/13/19	7.7	1343	13.3	8.04	130	20	41	59	=	0.39	=	8.8	0.33	=	0.002	DNQ	0.52	=	0.04	=	0.05	=	0.9	0.05	0.55	0.43	0.86	1.07	0.63	6	8	7	2.06	0.53	20	1.4	133	1.3	39%	72%	9.3
204BEL005	Belmont Creek	37.51770	-122.26910	U	5/13/19	10.7	1224	16.9	8.31	140	20	111	53	=	0.24	=	12.8	0.33	=	0.004	DNQ	0.52	=	0.06	=	0.07	=	0.9	0.07	0.46	0.63	0.67	0.81	0.84	9	5	4	4.09	0.33	51	1.4	94	1.2	41%	75%	9.6
202TUN040	Tunitas Creek	37.38840	-122.37090	NU	5/14/19	10.3	601	11.9	8.26	69	22	143	260	=	0.22	=	7.6	-0.02	ND	0.001	DNQ	0.14	=	0.04	=	0.04	=	0.2	0.04	0.94	0.61	0.78	0.54	1.09	20	17	9	0.29	0.5	50	1.6	111	1.7	1%	0%	1.7
202TUN030	Tunitas Creek	37.37940	-122.37483	NU	5/14/19	9.8	756	12.7	8.26	72	22	55	10	=	0.28	=	10.2	0.07	=	0.002	DNQ	0.083	DNQ	0.04	=	0.05	=	0.2	0.05	0.84	0.79	0.82	0.37	0.77	19	17	11	1.08	0.59	35	1.7	209	1.7	1%	0%	1.6
204R04160	Burlingame Creek	37.47890	-122.26126	U	5/15/19	7.2	1160	13.7	8.23	60	47	390	132	=	0.15	=	5.4	0.15	=	-0.001	ND	0.69	=	0.13	=	0.16	=	0.8	0.16	0.51	0.66	0.72	0.81	0.92	13	11	6	1.41	0.44	34	1.9	146	1.8	37%	93%	10.8
204R04428	Cordilleras Creek	37.45430	-122.20001	U	5/15/19	8.2	918	14.7	8.15	58	20	83	49	=	0.08	=	2.5	0.18	=	0.004	DNQ	0.44	=	0.04	=	0.05	=	0.6	0.05	0.60	0.85	0.73	0.81	0.84	10	9	6	4.7	0.73	44	1.7	122	1.5	19%	46%	5.5
204R04600	Atherton Creek	37.43610	-122.21560	U	6/10/19	10.1	2102	17.4	8.1	170	30	51	10	=	0.13	=	4.4	0.53	=	0.004	DNQ	0.63	=	0.15	=	0.17	=	1.2	0.17	0.53	0.57	0.67	1.28	0.49	2	1	16	3.66	0	2	1.0	101	1.0	24%	61%	6.6
204R03635	Atherton Creek	37.51522	-122.28230	U	6/10/19	11.5	2113	20.4	8.43	220	24	145	220	=	0.11	=	9.3	0.50	=	0.005	=	0.66	=	0.15	=	0.18	=	1.2	0.18	0.49	0.35	0.46	0.55	0.4	0	1	15	4.64	0	0	0.5	206	0.0	24%	71%	7.0
205R05044	Dry Creek	37.42820	-122.25179	U	6/11/19	6.7	722	20.2	7.94	58	18	117	37	=	0.08	=	2.5	0.16	=	0.013	=	0.47	=	0.09	=	0.11	=	0.6	0.11	0.48	0.47	0.51	1.28	0.92	15	10	6	4.18	0.21	34	1.8	136	1.7	13%	63%	6.4
205R04056	Dry Creek	37.43903	-122.26530	U	6/11/19	7.1	799	17	7.92	43	30	87	51	=	0.11	=	2.5	0.23	=	0.004	DNQ	0.3	=	0.07	=	0.08	=	0.5	0.08	0.49	0.58	0.63	0.37	0.87	15	14	9	3.65	0.29	23	1.7	146	1.7	14%	62%	6.3

Land Use: U - Urban, NU - Non-urban
QA Flag: ND - Non-detect (used ½ value of the method detection limit), DNQ - Detected Not Quantifiable (used measured value)
NR - Not Recorded
UIA- Un-ionized Ammonia
TKN - Total Kjeldahl Nitrogen
CSCI - California Stream Index
ASCI_D - Algae Stream Condition Index (Diatoms)
ASCI_H - Algae Stream Condition Index (Hybrid)
ASCI_SB - Algae Stream Condition Index (Soft Body)
IPI - Index Physical Habitat Integrity

Attachment 3

Technical Report: SMCWPPP Creek Status Bioassessment Monitoring, 2012 Through 2019

Prepared by Melwani, A., Applied Marine Sciences

SAN MATEO COUNTYWIDE WATER POLLUTION PREVENTION PROGRAM

CREEK STATUS BIOASSESSMENT MONITORING 2012 THROUGH 2019

TECHNICAL REPORT

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Submitted to:
EOA, Inc.

DRAFT
January 14, 2020

List of Acronyms

Acronym	Definition
ASCI	Algae Stream Condition Index
BASMAA	Bay Area Stormwater Management Agencies Association
BMI	Benthic Macroinvertebrate
CDF	Cumulative Distribution Function
CSCI	California Stream Condition Index
MDL	Method Detection Limit
MRP, MRP 2.0	Municipal Regional Stormwater Permit
MSE	Mean Square Error
ND	Non-detect
NPDES	National Pollutant Discharge Elimination System
QAPP	Quality Assurance Project Plan
RF	Random Forest
RMC	Regional Monitoring Coalition
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board (California Regional Water Quality Control Board, San Francisco Bay Region)
SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
SOP	Standard Operating Procedure
SWAMP	Surface Water Ambient Monitoring Program
WY	Water Year

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1 Introduction

The San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) conducts Creek Status Monitoring as required by Provision C.8 of the Municipal Regional National Pollutant Discharge Elimination System (NPDES) Stormwater Permit (SFRWQCB 2009, 2015). Since 2012, SMCWPPP has worked with several members of the Bay Area Stormwater Agencies Association (BASMAA) to form the Regional Monitoring Coalition (RMC), to coordinate and oversee water quality monitoring required by the Municipal Regional NPDES Stormwater Permit (in this document the permit is referred to as MRP). A key component of the coordinated effort has been to implement bioassessment monitoring in accordance with standardized methodologies established by the California Surface Water Ambient Monitoring Program (SWAMP), including sampling of benthic macroinvertebrates (BMIs), benthic algae (i.e., diatoms and soft algae), water chemistry, and the characterization of physical habitat (BASMAA 2016a, 2016b).

In coordination with the BASMAA RMC, the SMCWPPP is required to conduct bioassessments at 10 monitoring sites at streams/channels in San Mateo County each year. The vast majority of sites were probabilistically (i.e., randomly) selected from a sample frame comprising perennial and non-perennial streams, channels and rivers within the five participating counties that overlap with the San Francisco Bay Regional Water Quality Control Board (Region 2) boundary and the eastern portion of Contra Costa County that drains to the Central Valley region (Region 5). Bioassessments were conducted at three targeted sites in Water Year (WY) 2019 (October 1, 2018 through September 30, 2019). Over the past eight years (WY 2012 through WY 2019), SMCWPPP has sampled a total of 87 probabilistic sites and 3 targeted sites.

The goal of this report is to summarize the key results on a regional (i.e., countywide) basis from SMCWPPP's bioassessment data collection over the past eight years of MRP monitoring. The findings are intended to help the SMCWPPP better understand the current condition of water bodies in the County, identify stressors that are likely to pose the greatest risk to the health of those streams, and suggest key characteristics of streams that may help prioritize locations for future monitoring.

2 Statistical Analyses

All statistical analyses described in this report were conducted in R Studio, running R version 3.5.0 (R Core Team 2018). SMCWPPP data were assembled for analysis by querying a relational database consisting of bioassessment data collected in San Mateo County over an eight-year period (WY 2012 and WY 2019). Prior to all analyses, censored water quality results (i.e., non-detects) were substituted with 50% of the method detection limit (MDL). Biological data were then graphed and used to generate cumulative distribution functions (CDFs) and evaluate correlational statistics. Subsequently, missing values were estimated by imputation to facilitate use of all sites in the multivariate analysis. Silica and unionized ammonia (UIA) were found to have a handful of missing values and were subject to imputation using the R-package *mice* (van Buuren and Groothuis-Oudshoorn, 2011). In this method, replacement values were randomly selected from the distribution of observed data. Overall, 11 datapoints were imputed (Silica, n = 7; UIA, n = 4).

Spatial patterns were evaluated by grouping the results by watershed/sub-watersheds and strata (Pacific Ocean or San Francisco Bay). Due to the large number of relatively small sub-watersheds in San Mateo County, statistical analyses focused on evaluations by strata only.

2.1 Estimating Extent of Healthy Streams

Stream health was evaluated using biological indices developed for the State of California. The California Stream Condition Index (CSCI) (Mazor et al. 2016) was used to assess benthic macro-invertebrate data and the Algae Stream Condition Index (ASCI) (Theroux et al. in prep) was used to assess benthic algae data. Three different indices were used for ASCI representing diatoms (ASCI-D); soft-bodied algae (ASCI-SB) and hybrid of both diatoms and soft-bodies algae (ASCI-H).

Following the methods described in BASMAA (2019), the overall extent of biological conditions in San Mateo County streams was estimated using cumulative distribution functions (CDFs). CDF sample weights were calculated as the total stream length in the RMC sample frame, and divided by the stream length evaluated in each land use category (urban or non-urban). The adjusted sample weights were used to estimate the proportion of stream length (average and 95% confidence interval) represented by CSCI and ASCI scores for all SMCWPPP sites combined, and then for urban and non-urban sites separately. Post-stratification of San Mateo County data was performed to generated the county-specific CDFs. All calculations were conducted using the R-package *spsurvey* (Kincaid and Olsen 2016).

2.2 Biological Indicator Thresholds

Existing thresholds for the CSCI (Mazor et al. 2016) and ASCI (Theroux et al. in prep) were used to evaluate bioassessment data compiled and analyzed in this report ***(Table 1)***. The thresholds for each index were based on the distribution of scores for data collected at reference calibration sites in California. Four condition categories are defined by these thresholds: "likely intact" (greater than 30th percentile of calibration reference site scores); "possibly altered" (between the 10th and the 30th percentiles); "likely altered" (between the 1st and 10th percentiles; and "very likely altered" (less than the 1st percentile).

Table 1. Biological Condition Indices, Categories and Thresholds

Index	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Benthic Macroinvertebrates (BMI)				
CSCI	≥ 0.92	≥ 0.79 to < 0.92	≥ 0.63 to < 0.79	< 0.63
Benthic Algae				
ASCI-D (Diatom)	≥ 0.92	≥ 0.81 to < 0.92	≥ 0.66 to < 0.81	< 0.66
ASCI-SB (Soft Bodied Algae)	≥ 0.92	≥ 0.80 to < 0.92	≥ 0.65 to < 0.80	< 0.65
ASCI-H (Hybrid)	≥ 0.95	≥ 0.88 to < 0.95	≥ 0.78 to < 0.88	< 0.78

2.3 Stressor Analysis

Stressors related to biological condition scores were evaluated using Spearman's rank correlation analysis and random forest (RF) statistical models. The stressor variable list (*Appendix 1*) consisted of 50 quantitative environmental variables that are related to water quality, physical habitat, and landscape factors that could potentially influence biological condition scores, and two categorical factors (Land Use and Strata) that could potentially differentiate condition scores for different types of streams.

Correlation statistics were employed as a variable reduction technique to isolate a shortened list of explanatory variables that significantly correlate with biological condition scores (each of the four biological indicators were evaluated separately). Correlation analysis was performed with all sites pooled, as well as by stratification of sites that are in watersheds that drain either to the Pacific Ocean or San Francisco Bay. Subsequently, CSCI and the ASCI-H were prioritized for RF analysis as they exhibited the best correlation statistics with stressor variables. Of the three algae indices, ASCI-H was reported to exhibit the best response to environmental disturbance gradients for the statewide dataset (Theroux et al. in prep).

RF regression tree methods were used to evaluate the relative importance of the selected explanatory variables for CSCI and ASCI-H, and create an ordered list of explanatory variables related to biological condition scores. Both sets of analyses initially were run with the same sets of optimized predictor variables based on the correlation results, and then further refined during model runs. RF models were developed using the R-package *randomForest*. Data were standardized (i.e. scaled to account variables having different units and ranges) and partitioned into training (80%) and validation (20%) sets for model testing. A random selection of samples was generated by sub-sampling from both the San Francisco Bay and Pacific Ocean strata to maintain a regional balance of samples within the partitioned datasets. The training dataset for CSCI modeling had 72 sites, while the validation data encompassed 18 sites. Due to a few sites where ASCI-H scores could not be calculated due to insufficient number of soft-algae taxa needed to calculate index scores, the training dataset for ASCI-H modeling had 70 sites, while the validation data had 15 sites.

Several runs of the model procedure were performed with the training data set to optimize the random forests, including tuning the model to the maximum number of predictors per branch, the number of trees to build, and validation of the predictions. The final set of models evaluated a maximum of 4 predictor interactions and 1000 trees. Two variable importance statistics were used to estimate the relative influence of predictor variables: (1) % Increase in MSE = percent increase in mean-square-error of predictions as a result of variable values being permuted; (2) Increase in Node Purity = difference between the residual sum-of-squares before and after a split in the tree. Variables of greater importance to predictions will exhibit larger changes in MSE and values of node purity.

Random forest tuning was performed by evaluating the corresponding variable importance scores, partial dependency plots, and the change in R^2 once the variable was excluded. Partial dependency plots show the predicted biological response based on an individual explanatory variable with all other variables removed. No variable with less than 10% influence on CSCI or ASCI-H predictions was retained in the final models. Finally, the random forest models were used to predict CSCI and ASCI-H scores for the validation data set. Appendix 2 presents the observed and predicted values for the final validation models.

3 Results

3.1 SMCWPPP Site Evaluations

A total of 514 randomly selected monitoring sites were sampled in the RMC region between 2012 and 2019. Eighty-seven of these sites (17%) were assessed in San Mateo County, representing a total stream length of 91.6 km *(Table 2*Table 2*)*. Sixty-four of the sites in San Mateo County (74%) were from urban streams and channels of the County.

