Contra Costa Clean Water Program

Marsh Creek Stressor and Source Identification Study:

Year 1 Status Report

Submitted to

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

March 27, 2019

Submitted by

Wood Environment & Infrastructure Solutions, Inc.
180 Grand Avenue, Suite 1100
Oakland, California 94612

and

ADH Environmental
3065 Porter Street, Suite 101
Soquel, California 95073

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Acronyms and Abbreviations

BOD	biochemical oxygen demand
Brentwood	City of Brentwood
CCCWP	Contra Costa Clean Water Program
CDFW	California Department of Fish and Wildlife
mgd	million gallons per day
MRP	Municipal Regional Stormwater NPDES Permit
NPDES	National Pollutant Discharge Elimination System
SFRWQCB	Regional Water Quality Control Board, San Francisco Region
SSC	suspended sediment concentration
SSID	stressor and source identification
WTP	wastewater treatment plant

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EXECUTIVE SUMMARY

This stressor and source identification (SSID) study (study) addresses the root causes of fish kills in Marsh Creek. The study approach follows a work plan developed by CCCWP and approved by the CCCWP Monitoring Committee. The study focuses on low dissolved oxygen as the primary suspect cause of fish kills. The possibility that pesticides or other factors contributed to fish mortality was also evaluated in this study.

Continuous monitoring of water levels, dissolved oxygen, temperature, conductivity, turbidity, and pH at three locations along Marsh Creek helps understand daily and season factors that affect dissolved oxygen. The locations monitored were just upstream of the City of Brentwood Wastewater Treatment Plant (WTP) and immediately downstream of the WTP. Grab sampling was performed during dry weather flow events to quantify pesticides and biochemical oxygen demand. Additional water level sensors and field investigations helped identify sources of dry weather flow.

In contrast to prior years during this study, there were no mass fish mortality events observed in 2018. There was a minor event on May 16, 2018 when Friends of Marsh Creek volunteers observed six dead fish and around 10 dead crayfish in Marsh Creek. Crayfish mortality was concurrently observed by CCCWP monitoring contractors. The suspected cause of fish mortality is stranding in isolated pools following a marked decrease in flows, associated with elevated temperature, pH and low dissolved oxygen. The crayfish mortality is more puzzling, because they are generally hardier compared to fish in coping with low dissolved oxygen and high temperatures in marginal habitats (Grow and Merchant, 1980; Westoff et al., 2016).

Dissolved oxygen concentrations cycle on a daily basis at all three locations monitored. Supersaturated concentrations exceeding 10 mg/L are reached at mid-day when photosynthesis peaks. The pH also peaks at mid-day, at times exceeding 9 in isolated pools upstream of the WTP, but not downstream. Dissolved oxygen minima (and associated pH minima) occur nightly between about 2:00 a.m. and daybreak due to the metabolic shift of attached algae and aquatic plants from photosynthesis to respiration. At the monitoring station immediately downstream of the WTP, the nightly dissolved oxygen minimum rarely went below 5 mg/L (the water quality objective for warm water fisheries habitat), and never went below 3 mg/L (a threshold below which mortality becomes increasingly likely). However, at the monitoring stations both upstream of the WTP and 2 miles downstream from the WTP, dissolved oxygen concentrations dipped below 5 mg/L on a nightly basis from June through October, and in August went below 2 mg/L, a level at which fish mortality is highly likely if escape or avoidance is impossible.

Antecedent flow conditions appear to affect the nightly dissolved oxygen minimum. The nightly dissolved oxygen minimum declined steadily through the summer until about September. During this period of decline, dry weather flow events were followed a few days later by a slight uptick in the nightly dissolved oxygen minimum compared to the running seven-day average. At the beginning and the end of the summer, during more prolonged periods of dry weather flow, cessation of flows was associated with a drop in the nightly dissolved oxygen minimum.

Sources of dry weather flows varied. In early June, dry weather flows appeared to originate from different tributaries to Marsh Creek (Sand Creek, Deer Creek and Dry Creek) at different times. On May 15-16, a dry weather flow that preceded the observation of crayfish and fish mortality appeared to originate from an 18-inch corrugated metal pipe located along the west bank of Marsh Creek near Sunset Road. At the end of June, a substantial dry weather flow event originated from Dry Creek. On July 17-18, field inspectors identified Deer Creek as the predominant source of the dry weather flow event. Field crews collecting water samples from that Deer Creek event also noted a strong smell of chlorine. A five-week period of dry weather flow ensued beginning in late August and ending in early October. Field inspectors determined the origin of the flow was an agricultural drainage discharging to Sand Creek

Chemical analysis of samples grabbed during the July 17 dry weather flow event and during the prolonged September flow event were mostly non-detect for pesticides. Detections of fipronil breakdown products and bifenthrin were very close to or just below reporting limits. Nothing unusual was noted about the concentrations of other constituents analyzed (e.g., ammonia, sulfide, biochemical oxygen demand).

At the conclusion of Year 1, the findings indicate that the study appears to be on the right track by focusing on low dissolved oxygen. Dissolved oxygen levels low enough to cause fish mortality were indeed observed about 2 miles downstream from the Brentwood WTP at Cypress Boulevard during August of 2018, although no fish mortality events were observed. The daily cycling of dissolved oxygen and pH points to photosynthesis and respiration by algae and aquatic plants as the main cause of night time dissolved oxygen depression. The minimum dissolved oxygen levels reached appear to be influenced by flow, regardless of flow source.

The detection (by smell only) of chlorine in a dry weather flow event raises the possibility of planned or unplanned potable water discharge as a potential source of flow. This will be looked into during Year 2 by communicating with East Bay Municipal Utility District, which has a water supply main that crosses Marsh Creek. The goal of communication will be to better understand their schedule of planned discharges for system maintenance, record of 2018 discharges, and chlorine removal best management practices implemented.

In 2019, continuous water quality monitoring using Sondes will continue at the same three locations monitored in 2018. Opportunistic grab sampling of dry weather flow will also continue, and field crews will bring a chlorine test kit to make field chlorine measurements during future site inspections and sampling events. CCCWP staff will work with the City of Brentwood WTP to develop a pilot project concept to evaluate the potential for overnight flow equalization from the WTP to increase the nightly dissolved oxygen minima 2 miles downstream at Cypress Boulevard.

1. INTRODUCTION AND BACKGROUND

This stressor and source identification (SSID) study (study) addresses the root causes of fish kills in Marsh Creek. Completion of this study will fulfill the requirements for Contra Costa Permittees of Provision C.8.e of the Municipal Regional Stormwater NPDES Permit (MRP) issued by the San Francisco Bay Regional Water Quality Control Board.

