SAN MATEO CREEK LOW DISSOLVED OXYGEN STRESSOR/SOURCE IDENTIFICATION STUDY

Prepared in support of provision C.8.d.i of NPDES Permit # CAS612008

Final Project Report

SAN MATEO COUNTYWIDE
Water Pollution Prevention Program
Clean Water. Healthy Community.

San Mateo Countywide Water Pollution Prevention Program

June 23, 2015

EXECUTIVE SUMMARY

This report presents the results of the San Mateo Creek Low Dissolved Oxygen Stressor/Source Identification (SSID) project which was conducted to address requirements in the San Francisco Bay Municipal Regional Permit (MRP) for discharges of stormwater runoff. Per MRP Provision C.8.d.i, the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) has conducted two SSID Projects focused on follow-up to creek status monitoring data that exceed trigger thresholds (the second SSID project addressed indicator bacteria and will be reported on separately). SSID projects are designed to identify and isolate potential sources and/or stressors associated with observed potential water quality impacts. Additional actions required by Provision C.8.d.i are to identify and evaluate the effectiveness of potential actions for controlling the cause(s) of the trigger stressor/source and to confirm the problem was addressed.

Historical and more recent (WY2013) monitoring data collected in the vicinity of De Anza Park in the San Mateo Creek watershed showed dissolved oxygen (DO) concentrations below the water quality objective (WQO) of 7 mg/L for waters designated as cold water habitat. During WY2014 SMCWPPP conducted a SSID project to address this potential water quality concern. Results of the SSID investigation suggest that low DO conditions are no longer expected in this reach of San Mateo Creek due to a recently implemented ongoing schedule of increased dry season releases of water from the upstream Crystal Springs Reservoir. These findings are currently being confirmed through one additional year of Creek Status Monitoring conducted per MRP Provision C.8.c. No additional management measures are recommended at this time (beyond the new ongoing dry season controlled releases) and the SSID project should be considered complete.

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1.0 INTRODUCTION

This report presents the results of the San Mateo Creek Low Dissolved Oxygen Stressor/Source Identification (SSID) Project which was conducted in WY2014 to address requirements listed under Provision C.8.d.i of the San Francisco Bay Region National Pollutant Discharge Elimination System (NPDES) Municipal Regional Permit (MRP) for discharges of stormwater runoff. Per MRP Provision C.8.d.i, the San Mateo Countywide Water Pollution Prevention Program (SMCWPPP) is conducting two SSID Projects focused on follow-up to creek status monitoring data that exceed trigger thresholds (per Table 8.1 of the MRP). SSID projects are designed to identify and isolate potential sources and/or stressors associated with observed potential water quality impacts. Additional actions required by Provision C.8.d.i are to identify and evaluate the effectiveness of potential actions for controlling the cause(s) of the trigger stressor/source, and to confirm the problem was addressed.

Based on historical and recent monitoring data with results below the dissolved oxygen (DO) water quality objective (WQO) of 7 mg/L for waters designated as cold water habitat, SMCWPPP conducted a low DO SSID Project in the San Mateo Creek watershed. The SSID field investigations in WY2014 did not identify low DO concentrations similar to those recorded in WY2003 (SFRWQCB 2007) and WY2013 (SMCWPPP 2014b). It is likely that reduced DO concentrations can develop in pockets at the bottom of deep pools during low flow conditions. However, these pockets are currently less likely to form due to a new dry season controlled release schedule from an upstream reservoir. Furthermore, the low DO pockets are limited in geographic extent and duration due to daily recirculation/turnover of the pools. Therefore, they probably do not impact cold fresh water habitat beneficial uses for the overall reach investigated. No management measures are recommended at this time (beyond the new ongoing dry season controlled releases) and the SSID project should be considered complete.

Chapter 2.0 of this report describes the watershed. Chapter 3.0 summarizes previous water quality monitoring background on WQOs. Chapter 4.0 presents the SSID field methods and findings. Chapter 5.0 includes a discussion of the results and recommendations for future monitoring. Chapter 6.0 is a list of referenced citations.

1.1 Dissolved Oxygen

Dissolved oxygen is a measure of how much oxygen is dissolved in water. Because it is crucial for aquatic organisms, DO is commonly measured to assess stream health. Different types of organisms require different amounts of DO, with salmonids and Plecoptera (stoneflies) typically requiring higher concentrations than warm water organisms. The Water Quality Control Plan for the San Francisco Bay Basin (Basin Plan; SFRWQCB 2013) lists WQOs for DO in non-tidal waters as follows: 5.0 mg/L minimum for waters designated as warm water habitat (WARM) and 7.0 mg/L minimum for waters designated as cold water habitat (COLD). Although these WQOs provide suitable thresholds to evaluate triggers, further evaluation may be needed to assess the overall extent and degree that COLD and/or WARM beneficial uses are supported at a specific location. For example, lower reaches of a stream may not support salmonid spawning or rearing habitat, but may be important for upstream or downstream fish migration. Salmonid use, life stage, and/or other fish communities should be considered when evaluating DO concentrations in a stream.

Oxygen enters streams through the atmosphere and, sometimes, through groundwater discharge. In fast-moving stream reaches, water is aerated by bubbles as it moves through riffles. In slow-moving stream reaches, oxygen may only enter via the top layer of water. Cold water can hold more oxygen than warm water; therefore, the concentration of DO in water is inversely related to water temperature and daily and seasonal fluctuations are typical. Natural processes also affect DO concentration in water including aquatic plant photosynthesis, which releases oxygen, and respiration by plants, bacteria, and other organisms, which consumes oxygen.

1.1.1 Dissolved Oxygen Reduction Factors

There are several factors that may have been driving the previously observed reduction in dissolved oxygen in San Mateo Creek. These include increased residence time, reduced potential for re-aeration, and increased loading of organic material and nutrients. These factors in combination may result in higher rates of biological oxygen demand (BOD) and sediment oxygen demand (SOD).

- **Residence time** is the amount of time that water remains in a water body (i.e., reduced flow increases the residence time).
- **Re-aeration** is the net rate of transfer of oxygen from the atmosphere to a body of water at the air/water interface. The transfer rate increases with greater surface area-to-volume ratio and water turbulence.
- **Biochemical oxygen demand (BOD)** is the consumption (or decrease) of dissolved oxygen in water caused by microorganisms during the break down of organic material, oxidation of reduced inorganic compounds, conversion of organic nitrogen into ammonia and nitrate by bacteria, or respiration by plants, bacteria, and invertebrates. **Sediment oxygen demand (SOD)** refers to consumption of oxygen by these same processes when they occur in the channel substrate.

Human activities, including residential/commercial development, agriculture, and industrial practices can contribute to DO depletion in the receiving waters. Land use changes may result in modifications to both stream flow and channel geometry. In addition, anthropogenic activities may directly introduce chemical contaminants, organic material, and nutrients to the creek, via non-point sources such as vehicle emissions, fertilizers, pesticides, yard and animal wastes, and septic systems. These substances can increase the chemical and biochemical oxygen demand, primarily through increased respiration of plants and microbes.