A total of 250 sites were initially evaluated to obtain the 87 sites that were ultimately sampled. This equates to a rejection rate of ~ 65%, which can largely be attributed to sites corresponding to areas that were not sampleable, e.g. due to lack of flow, lack of creek, tidal influence, or accessibility. As of WY 2020, there are 500 sites remaining in the RMC sample draw for San Mateo County (*Table 3*). The vast majority of these sites correspond to the non-urban portion of the County (472 of 500 sites). Therefore, assuming a rejection rate of 65%, the sample draw will likely only be sufficient to complete the current MRP term through 2020.

Table 2. Site Evaluations for San Mateo County (2012-2019)

	Urban		Non-Urban		Total	
	Sites	Stream Length (km)	Sites	Stream Length (km)	Sites	Stream Length (km)
Target	64	67.4	23	24.2	87	91.6
Non-Target	62	65.3	10	10.5	72	75.8
Target Not-Sampled (denial, physical barrier, other)	68	71.6	23	24.2	91	95.8
Total	194	204.3	56	59.0	250	263.3

Table 3. Probabilistic Sites Remaining in San Mateo County

	Sites	Stream Length (km)
Urban	28	29.5
Non-Urban	472	497.0
Total	500	526.5

3.2 Biological Condition of Streams in San Mateo County

The distribution of biological index scores observed in San Mateo County during 2012-2019 suggests that many streams do not support healthy biological conditions. *Figures Figure* **1***Figure 2Figure 3Figure 4* show cumulative distribution functions of the BMI and algae index scores for the entire SMCWPPP dataset (i.e., urban and non-urban sites combined) and the urban and non-urban dataset separately. The median (50th percentile) CSCI score based on all 87 probabilistic sites was estimated at 0.82, which corresponds to the Possibly Altered condition class. However, the 50th percentile of CSCI scores from urban sites was 0.51, corresponding to the Very Likely

Altered and substantially below the MRP trigger (0.795) for potential follow-up studies. The non-urban sites indicated a median score of 0.92 but this estimate is highly variable (wide confidence intervals) due to the fewer number of sites (n = 23 of 87) represented.

ASCI scores based on diatoms and the hybrid method exhibited similar CDFs to CSCI, with urban sites scoring much lower than non-urban sites. The median ASCI-D and ASCI-H scores at urban sites was 0.60 and 0.64 (both Very Likely Altered) compared to 0.91 (Possibly Altered) and 0.92 (Likely Intact), respectively. Overall, when all sites are combined the median was 0.83 (Possibly Altered) for ASCI-D and 0.82 (Likely Altered) for ASCI-H. In contrast, the ASCI scores based on soft-algae (ASCI-SB) did not vary greatly between urban and non-urban sites. Considering all sites together, the median ASCI-SB score was 0.97 (Likely Intact) compared to the 50th percentile for urban sites of 0.90 (Possibly Altered) and non-urban sites of 0.98 (Likely Intact).

Comparison of the number of sites in each biological condition class by strata and land use shows that most of the urban waterbodies in poor condition are associated with San Francisco Bay watersheds (*TablesTable* 4*, Table 5, Table 6, and Figure 5*). All together 50 sites were characterized as corresponding to the Very Likely Altered condition category, with 86% (n = 43) representing sites from the San Francisco Bay / Urban strata. Conversely, 19 sites were characterized as Likely Intact based on BMIs, with 68% (n = 13) representing sites from the Pacific Ocean / Non-urban strata.

CSCI scores and the diatom and hybrid ASCI indicator scores showed a high degree of similarity when data were stratified by San Francisco Bay or the Pacific Ocean (*Figure 5*). For example, the Pacific Ocean strata exhibited 13 of 23 (57%) sites from non-urban areas as Likely Intact and 4 of 12 (33%) sites from urban area as Very Likely Altered. This was very similar to the pattern of ASCI-D and ASCI-H condition scores, where 9 of 23 (39%) and 8 of 23 (35%), respectively from non-urban areas were scored as Likely Intact, and 2 of 12 (17%) and 5 of 12 (42%) from urban areas were scored as Very Likely Altered. This trend was also apparent for San Francisco Bay, where the vast majority of urban sites coincided. Based on CSCI scoring, 43 of 53 sites from urban areas were scored as Very Likely Altered, compared to 37 of 53 (70%) sites using ASCI-D and 42 of 53 (79%) sites using ASCI-H.

The ASCI-SB index showed congruency with CSCI scoring at non-urban sites, but not for urban sites. For example, exactly the same number of non-urban sites from the Pacific Ocean strata were scored as Likely Intact in the CSCI and ASCI-SB. However, none of the urban sites were similarly scored as Very Likely Altered, when the CSCI scoring identified four sites in this condition class. For San Francisco Bay sites, only 10 of 53 (19%) urban sites were in the poorest condition category, which was significantly less than was found for CSCI scoring (86%).

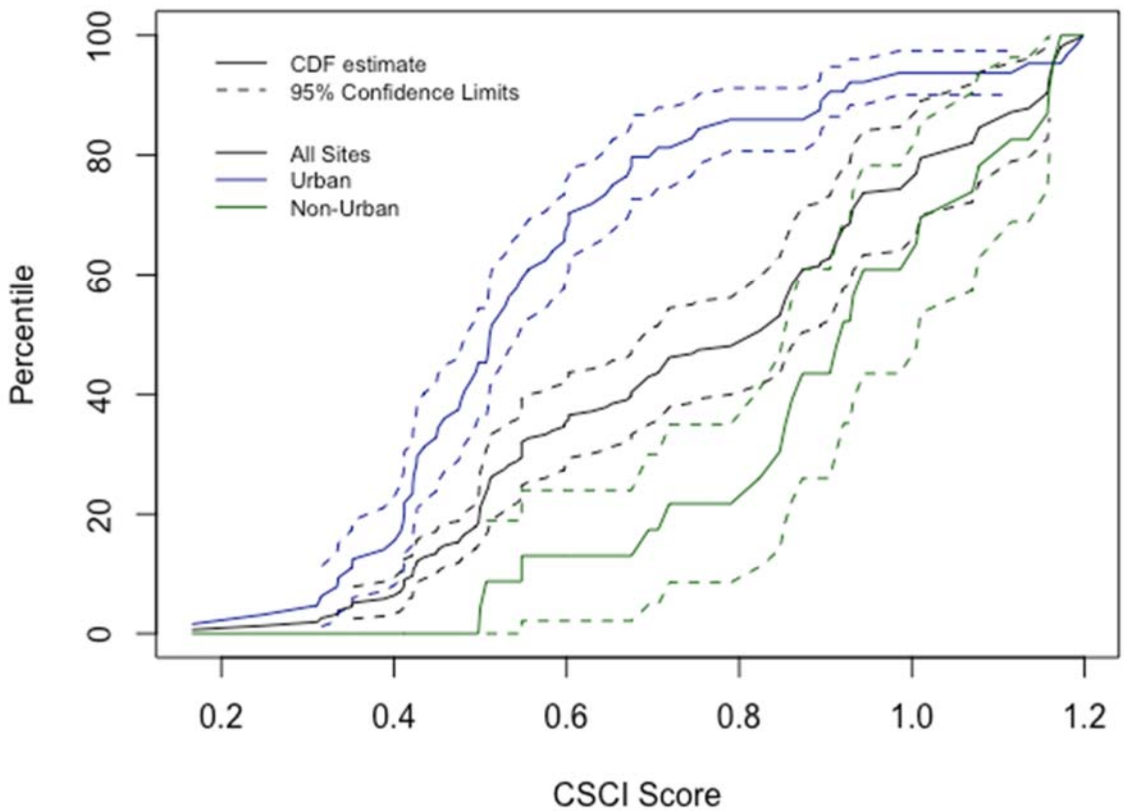

Figure 1. Cumulative Distribution Function of CSCI Scores in San Mateo County (n = 87)

Table 4. Number of Sites in each CSCI Condition Class by Strata and Land Use (including 3 targeted WY2019 sites)

Strata	Land Use	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Pacific Ocean	Urban	1	3	4	4
San Francisco Bay	Urban	5	1	4	43
Pacific Ocean	Non-Urban	13	6	1	3
San Francisco Bay	Non-Urban	0	1	1	0

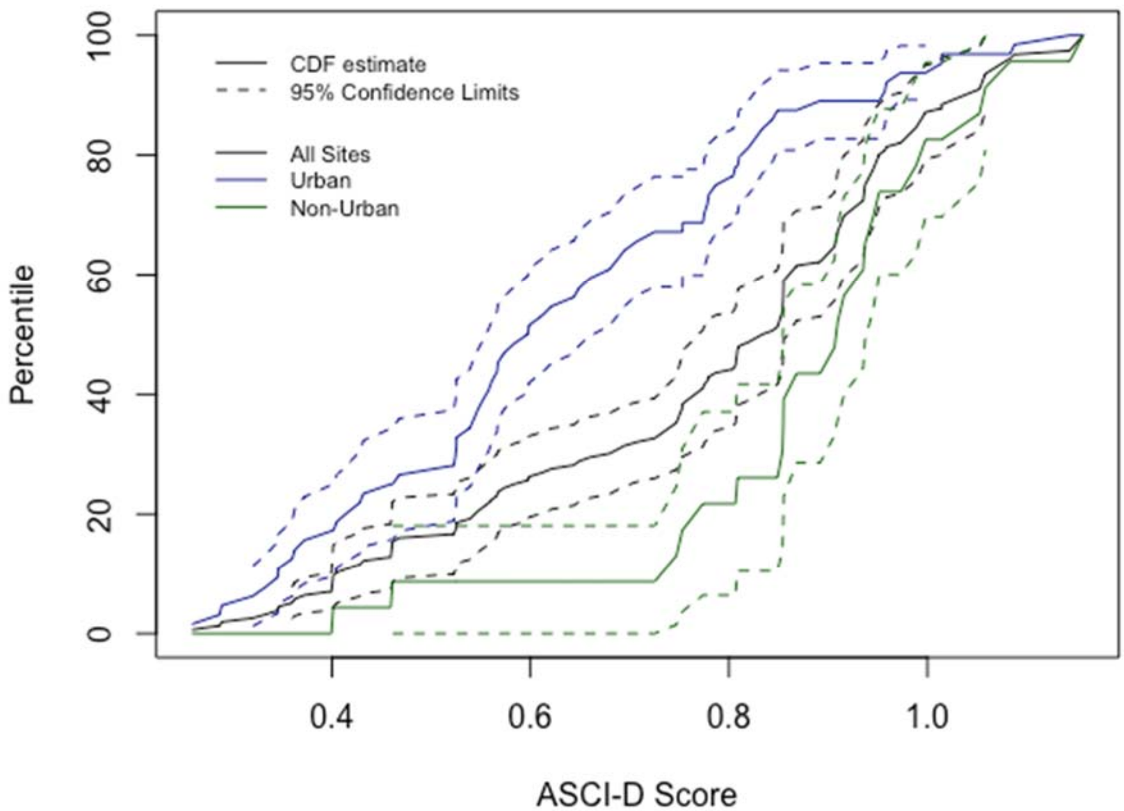

Figure 2. Cumulative Distribution Function of ASCI-D Scores in San Mateo County (n = 87)

Table 5. Number of SMCWPPP Sites in each ASCI-D Condition Class by Strata and Land Use (including 3 targeted WY2019 sites)

Strata	Land Use	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Pacific Ocean	Urban	4	2	4	2
San Francisco Bay	Urban	3	5	8	37
Pacific Ocean	Non-Urban	9	7	4	3
San Francisco Bay	Non-Urban	1	0	1	0

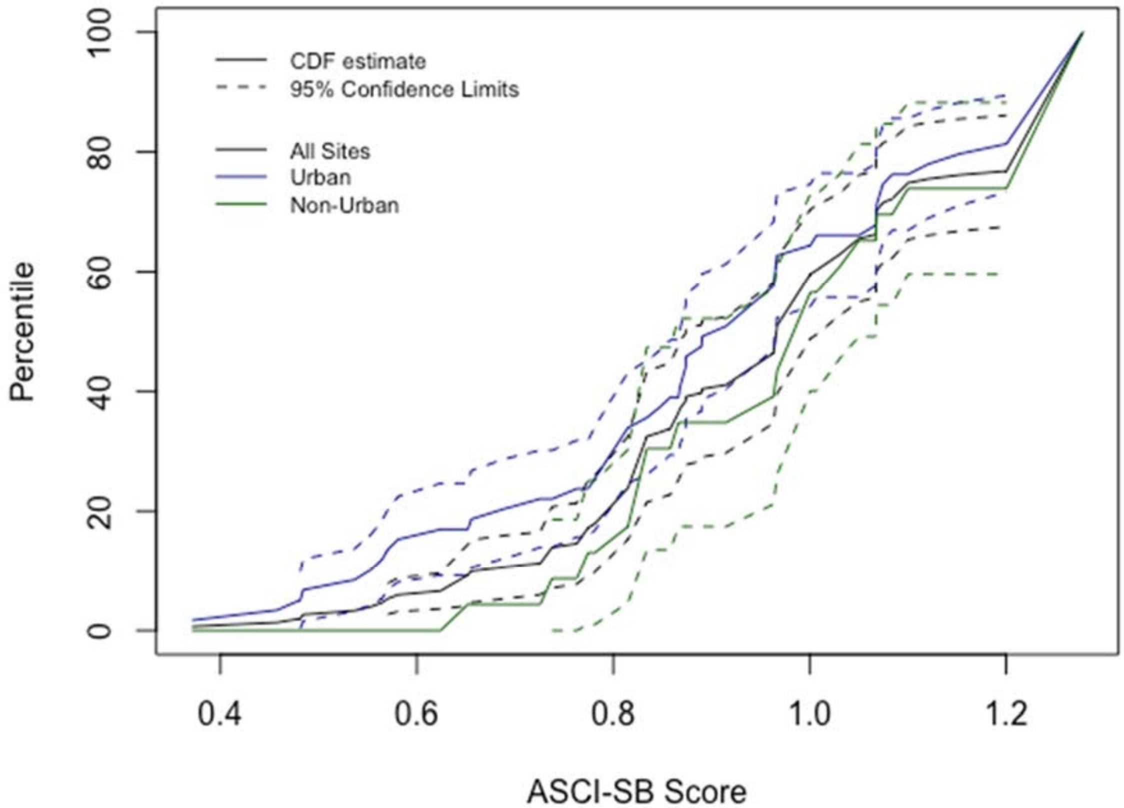

Figure 3. Cumulative Distribution Function of ASCI-SB Scores in San Mateo County (n = 87)