The primary objective of the study is to identify root causes of fish kills in Marsh Creek. Following the assumption that the most common cause of fish kills is hypoxia, the first step has been to determine whether low dissolved oxygen causes fish kills in Marsh Creek and, if so, to determine the causes of the low dissolved oxygen. A primary suspected cause of low dissolved oxygen is algal growth in reaches subject to intermittent non-stormwater flows; therefore, identifying sources of non-stormwater flow is an important objective of this study. An alternate hypothesis, not necessarily exclusive of low dissolved oxygen, is that pesticide toxicity causes fish kills. Proving or disproving pesticide linkages is more complex compared to identifying low dissolved oxygen as a root cause; therefore, the objective for the pesticide assessment is to provide the most substantive weight of evidence achievable within the schedule and budget for this study.

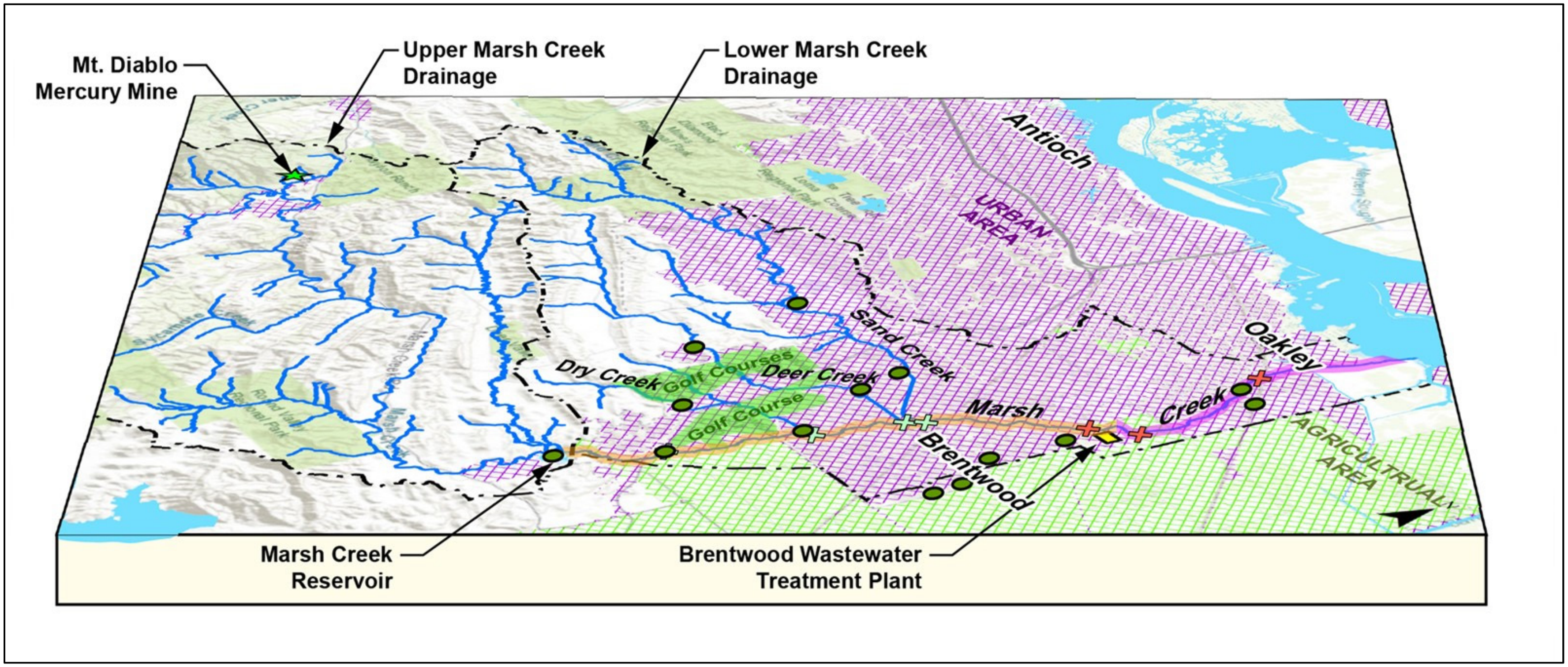
There have been nine documented fish kills over the past 14 years in Marsh Creek, dating back to 2005 (CCCWP, 2018 and citations therein). These events are often associated with intermittent dry season flows or storm events with varying antecedent dry periods. The most recent event occurred in October 2017.

The study area extends from below the Marsh Creek Reservoir downstream to the City of Oakley (Figure 1). Tributaries entering this portion of Marsh Creek include Dry Creek, Sand Creek, and Deer Creek. Streamflow in the creek is generally low, but rarely dry, during most of the summer. Known sources of dry weather flow are associated with wastewater treatment plant discharge, agricultural irrigation return flows, and non-stormwater urban drainage from the Brentwood area. Seasonal stormwater flows, the effects of urban development, and agricultural runoff contributions have significant impacts on the quality and quantity of water in Marsh Creek.

The City of Brentwood Wastewater Treatment Plant (WTP), located approximately 3.6 miles southwest of the Delta at Big Break, treats sanitary wastewater from nearby residential areas and discharges its effluent into Marsh Creek, as authorized by a National Pollutant Discharge Elimination System (NPDES) permit. The treatment plant has a design capacity of 5 million gallons per day (mgd); present actual flows are more typically in the range of 2 to 3 mgd, depending in part on recycled water consumption by irrigators.

The WTP creates a relatively constant body of flowing water in Marsh Creek downstream of its outfall. In the region below the WTP flow rates tend to peak mid-day, following peaks in early morning residential usage, and are at minimum in the pre-dawn hours. Upstream of the WTP outfall, flows are more intermittent, resulting from more intermittent activities. There are a multitude of farms, businesses, and storm drains which discharge stormwater and non-stormwater runoff into Marsh Creek. Agricultural and golf course irrigation, hydrant flushing, planned discharges during water transmission system maintenance, and residential irrigation are all potential sources of non-stormwater flow into Marsh Creek.

Figure 1. Map of Study Area and Relevant Watershed Features



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2. APPROACH

The study approach follows a work plan developed by CCCWP and approved by the CCCWP Monitoring Committee (CCCWP, 2018). Continuous monitoring of water levels, dissolved oxygen, temperature, conductivity, turbidity, and pH at three locations along Marsh Creek helps understand daily and season factors that affect dissolved oxygen. The locations monitored were just upstream of the City of Brentwood Wastewater Treatment Plant (WTP), immediately downstream of the WTP, and 2 miles downstream at Cypress Boulevard, grab sampling was performed during dry weather flow events to quantify pesticides and biochemical oxygen demand. Additional water level sensors and field investigations helped identify sources of dry weather flow. Locations of water quality and water level sensors are indicated in Figure 2.

Constituents analyzed in grab samples are summarized in Table 1. During grab sampling events, field staff also inspected Marsh Creek upstream of the WTP to attempt to identify sources of dry weather flow.

