Fecal Indicator Bacteria and Source Identification in the Pajaro River Watershed, Santa Clara County

1: Potential source animals upstream of WAT on Llagas Creek. 2: Swallow nests under an overpass crossing at Uvas Creek. 3: Animal tracks on bank of Llagas Creek upstream of MON. 4: K. Mann sampling at the Pajaro River.

Environmental Planning Unit (#247)

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Executive Summary

Past sampling conducted by the Central Coast Regional Water Quality Control Board (CCRWQCB) and related programs has shown that fecal indicator bacteria (FIB) in the Pajaro River Watershed often exceed Basin Plan Objectives and EPA recommended thresholds. FIB presence in water is used to indicate recent fecal contamination of water, and assess illness risks for those that come in to contact with the water. Illness risks vary based on the level of FIB present, as well as the extent of bodily contact with the water. A Total Maximum Daily Load (TMDL) has been initiated for fecal coliform bacteria in multiple waterways of the Pajaro River Watershed. The City of Gilroy, City of Morgan Hill, and County of Santa Clara implemented a regional pathogen indicator sampling program in response to the TMDL from October 2012 to June 2014. However, this program was suspended by the CCRWQCB in July of 2014, and a new sampling program was requested. In July of 2015 the City of Morgan Hill and County of Santa Clara developed a new 2015 TMDL monitoring plan that focused on bacteria source identification and coordinated with the Santa Clara Valley Water District microbial source tracking effort.

To meet a key performance indicator of the Safe, Clean Water and Natural Flood Protection Program (Safe Clean Water) Project B2 (Interagency Urban Runoff Program), the Santa Clara Valley Water District (District) collaborated with the City of Gilroy, City of Morgan Hill, and County of Santa Clara to enhance their efforts through interagency cooperation by:

- testing for FIB (*Escherichia coli* [*E. coli*] and enterococci) in the Pajaro River Watershed and comparing results to Federal water quality criteria,
- engaging in a Microbial Source Tracking (MST) investigation of select sites to determine possible sources of pathogens in the watershed, and
- focusing on sites within the Pajaro River Watershed where District employees and the public may be potentially exposed to microbial pathogens in the water.

A District pilot study was conducted in March and April of 2015 on five sites that exhibited flowing water. Preliminary results indicated birds were contributors to fecal pollution at three of the sampled sites. The District, in collaboration with the County of Santa Clara, then initiated a larger scale study in March of 2016 to continue to identify and assess sources of pathogens.

Elevated concentrations of FIB were observed throughout the Pajaro watershed in Santa Clara County, particularly within the Llagas sub-watershed. Uvas sub-watershed appears to be less impaired than Llagas. *E. coli* concentration at the county line were within accepted limits for recreational water body contact but not Enterococci at the time of sample collection. Results of the 2016 study indicate livestock, domesticated animals, birds, and trace human sources contributed to FIB levels. Locations of different contributors vary throughout the study area, and the results can inform site specific recommendations to reduce fecal bacteria pollution.

First flush phenomena were also observed at several sampling sites and likely explain the increase in FIB concentrations and fecal source detection during the first two weeks of the study. First flush occurs during initial rain events as pollutants that have built up on land between dry periods are washed to creeks. FIB levels are often higher during first flush events compared to rain events following the first flush.

Recommendations and approaches to improve surface water quality within the Pajaro River watershed are provided.

Introduction and Background

Introduction

Surface water bodies in the County that are impacted by animal or human waste possess the potential for human risk from fecal bacteria and viruses that may cause illness. In accordance with a MOU between the City of Gilroy, the City of Morgan Hill, and Santa Clara County, and in response to the fecal coliform TMDL, the City of Gilroy led sampling in the Pajaro River Watershed from October 2012 through June 2014. During this period, samples were collected approximately once a week at four CCRWQCB sample locations when water was present. Additional sampling of outlets was attempted by the cities of Gilroy and Morgan Hill, but efforts were hindered by dry conditions. The regional sampling program was suspended by the CCRWQCB beginning July 2014 and a new program was developed in 2015 that focused more on source identification rather than receiving water monitoring for TMDL compliance.