Table 6. Number of SMCWPPP Sites* in each ASCI-SB Condition Class by Strata and Land Use (including 3 targeted WY2019 sites)

Strata	Land Use	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Pacific Ocean	Urban	6	2	0	0
San Francisco Bay	Urban	23	14	5	10
Pacific Ocean	Non-Urban	13	5	3	2
San Francisco Bay	Non-Urban	2	0	0	0

* Insufficient data for scoring at 4 Pacific, Urban sites and 1 SF Bay, Urban site

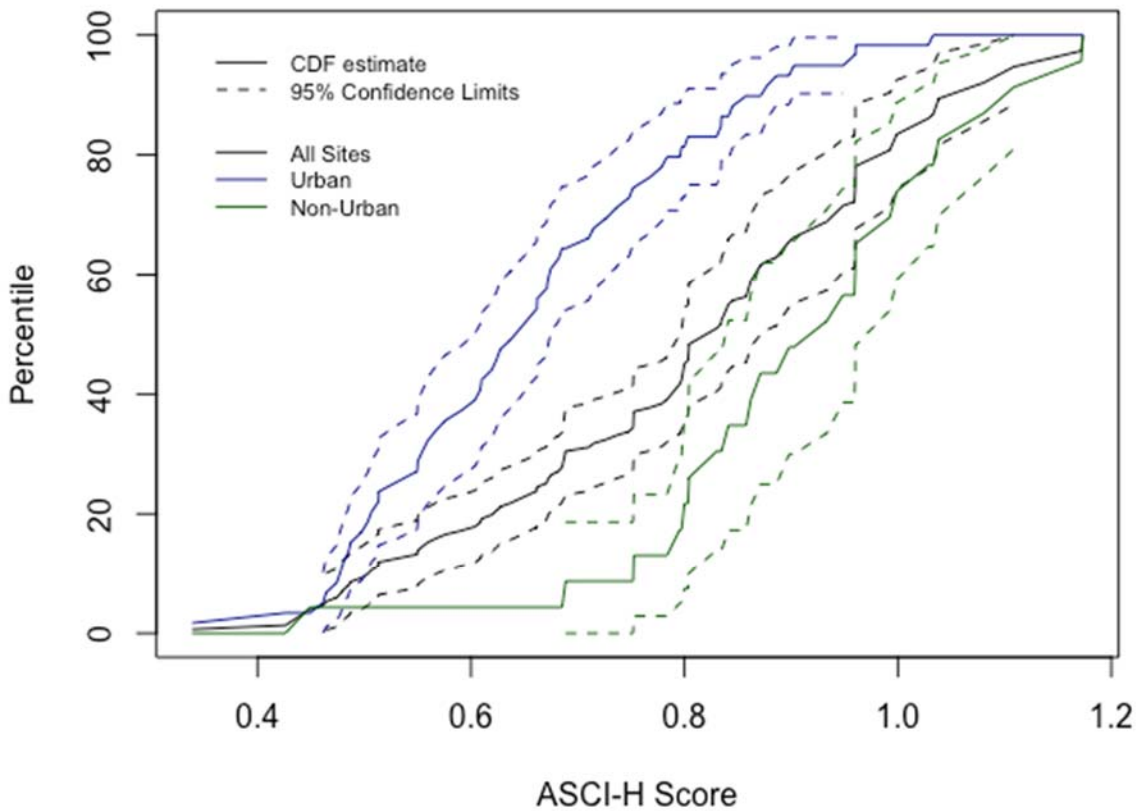

Figure 4. Cumulative Distribution Function of ASCI-H Scores in San Mateo County (n = 87)

Table 7. Number of SMCWPPP Sites* in each ASCI-H Condition Class by Strata and Land Use (including 3 targeted WY2019 sites)

	Land Use	Likely Intact	Possibly Altered	Likely Altered	Very Likely Altered
Pacific Ocean	Urban	0	2	1	5
San Francisco Bay	Urban	1	3	7	42
Pacific Ocean	Non-Urban	8	3	9	3
San Francisco Bay	Non-Urban	2	0	0	0

* Insufficient data for scoring at 4 Pacific, Urban sites and 1 SF Bay, Urban site

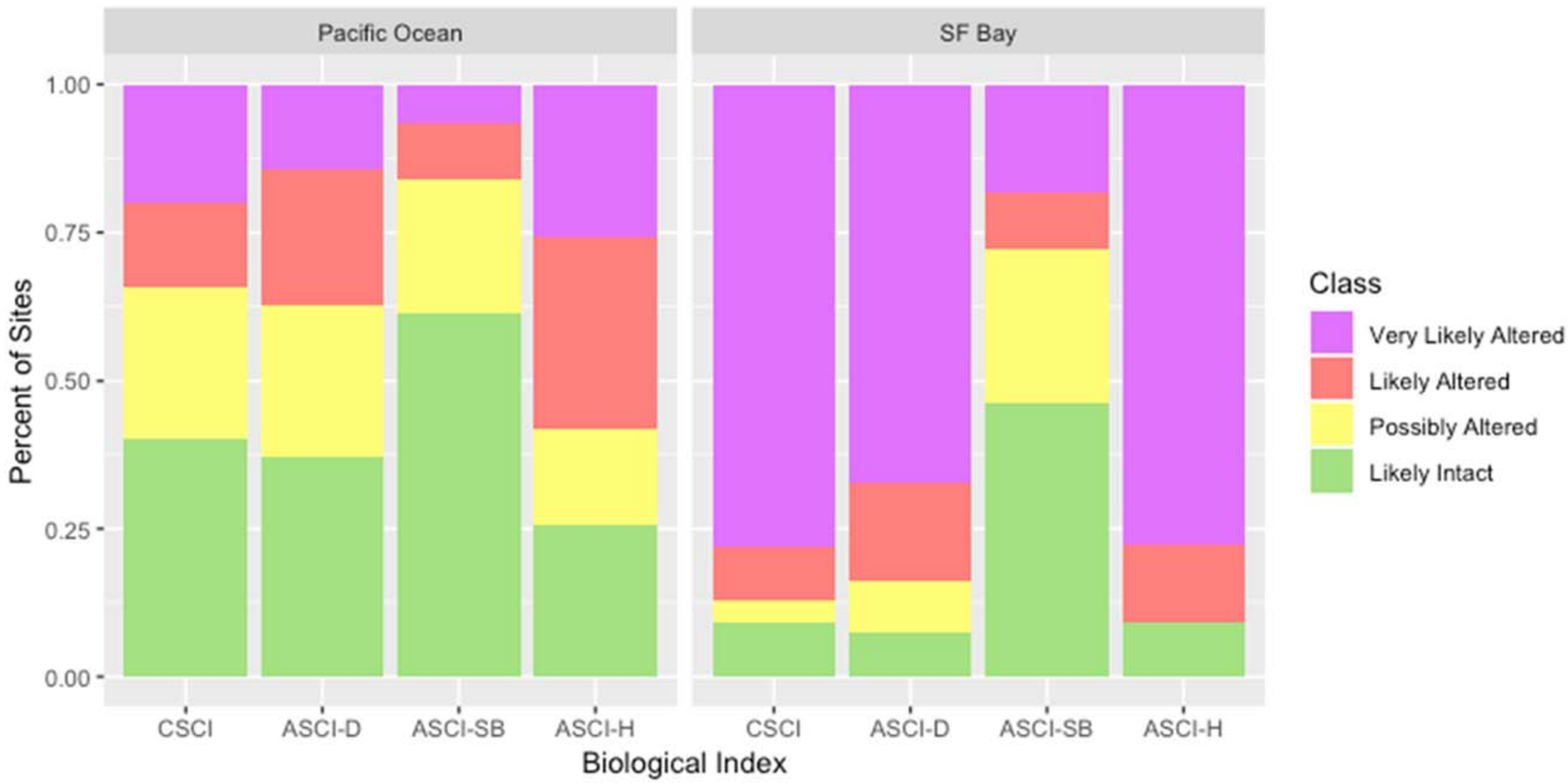

Figure 5. All San Mateo County Biological Condition Scores (2012-2019) Grouped by Condition Category and Strata (including 3 targeted WY2019 sites)

3.3 Stressors Associated with Biological Conditions

To evaluate stressors associated with biological condition, correlation analysis and random forest modeling was performed. Correlation results indicated 19 of 50 quantitative variables exhibited a statistically significant correlation with one or more of the biological indices (*Table 8*). A Spearman's rho value of < -0.5 or > 0.5 was considered the minimum cutoff for correlated variables. Many of the correlated variables were representative of land use (i.e., road density, road crossings, impervious and urban area; *FiguresFigure* **6**,*Figure* **7**, *Figure* **8** *and Figure* **9***).* Additionally, three variables were related to water quality (Total Nitrogen, TKN, and temperature*; FiguresFigure* **10**,*Figure* **11** ,*Figure* **12***)* and four variables were representative of physical habitat (filamentous algae cover, channel alteration, epifaunal substrate and combined human disturbance index; *Figures Figure* **13**,*Figure* **14**,*Figure* **15**, *and 16).*

The number of significant variables that met the cutoff of +/- 0.5 varied among indices. All 19 variables were significant for CSCI and ASCI-D. Seventeen variables (except TKN and Total Nitrogen) were statistically significant for the ASCI-H index. However, only Temperature and filamentous algae cover was significantly correlated to ASCI-SB. Most of the variables that were found to be significantly correlated with index scores were negatively correlated. Only the Channel Alteration and Epifaunal Substrate physical habitat scores were positively correlated with CSCI and ASCI indices.

Correlation analyses were also performed to evaluate stressors that associated with CSCI and ASCI-H scores in watersheds draining to the Pacific Ocean compared to San Francisco Bay (

Table 9*).* CSCI and the ASCI-H were prioritized for this comparison as they exhibited the best correlation statistics when all data were pooled, and since the indices were designed to be relatable with respect to environmental disturbance gradients (Theroux et al. in prep). The results of this analysis suggest that most of the significant correlations were as a result of the sites in the San Francisco Bay region. A notable spatial difference in the stressor correlations was that CSCI and ASCI-H were only significantly correlated with 5 and 9 variables, respectively in the Pacific Ocean stratum, while these two indices were correlated with 16 variables and 12 variables each in the San Francisco Bay stratum. This observation may suggest spatial differences to stressor impacting upon stream health, as well as the larger sample size of San Francisco Bay sites for evaluating correlations.

The prioritized list of 19 variables were used in random forest model development for CSCI and ASCI-H. RF model results clearly indicated better relationships to stressors using CSCI scores compared to the ASCI-H index. Validation of the final random forest models showed that the CSCI model explained 64% of the variance using eight predictor (stressor) variables, while the ASCI-H model only explained 43% of the variance using seven predictors.

The CSCI RF model indicated that land use and physical habitat variables were most influential to most biological condition (*Table 10*). Of the eight variables in the final CSCI model, five consisted of landscape variables calculated on various spatial scales (e.g., PctImp_5K and PctImp), three variables were associated with water quality (Total Nitrogen, TKN, temperature), and one was a habitat variable (Epifaunal Substrate cover). The landscape variables that were most influential to CSCI scores were associated with the degree of human impact/imperviousness and the water quality variables were associated with nutrient dynamics.

Overall, three groups of stressor variables exhibited the largest influence on the CSCI random forest model (14.1 – 15.8%). These variables were percent impervious area (reach and 5 km scale), road density (1 km and watershed scale), and total Nitrogen. The remaining variables in the final model exerted a lesser degree of influence (10.1 – 12.1%) on CSCI scores.

The ASCI-H RF model indicated that land use and water quality variables were most influential to biological condition (*Table 11*). Of the seven variables in the final ASCI-H model, five were comprised of landscape variables at various spatial scales (e.g., PctImp_5K, PctImp_1K, PctImp) and two were water quality variables (TKN and temperature). It was notable that several of the same variables were indicated in this model to the CSCI RF. Overall, three stressor variables exhibited the largest influence on the ASCI-H scores (13.9– 15.5%). These variables were percent impervious area (reach), road density (1 km), and percent urban area (5 km). The other four variables exerted a similar degree of influence (10.0 – 11.7%) on ASCI-H scores.

Table 8. Spearman's rank correlation (rho) statistics for stressor variables with < -0.5 or > 0.5 with one or more biological indices (CSCI, ASCI-D, ASCI-SB, or ASCI-H). Data for both urban and non-urban land use and Pacific Ocean and San Francisco Bay strata were pooled. Variables are color coded according to: physical habitat (green), land use (orange), and water quality (blue). All rho values were statistically significant, except those marked with 'ns'.

Stressor	CSCI	ASCI-D	ASCI-SB	ASCI-H

Algae Cover	-0.50	-0.44	-0.37	-0.45
ChanAlt	0.56	0.51	0.33 ns	0.55
EpiSub	0.63	0.46	0.19 ns	0.51
HDI	-0.55	-0.46	-0.25 ns	-0.57
PctImp	-0.64	-0.49	-0.17 ns	-0.54
PctImp_1K	-0.62	-0.37	-0.13 ns	-0.50
PctImp_5K	-0.69	-0.54	-0.19 ns	-0.60
PctUrb	-0.68	-0.62	-0.21 ns	-0.63
PctUrb_1K	-0.64	-0.56	-0.20 ns	-0.61
PctUrb_5K	-0.68	-0.60	-0.19 ns	-0.63
RdCrs_1K	-0.56	-0.43	-0.16 ns	-0.51
RdCrs_5K	-0.42	-0.40	-0.21 ns	-0.58
RdCrs_W	-0.36	-0.36	-0.20 ns	-0.56
RdDen_1K	-0.71	-0.49	-0.18 ns	-0.57
RdDen_5K	-0.69	-0.56	-0.19 ns	-0.58
RdDen_W	-0.68	-0.59	-0.21 ns	-0.59
Temp	-0.51	-0.48	-0.34	-0.63
TKN	-0.56	-0.37	0.08 ns	-0.28 ns
Total N	-0.59	-0.35	-0.06 ns	-0.29 ns

Table 9. Spearman's rank correlation (rho) statistics for stressor variables with < -0.5 or > 0.5 with CSCI or ASCI-H for the Pacific Ocean and San Francisco Bay strata. Data for both urban and non-urban sites were pooled. Variables are color coded according to: physical habitat (green), land use (orange), and water quality (blue). All rho values were statistically significant, except those marked with 'ns'.