Table 1. Analytical Tests, Methods, Reporting Limits and Holding Times for Water and Sediment Chemistry Testing

Analyte	Matrix	Test Method	Reporting Limit	Holding Time
Suspended Sediment Concentration	Water	ASTM D3977-97B	3 mg/L	7 days
Pesticides[1]	Water	EPA 8270M	1.5 ng/L to 2 µg/L	7 days
Ammonia	Water	SM 4500 NH3 C	0.1 mg/L	28 days
Biochemical Oxygen Demand 5-Day	Water	SM 5210B	2 mg/L	48 hours
Total Sulfides	Water	SM 4500-S2	0.1 mg/L	7 days
Total Organic Carbon	Water	SM 5310 B-00/-11	±0.1 %	28 days
Dissolved Organic Carbon	Water	SM 5310 B-00/-11	0.50 mg/L	Filter 48 hours, 28 days

1 Pyrethroids, chlorpyrifos, diazinon, fipronil and degradates

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3. FINDINGS

This section presents the findings from year 1 of the study. Relevant observations by field staff are presented first, followed by results of chemical analysis of grab samples collected from dry weather flow events. Continuous monitoring results for water are summarized to help understand the major processes affecting water quality during the dry season. Water level monitoring results from locations upstream of the water quality sensors are presented at the end of the section to help understand different sources of dry weather flow.

3.1 2018 Observations by Field Staff

While performing bioassessments on May 16, CCCWP noted six dead crayfish in Marsh Creek in the vicinity of Dainty Avenue. This observation was corroborated by volunteer monitors working with Friends of Marsh Creek and American Rivers, who were also performing bioassessment surveys May 14-16. The volunteers reported that six dead fish and around 10 dead crayfish were observed in Marsh Creek near Creekside Park. The creek was mostly dry with isolated pools during the previous week; a dry weather flow event peaking around mid-day on May 15 preceded the May 16 observations of dead crayfish. Field crews observed that the origins of the May 15-16 flows appeared to be an 18-inch corrugated metal pipe outfall located on the west bank of Marsh Creek. The outfall is adjacent to a what appears to be a pump house located at the intersection of McHenry Way and Sunset Road, about three miles downstream of the dead crayfish observations.

Field crews were present for equipment maintenance during two other dry weather flow events, on July 17, 2018 and on October 4, 2018. On July 17, flows were traced to Deer Creek, from evidence of pooled water, field crews noted that where their arms had necessarily come into contact with the creek during sampling, they smelled of chlorine, as if they had been in a swimming pool. Field crews did not have chlorine test kits available at that time. The October 4 flows were traced to Sand Creek. Both the July 17 and the October 4 dry weather flow events were sampled for the constituents listed in Table 1.

3.2 Grab Sample Results

Results from chemical analysis of grab samples collected during dry weather flow events in July and October of 2018 are summarized in Table 2. Neither flow event showed particularly unusual or concerning water quality characteristics. Suspended sediment concentrations were either low (3.2 mg/L) or non-detect. Most pesticides were at or below the reporting limit and many were below the detection limit. Biochemical oxygen demand (BOD) was relatively low (6 mg/L) in July and non-detect (<5 mg/L) in October. Ammonia concentrations ranging from 0.03 to 0.05 mg/L are comparable to background ammonia concentrations in natural waters.

Table 2. Results of Chemical Analysis of Grab Samples

Constituent (Units)	Results			MDL	RL
	Marsh Creek at M2 07/17/18	Marsh Creek at M2 10/03/18	Sand Creek at Flow Source 10/04/18		
Suspended Sediment Concentration (mg/L)	3.2	<2	<2	2	3
Allethrin (ng/L)	<0.1		<0.1	0.1	0.5
Bifenthrin (ng/L)	0.4 J		1.1	0.1	0.5
Chlorpyrifos (ng/L)	<0.5		<0.5	0.5	1
Cyfluthrin, total (ng/L)	<0.2		<0.2	0.2	0.5
Cyhalothrin, Total lambda- (ng/L)	<0.2		<0.2	0.2	0.5
Cypermethrin, total (ng/L)	<0.2		0.4 J	0.2	0.5
Diazinon (ng/L)	<0.1		<0.1	0.1	0.5
Deltamethrin/Tralomethrin (ng/L)	<0.2		<0.2	0.2	1
Esfenvalerate/Fenvalerate, total (ng/L)	<0.2		<0.2	0.2	1
Fenpropathrin (ng/L)	<0.2		<0.2	0.2	0.5
Fipronil (ng/L)	<0.5		<0.5	0.5	1
Fipronil Desulfinyl (ng/L)	1.2		<0.5	0.5	1
Fipronil Sulfide (ng/L)	<0.5		<0.5	0.5	1
Fipronil Sulfone (ng/L)	1.7		0.8J	0.5	1
T-Fluvalinate (ng/L)	<0.2		<0.2	0.2	0.5
Permethrin, Total (ng/L)	<2		<2	2	10
Tetramethrin (ng/L)	<0.2		<0.2	0.2	0.5
Ammonia as N (mg/L)	0.05		0.032	0.015	0.02
BOD (mg/L)	6	<5	<5	5	5
Sulfide, Total (mg/L)	<0.03		<0.03	0.03	0.1
Total Organic Carbon (mg/L)	7.6		2.9	0.3	1
Dissolved Organic Carbon (mg/L)	7.3		2.5	0.3	1

3.3 Continuous Water Level and Quality Monitoring

Water levels and quality were successfully monitored in Marsh Creek at three locations upstream of the WTP (Station M2), immediately downstream of the WTP (Station M1), and 2 miles downstream at Cypress Boulevard (Station M0), as shown in Figure 3 and Figure 4. A stick diagram of Marsh Creek and its tributaries shown with Figure 2 helps organize the spatial distribution of monitoring locations.

Water level monitoring confirms that flows are intermittent upstream of the WTP, whereas downstream water levels peak daily and diminish to their minima at night, as evidenced by the daily oscillations in stage at M1 and M0. The fact that all three monitoring locations have some measurable water levels, even at times of no flow (for example, M1 had measurable water levels [stage values] even when flow from the WTP drops to zero for a few hours most nights), underscores an important observation about Marsh Creek that was first noted during development of the work plan for this study: Marsh Creek functions as a series of interconnected pools during low flow periods.