1.1.1.1 Residence Time and Re-aeration

Stream impoundments and/or diversions can reduce flow velocity and turbulence resulting in higher residence times. Straightening and/or deepening of the channel can reduce the surface-to-volume ratio leading to lower re-aeration rates. Anthropogenic activities that result in decreases in channel gradient (e.g., channel subsidence, increased sediment loading) can reduce the flushing and/or mixing of water. The removal of vegetation along the riparian corridor can lower potential inputs of large woody debris that provide habitat and channel complexity that may also increase the potential for water turbulence.

1.1.1.2 Organic and Nutrient Loading

Anthropogenic activities (e.g., vegetation management, landscaping) may result in a greater amount of organic material and nutrients being delivered to the stream. Organic material in the stream may come from two sources: 1) aquatic macrophytes and algae growing in the stream (autochthonous source); and 2) external sources such as leaf/grass litter, soil erosion and animal waste (allochthonous sources). Increase in nutrient concentrations can result in increased rates of primary productivity, which in turn, can increase DO concentrations at the water surface during the day, but reduce DO levels at night or at the stream bottom where light is unable to sufficiently penetrate. Following algal blooms, DO reductions can occur as algae community shifts to respiration (in the absence of light) and during the process of decomposition of dead algae by bacteria.

1.1.1.3 Biological and Sediment Oxygen Demand

Changes in channel geometry that result in reduced rates of mixing and/or flushing of water, coupled with increased loading of organic material, may result in higher levels of BOD and SOD (i.e., increasing the period that substances can exert an oxygen demand in the reach). These conditions may result in an increased potential for oxygen consumption associated with microbial decomposition of organic matter and respiration by plants, bacteria and invertebrates. During periods of low flow conditions, oxygen demand may be driven by external sources (i.e. water flowing from upstream and urban runoff inputs), or internal sources (i.e., fine sediment, chemical substances and organic material deposited on bottom of stream).

1.1.1.4 Secondary Drivers (Temperature and Sediment)

Temperature and sediment are considered secondary drivers that affect the primary drivers. Human activities (e.g., riparian vegetation removal) can result in higher solar radiation and increase water temperatures in the stream. Increasing temperature tends to reduce DO concentrations by reducing oxygen's solubility in water. Surface heating (i.e., stratification) can decrease re-aeration of water below the surface. Increase in water temperatures can also result in higher algal growth rates, as well as increasing the rates of DO-depleting reactions such as decomposition and respiration.

High suspended sediment concentrations can potentially impact DO concentrations by reducing the light penetration and visibility in the stream, which may in turn reduce photosynthesis and growth by submerged aquatic plants, phytoplankton, and periphyton. High suspended sediment can also result in an increase in heat absorption, leading to increased water temperatures (and lower DO levels). Deposited and bedded sediments may lead to reduced oxygen levels by either restricting flow through streambed substrates or by oxygen consumption by bacterial respiration, especially when sediments contain a high concentration of organic matter.

Another important effect on BOD concentrations is the BOD originating from upstream sources. Imported BOD concentrations are the concentration of BOD-generating substances (e.g., algal biomass) from upstream reaches, tributaries or storm water outfalls.

2.0 Study Area

San Mateo Creek drains a 33-square mile watershed including parts of unincorporated San Mateo County, the City of San Mateo, and the Town of Hillsborough. The upper 88 percent of the watershed is characterized by the northwest/southeast trending ridges and valleys of the San Andreas Rift Zone and the Santa Cruz Mountains. Runoff from this undeveloped 29-square mile area drains to a system of reservoirs which were constructed in the late 1800s and are now owned and operated by the San Francisco Public Utilities Commission (SFPUC). These include the San Andreas Reservoir, Upper Crystal Springs Reservoir, and Lower Crystal Springs Reservoir, all of which are oriented along the northwest trending San Andreas Rift Zone.

Below the Lower Crystal Springs reservoir dam, the watershed encompasses approximately five square miles and is mostly urbanized. The overall watershed imperviousness below the dam is approximately 38 percent (STOPPP 2002). Low and medium density residential uses characterize the area upstream of El Camino Real. High density residential and commercial uses characterize the watershed downstream of El Camino Real. Runoff from these areas is conveyed to the creek via a network of underground storm drain pipes (i.e., the MS4). Nearly 50 percent of the creek channel below the dam is modified (STOPPP 2002). Flows are conveyed within engineered channels and underground pipes, including a 2,000 foot culvert that begins downstream of El Camino Real. San Mateo Creek flows to San Francisco Bay at Ryder Park, just south of Coyote Point.

2.1 Lower Crystal Springs Dam Improvements

The Crystal Springs Reservoir System serves as the emergency water supply for San Mateo and San Francisco Counties. It is owned and operated by the SFPUC and consists of Upper and Lower Crystal Springs Reservoirs, San Andreas Reservoir, and various tunnels, pipes, pumps, and outlet structures. SFPUC's Water System Improvement Program (WISP) includes two related projects that affect baseflows in San Mateo Creek. Together, the Crystal Springs/San Andreas Transmission System Upgrade and the Lower Crystal Springs Dam Improvements projects repair existing leaks in the system and set a schedule for controlled releases.

Construction on the Lower Crystal Springs Dam and Pump Station was conducted between January and October 2014. Prior to construction, dry weather flows below the dam were limited to approximately 0.6 cubic feet per second (cfs) as the result of water leaks from aging pipes at the Pump Station. During the construction period, leaks were sealed and water was pumped from the reservoir directly into the creek, resulting in dry season flows that averaged about 1.0 cfs. Occasional flow pulses were also generated to maintain water temperature targets below the dam (Aaron Brinkerhoff, SFPUC, personal communication, January 2015). The WISP projects were officially completed in January 2015, following a successful test of the emergency high flow release valve[1]. With completion of the project, the SFPUC began implementation of a defined water release schedule intended to enhance habitat for steelhead and other native fish in lower San Mateo Creek. Release schedule baseflows, measured at the U.S. Geological Survey (USGS) gage located approximately 0.2 mile downstream of the dam (USGS Gage #11162753),

[1] Approximately 350 cfs was released during a 2-hour period on January 15, 2015.

must range from 3 to 17 cfs, depending on the water year type (e.g., dry, normal, wet) and the time of year (NMFS 2010). The release schedule was approved by the U.S. Army Corps of Engineers as part of the formal consultation process with the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG) for Endangered Species Act compliance for the WISP projects (San Francisco Planning Department 2010). In addition to minimum releases, the SFPUC will conduct aquatic resource monitoring for ten years following project completion. SFPUC monitoring in San Mateo Creek below the dam will consist of water quality measurements (continuous temperature and DO, pH and turbidity grab samples), steelhead spawning surveys, smolt migrant trapping, fish population surveys, and benthic macro-invertebrate community sampling (ENTRIX/MSE 2009).