The Pajaro River, Llagas Creek, Furlong (Jones) Creek, and Uvas-Carnadero Creek are 303(d) listed for fecal coliform and *E. coli*. Pacheco Creek is also 303(d) listed for fecal coliform. TMDL requirements have been enacted for fecal coliform in all the above listed waterways, as well as others within the Pajaro River hydrologic unit (U.S. Environmental Protection Agency [U.S. EPA], 2010).

Regulatory Background

Section 303(d) of the Federal Clean Water Act requires the State and Regional Water Boards to assess water quality data for California's waters every two years to determine if they contain pollutants at levels that exceed protective water quality criteria and standards. This review generates the 303(d) list of impaired water bodies, which is then approved by the U.S. Environmental Protection Agency (USEPA). Placement of a water body and its relevant pollutant(s) on the 303(d) list may initiate the development of a Total Maximum Daily Load (TMDL). A TMDL determines the value of the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. The TMDL then establishes allocations typically in the form of load limits or other regulatory measures to the pollutant sources with the goal of reducing the amount of the pollutant entering the water body to meet water quality standards. Water Quality Standards are set based on the beneficial uses assigned to a water body. Such uses include freshwater habitat (cold/warm), water supply (agricultural, municipal and domestic), recreation (contact and non-contact), fishing, and wildlife habitat

Pathogens in Water Bodies and Fecal Indicator Bacteria

Fecal bacteria concentrations in the waterways vary significantly seasonally. During the wet season, rain may affect bacteria concentrations in rivers and creeks in two competing ways: rainfall, particularly from first flush rain events, may increase bacteria levels in waterways by transporting fecal matter from land surfaces to creeks and rivers by stormwater runoff; alternatively, increased rainfall to waterways dilutes preexisting levels of fecal bacteria and provides a fresh water source (Hathaway et al., 2011). Disturbance of sediment in the creek by inflow of storm runoff can also increase bacteria concentrations by causing resuspension of bacteria that had previously settled out of the water column (Anderson et al., 2005; Brinkmeyer et al., 2015; Byappanahalli et al., 2012).

Examples of pathogens (microorganisms that cause disease) of concern in recreational water include *Cryptosporidium* spp., *Giardia lamblia*, *Legionella* spp., and enteroviruses (U.S. EPA, December 13, 2013). Pathogens reach water bodies through transport of fecal matter via runoff, combined sewer overflows, leaking sanitary sewer lines, and by direct input from domestic animals, wildlife and occasionally humans. These specific microorganisms can be difficult to test for in water due to their variety and low concentrations. Instead, FIB are used to determine the presence of fecal matter in water. Ideally FIB should:

- *Be easily detected using simple laboratory tests.*
- *Generally, not be present in unpolluted waters.*
- *Appear in concentrations that can be correlated with the extent of contamination.*
- *Have a die-off rate that is not faster than the die-off rate of the pathogens of concern*

-(U.S. EPA, June 20, 2013).

The most common FIB used to test water quality are: total coliform bacteria, fecal coliform bacteria, *Escherichia coli (E. coli)*, fecal streptococci bacteria, and enterococci bacteria (U.S. EPA, March 6, 2012). See Figure 2 for visual depiction of the relationship between different types of FIB.