Figure 2. Stick Diagram of Monitoring Stations and Continuous Stage and Water Quality Monitoring Data from Stations M2

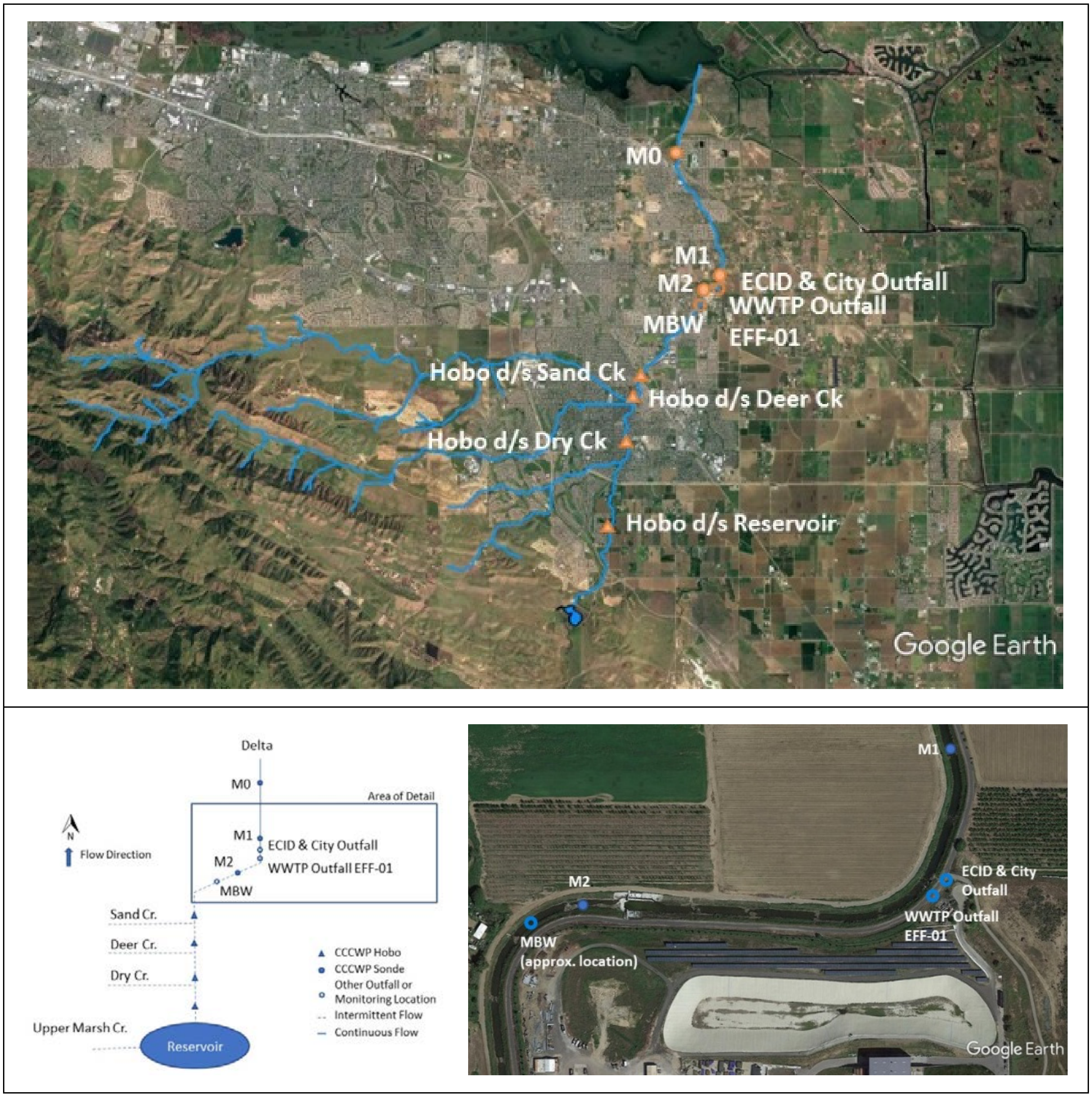


Figure 3. Stick Diagram of Monitoring Stations and Continuous Stage and Water Quality Monitoring Data from Station M2