Stressor	CSCI	ASCI-H	CSCI	ASCI-H
	Pacific Ocean		San Francisco Bay	
Algae Cover	-0.14 ns	-0.20 ns	-0.40	-0.26 ns
ChanAlt	0.35	0.20 ns	0.39	0.46
EpiSub	0.52	0.16 ns	0.43	0.39
HDI	-0.24 ns	-0.48	-0.39	-0.28
PctImp	-0.08 ns	-0.04 ns	-0.72	-0.35
PctImp_1K	-0.27 ns	-0.33 ns	-0.44	-0.18 ns
PctImp_5K	-0.16 ns	-0.32 ns	-0.67	-0.33
PctUrb	-0.20 ns	-0.40	-0.61	-0.35
PctUrb_1K	-0.39	-0.48	-0.36	-0.28
PctUrb_5K	-0.22 ns	-0.38	-0.58	-0.34
RdCrs_1K	-0.23 ns	-0.40	-0.44	-0.23 ns
RdCrs_5K	-0.25 ns	-0.47	-0.09 ns	-0.26 ns
RdCrs_W	-0.15 ns	-0.47	-0.01 ns	-0.21 ns
RdDen_1K	-0.39	-0.59	-0.59	-0.16
RdDen_5K	-0.22 ns	-0.33 ns	-0.66	-0.28
RdDen_W	-0.17 ns	-0.34 ns	-0.70	-0.30
Temp	-0.33 ns	-0.37	-0.13 ns	0.46
TKN	-0.21 ns	-0.05 ns	-0.46	-0.12 ns
Total N	-0.34	-0.17 ns	-0.53	-0.11 ns

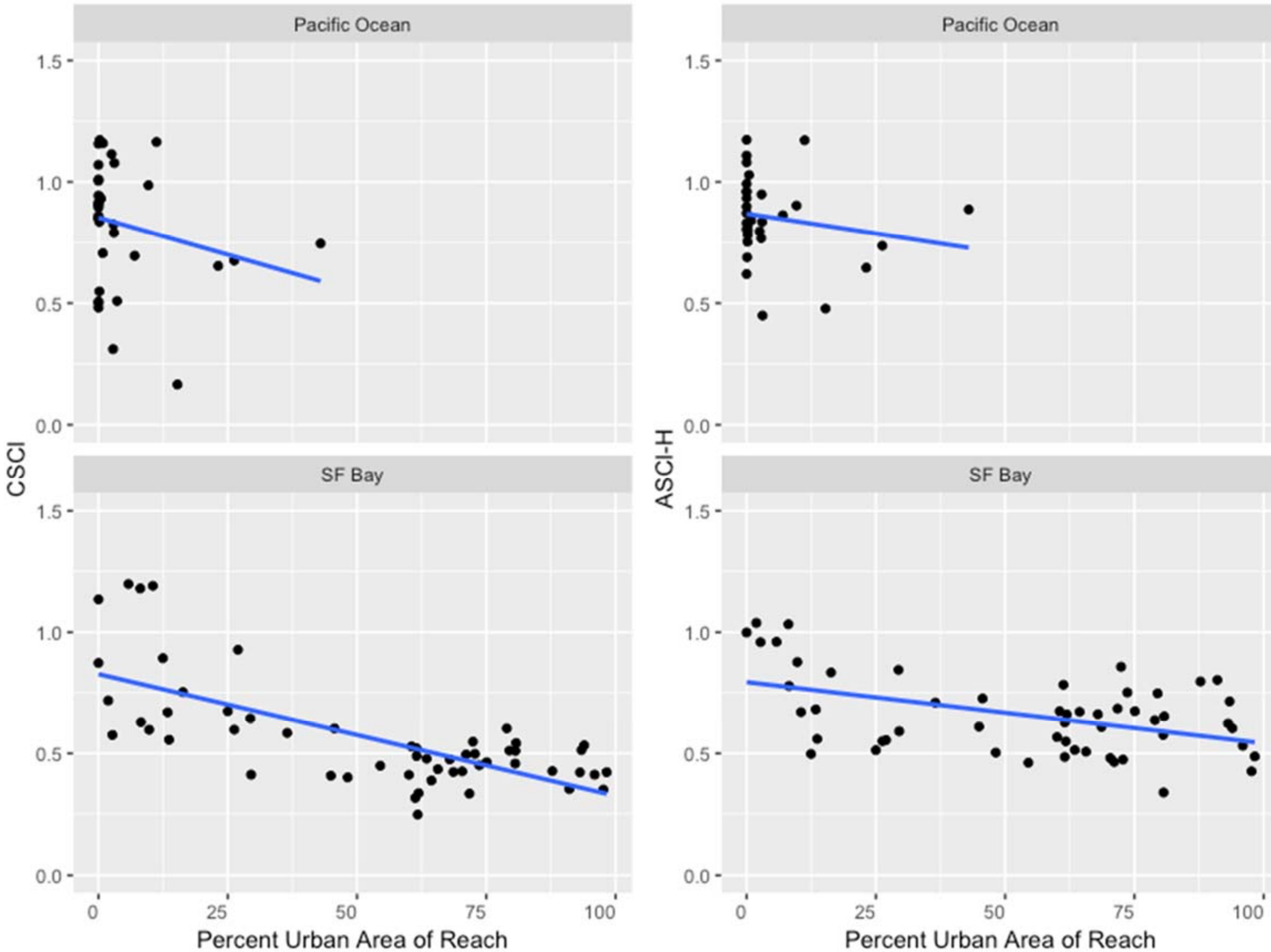

Figure 6. Percent Urban Area vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

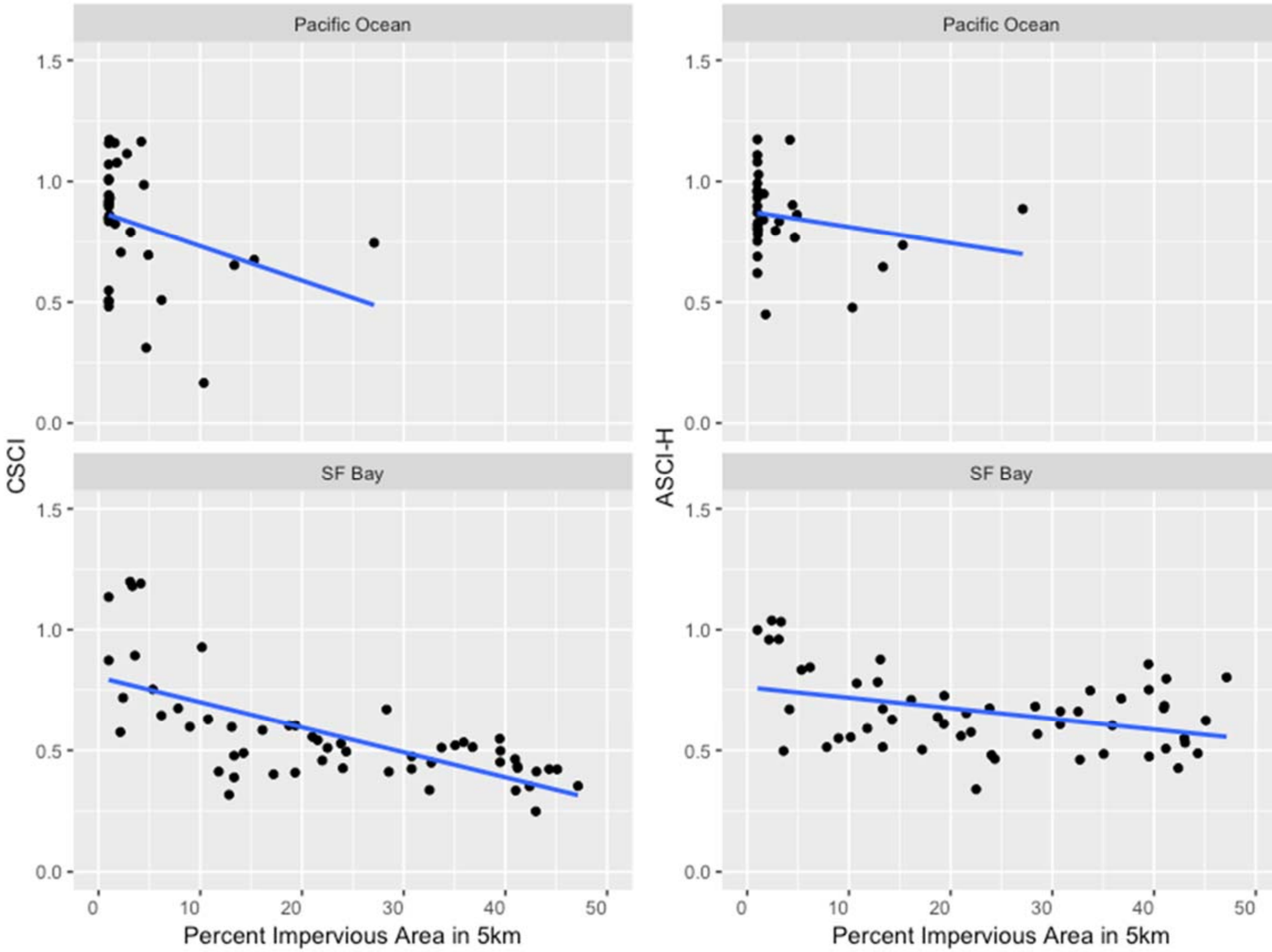

Figure 7. Percent Impervious Area in 5 km vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

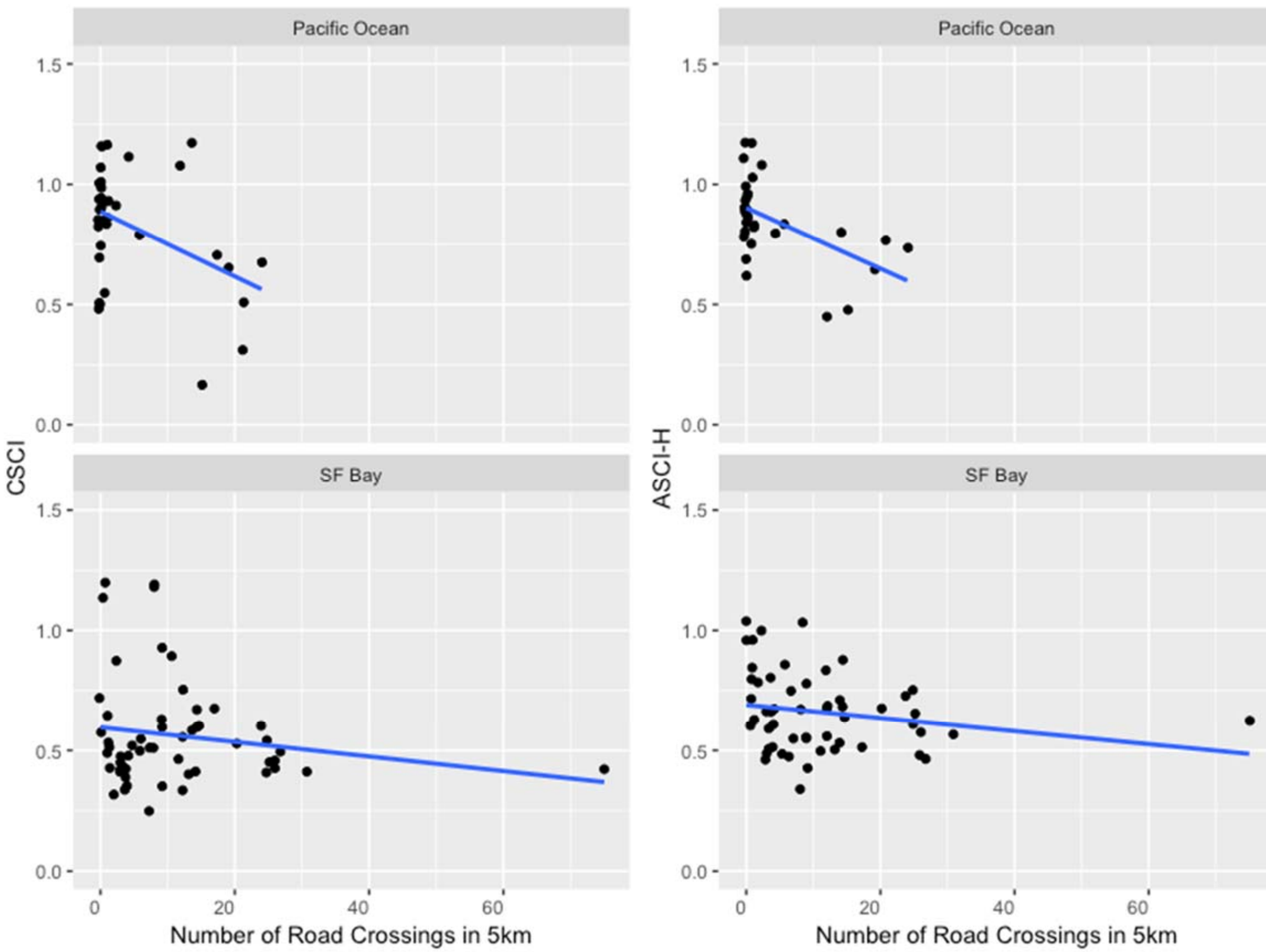

Figure 8. Number of Road Crossings in 5 km vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