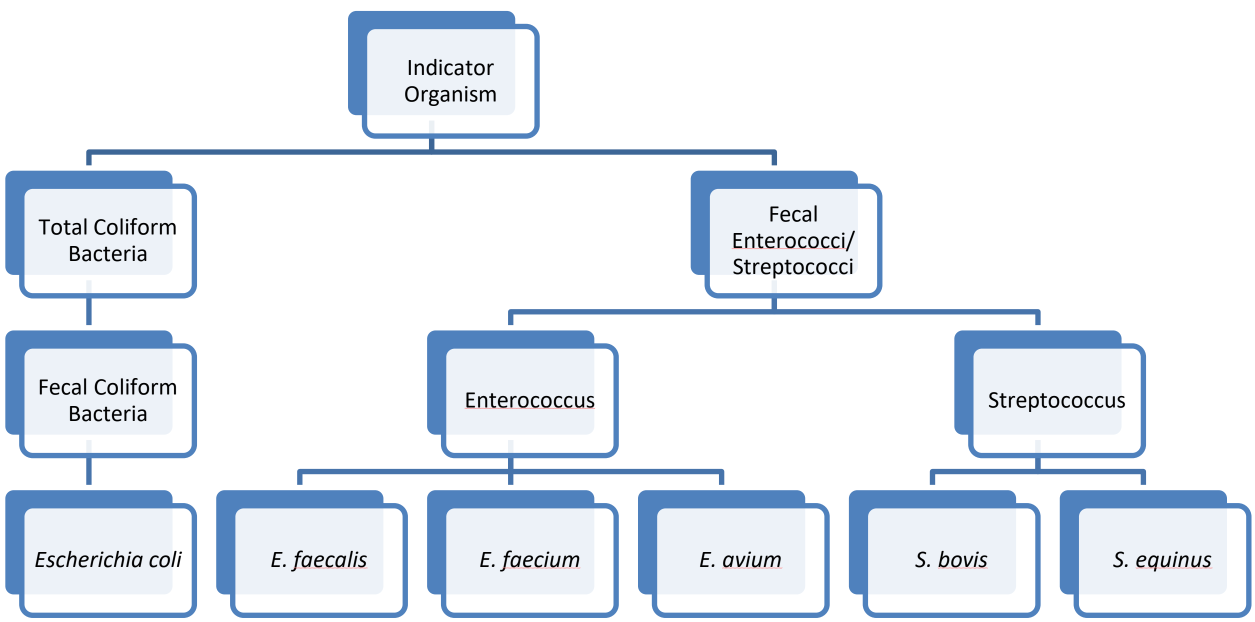

Figure 1. Fecal Indicator Bacteria relationship hierarchy, recreated from U.S. EPA website (U.S. EPA, June 20, 2013).

Human exposure to microbial pathogens can occur from accidental or intentional ingestion of water during activities such as swimming, wading, playing, or washing in waterways with potential pathogen problems. These types of activities categorize water use as contact recreational (REC-1). Other recreational activities such as boating in, hiking along or camping near lakes or waterways categorize such water uses as non-contact recreational (REC-2) due to lower risk of accidental ingestion. Most waterways in the Pajaro River hydrologic unit, including Pajaro River, Pacheco Creek, Llagas Creek, and Uvas-Carnadero Creek, are categorized for REC-1 uses. The extent to which these waterways are used for REC-1 activities has not been confirmed prior to this study, however certain locations such as Christmas Hill Park have a high likelihood of REC-1 usage.

Regulatory Recommendations for Fecal Indicator Bacteria

Specific regulation for contact and non-contact recreational use in California water bodies is stated in each region's Water Board Basin Plan. A summary of the 2016 CCRWQCB Basin Plan thresholds for fecal coliforms is provided in Table 1. The REC-1 thresholds are consistent with the fecal coliform TMDL requirements for the Pajaro River Watershed.

Table 1. CCRWQCB Basin Plan Requirements. Values are given as Most Probable Number (MPN) of colony forming units of fecal coliforms, based on the logarithmic mean of a minimum of 5 samples collected over a 30-day period.

Use	**Fecal Coliforms (MPN/100 mL)**
Water Contact Recreation (REC-1)	Log mean < 200 90th percentile < 400
Non-contact Water Recreation (REC-2)	Log mean < 2000 90th percentile < 4000

Based on the CCRWQCB Basin Plan, regulatory compliance testing should include fecal coliform bacteria. However, *E. Coli* and enterococci test results are recommended by the U.S. EPA as superior indicators of fecal matter presence:

> *Studies conducted by EPA to determine the correlation between different bacterial indicators and the occurrence of digestive system illness at swimming beaches suggest that the best indicators of health risk from recreational water contact in fresh water are E. coli and enterococci. For salt water, enterococci are the best. Interestingly, fecal coliforms as a group were determined to be a poor indicator of the risk of digestive system illness. However, many states continue to use fecal coliforms as their primary health risk indicator.*
>
> *If your state is still using total or fecal coliforms as the indicator bacteria and you want to know whether the water meets state water quality standards, you should monitor fecal coliforms.* ***However, if you want to know the health risk from recreational water contact, the results of EPA studies suggest that you should consider switching to the E. coli or enterococci method for testing fresh water.*** *In any case, it is best to consult with the water quality division of your state's environmental agency, especially if you expect them to use your data.*
>
> - (U.S. EPA, March 6, 2012)

Current U.S. EPA recommended water quality criteria for *E. coli and* enterococci to protect primary water contact activities are summarized in Table 2. In this study, Recommendation 1 (Rec-1) will be used for comparison. EPA recommendations are provided in colony forming units (cfu) of indicator bacteria per 100 mL. CCRWQCB fecal coliform criteria and previous studies in the Pajaro River Watershed report indicator bacteria levels in most probable number (MPN) units. The MPN method of bacterial analysis provides a probability estimate for cfu. Although some studies have shown that MPN results are on average higher than cfu values (Gronewold and Wolpert, 2008), the MPN value is often used interchangeably when comparing with CFU value.

Table 2. U.S. EPA Recommended Testing, 2012. Duration and Frequency for Primary Contact:

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

* The water body geometric mean (GM) should not be greater than the selected GM magnitude in any 30-day interval.
[t] There should not be greater than a ten percent excursion frequency of the selected statistical threshold value (STV) magnitude in the same 30-day interval (U. S. EPA, Office of Water, 2012).

Frequency of Recommended Testing for Fecal Indicator Bacteria

Both CCRWQCB Basin Plan regulations and U.S. EPA recommendations necessitate FIB assessments to be based on a minimum of 5 samples collected within a 30-day window at each site for best results in determining the level of potentially harmful fecal bacteria present. The results of the 5 samples are then used to calculate a mean value (logarithmic or geometric mean) of the dataset for the sampling site. The statistical threshold value (STV) approximates the 90th percentile maximum value recommended for recreational water quality: this value should not be exceeded by more than 10% of the samples collected at each site.

Land Use and Fecal Indicating Bacteria Sources within the Pajaro River Watershed

Most land use in the South Santa Clara County section of the Pajaro River Watershed is agricultural: farmland and grazing land (Figure 1, data from the California Department of Conservation, 2012). The Santa Clara Valley lowlands of the Pajaro River watershed, historically covered by grasslands, wet and alkali meadows, oak savannah, oak woodlands, and freshwater marshes, are now predominantly developed for agriculture and urban land uses. Stream flows in this region range from perennial to intermittent.