2.2 Beneficial Uses

Beneficial uses in San Mateo Creek are designated by the San Francisco Bay Regional Water Quality Control Board (SFRWQCB) and generally apply to all tributaries. Designated beneficial uses include: freshwater replenishment (FRSH), cold freshwater habitat (COLD), fish migration (MIGR), preservation of rare and endangered species (RARE), fish spawning (SPWN), warm freshwater habitat (WARM), wildlife habitat (WILD), water contact recreation (REC-1), and non-contact recreation (REC-2).

Review of historical records suggests that San Mateo Creek once supported coho salmon, steelhead trout (anadromous), rainbow trout (nonanadromous), and California roach (Leidy et al. 2005). Steelhead trout may still use San Mateo Creek for both spawning and rearing; however, Crystal Springs Dam forms a barrier to fish migration, limiting access to higher quality habitat in the upper watershed. If steelhead do spawn in Lower San Mateo Creek, it would occur sometime between January and April. Young fry would stay in the creek for several years before heading out to sea.

3.0 Previous Water Quality Monitoring

3.1 Surface Water Ambient Monitoring Program (2003)

In 2003, the SFRWQCB monitored seven stations within the San Mateo Creek Watershed to assess water quality and establish regional reference sites as part of the Surface Water Ambient Monitoring Program (SWAMP) (Figure 1). The seven stations were selected to represent a range of subwatershed, ecoregion subsections, elevations, stream characteristics, and land use. Sondes programmed to continuously monitor pH, DO, temperature, and specific conductivity were deployed for one or two week "episodes" during three parts of the annual hydrograph: wet season, decreasing hydrograph/spring, and dry season (SFRWQCB 2007). DO concentrations measured at two of the stations below Crystal Springs reservoir were below the cold water minimum WQO of 7 mg/L during the spring (April 27 to May 12, 2003), summer (August 7 to 25, 2003), and fall (October 20 to 31, 2003) episodes. These stations were located at Gateway Park (station SMA020) near the upstream extent of the tidally-influenced reach of San Mateo Creek, and at Arroyo Court/De Anza Historical Park (SMA060) approximately 200 feet upstream of the El Camino Real crossing. Due to large fluctuations in DO (i.e., maximum DO percent saturation levels were measured above 120 percent), the SFRWQCB (2007) report concluded that the pattern of DO concentrations was consistent with excessive photosynthesis.

The SWAMP sampling program also included benthic macroinvertebrate sampling and physical habitat measurements conducted in spring 2003 to assess ecological condition (SFRWQCB 2007). All stations below Crystal Springs Dam were categorized as having poor conditions based on low benthic macroinvertebrate taxa richness and low abundance of sensitive species (Ephemeroptera, Plecoptera, Tricoptera [EPT]). These findings are typical of urban streams.

3.2 Watershed Assessment and Monitoring Program (2004)

SMCWPPP (formerly referred to as STOPPP) performed screening-level biological and chemical water quality monitoring in 2004 as part of its Watershed Assessment and Monitoring Program (SMCWPPP 2005). Benthic macroinvertebrates were collected, visual assessments of physical habitat were conducted, and conventional water quality parameters (temperature, pH, conductivity, and DO) were measured in April 2004 at six of the SWAMP stations, including SMA020 and SMA060. Grab water samples were collected in February 2004 at four of the stations, including SMA020 and SMA060, and were tested for organophosphorus pesticides and toxicity (ceriodaphnia, pimephales, selenastrum). Benthic macroinvertebrate assemblages measured in April 2004 by SMCWPPP were similar to those measured by SWAMP in 2003. Low concentrations of DO were not recorded in the spot measurements, organophosphorus pesticides were not detected, and toxicity was not observed at SMA020 and SMA060. SMCWPPP (2005) concluded that poor ecological conditions measured in San Mateo Creek below Crystal Springs Dam were likely the result of urbanization in the lower part of the watershed.

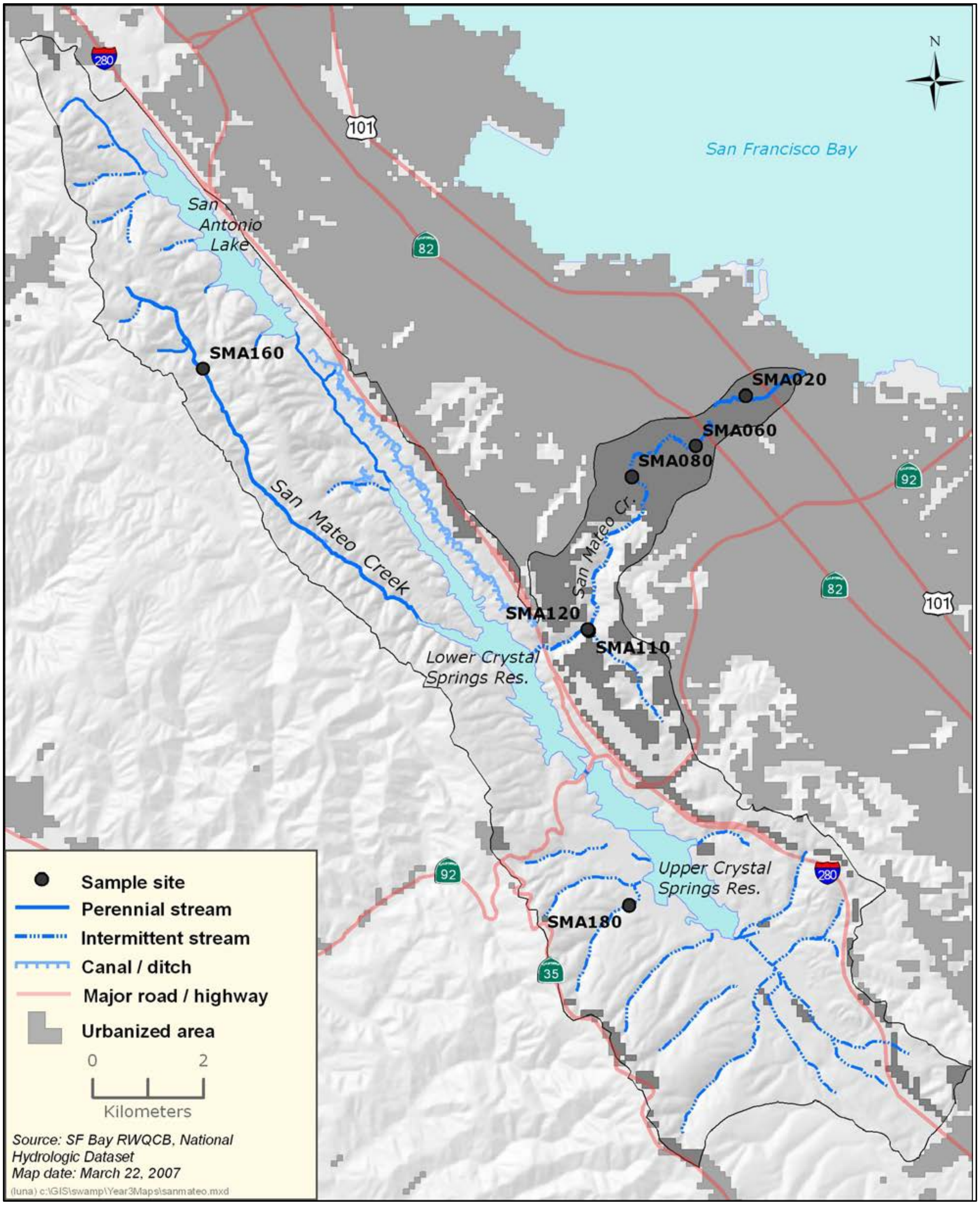

Figure 1. Location of stations monitored by SWAMP in San Mateo Creek in 2003 (source of figure: SFRWQCB 2007).