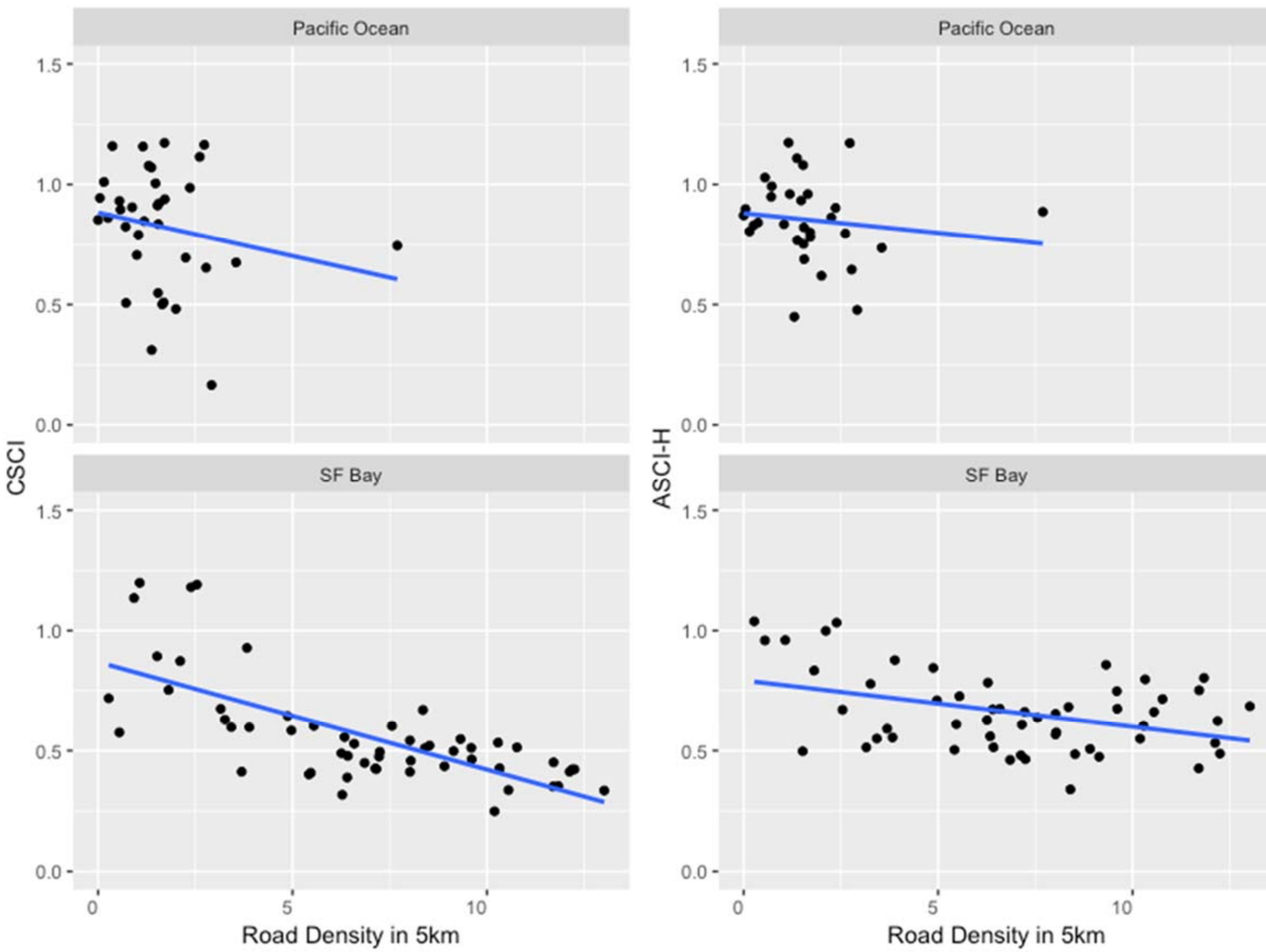

Figure 9. Road Density in 5 km vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

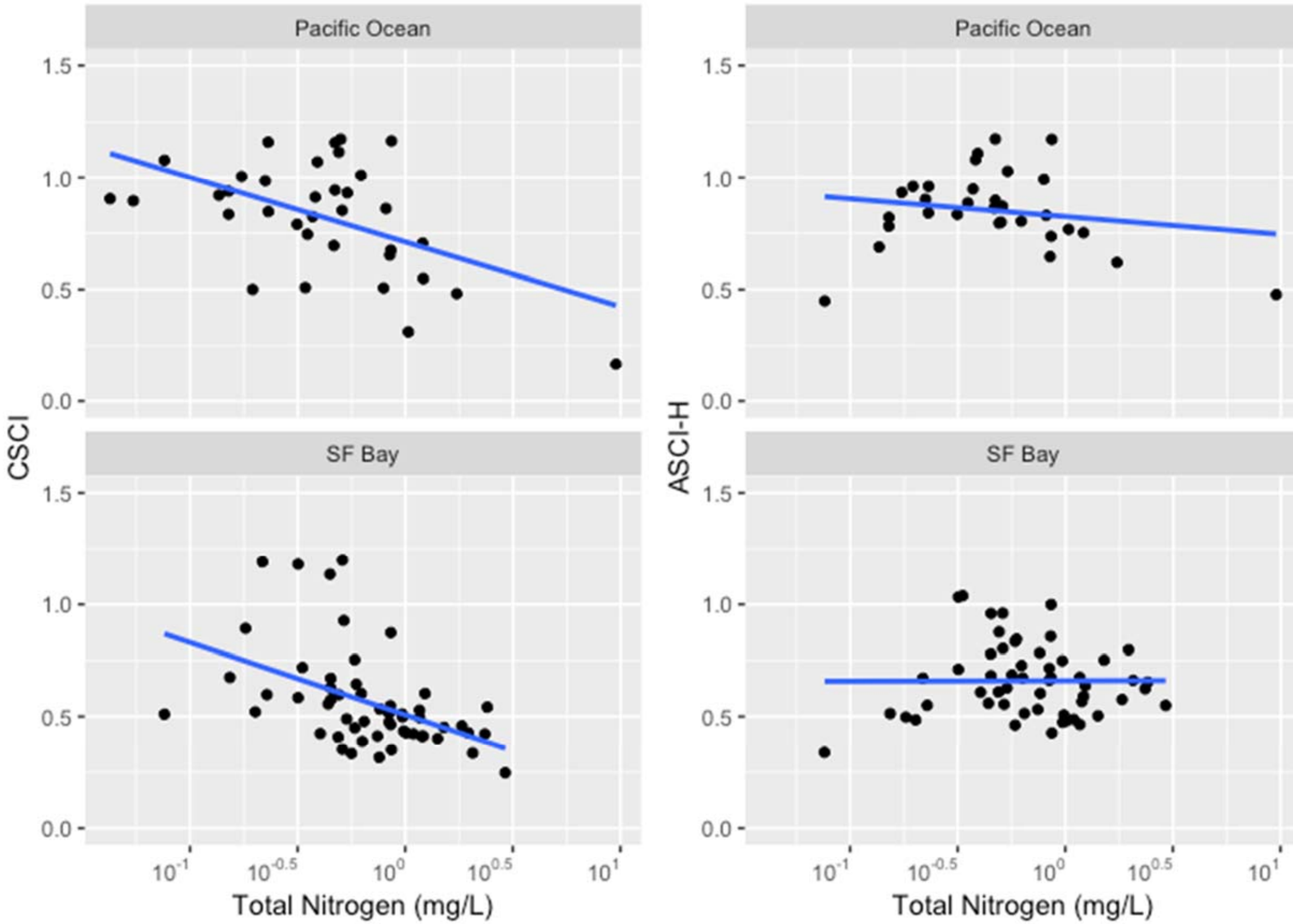

Figure 10. Total Nitrogen vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

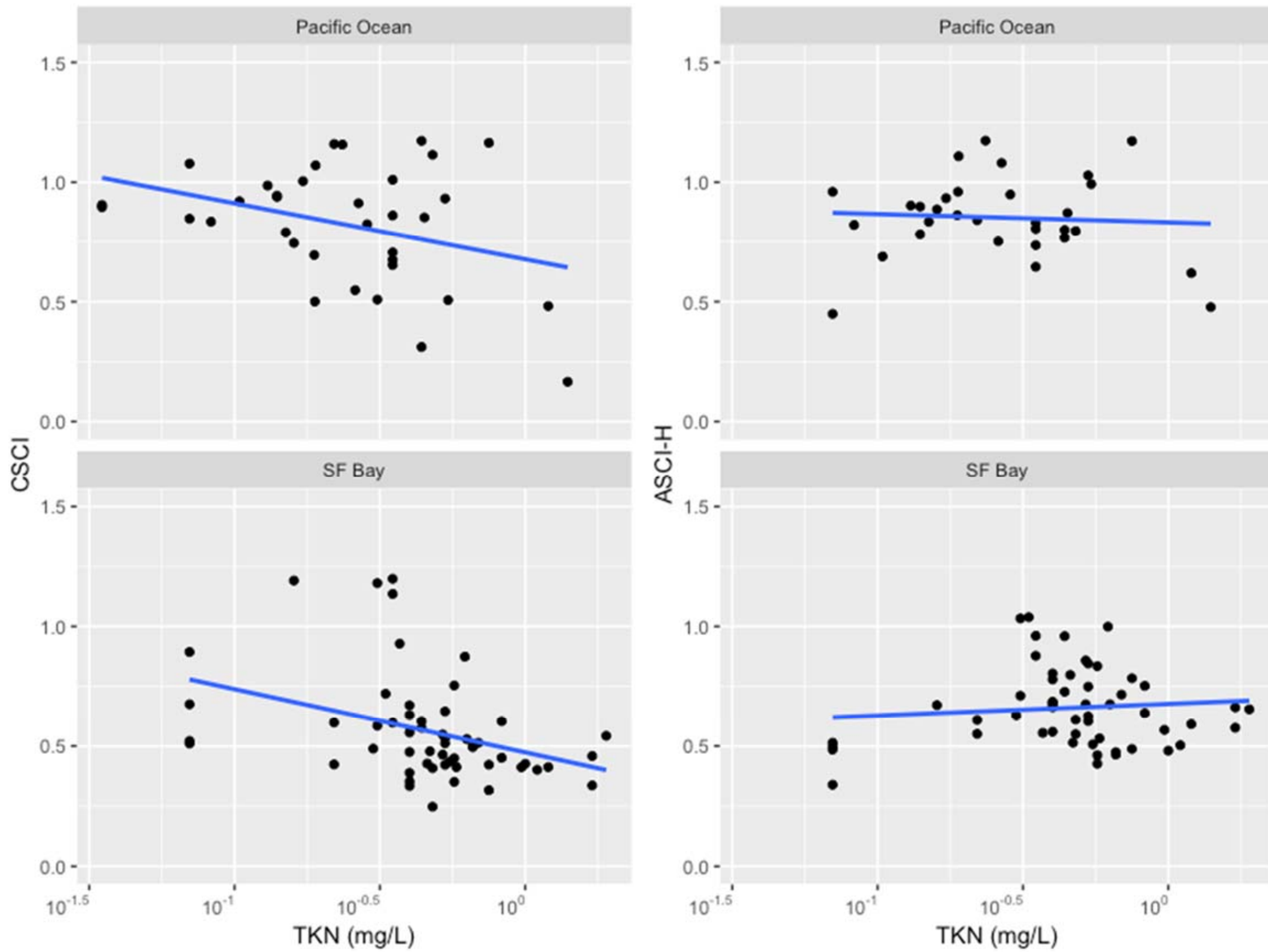

Figure 11. Total Kjeldahl Nitrogen vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