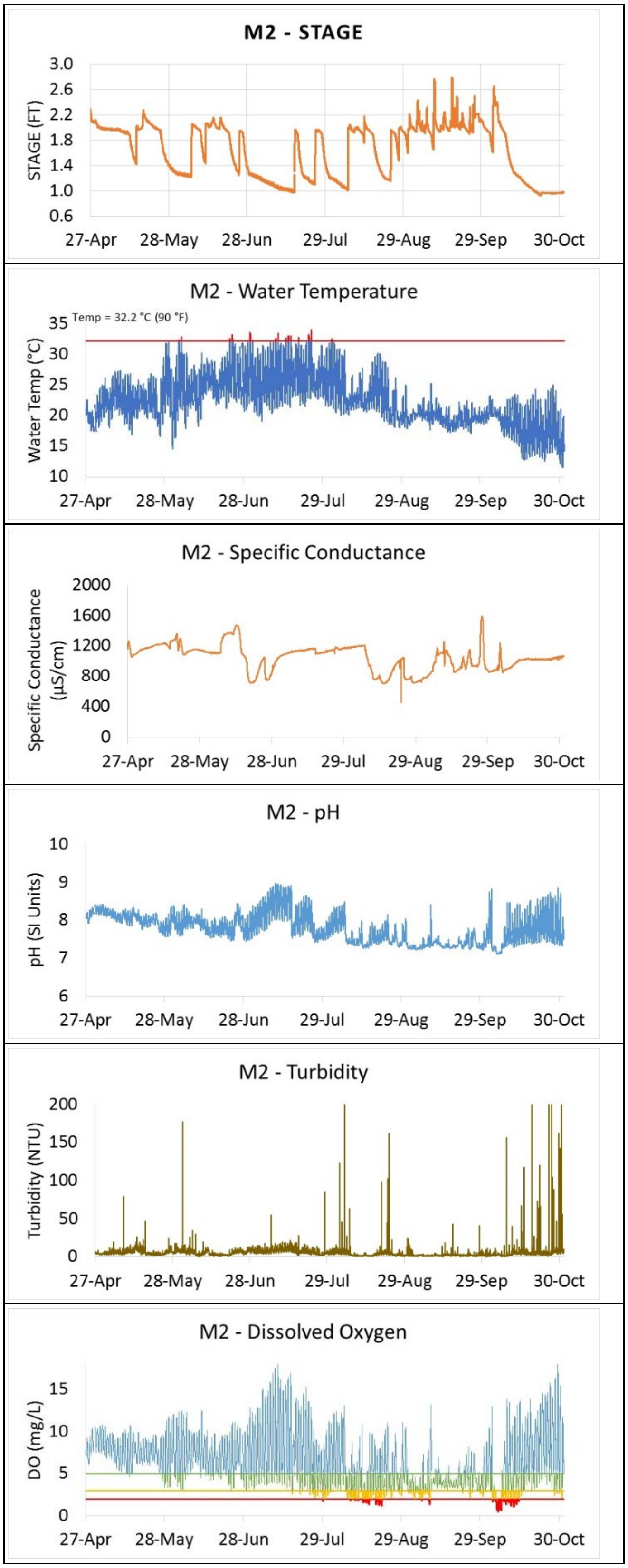
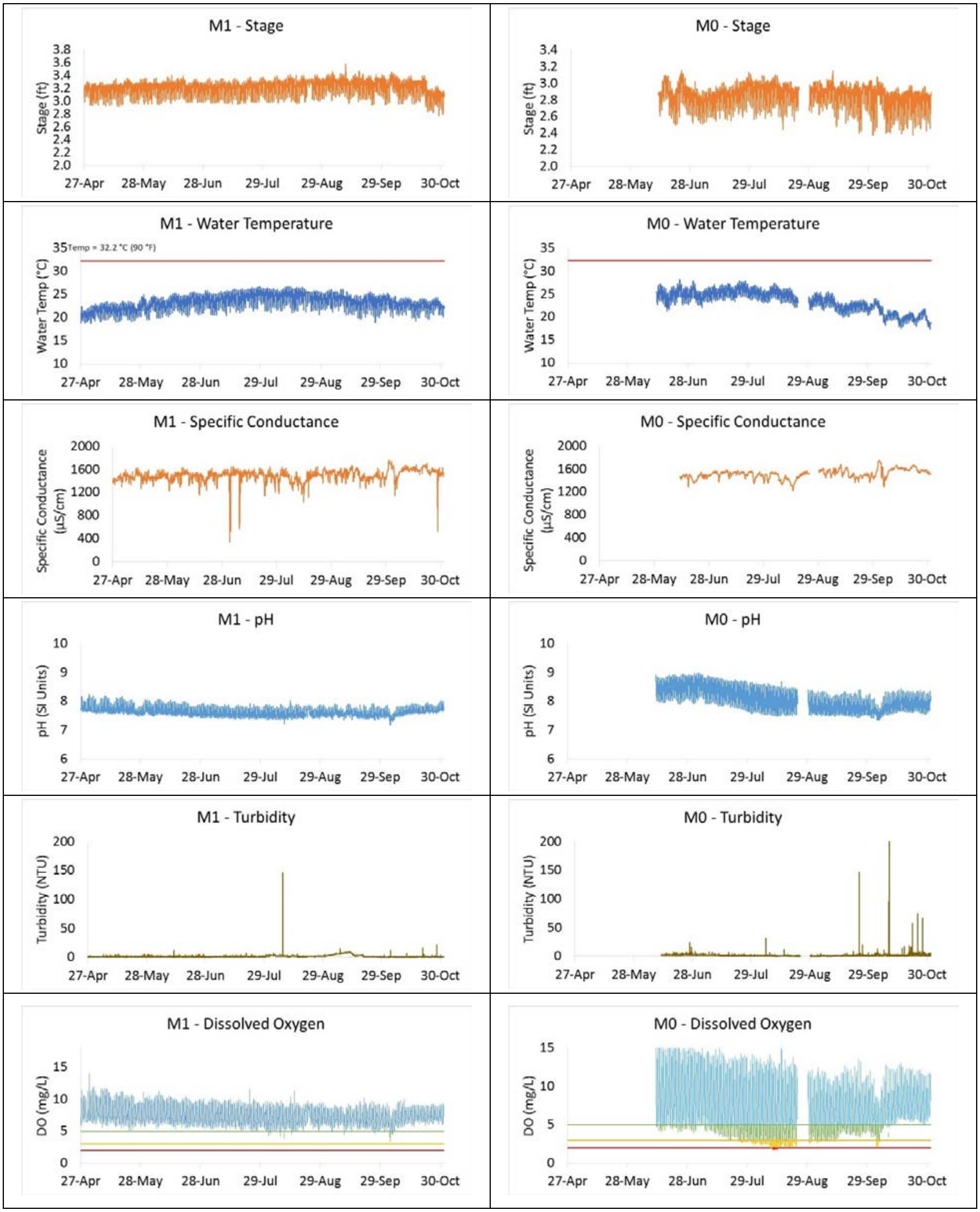


Figure 4. Continuous Stage and Water Quality Monitoring Data from Stations M1 and M0*



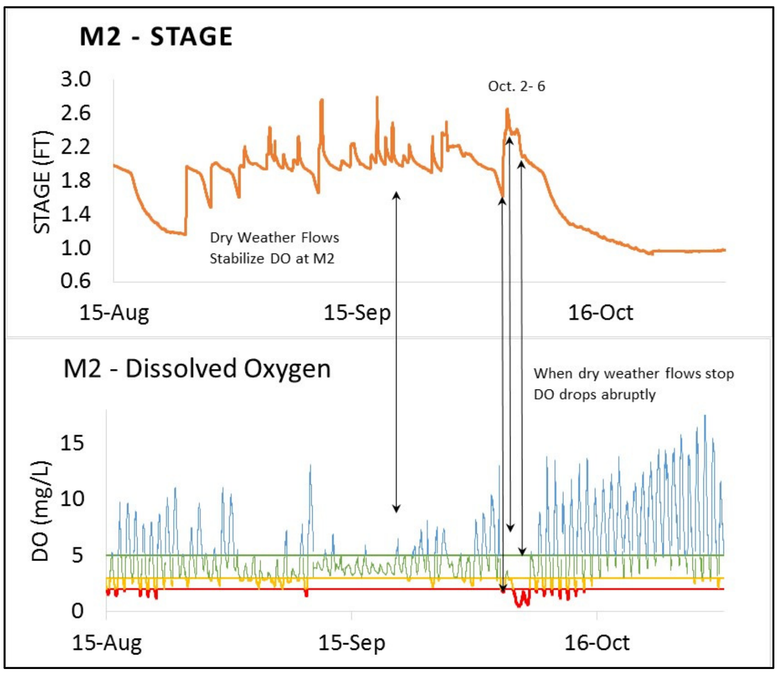
*An equipment malfunction at M0 resulted in missing stage data between August 24-29 and missing water quality data from August 26-29.

Marsh Creek downstream of the reservoir has been highly modified over the past several decades. The channel has been straightened, hardened and grade control structures have been installed to reduce erosion of the channel bottom that resulted from channel modifications. These structures create a series of pools and riffles that provide habitat for aquatic species, plant and algae. The pools and riffles also affect water quality. Upstream of the WTP, pools that are filled by intermittent dry weather flows tend to stagnate during summer months when flows cease, reaching temperatures exceeding 90˚ Fahrenheit and dissolved oxygen concentrations below 2 mg/L.

Water quality conditions steadily deteriorated at M2 through the summer. Water temperatures exceeded 90˚ Fahrenheit regularly at M2 in June and July. Dissolved oxygen and pH showed daily oscillations that are typical of streams with abundant algae. Photosynthesis during the day produces oxygen, leading to supersaturation at mid-day; at the same time, carbon dioxide is consumed, increasing the pH of water by day to nearly 9. The opposite occurs at night, when plant metabolism consumes dissolved oxygen and releases carbon dioxide, thereby concurrently lowering pH.