3.3 Creek Status Monitoring Program (2013)

In water year[2] 2013 (WY2013), SMCWPPP conducted continuous water quality monitoring at two sites in San Mateo Creek (Figure 2). Creek status monitoring of water quality was conducted to fulfill MRP Provision C.8.c. A monitoring site at Arroyo Court/De Anza Historical Park (SMA059 – labeled 59 in Figure 2), previously sampled by SFRWQCB (SMA060), was selected in an effort to confirm reduced DO levels observed in 2003 at that location in San Mateo Creek (SFRWQCB 2007). A second station on San Mateo Creek, just below Crystal Springs Dam (SMA122), was also sampled by SMCWPPP to assess the extent of the low DO conditions.

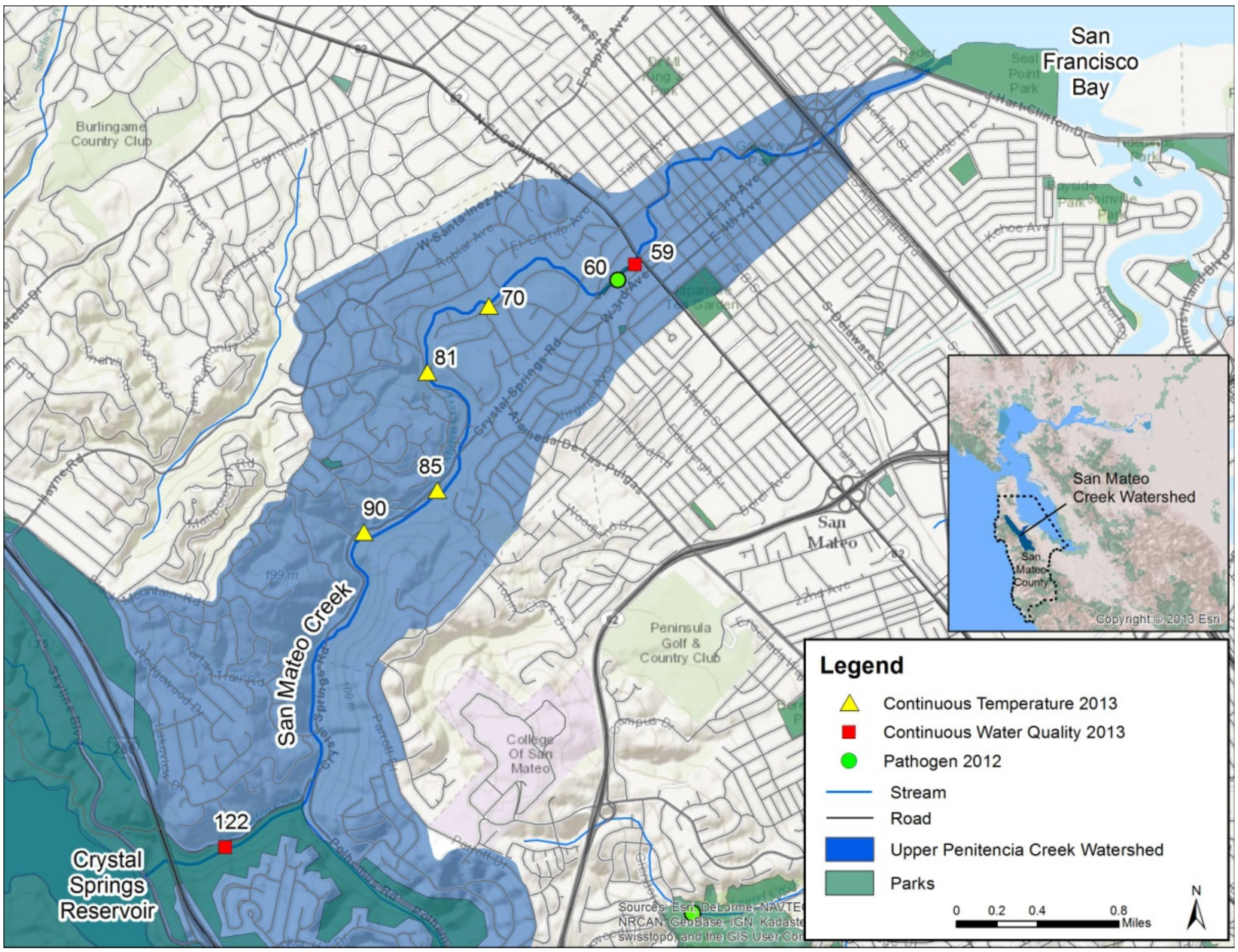

Figure 2. Continuous water quality and temperature sampling stations monitoring by SMCWPPP in WY2013.

Water quality sondes measuring pH, DO, temperature, and specific conductance were installed at both sites for two two-week periods in June and September 2013. The sonde at station SMA059

[2] 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 2013 (WY2013) began on October 1, 2012 and concluded on September 30, 2013.

was suspended just above the bottom of a relatively deep pool at the downstream end of De Anza Park. The sonde was encased in a protective 4-inch diameter PVC tube to prevent damage and to keep the probes off the creek bottom. The right bank (looking downstream) consists of a wooden retaining wall (Figure 3).

Figure 3. Pool at downstream end of De Anza Park (SMA059).

Dry season conditions in the pool were characterized by slow flow velocity and fine, soft, organic bottom sediments that contain anaerobic bacteria as evidenced by sulfide odor when disturbed. It is possible that the soft, organic bottom sediments shifted after installation, partially burying the probes. It is unknown whether the 2003 sonde deployment was within the same pool or in an area with similar bottom sediments; the SFRWQCB (2007) report does not include specific site or installation details.

The June 2013 monitoring results from station SMA059 indicate a strong daily fluctuation in DO concentrations (Figure 4). However, the pattern was not consistent with excessive photosynthesis resulting from algal blooms as suggested in the SFRWQCB (2007) report. In algal bloom settings there is typically a gradual increase in DO beginning at sunrise (caused by algal photosynthesis converting carbon dioxide to oxygen and carbohydrates) with peak levels occurring in late afternoon or at dusk. After sunset, algal photosynthesis ceases but organisms in the water continue to consume oxygen causing DO levels gradually decrease through the night with the lowest levels recorded just before sunrise. In contrast, the San Mateo De Anza record has DO concentrations peaking just before midnight within an hour after the lowest levels are recorded (Figure 4). Following the peak, DO concentrations drop sharply but stay elevated for approximately 10 hours before another sharp drop to the lowest concentration of the day. This pattern is more consistent with daily stratification of the pool (possibly as a result of low streamflow, high air temperatures, cold groundwater seepage, or some combination of these factors) followed by mixing of the water column at night as air temperatures cool and the surface layer sinks. Data collected at the upstream sonde (SMA122) showed more typical patterns but lowest and highest DO concentrations were slightly shifted from expected. Similar patterns have been observed in Coyote Creek by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP 2014).