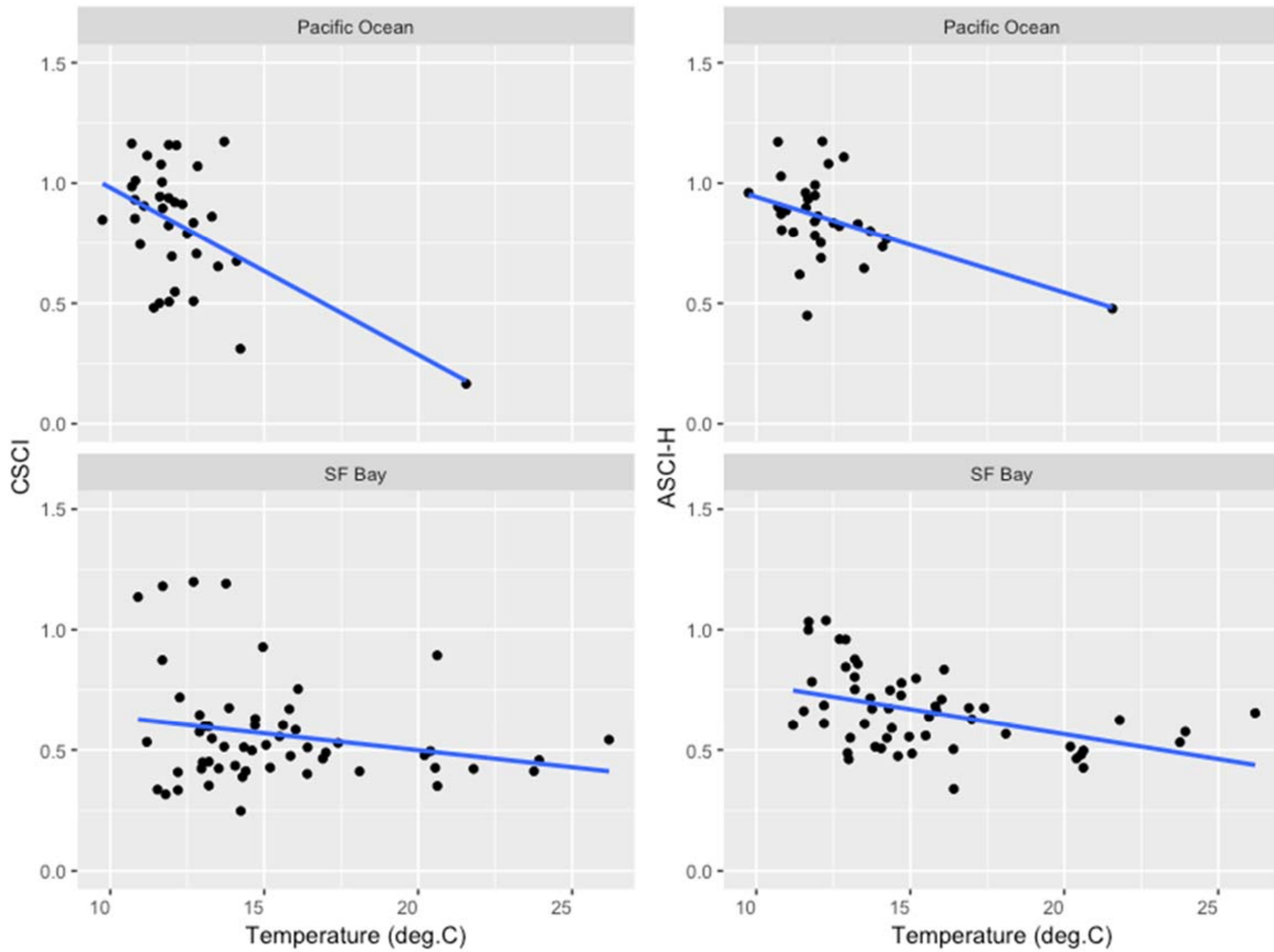

Figure 12. Temperature vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

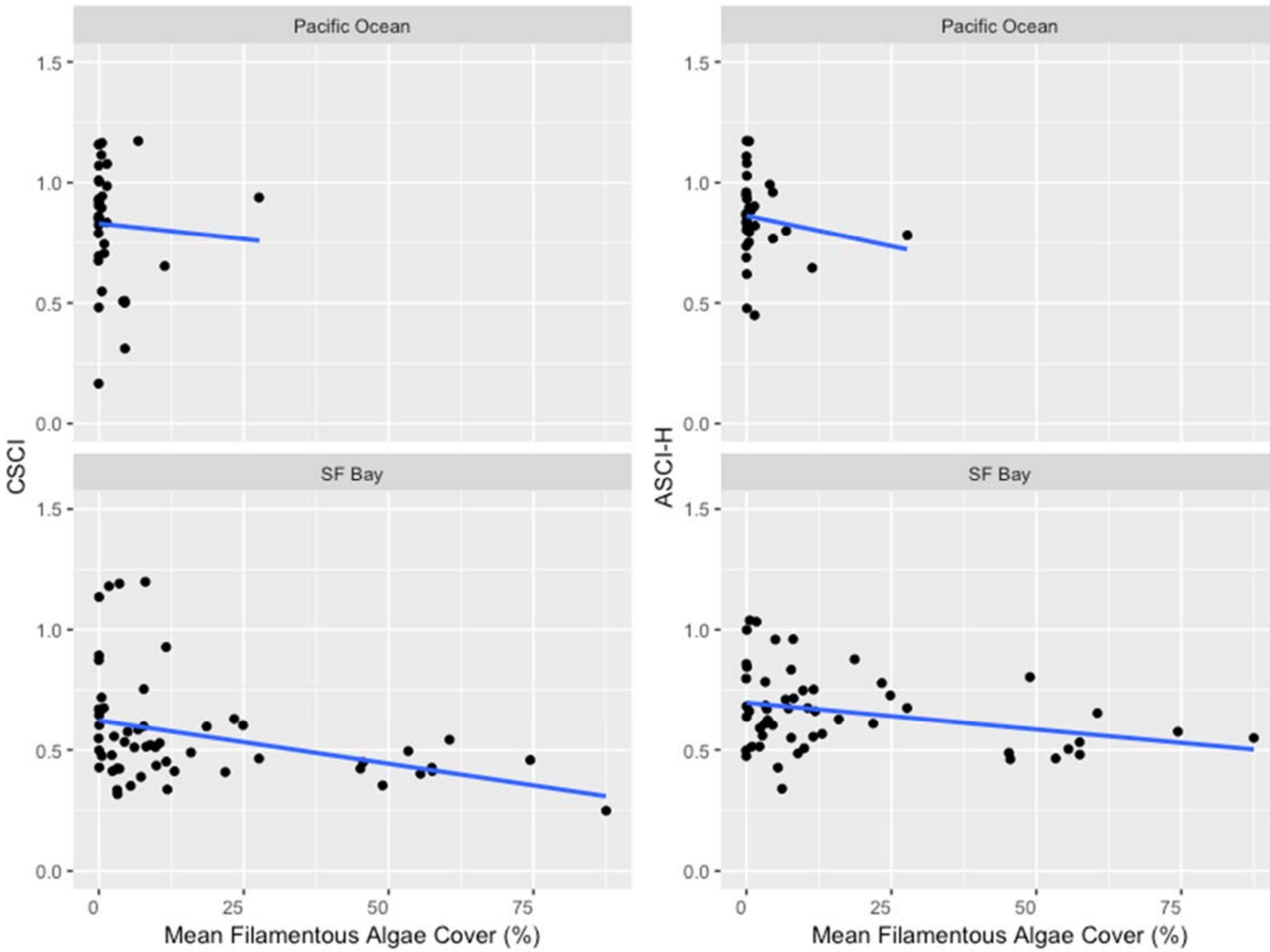

Figure 13. Mean Filamentous Algae Cover vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

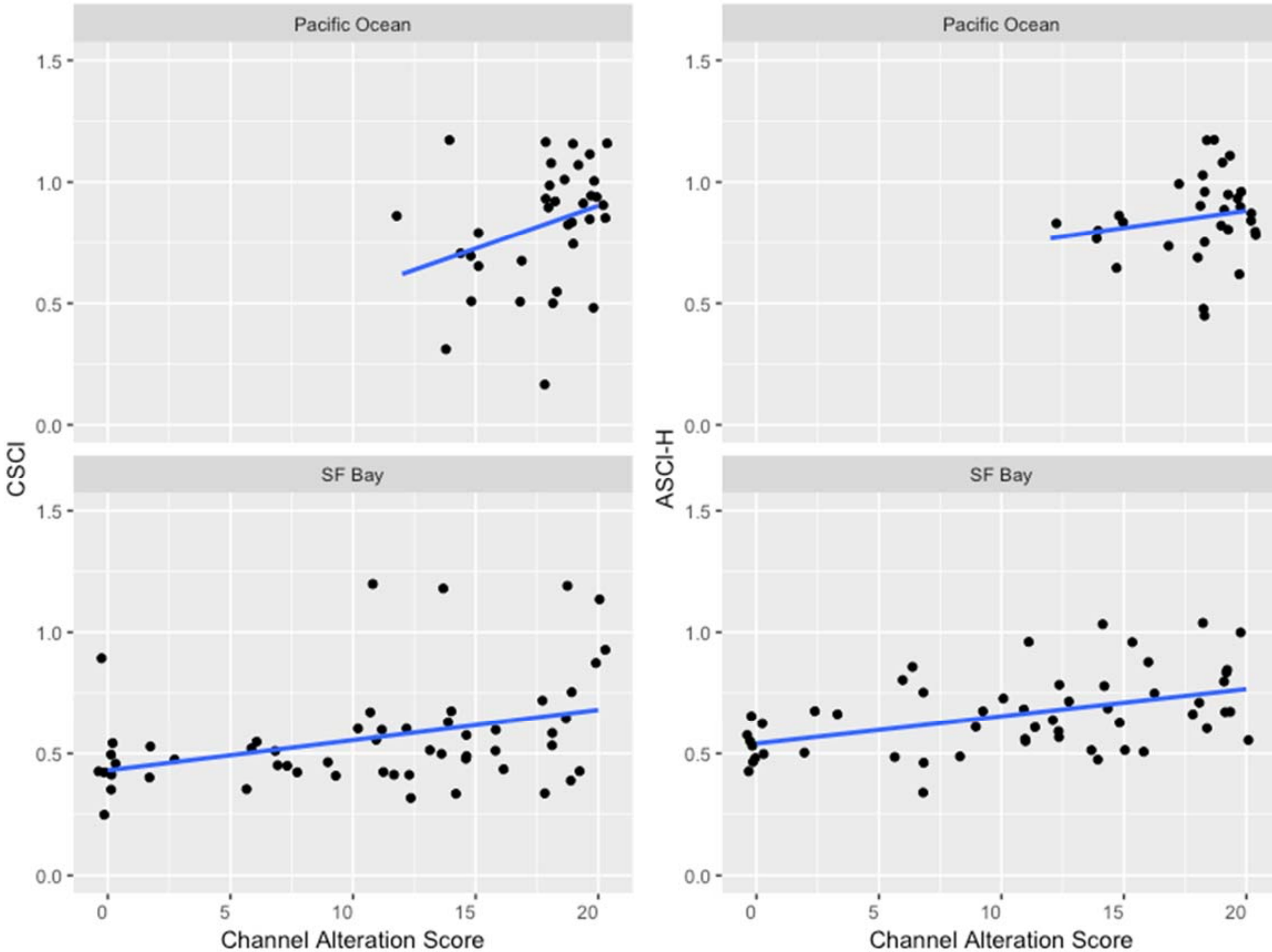

Figure 14. Channel Alteration Score vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

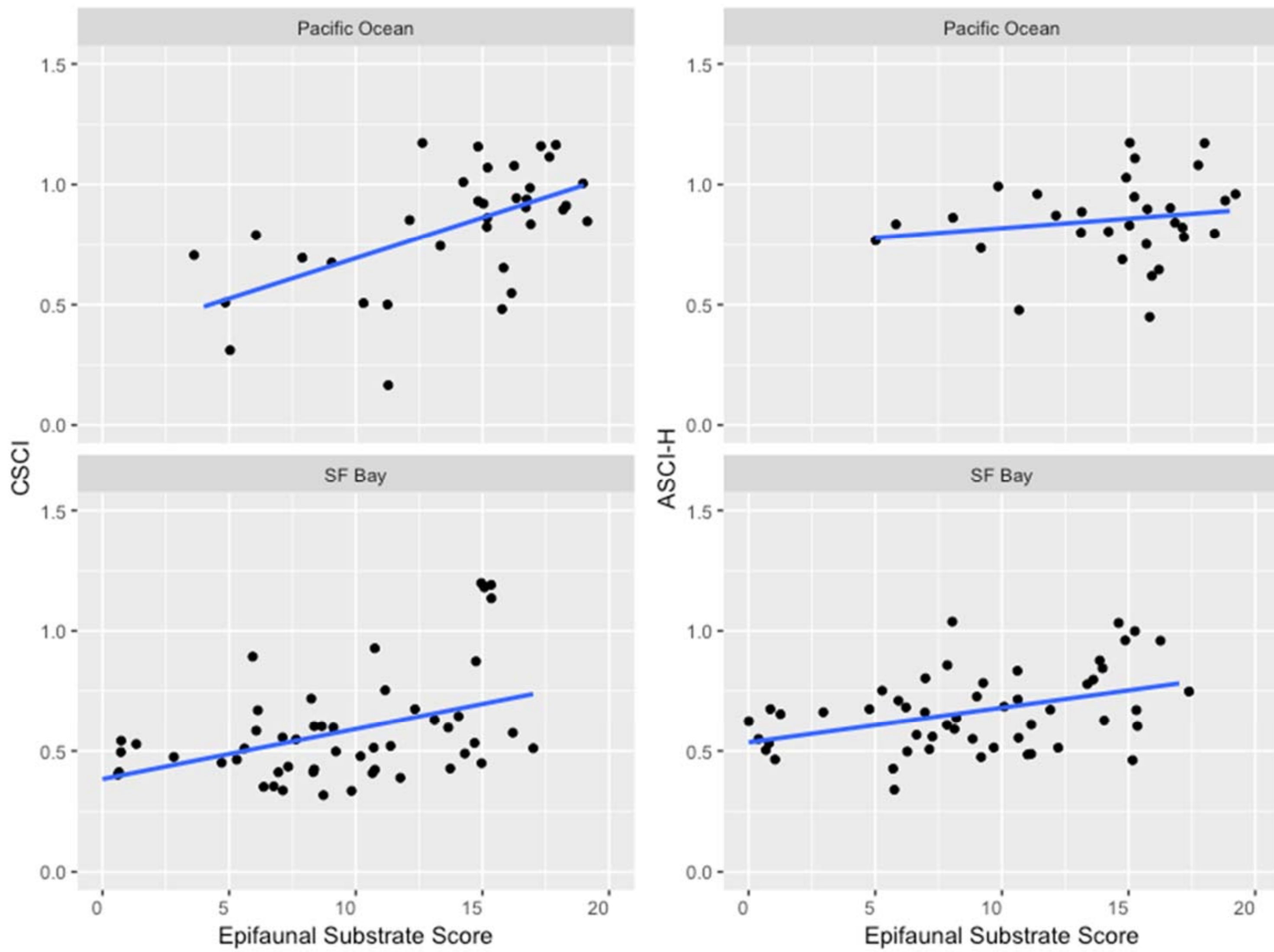

Figure 15. Epifaunal Substrate Score vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