Dissolved oxygen began dropping below the water quality objective of 5 mg/L at M2 on a nightly basis starting in late May. By the end of July, the nightly dissolved oxygen minimum at M2 was consistently below 3 mg/L, and at times was below 2 mg/L. Dissolved oxygen at M2 picked up with the onset of dry weather flows from Sand Creek in September, and then crashed abruptly to below 2 mg/L when those dry weather flows tailed off October 2-6. Dissolved oxygen at M2 clearly responds directly to flow, as seen by the sudden drop in dissolved oxygen in responses to the falling stage on October 2, followed by a dissolved oxygen uptick concurrent with a stage rise on October 4, followed by another sudden drop as flows tailed off October 5-6 (Figure 5). Temperature also stabilized at M2 during the dry weather flow event of September (see Figure 3).

Figure 5. Comparison of Stage to Dissolved Oxygen at M2, August 15-October 31, 2018



Water quality was relatively stable at M1, immediately downstream of the WTP outfall, during the period monitored (see Figure 4). Dissolved oxygen and pH showed daily oscillations consistent with photosynthesis and respiration. In contrast with location M2, pH at M1 remained within a much tighter range (7.2 to 8.2) and dissolved oxygen went below 5 mg/L only a few times, and never went below 3 mg/L during the period monitored. This stable behavior of water quality is attributable to daily flows from the WTP. Without daily replenishment from WTP discharges, water quality in the pool at M1 would likely resemble that of the pool at M2, upstream of the WTP.

Daily flows from the WTP reach 2 miles downstream to station M0. Stage peaks at M0 occur about 5 to 6 hours after stage peaks at M1, implying a transit time of about 5 to 6 hours between the two locations at peak daily flow. Although Marsh Creek at M0 should have roughly the same flows as 2 miles upstream at M1, dissolved oxygen is notably worse at M0 compared to M1 (see Figure 4). The nightly dissolved oxygen minimum at M0 began regularly dropping below 5 mg/L by the end of July and fell below 2 mg/L by mid-August.

Dissolved oxygen at M0 is of interest in this study because of the location in relation to fish habitat and passage. The most likely place to find fish during the late summer and early fall is downstream of the WTP, because upstream habitat quality is demonstrably less hospitable during those times. Based on the observations from the summer of 2018, a potential scenario leading to a fish kill would be if fish in reaches downstream from the WTP are trapped in pools during overnight no-flow periods, when lethally low dissolved oxygen levels (<2 mg/L) can occur. Station M0 is an important indicator of the potential for this scenario.

A more detailed analysis helps understand factors affecting dissolved oxygen at M0 (Figure 6). The overall seasonal pattern is displayed in the top of Figure 5, and four different snapshots of the 24-hour photosynthesis/metabolism cycle are shown in the bottom of Figure 6. The hysteresis loops observed in the bottom of Figure 6 result from daily oscillations in dissolved oxygen and water level that are out of phase. Dissolved oxygen at M0 drops overnight because of net respiration, and also because diminishing flows lead to diminished re-aeration rates. Of the two factors, the photosynthesis/respiration cycle seems to exert a more potent effect on dissolved oxygen than diminishing flow. At daybreak, dissolved oxygen at M0 increases even as the stage continues to drop at that location. At those lower pre-dawn water levels, the waterbody is essentially functioning as a pool; a stage drop of a few more inches does not significantly alter the “pool-like” characteristics. The onset of daylight and associated shift from metabolism to photosynthesis turns the dissolved oxygen state from net consumptive to net productive each day.

Figure 6. Stage at Station M2 and Daily Minimum Dissolved Oxygen at M0 (Upper) and Dissolved Oxygen at M0 vs Stage at M0 for Four 3-day Periods (Lower)