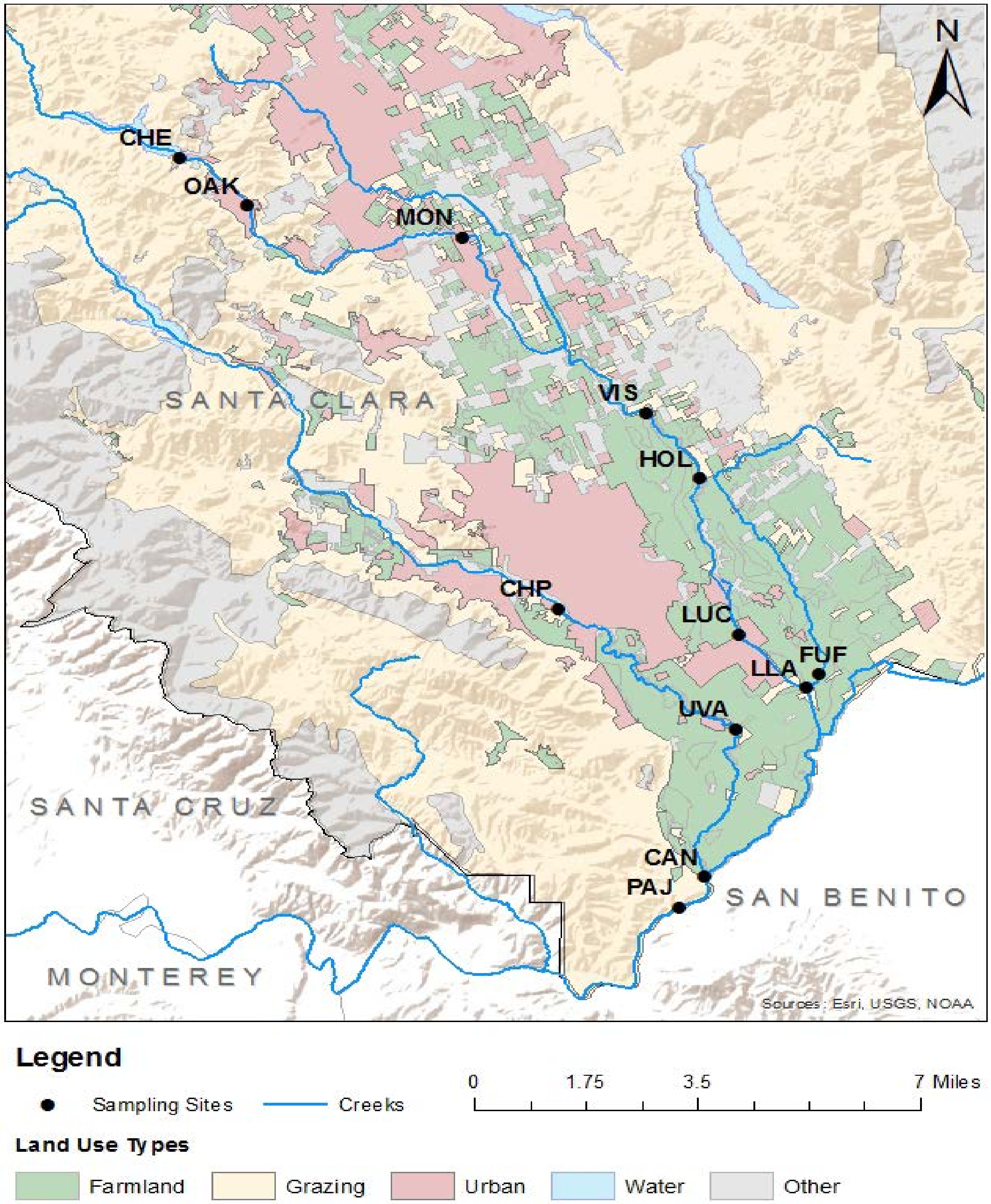

Figure 2. Land use types surrounding waterways of the Pajaro River Watershed in Santa Clara County. Sampling sites discussed in this report are included for reference. Land use GIS data is from the California Department of Conservation: Farmland Mapping and Monitoring Program, 2012.

Fecal coliform sources for the Pajaro River watershed are described as follows:

> *The relative order of controllable sources contributing fecal coliform in the Pajaro River Watershed, in decreasing order of contribution are: (1) storm drain discharges to municipally owned and operated storm sewer systems required to be covered by an NPDES permit (MS4s); (2) domestic animal discharges that do not discharge to MS4s; (3) spills and leaks from Sanitary*

Sewer Collection and Treatment Systems; and (4) private sewer laterals connected to municipal sanitary sewer collection systems. Natural, uncontrollable sources also contribute fecal coliform in the Pajaro River Watershed. - (CCRWQCB, 2016)

Microbial Source Tracking

In addition to identifying contact recreational waterways and water bodies with potentially hazardous levels of harmful bacteria from fecal matter, determining possible sources of the fecal matter is key to reducing public health risk. Microbial Source Tracking (MST) is a method of identifying origins of fecal bacteria by analyzing genetic markers. Successful identification of the main sources of fecal matter to waterways can allow actions to be implemented to limit fecal matter input at the source.