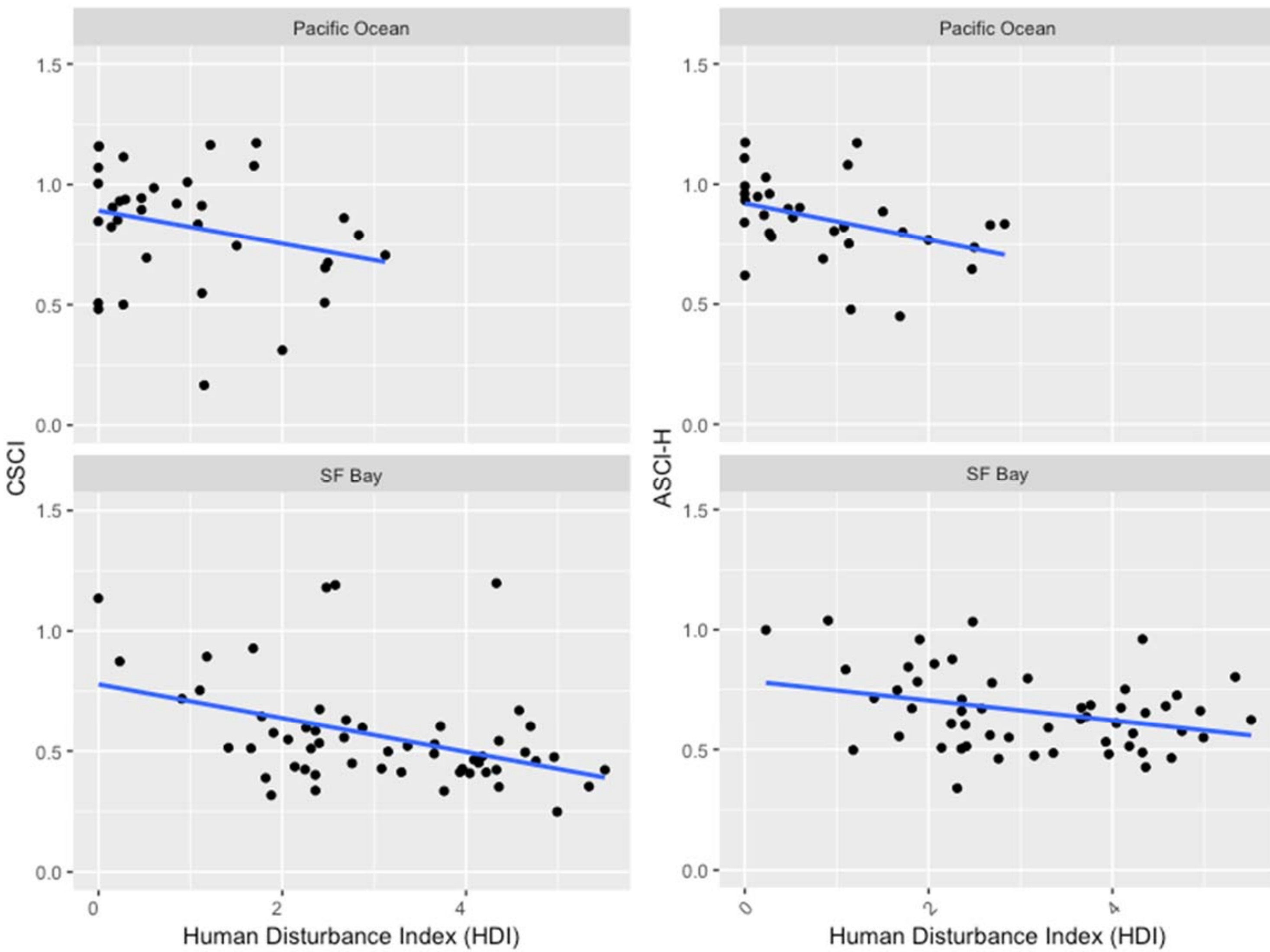

Figure 16. Combined Human Disturbance Index vs. CSCI and ASCI-H scores. Data grouped by strata: Pacific Ocean vs. San Francisco Bay

Table 10. Summary statistics for the CSCI random forest model. Ranking of most influential predictor variables are colored according to: physical habitat (green), land use (orange), and water quality (blue). Variables were trimmed based on a cutoff of >=10% increase MSE.

Stressor Variable	% Increase MSE	Increase Node Purity
Percent Impervious Area in 5km (PctImp_5K)	15.8	0.81
Road Density in 1 km (RdDen_1K)	15.5	0.72
Total Nitrogen (TotalN)	15.2	0.33
Road Density in Watershed (RdDen_W)	15.1	0.43
Percent Impervious Areas of Reach (PctImp)	14.1	0.44
Total Kjeldahl Nitrogen (TKN)	12.1	0.32
Epifaunal Substrate Score	12.1	0.36
Percent Urban in 5 km (PctUrb_5K)	10.9	0.39

Table 11. Summary statistics for the ASCI-H random forest model. Ranking of most influential predictor variables are colored according to: physical habitat (green), land use (orange), and water quality (blue). The rank correlation coefficient (rho) for each stressor variable is also presented based on the training dataset used for model development. Variables were trimmed based on a cutoff of >=10% increase MSE.

Stressor Variable	% Increase MSE	Increase Node Purity
Percent Urban Area in 5 km (PctUrb_5K)	15.5	0.39
Percent Impervious Areas of Reach (PctImp)	14.9	0.22
Road Density in 1 km (RdDen_1K)	13.9	0.34
Road Crossings in 5 km (RdCrs_5K)	11.7	0.23
Temperature (Temp)	11.6	0.28
Road Density in 5 km (RdDen_5K)	11.2	0.28
Total Kjeldahl Nitrogen (TKN)	10.0	0.13

4 Summary

4.1 Biological Conditions of Streams

During WY 2012 – WY 2019, the ecological health of San Mateo County streams was assessed using standardized multi-metric indices for two biological indicators: BMIs and algae. Sites were selected from a probabilistic sample frame of San Francisco Bay area streams to provide estimates of biological condition for the region and at the countywide scale. In San Mateo County, bioassessment survey results indicate that a moderate proportion of the total stream length are in poor biological condition:

- The CSCI scores for BMI assemblages indicate that 37% of stream length are in the Very Likely Altered (lowest) condition category and 32% of stream length are in the Likely Intact (or highest) condition category. Nearly half (48%) of the stream length exhibit CSCI scores below 0.795, the MRP trigger for potential follow-on activity.
- The ASCI-D scores for diatoms indicates that 29% of the stream length are in the Very Likely Altered (lowest) condition category and 30% of stream length are in the Likely Intact (or highest) condition category. MRP triggers have yet to be established for ASCI indices.
- The ASCI-SB scores for soft-bodied algae indicates that only 7% of the stream length are in the Very Likely Altered (or lowest) condition category and 59% of stream length are in the Likely Intact (or highest) condition category. This was notable different distribution of scores to the other biological indices.
- The ASCI-H scores for diatoms and soft-algae combined indicates that 38% of the stream length are in the Very Likely Altered (lowest) condition category and 28% of stream length are in the Likely Intact (or highest) condition category. MRP triggers have yet to be established for ASCI indices.

Comparison among indices by strata in San Mateo County indicated that BMIs and algae often scored in different condition classes:

- About 40% of sites were classed as Very Likely Altered using CSCI and one or more of the algae indices. These streams predominantly occurred in the urban area of San Francisco Bay watersheds.
- Only 10% of sites were classed as Likely Intact using CSCI and one or more the algae indices. These sites may already support beneficial uses and should be considered as the highest priorities for protection. These streams predominantly occurred in non-urban area of Pacific Ocean watersheds.
- CSCI and ASCI-D scores were consistently lower at urban than non-urban sites, indicating that sites with a higher levels of landscape influences may not support healthy biological communities.
- ASCI-SB scores were similar between urban and non-urban sites, indicating that the soft-bodied algae index may not respond well to urban disturbance gradients.

4.2 Stressors Associated with Biological Conditions

The stressor analysis of BMIs and algae condition in San Mateo County streams has shown that both types of stream assemblages correlate with landscape factors, as well as unique sets of water quality and habitat stressors. These observations support the need for multiple indicators to assess potential causes of biological conditions in streams.

- Nutrients (total Nitrogen and TKN) correlated better with CSCI scores from the San Francisco Bay region than sites from the Pacific Ocean stratum. TKN or Total Nitrogen also ranked as important variables in the RF models.

- The RF model of CSCI scores indicates that landscape, habitat, and water-quality stressors, specifically road density, impervious area, and total nitrogen were the best predictors of biological condition.

- The RF model of ASCI-H scores indicates habitat and water-quality stressors, specifically temperature, channel alteration, and combined human disturbance (HDI) were the best predictors of biological condition.

- CSCI scores appear highly sensitive to physical habitat degradation, which occurs frequently in the many highly modified urban streams monitored by the SMCWPPP. It is not clear how well the CSCI tool can demonstrate responses to stressors associated with water quality, when physical habitat is usually the primary factor affecting BMI communities.

- The ASCI-D and ASCI-H indices were similarly responsive to environmental-stressor gradients, and were particularly associated with water quality and habitat factors.

- The ASCI-SB index was not a reliable indicator of streams in poor condition due to high scoring at both disturbed and undisturbed sites throughout San Mateo County. In addition, ASCI-SB scores could not be calculated in a few streams due to insufficient number of soft algae taxa to calculate the index, resulting in data gaps and lack of utility of the ASCI-SB index for model testing. Additional evaluations of the ASCI-SB index performance are needed to assess the utility of this indicator in future bioassessment surveys.

- It should be acknowledged that despite these apparent relationships to stressors, these analyses do not determine causation, particularly as stressors from habitat/landscape factors are often present at the same sites that exhibit water quality impairment.

5 Recommendations

Based on this evaluation of data collected during the eight years of SMCWPPP bioassessment surveys, three design option are briefly introduced below for consideration during future monitoring design discussions:

1. The SMCWPPP could continue to sample probabilistic sites in coordination with the RMC by selecting sites from a revised sample frame to establish baseline conditions over finer spatial scales. The current RMC sample frame will likely be exhausted for San Mateo County sites after WY 2020, which provides an opportunity to implement an improved sample frame / draw. In this manner, estimates of biological condition may continue at the regional or countywide scale, as well as for finer scales (e.g., watersheds) of interest. Smaller, more focused geographic scales of probabilistic assessments may provide stronger associations between biological conditions and stressors, while continuing to report on ambient stream health. Watershed or other spatial strata may also provide managers opportunities to focus on improved understanding of spatial patterns, track temporal trends, and build a weight-of-evidence for stressors influencing specific areas or stream types in the County.

2. Alternatively, targeted studies could become the focus of future bioassessment surveys. Targeted studies may be used in several ways to support Creek Status Monitoring requirements. For example, targeted studies could evaluate the effectiveness of stream restoration or BMP projects; monitor sources or stressors at impaired sites or watersheds; establish baseline conditions at reference sites; and investigate variability in biological conditions over time.

3. The SMCWPPP should also consider the management needs for implementing a hybrid monitoring approach that combines random and targeted surveys. In such a design, probabilistic sites could be used to evaluate the status of ambient stream condition, while supplemented by targeted assessments in streams requiring follow-up action. RMC participants could evaluate similar objectives at the regional scale while the SMCWPPP could use its own assessment for identifying targeted sites/watersheds in need of focused investigation.

6 References

Bay Area Stormwater Management Agencies Association (BASMAA). 2016a. Regional Monitoring Coalition Creek Status Monitoring Standard Operating Procedures. Version 3, March 2016.

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

Bay Area Stormwater Management Agencies Association (BASMAA). 2019. Regional Monitoring Coalition Five Year Bioassessment Report., Final Report, March 2019.

Beck, M.W., Mazor, R. D., Johnson, S., Wisenbaker, K., Westfall, J., Ode, P. R. Hill, R. Loflen, C., Sutula, M. and Stein, E. D., 2019. Prioritizing management goals for stream biological integrity within the developed landscape context},Freshwater Science Vol. 38 (4): 883-898

Kincaid, T. M. and Olsen, A. R. 2016. spsurvey: Spatial Survey Design and Analysis. R package version 3.3.

Mazor, R., Ode, P.R., Rehn, A.C., Engeln, M., Boyle, T., Fintel, E., Verbrugge, S., and Yang, C. 2016. The California Stream Condition Index (CSCI): Interim instructions for calculating scores using GIS and R. SWAMP-SOP-2015-0004. Revision Date: August 5, 2016.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/ (https://www.R-project.org/).

Rehn, A.C., Mazor, R.D. and Ode, P.R. 2015. The California Stream Condition Index (CSCI): A new statewide biological scoring tool for assessing the health of freshwater streams. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) TM-2015-0002. September 2015.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2015. California Regional Water Quality Control Board San Francisco Bay Region Municipal Regional Stormwater NPDES Permit (MRP 2.0). Order No. R2-2015-0049. NPDES Permit No. CAS612008. November 19, 2015.

San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2009. California Regional Water Quality Control Board San Francisco Bay Region Municipal Regional Stormwater NPDES Permit (MRP 1.0). Order No. R2-2009-0049. NPDES Permit No. CAS612008. October 14, 2009.

Stevens, D.L., Jr., and Olsen, A.R. 2004. Spatially-balanced sampling of natural resources. Journal of the American Statistical Association 99: 262-278.

Theroux, S., Mazor, R.D., Beck, M.W., Ode, P., Stein, E.D., Sutula, M. (in prep).

Predictive multimetric indices for algae populations in diverse landscapes, Ecological Indicators

van Buuren, S. and Groothuis-Oudshoorn, K. 2011. mice: Multivariate Imputation by Chained Equations in R. Journal of Statistical Software, 45(3), 1–67.

Appendix 1 Stressor Variables Evaluated in Correlation and Random Forest Models

Table 1-A. Description of response variables and explanatory environmental variables used for model development.