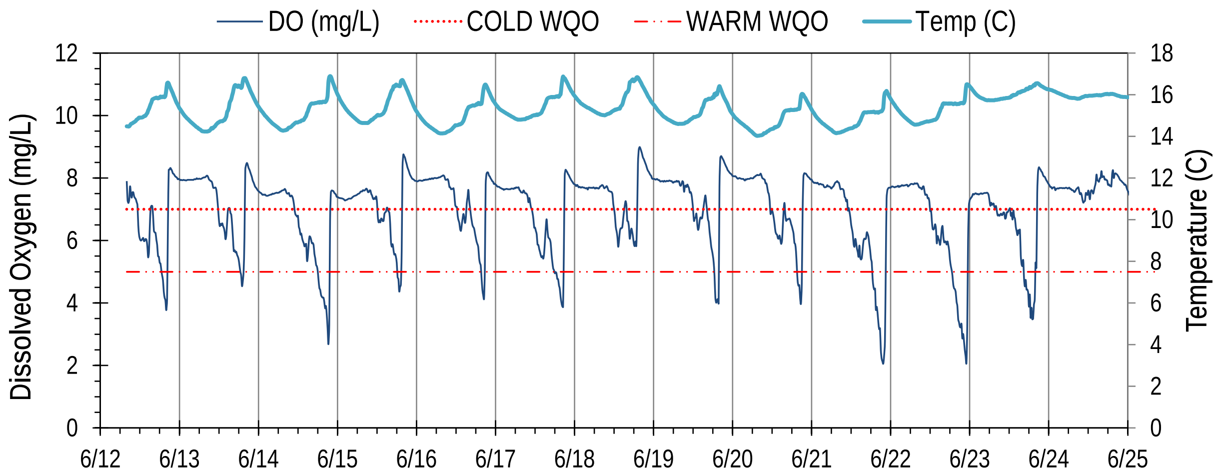

Figure 4. DO and temperature) measured at 15-minute intervals in June 2013, San Mateo Creek at De Anza Historical Park (SMA059). Both parameters exhibit daily fluctuations with lowest DO and highest temperatures recorded shortly before midnight.

The September 2013 deployment at De Anza Park showed a similar DO pattern observed during the June deployment for the first two days (Figure 5). After the first flush storm on September 21 (0.39 inches recorded at San Francisco International Airport), the pattern changed dramatically. The daily pattern became muted and there was a gradual increase in DO concentrations over the course of the next seven days.

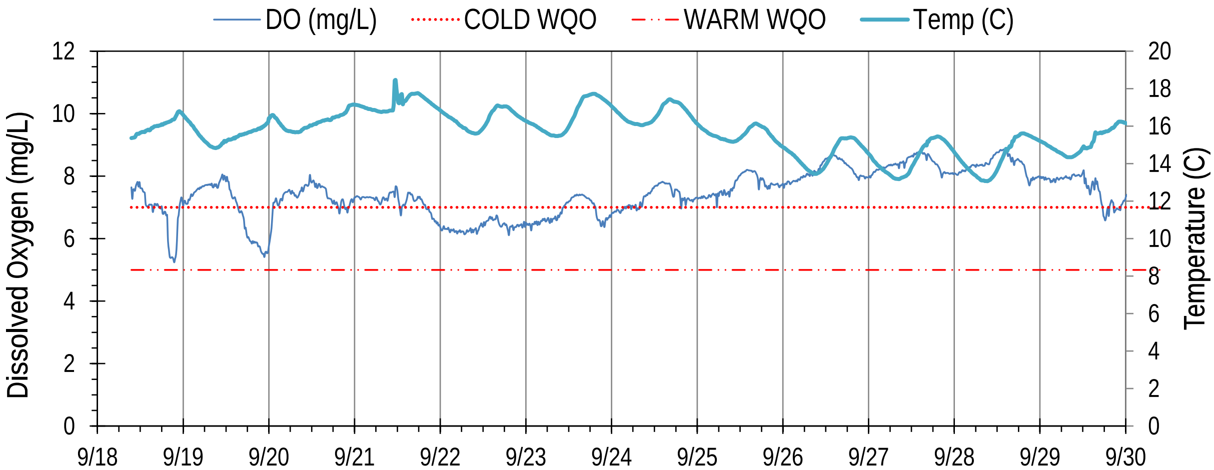

Figure 5. DO concentration (blue line) and temperature (red line) measured at 15-minute intervals in September 2013. A daily DO pattern, with lows recorded shortly before midnight, is recorded during the 2-day period before the September 21 storm event.

Results of the WY2013 sampling at De Anza Park exceeded the MRP trigger threshold for DO (i.e., 20% of results below the DO WQO of 7 mg/L).

Table 1. Percent of DO data recorded during two events in 2013 at two sites in San Mateo Creek that exceeded the MRP trigger for DO.

Site ID	Creek Name	Site	Monit-oring Event	***Percent Results DO < 5.0 mg/L***	***Percent Results DO < 7.0 mg/L***
204SMA059	San Mateo Creek	De Anza Park	June 2013	8%	36%
			Sept 2013	0%	24%
204SMA122		Below Reservoir	June 2013	0%	0%
			Sept 2013	0%	0%

The trigger in DO at this site was the impetus for conducting the San Mateo Creek Low DO SSID Project in WY2014, which is described in Section 4.0.

4.0 SSID Investigation

The San Mateo Creek Low Dissolved Oxygen SSID Project investigated the magnitude, duration, and geographic extent of low DO in San Mateo Creek. Methods included deployment of continuous water quality monitoring equipment (sondes) at two locations in the creek during the dry season of WY2014, and spot measurements of DO concentration at the bottom of pool habitats throughout a 0.75 mile reach of San Mateo Creek. Field methods and findings are described in the sections below.

4.1 Continuous Water Quality Monitoring

Sondes were deployed at two locations in San Mateo Creek during WY2014 (Figure 6). One sonde was deployed at De Anza Park (SMA059) for the entire dry season (May 9 through September 2, 2014). A second sonde (SMA080) was deployed approximately 1 mile upstream near the Sierra Drive crossing for two two-week periods: May 9 through May 27, 2014 and August 15 through September 2, 2014.

Figure 6. Continuous water quality stations in San Mateo Creek monitored in 2014. Stream reach with spot DO measurements is also shown.