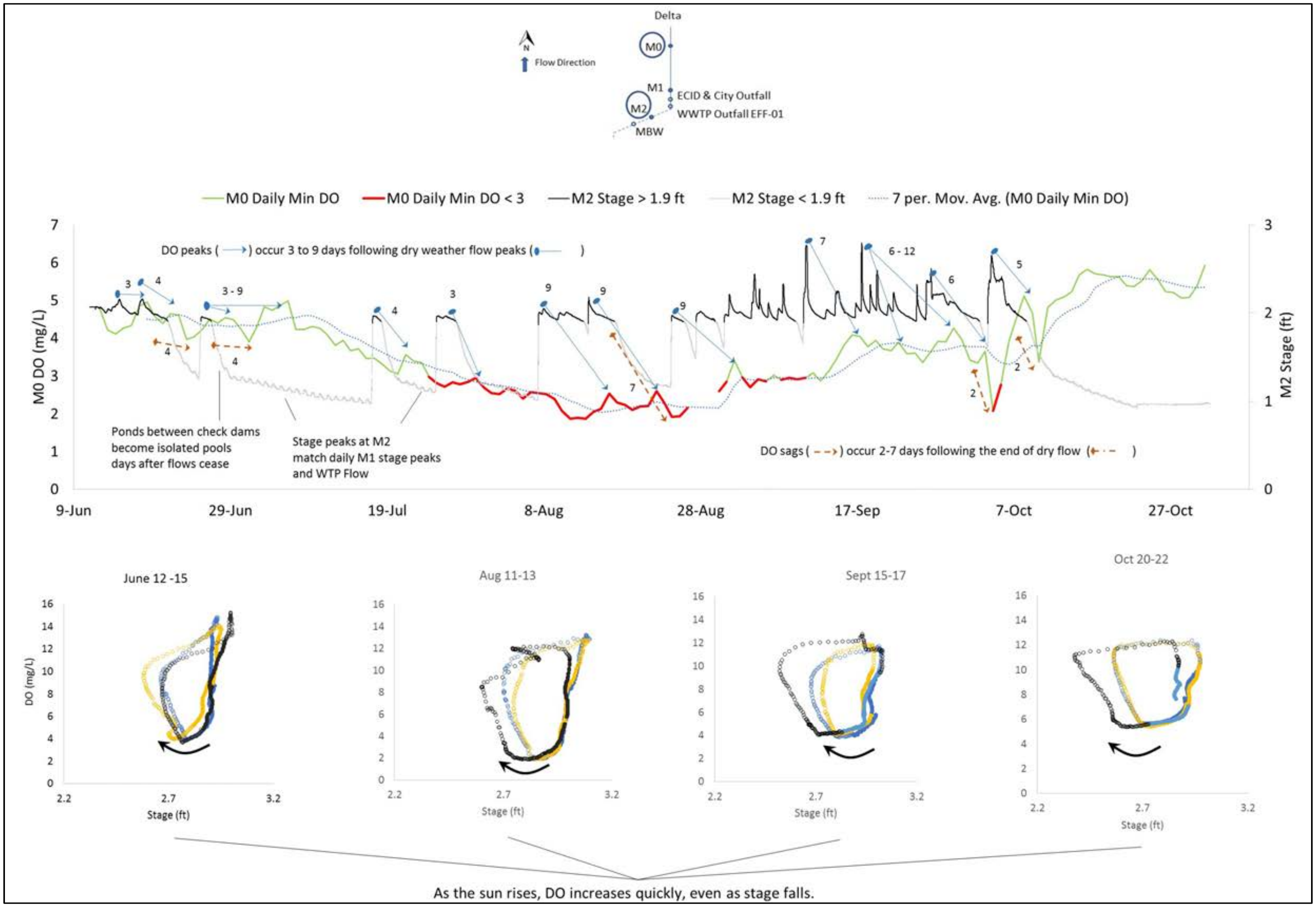
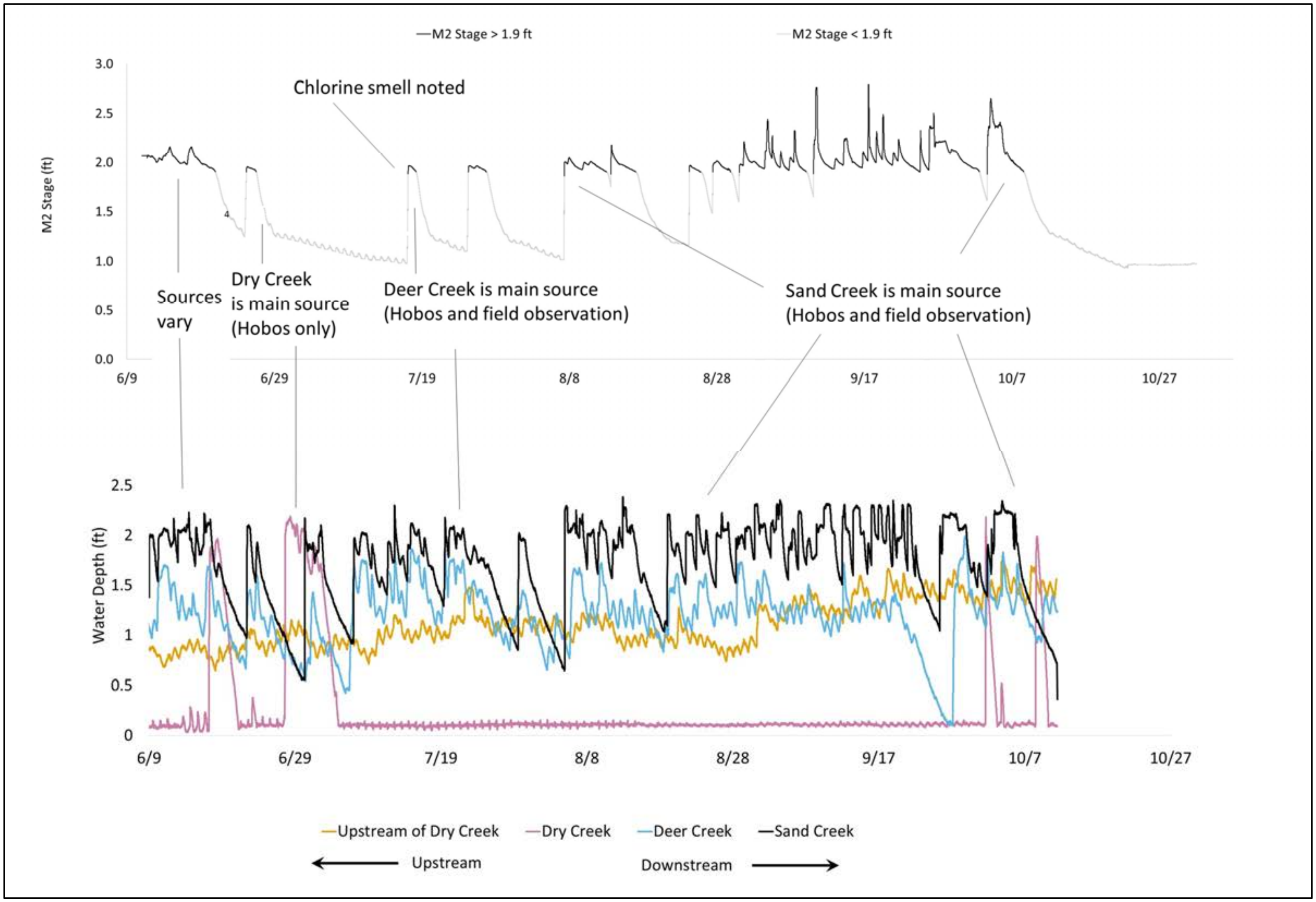


Figure 7. Stage at M2 (Upper) and at Upstream HOBO Water Level Monitoring Stations (Lower) During Year 1 Monitoring



Flow from upstream of the WTP appears to affect the nightly minimum dissolved oxygen concentrations reached at M0. This is important because it is the minimum dissolved oxygen that would cause fish mortality, rather than the daily average or the daily maximum. It appears the dissolved oxygen at M0, like at M2, tracks with dry weather flows recorded at M2. Even though WTP flows drop to zero on a nightly basis, the nightly minimum of dissolved oxygen appears to be higher at M0 after dry weather flows occur at M2.

As indicated by the numbered dots and arrows in Figure 6, peak dry weather flows are followed three to nine days later by a peak in the daily minimum dissolved oxygen compared to the running seven-day average of daily dissolved oxygen minima. Likewise, two to four days after a dry weather flow event ceases, there is an abrupt sag in the daily dissolved oxygen minimum compared to the running seven-day average of minima.

The nature of this dry weather flow regime upstream of the WTP is also evidenced in the pattern of stage rising and falling. Actual surface flow occurs at M2 when water levels at M2 exceed 1.9 feet (bold black line in upper portion of Figure 6). Below 1.9 feet, water between grade control structures at M2 seeps off to become an isolated pool over a period of days. Following that, daily stage peaks are observed mid-day at M2, coincident with the stage peak at M1 and daily peak flows from the WTP. This oscillation indicates that M2 remains hydraulically connected to M0 via the hyporheic zone (the zone of mixed surface and groundwater below and adjacent to a stream). The sandy soils beneath Marsh Creek are highly transmissive (City of Brentwood, 2016), allowing water to flow freely back and forth between adjacent ponds as water levels rise and fall.

The combination of intermittent dry weather flows upstream of the WTP, grade control structures forming a series of pools, and a highly transmissive hyporheic zone sets the dry weather flow regime for the Marsh Creek watershed between the reservoir and the WTP. Intermittent flows would drain off more quickly were it not for the grade control structures. Instead, water from dry weather flows is retained in pools behind the grade control structures and slowly released downstream by seepage through the hyporheic zone. This establishes a “tail-off” period following dry weather flows, leading to the observed lag time between cessation of dry weather flows and drops in the dissolved oxygen daily minimum compared to antecedent conditions. Even though the cycle of photosynthesis and respiration is a dominant factor affecting dissolved oxygen at M0, a small amount of residual dry weather flow from upstream of the WTP appears to have a detectable positive effect of increasing the nightly dissolved oxygen minimum reached two miles downstream of the WTP at M0.