Variable Name	Description
CSCI	California Stream Condition Index
ASCI-H	Hybrid Algae Stream Condition Index
Strata	Site Classification: Pacific Ocean or San Francisco Bay
Land Use	Site Classification: Urban or Non-urban
Avg Algae Cover	Mean Filamentous Algae Cover
Avg Boulders	Mean Boulders cover
Avg Wetted Width	Mean Wetted Width/Depth Ratio
Avg Wood Debris	Mean Woody Debris <0.3m cover
Chan-Alt	Channel Alteration Score
Epi-Sub	Epifaunal Substrate Score
Sed-Dep	Sediment Deposition Score
Flow Hab	Evenness of Flow Habitat Types
Nat Shelt	Natural Shelter cover - SWAMP
Nat Sub	Evenness of Natural Substrate Types
Pct Bold_L	Percent Boulders - large
Pct Bold_LS	Percent Boulders - large & small
Pct Bold_S	Percent Boulders - small
Pct Fines	Percent Fines
Pct Fst Water	Percent Fast Water of Reach
Pct Gravel	Percent Gravel - coarse
Pct Slow Water	Percent Slow Water of Reach
Pct Smaller Sand	Percent Substrate Smaller than Sand (<2 mm)
Pct Sand	Percent Sand
ShD Aquatic Habitat	Shannon Diversity (H) of Aquatic Habitat Types
ShD Natural Substrate	Shannon Diversity (H) of Natural Substrate Types
HDI	Combined Riparian Human Disturbance Index - SWAMP
Pct Impervious	Percent Impervious Area of Reach
Pct Impervious 1K	Percent Impervious Area in 1km
Pct Impervious 5K	Percent Impervious Area in 5km

Variable Name	Description
Pct Urban	Percent Urban Area of Reach
Pct Urban 1K	Percent Urban Area in 1km
Pct Urban 5K	Percent Urban Area in 5km
Rd Crossings 1K	Number Road Crossings in 1km
Rd Crossings 5K	Number Road Crossings in 5km
Rd Crossings W	Number Road Crossings in watershed
Rd Density 1K	Road Density in 1km
Rd Density 5K	Road Density in 5km
Rd Density W	Road Density in watershed
AFDM	Ash Free Dry Mass
Ammonia	Ammonia
Chla	Chlorophyll a
Chloride	Chloride
DO	Dissolved oxygen concentration
Nitrate	Nitrate
Nitrite	Nitrite
OP	Orthophosphate
pH	pH
Phosphorus	Total Phosphorus
Silica	Silica
Specific Cond	Specific conductivity
Temp	Temperature
TKN	Total Kjeldahl Nitrogen
Total N	Total Nitrogen
UIA	Unionized Ammonia

Appendix 2 Predicted Condition Scores Based Upon Random Forest Models

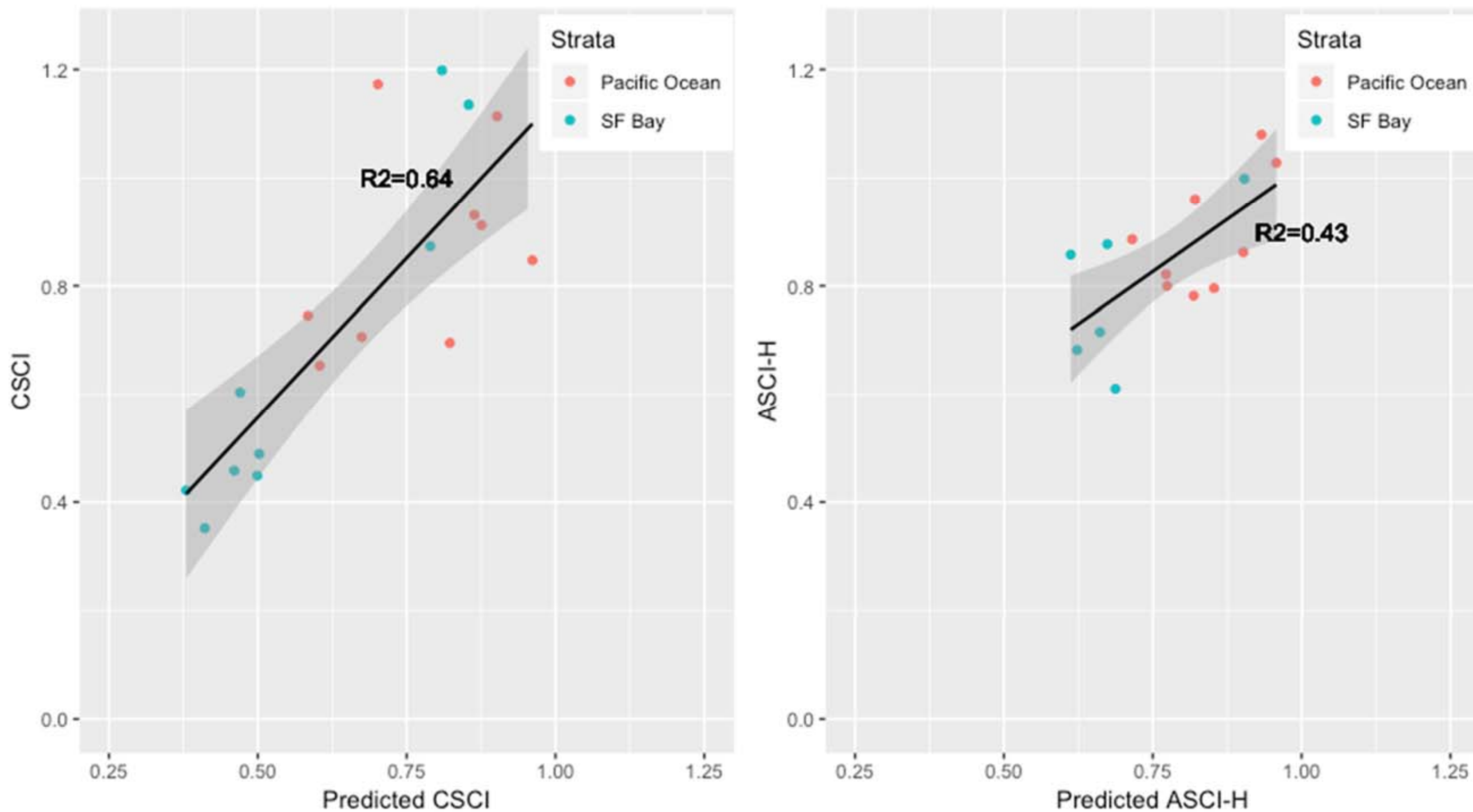

Figure 1-A. Relationship of observed to predicted CSCI and ASCI-H scores in the validation dataset using the most influential explanatory variables shown in Tables 10 and 11, respectively.

Attachment 4

MRP Trigger Exceedance Tables
WY 2014 Through WY 2019

Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2014. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Probabilistic Sites						Targeted Sites			
		Bioassessment	Nutrients	Chlorine	Water Toxicity	Sediment Toxicity	Sediment Chemistry	Temperature	Dissolved Oxygen	pH	Pathogen Indicators
202R00328	Pilarcitos Creek	No	No	No	--	--	--	--	--	--	--
202R00972	Arroyo de en Medio	Yes	No	No	--	--	--	--	--	--	--
202R01308	Pilarcitos Creek	Yes	No	No	No	No	Yes	--	--	--	--
204R01012	Cordilleras Creek	Yes	Yes[a]	Yes	--	--	--	--	--	--	--
204R01204	Burlingame Creek	Yes	No	No	--	--	--	--	--	--	--
204R01256	Arroyo Ojo de Agua	Yes	No	No	--	--	--	--	--	--	--
204R01268	Redwood Creek	Yes	No	No	--	--	--	--	--	--	--
204R01288	Laurel Creek	Yes	No	Yes	No	No	Yes	--	--	--	--
204R01460	Sanchez Creek	Yes	No	No	--	--	--	--	--	--	--
204SMA059	San Mateo Creek	--	--	--	--	--	--	No	No	No	--
204SMA060	San Mateo Creek	--	--	--	--	--	--	--	--	--	Yes
204SMA080	San Mateo Creek	--	--	--	--	--	--	No	No	No	No
204SMA100	San Mateo Creek	--	--	--	--	--	--	--	--	--	No
204SMA110	Polhemus Creek	--	--	--	--	--	--	--	--	--	No
204SMA119	San Mateo Creek	--	--	--	--	--	--	--	--	--	No
205ALA015	Alambique Creek	--	--	--	--	--	--	No	--	--	--
205BCR010	Bear Creek	--	--	--	--	--	--	No	--	--	--
205BCR050	Bear Creek	--	--	--	--	--	--	No	--	--	--
205BCR060	Bear Creek	--	--	--	--	--	--	No	--	--	--
205R01192	Corte Madera Creek	Yes	No	No	--	--	--	--	--	--	--
205WUN150	West Union Creek	--	--	--	--	--	--	No	--	--	--
205WUN650	West Union Creek	--	--	--	--	--	--	No	--	--	--

[a] The unionized ammonia concentration was flagged as questionable due to an unusually high field pH used in the calculation.

Summary of SMCWPPP trigger threshold exceedance analysis, WY 2015. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of an MRP trigger.

Station Number	Creek Name	Bioassessment	Nutrients	Chlorine	Water Toxicity	Sediment Toxicity	Sediment Chemistry	Continuous Temperature	Dissolved Oxygen	pH	Specific Conductance	Pathogen Indicators
202R00378	Pescadero Creek	No	No	No	--	--	--	--	--	--	--	--
202R00440	Purisima Creek	No	No	No	--	--	--	--	--	--	--	--
202R01356	Middle Fork San Pedro Creek	No	No	No	--	--	--	--	--	--	--	--
202R01612	Middle Fork San Pedro Creek	No	No	No	--	--	--	--	--	--	--	--
204R01448	Atherton Creek	Yes	No	Yes	No	No	Yes	--	--	--	--	--
204R01972	Cordilleras Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R02056	Laurel Creek	Yes	No	No	No	Yes	Yes	--	--	--	--	--
204R02248	Laurel Creek	Yes	No	Yes	--	--	--	--	--	--	--	--
205R01704	Dry Creek	Yes	No	No	--	--	--	--	--	--	--	--
205R01816	Corte Madera Creek	No	No	No	--	--	--	--	--	--	--	--
204SMA058	San Mateo Creek	--	--	--	--	--	--	Yes	No	No	No	--
204SMA059	San Mateo Creek	--	--	--	--	--	--	Yes	No	No	No	--
204SMA060	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	Yes
204SMA080	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	Yes
204SMA100	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	No
204SMA110	Polhemus Creek	--	--	--	--	--	--	--	--	--	--	No
204SMA119	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	No
205ALA015	Alambique Creek	--	--	--	--	--	--	No	--	--	--	--
205BCR010	Bear Creek	--	--	--	--	--	--	Yes	--	--	--	--
205BCR050	Bear Creek	--	--	--	--	--	--	Yes	--	--	--	--
205BCR060	Bear Creek	--	--	--	--	--	--	Yes	--	--	--	--
205WUN150	West Union Creek	--	--	--	--	--	--	No	--	--	--	--

Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2016. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Bioassessment [1]	Nutrients [2]	Chlorine [3]	Water Toxicity [4]	Sediment Toxicity [4]	Sediment Chemistry [5]	Continuous Temperature [6]	Dissolved Oxygen [7]	pH [8]	Specific Conductance [9]	Pathogen Indicators [10]
202R00488	Tunitas Creek	Yes	No	Yes	--	--	--	--	--	--	--	--
202R00506	Peters Creek	No	No	No	--	--	--	--	--	--	--	--
202R02332	Pilarcitos Creek	Yes	No	Yes	--	--	--	--	--	--	--	--
204R02228	San Mateo Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R02504	Polhemus Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R02548	Cordilleras Creek	Yes	No	No	--	--	--	--	--	--	--	--
205R02408	Bull Run Creek	Yes	No	Yes	--	--	--	--	--	--	--	--
205R02728	Dry Creek	Yes	No	No	--	--	--	--	--	--	--	--
205R02920	Bear Creek	Yes	No	No	--	--	--	--	--	--	--	--
205R03032	West Union	Yes	No	No	--	--	--	--	--	--	--	--
204LAU010	Laurel Creek	--	--	--	No	No	Yes	--	--	--	--	--
204SMA060	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	Yes
204SMA080	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	Yes
204SMA100	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	No
204SMA119	San Mateo Creek	--	--	--	--	--	--	--	--	--	--	No
204SMA110	Polhemus Creek	--	--	--	--	--	--	--	--	--	--	No
205ALA015	Alambique Creek	--	--	--	--	--	--	No	--	--	--	--
205BCR010	Bear Creek	--	--	--	--	--	--	Yes	Yes	No	No	--
205BCR050	Bear Creek	--	--	--	--	--	--	Yes	--	--	--	--
205BCR060	Bear Creek	--	--	--	--	--	--	No	--	--	--	--
205WUN150	West Union Creek	--	--	--	--	--	--	No	Yes	Yes	No	--

Notes:

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

Summary of SMCWPPP MRP trigger threshold exceedance analysis, WY 2017. "No" indicates samples were collected but did not exceed the MRP trigger; "Yes" indicates an exceedance of the MRP trigger.

Station Number	Creek Name	Bioassessment [1]	Nutrients [2]	Chlorine [3]	Water Toxicity [4]	Sediment Toxicity [4]	Sediment Chemistry [5]	Continuous Temperature [6]	Dissolved Oxygen [7]	pH [8]	Specific Conductance [9]	Pathogen Indicators [10]
202R00550	Jones Gulch	No	No	No	--	--	--	--	--	--	--	--
202R00552	Lawrence Creek	No	No	No	--	--	--	--	--	--	--	--
204R02472	Redwood Creek	Yes	No	Yes	--	--	--	--	--	Yes	--	--
204R02611	Atherton Creek	Yes	No	No	--	--	--	--	--	Yes	--	--
204R03240	Atherton Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R03252	San Mateo Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R03272	San Mateo Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R03316	Arroyo Ojo de Agua	Yes	No	No	--	--	--	--	--	Yes	--	--
204R03336	Belmont Creek	Yes	No	No	--	--	--	--	--	--	--	--
204R03496	Redwood Creek	Yes	No	No	--	--	--	--	--	--	--	--
202SPE005	San Pedro Creek	--	--	--	No	No	Yes	--	--	--	--	--
202DEN017	NA (MS4)	--	--	--	--	--	--	--	--	--	--	NA
202DEN005	Denniston Creek	--	--	--	--	--	--	--	--	--	--	No
202DEN020	Denniston Creek	--	--	--	--	--	--	--	--	--	--	Yes
202CAP001	NA (MS4)	--	--	--	--	--	--	--	--	--	--	NA
202CAP025	NA (MS4)	--	--	--	--	--	--	--	--	--	--	NA
202SPE019	San Pedro Creek	--	--	--	--	--	--	No	--	--	--	--
202SPE040	San Pedro Creek	--	--	--	--	--	--	No	No	No	No	--
202SPE050	San Pedro Creek	--	--	--	--	--	--	No	--	--	--	--
202SPE070	San Pedro Creek	--	--	--	--	--	--	No	No	No	No	--
202SPE085	San Pedro Creek	--	--	--	--	--	--	No	--	--	--	--

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7. DO < 7.0 mg/L in COLD streams or DO < 5.0 mg/L in WARM streams.
8. pH < 6.5 or pH > 8.5.
9. Specific conductance > 2000 uS.
10. Enterococcus ≥ 130 cfu/100ml or *E. coli* ≥ 410 cfu/100ml.

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

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

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2. Unionized ammonia (as N) ≥ 0.025 mg/L, nitrate (as N) ≥ 10 mg/L, chloride > 250 mg/L.
3. Free chlorine or total chlorine residual ≥ 0.1 mg/L.
4. Test of Significant Toxicity = Fail and Percent Effect ≥ 50 %.
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8. pH < 6.5 or pH > 8.5.
9. Specific conductance > 2000 uS.
10. Enterococcus ≥ 130 cfu/100ml or *E. coli* ≥ 410 cfu/100ml.