The sondes were programmed to record general water quality parameters (DO, temperature, specific conductivity, and pH) at 15-minute intervals. The accuracy of sonde probe readings was checked against calibration standard solutions at three different stages during the project: 1) pre-deployment; 2) field checks; and 3) post-deployment. Field checks were conducted at site SMA059 every two to three weeks to assess whether the equipment was working properly. Field checks consisted of data retrieval, battery replacement (if needed) and cleaning and re-calibration of sensors. Procedures used for calibrating, deploying, programming and downloading data are described in the Regional Monitoring Coalition (RMC) Standard Operating Procedures (SOP) FS-4 (BASMAA 2014a). The calibration checks were compared to Measurement Quality Objectives (MQO) for data accuracy (Table 2) as defined in the RMC Quality Assurance Project Plan (QAPP) Version 2.0 (BASMAA 2014b). All data met the MQOs.

Table 2. Measurement Quality Objectives (MQOs) for continuous water quality parameters.

Parameter	Measurement Quality Objectives
Dissolved Oxygen (mg/l)	± 0.5 mg/L
pH 7.0 and pH 10.0	± 0.2
Specific Conductance (uS/cm)	± 0.5 %

The sonde at De Anza Park (SMA059) was re-positioned several times throughout the monitoring period to check for potential variability of low DO conditions and to reduce the chances of vandalism or theft. A summary of the deployment events at the De Anza site are as follows:

- Initial deployment of sonde on May 9 was in approximately the same position as the WY2013 deployment (i.e., within the pool along the right bank). However, in WY2014, the sonde was placed in a metal cage rather than the PVC casing. The metal cage was used to provide more space between sensors and the soft, organic bottom sediments (Figure 7).
- The sonde was re-positioned during a field check on June 9 to a location approximately five feet downstream of the initial location to decrease visibility of the equipment from the shore and reduce the potential for vandalism or theft.
- On July 29, the sonde was removed from the metal cage and placed in the PVC casing. The goal was to lower the probes in the water column to investigate DO conditions closer to the stream bed (i.e., similar deployment method that was used in WY2013).

Figure 7. Photograph of sonde within metal cage, showing how probes would be elevated approximately six inches off the stream bed.

Descriptive statistics for data collected at the two continuous water quality monitoring sites in San Mateo Creek during the dry season in 2014 are presented in Table 3. The distribution of DO measurements for both sites is shown as box plots in Figure 8 and as a continuous plot in Figure 9. Water quality data collected at the De Anza Park site (SMA059) are presented for the entire four month deployment period, as well as for the two two-week intervals in May and August to provide comparison with the water quality data recorded at the upstream site (SMA080) for the same time periods.

There were minimal differences in water quality conditions between the two sites during the two sampling events. Overall, the upstream site (Sierra Drive) had marginally better water quality than the De Anza Park site (i.e., lower temperature, higher DO, lower pH, and lower specific conductance). In addition, the differences in water quality between the two stations were greater during the Aug/Sep deployment compared to the May deployment.

- There was no difference in mean DO between the sites during the May deployment (9.4 mg/L).
- DO was slightly higher at the Sierra site (mean DO 8.7 mg/L) during the Aug/Sept deployment compared to the De Anza site (mean DO 8.0 mg/L).
- DO concentrations at the De Anza Park site ranged between 5.7 to 11.0 mg/L for the entire deployment, with a mean value of 8.6 mg/L.
- Over 99 percent of the entire 15-minute DO record at De Anza exceeded the COLD WQO of 7.0 mg/L minimum.

- Temperature, pH, and specific conductance readings were slightly higher at De Anza site compared to the Sierra site.
- All pH measurements met the WQO (i.e., > 6.5 and < 8.5).

Table 3. Descriptive statistics for continuous water temperature, dissolved oxygen, conductivity, and pH data measured at two sites in San Mateo Creek during WY2014.

Parameter	Data Type	Site	De Anza Park (SMA059)			Sierra Dr (SMA080)	
		Start	May 9	Aug 15	May 9	May 9	Aug 15
		End	May 27	Sept 2	Sept 2	May 27	Sept 2
Temperature (° C)	Min		12.7	16.5	12.7	12.0	15.7
	Median		15.4	17.8	17.2	14.8	17.4
	Mean		15.5	17.9	17.1	14.9	17.4
	Max		18.7	19.8	21.3	17.6	17.4
	Max 7-day Mean		15.8	18.0	19.1	15.2	17.7
Dissolved Oxygen (mg/l)	Min		8.3	5.7	5.7	8.5	8.0
	Median		9.2	7.9	8.5	9.3	8.6
	Mean		9.4	8.0	8.6	9.4	8.7
	Max		11.0	8.9	11.0	10.5	10.1
	7-day Avg. Min		8.6	7.0	7.0	8.6	8.1
pH	Min		7.6	7.5	7.5	7.4	7.5
	Median		8.0	7.7	7.8	7.8	7.6
	Mean		8.0	7.7	7.8	7.8	7.6
	Max		8.4	7.9	8.4	8.1	8.0
Specific Conductance (µS/cm)	Min		199	261	199	177	232
	Median		330	270	298	299	242
	Mean		329	271	294	300	243
	Max		407	290	456	366	310
Total number data points (n)			1729	1735	11134	1725	1738

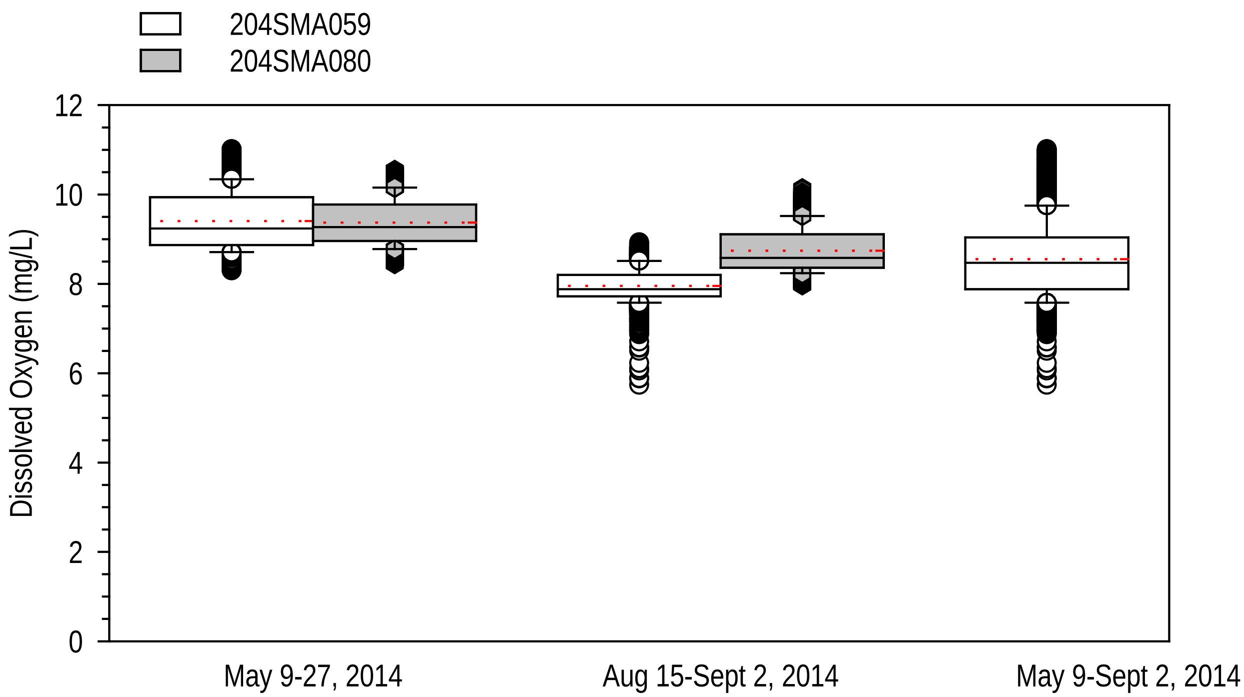

Figure 8. Box plots of DO concentrations recorded at two sites in San Mateo Creek during the dry season of 2014.