3.4 Sources of Dry Weather Flow

Water level monitoring upstream of the WTP using HOBO® data loggers (Figure 7), combined with observations from the field, confirm that there are a variety of dry weather flow sources to Marsh Creek. In the lower portion of Figure 7, stage rises detected by the HOBO® can be tied to stage rises at M2 (upper portion of Figure 7) to infer flow sources by tributary. When the black line in the lower portion of Figure 6 rises, indicating a stage rise Marsh Creek immediately downstream of Sand Creek, but none of the other three HOBO sensors show significant stage rises, this indicates flow is predominantly from Sand Creek. This was the case in September 2018 and was confirmed by field observation.

On July 17, 2018, when a chlorine smell was noted in dry weather flows sampled, the dry weather flow was predominantly from Deer Creek, again confirmed both by field observation and the fact that HOBOs downstream of Deer Creek and Sand Creek showed stage rises, but the two HOBO®s located further upstream did not. Around the end of June, Dry Creek contributed dry weather flow. Prior to that, tributary sources of flow varied.

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4. SUMMARY AND PLANNED ACTIVITIES FOR 2019 MONITORING

In summary, the first year of the Marsh Creek SSID study was successful in collecting data on dissolved oxygen and other water quality parameters, grab sampling dry weather flow events, and identifying the location and timing of different sources of tributary flow. Although a major fish kill event did not occur during Year 1, the dissolved oxygen data supports the hypothesis that previously observed mass fish kills (> 100 fish) observed in the reaches downstream of the WTP were likely caused at least in part by low dissolved oxygen events.

The Year 1 findings also show there may be more than one cause of fish kills. Continuous monitoring devices in place at M2 did not show lethally low dissolved oxygen and high temperatures on May 16, when dead fish and crayfish were observed by contractors and volunteer monitors. The dry weather flow event that took place immediately before the May 16 observations could have played a role, either by luring fish upstream to be stranded after the flow abated, or by the potential presence of toxic substances in the dry weather flow. Temperature also may have played a role following the cessation of dry weather flows.

Investigation of toxicity to date has focused on pesticides. Both from chemical analysis and from the history of toxicity testing, there has not been evidence to date of pesticide toxicity to higher organisms such as fish. The observation by field staff that the June 17 dry weather flow event smelled of chlorine is troubling, in that chlorine in a dry weather discharge could potentially explain crayfish mortality if chlorine was also present in the May 15-16 dry weather discharge.

For the coming year, continuous water quality monitoring and opportunistic grab sampling will continue per the work plan. The grab sampling program will be expanded to included chlorine testing in the field. CCCWP will work with local permittees (the City of Brentwood) to see if local support can provide rapid response testing of dry weather discharges for chlorine. CCCWP will also reach out to the irrigated agriculture monitoring coalition covering Marsh Creek to better understand the timing and volumes of irrigation runoff to Marsh Creek. CCCWP will also reach out to municipal water suppliers, such as East Bay Municipal Utility District, the Contra Costa Water District, and the City of Brentwood, to gather data on planned potable water discharges and implementation of chlorine-removing best management practices.

As a result of a recent pond rehabilitation project, the City of Brentwood's WTP will have the capability to store and equalize flows from its outfall beginning in 2019. The primary purpose of this capability is to provide irrigation customers with water at night, when they need it, and when water production from the WTP is at a minimum. The WTP operations manager has agreed in concept to evaluate a flow equalization pilot study during Year 2, to determine if storing water by day and releasing water by night can raise the nightly dissolved oxygen minimum. This would be attempted in the July-August time frame, targeting a window when dry weather flows are at a minimum.

Table 3 below summarizes the management hypotheses and evaluation approaches proposed in the work plan for this study, along with a statement of the current status for each item.

Table 3. Management Hypotheses, Associated Monitoring Approaches, and Status at Conclusion of Year 1

Hypotheses	Evaluation Approach	Schedule or Status
Low dissolved oxygen causes fish kills	Compile historic WTP effluent and receiving water monitoring Review and summarize time of day and antecedent weather for historic fish kills	Completed during work plan development
	Perform continuous monitoring of dissolved oxygen, pH, conductivity, turbidity, and temperature at three locations upstream and downstream of the WTP	Successfully completed in 2018. Pulled sondes and HOBOs as of December 2018. Will resume March 2019
Low dissolved oxygen upstream of the WTP is caused by excessive algal blooms	Compare algal abundance, ash free dry weight, and magnitude of dissolved oxygen swings among Contra Costa County creeks	Completed during work plan development
Episodic non-stormwater flows are the result of agricultural irrigation, golf course irrigation, residential irrigation, or maintenance flushing of potable water systems.	Perform continuous monitoring of water levels at several locations within the watershed using sondes and HOBOs (see Figure 1)	Water level sensors installed as of April 2018, will resume February 6, 2019 at the end of the rainy season
	Issue email alerts when non-stormwater flows increase in the creek commence	Email alerts are being sent as of April 2018
	Develop a map and inventory of storm drain outfalls Opportunistically dispatch inspectors to identify and potentially sample sources of flow	Map deferred, may not be necessary. 2018 field inspections identified two flow sources.
Stagnant water is flushed from upstream of M1 and the WTP to the lower creek during episodic dry weather flow spikes and first flush rain events	Collect water samples for BOD, sulfides, total organic carbon, and total suspended solids during dry weather base flow conditions, during dry weather flow surges, and during first flush storm events.	Three events sampled for BOD and SSC; two of three also analyzed for TOC and sulfide.
Flushing of stagnant water from upstream of the WTP can cause lethally low dissolved oxygen downstream	Develop a simple WASP-8 water quality model to determine BOD loads needed to explain observed sags in dissolved oxygen. Compared modeled BOD loads to monitored loads.	Preliminary modeling performed. Recommend 2019 flow equalization pilot in cooperation with Brentwood in lieu of additional modeling.
Non-stormwater discharges contain elevated levels of BOD and / or pesticides	Opportunistically dispatch inspectors to sample sources of flow	Two events sampled
Pesticides cause fish kills	Continue to monitor toxicity and pesticides in Marsh Creek in compliance with Provision C.8.g	Completed per permit
	Collect an opportunistic sample for pesticides and toxicity as soon as practicably possible immediately following a fish kill event	No sampleable fish mortality events occurred from June-November 2018
Pesticides cause crayfish kills	Coordinate with CDFW to find out if they would partner to provide analysis of pesticides in fish and crayfish tissues	Had discussion with CDFW in July 2018. They are willing to provide tissue analysis.
Daily pH peaks cause ammonia toxicity to increase, causing or contributing to mortality	Review data on ammonia toxicity vs. pH for affected species, compare to ambient conditions	To be completed in 2019 for inclusion in Year 2 report.
Daily temperature peaks in isolated pools cause or contribute to fish and/or crayfish mortality	Continuous monitoring of temperature, comparison of conditions at the time of a mortality event to stressful and lethal thresholds	Temperature monitoring performed in 2018.

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