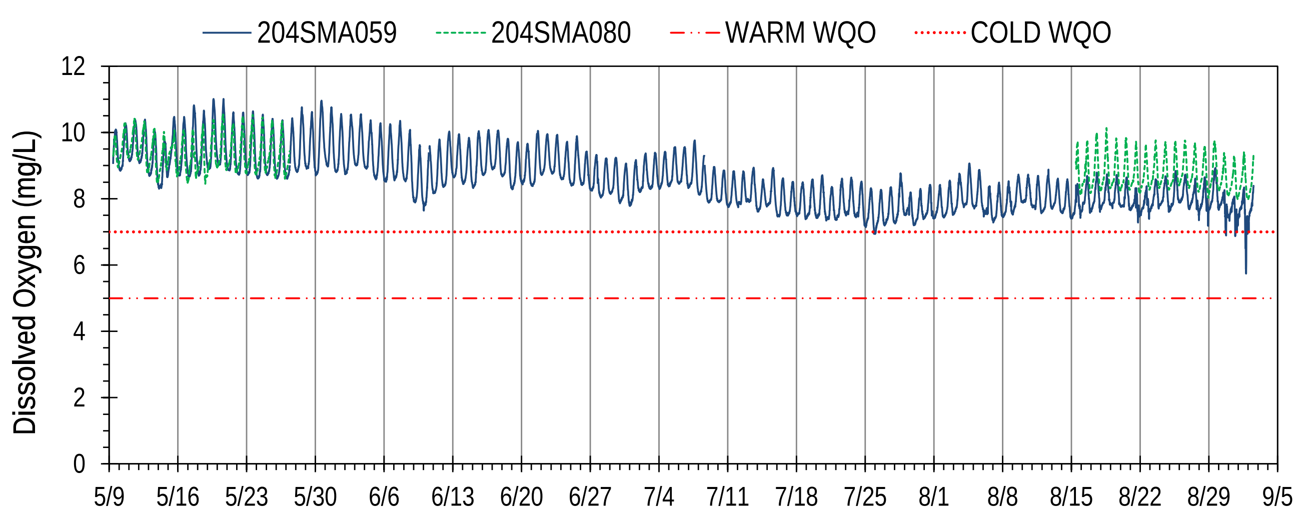

Figure 9. Plot of DO measurements recorded by sondes deployed at two sites in San Mateo Creek during the dry season of 2014.

4.2 Creek Walk

On July 29, 2014, a channel reach walk was conducted between the culvert at El Camino Real and Stonehedge Road (approximately 3,900 feet or 0.74 mile) (Figure 7). Spot measurements of

DO were conducted in 18 relatively deep pools along the reach using a multi-parameter YSI Pro-Plus handheld meter equipped with a Galvanic membrane DO sensor. General observations of pool depth and substrate were also made.

DO concentrations ranged from 6.6 mg/L to 9.2 mg/L with an average of 7.8 mg/L and a median of 7.6 mg/L. Depths of sampled pools ranged from 21 inches to 42 inches. There were no correlations between DO concentration and pool depth. Only two measurements were below the COLD WQO of 7 mg/L. Both of those pools were characterized by soft, organic bottom sediments and both were located within a subreach extending approximately 150 feet upstream of the culvert at El Camino Real. Station SMA059 is located within this subreach, approximately 100 feet upstream of the culvert. This 150-foot subreach was characterized as having soft, organic sediments within pools and relatively low flow velocities. Although channel gradients were not surveyed, it is likely that this subreach has a lower gradient than the upstream reach, a possible result of the El Camino Real culvert functioning as a grade control. Visual observations suggest that flow velocities are slower and more stagnant upstream of the culvert, causing fine sediment and organic matter to drop out of the water column and increased oxygen demand, and therefore potentially lowering DO concentrations in the subreach between De Anza Park and the El Camino Real crossing.

The 3,900-foot (0.74-mile) reach observed on July 29, 2014 was previously mapped and described by SMCWPPP (2007) using the Unified Stream Assessment (USA) protocol developed by the Center for Watershed Protection. SMCWPPP (2007) described a 260-foot subreach upstream of the El Camino Real culvert (i.e., the lower end of the WY2014 survey) as having turbid water, sedimentation zones, and hardened, steep banks. Upstream of this subreach, water clarity increases and substrates are dominated by coarser sediments (i.e., gravel and cobble). The WY2014 observations were consistent with SMCWPPP (2007) findings.

5.0 Discussion

SSID field investigations in WY2014 and WY2015 in and near San Mateo Creek at De Anza Park generally did not identify the low DO concentrations that were observed in previous monitoring studies conducted during the dry seasons of WY2003 (SFRWQCB 2007) and WY2013 (SMCWPPP 2014b). Between the May 9 and September 2, 2014 period of record, less than 0.1 percent of the DO readings collected at 15-minute intervals at the De Anza Park site (SMA059) fell below the COLD WQO of 7 mg/L. DO concentrations measured in pools upstream of the De Anza Park site during the dry season were consistently above the COLD WQO. However, the SSID study confirmed soft bottom sediments (likely the result of low gradients) and isolated low DO concentrations (less than 7 mg/L) in the subreach downstream of De Anza Park.

Higher stream baseflows during the dry season of WY2014, as compared to WY2013, were likely an important factor in improving water quality conditions (i.e., increasing DO concentrations). The higher baseflows in WY2014 are due to controlled discharges from Lower Crystal Springs Dam by the SFPUC during construction of the WISP projects. In WY2015, SFPUC began implementation of the San Mateo Creek minimum water release schedule that was required by NMFS during the WISP project approval process. The new minimum water release schedule requires baseflows at the USGS gage of 3 to 17 cfs, depending on the water year type (e.g., dry, normal, wet) and the time of year.

The higher flows result in higher flow velocities and re-aeration rates in the stream, as well as lower residence times for organic materials and other oxygen demanding substances. Figure 10 illustrates the differences in flow between the two years recorded by the USGS in San Mateo Creek below Crystal Springs Reservoir (USGS Station 11162753) which is located approximately 3.5 miles upstream of SMA059. The increase in baseflows in WY2014 may also have contributed to reduced water temperatures. Waters with lower temperature are able to dissolve more oxygen. Figure 10 illustrates differences in daily median water temperatures between the two years recorded by the USGS in San Mateo Creek below Crystal Springs Reservoir (USGS Station 11162753).

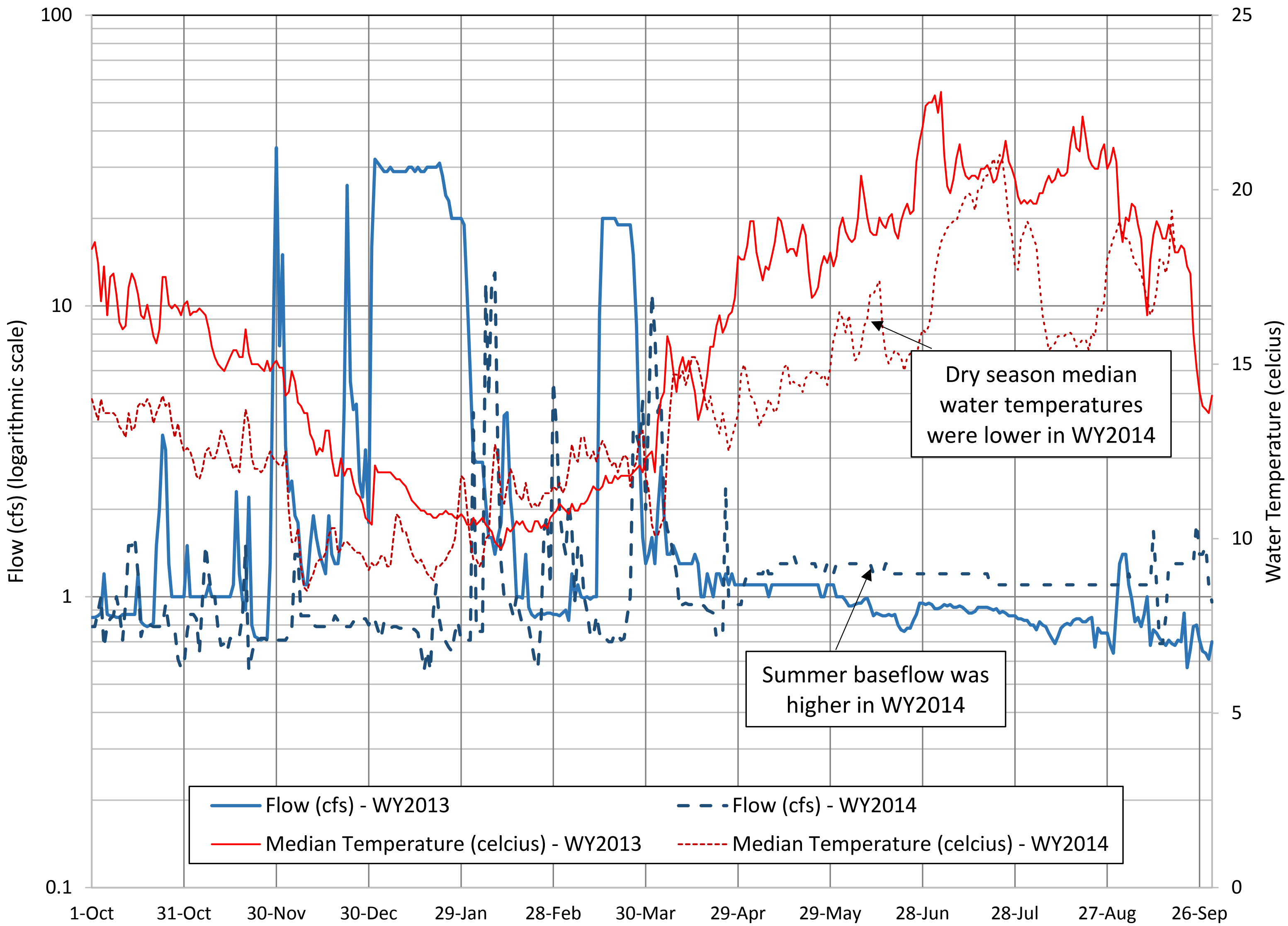

Figure 10. Mean daily flow and median daily temperature recorded at San Mateo Creek below Crystal Springs Reservoir, WY2013 and WY2014 (USGS Station 11162753).

Changes to physical habitat conditions may also have been an important factor influencing changes to the DO concentrations at the De Anza Park site. Large woody debris (LWD) plays a major role in stream morphology, pool formation, and sediment deposition (Lassettre and Harris 2001). LWD was noted upstream of SMA059 in WY2013 and WY2014, and was potentially responsible for the presence of the pool. However, field observations in WY2014 indicate less LWD in WY2014 compared to WY2013. Removal of the LWD (presumably naturally caused) could have altered sediment deposition processes in the downstream pool, resulting in less fine sediment and organic material accumulation at the sonde location.

It is likely that reduced DO concentrations may develop in pockets at the bottom of deep pools during periods of reduced flow and increased temperatures that typically occur during the late summer/fall season. These pockets are limited in geographic extent (i.e., bottom of deep pools with high accumulation of sediment and organic material) and duration due to daily recirculation/turnover of the pools. As a result, these isolated and temporary low DO conditions are not expected to impact COLD beneficial uses for the study reach (between El Camino Real and Sierra Drive).

The completion of the dam construction project at the Crystal Springs Reservoir and the establishment of a minimum baseflow of 3 cfs during the dry season are likely to result in significant improvements to the water quality conditions at De Anza Park. In addition, post construction monitoring for next ten years by the SFPUC for temperature, other water quality indicators, and condition of steelhead populations will provide valuable information to managers to ensure that dam operations are supporting aquatic life uses.

5.1 WY2015 Follow-up

On April 30, 2015[3], a site visit was conducted to observe whether streambed conditions had changed in response to the high flow test event (350 cfs) of January 15, 2015 and the new Crystal Springs Dam release schedule. The pool at the De Anza station (SMA059) was approximately one foot greater in depth with a firmer substrate than previously observed. Streambed substrate conditions farther downstream (near the El Camino Real culvert) were much coarser than previously observed. Furthermore, water clarity in the reach between De Anza Park and the El Camino Real culvert was also considerably improved compared to previous observations. It is hypothesized that the high flow event on January 15, 2015 functioned to scour fine sediments from the pool at De Anza Park and move gravels into the reach immediately upstream of the El Camino Real culvert. The reduction in fine sediments and organic material will likely decrease the occurrence of low DO in this reach.

5.2 Recommendations

Results of the SSID investigation suggest that low DO conditions are no longer expected in San Mateo Creek in the vicinity of De Anza Park (SMA059) as a result of a new release schedule

[3] Flow at the USGS gage (Station 11162753) was reported as about 5.5 cfs on April 30, 2015.

from Crystal Springs Reservoir. However, these findings are currently being confirmed through Creek Status Monitoring (MRP Provision C.8.c) in WY2015. Beyond the new ongoing dry season controlled releases, no management measures are recommended at this time and the SSID project should be considered complete.

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