MST involves assessing water samples for bacterial biomarkers, typically by polymerase chain reaction (PCR) technique, then comparing the results to a chosen library of bacteroidales genetic markers. Analytical results may be quantitative, semi-quantitative, or qualitative (present/absent). For comparison and determination of fecal matter origin, MST laboratories use either a library dependent or a library independent method. Library dependent MST relies on first creating a unique library of expected bacterial biomarkers for the study area by extensive sampling of potential fecal sources, then comparing sample results from the specific study site of interest to this library. Library independent MST compares collected samples to known host-specific identifying bacteria characteristics. Example bacteroidales markers of comparison include human, cattle, non-cattle ruminant, hog, avian, and domestic pet (BioVir, 2010). Results of MST analyses are typically provided as relative abundance of biomarkers of interest.

MST is a relatively new water quality assessment tool, and, as such, does not yet have standardized recommendations for testing by the U.S. EPA or local regulatory agencies. However, research performed by private and public agencies and laboratories suggests the following actions for best results:

- Pre-assessment of sites for potential sources to facilitate accurate analytical choices and interpretation of MST results;
- collection and analysis of multiple samples over an extended period for each study site to assess natural or unnatural temporal variations;
- study of several sites within a watershed or area of interest to appropriately determine geographic variation;
- determination of background levels by sampling upstream or far downstream from the location of interest for a specific predicted fecal matter source.

Additionally, MST results are best interpreted when collected alongside other water quality parameters such as specific conductance, dissolved oxygen, and turbidity. FIB in conjunction with MST sampling is vital to providing a quantitative value for the relative abundances of genetic sources identified (U.S. EPA et al., 2011).

To meet a key performance indicator of the Safe, Clean Water and Natural Flood Protection Program (Safe Clean Water) Project B2, the Santa Clara Valley Water District (District) collaborated with the City of Gilroy, City of Morgan Hill, and County of Santa Clara to enhance their efforts through interagency cooperation by:

- testing for FIB (*Escherichia coli* [*E. coli*] and enterococci) in the Pajaro River Watershed and comparing results to Federal water quality criteria,

- engaging in a Microbial Source Tracking (MST) investigation of select sites to determine possible sources of pathogens in the watershed, and
- focusing on sites within the Pajaro River Watershed where District employees and the public may be potentially exposed to microbial pathogens in the water.

The District's Environmental Planning Unit in collaboration with the City of Gilroy, the County of Santa Clara, and the City of Morgan Hill, led a pilot study in 2015 and a larger scale study in 2016 to identify and assess sources of pathogens within the District's jurisdictional boundaries of the Pajaro River Watershed.

Methods

Sampling Design

Five water samples were collected over a 30-day period, roughly weekly at each sampling site, to compare Fecal Indicator Bacteria (FIB) results with the Environmental Protection Agency (EPA) recommended threshold for recreational water body contact (Recommendation 1). The recommended levels are provided previously in Table 2.

Fecal Indicator Bacteria, *E. coli* and Enterococci, were analyzed from each water sample. Additional water samples and/or aliquots were collected for use in Microbial Source Tracking analysis.

Sampling Sites

Sampling sites were chosen based on

1. previous Central Coast Ambient Monitoring Program (CCAMP) monitoring sites,
2. sites where District employee and the public may be potentially exposed to microbial pathogen in the water, and
3. sites of interests to the County of Santa Clara and their consultant, EOA, Inc.

Table 3. Coordinates and description of sites identified for pathogen sampling in the Pajaro Watershed, South Santa Clara County.

NAME	Y	X	Location description
OAK	37.114735	-121.688343	Llagas Creek at Oak Glen Ave
WAT	37.084610	-121.653496	Llagas Creek at Watsonville Rd
WLL	37.107350	-121.635845	Llagas Creek at Creek at Watsonville Rd
COR	37.095927	-121.599441	Corrallitos Creek upstream of East Little Llagas
ELL	37.072884	-121.584672	East Little Llagas Creek at Church Ave
MON	37.095689	-121.616788	Llagas Creek at Monterey Hwy
VIS	37.048686	-121.559186	Llagas Creek at Buena Vista Ave
UTS	37.067981	-121.579161	Unnamed Tributary South at Columbet Ave
CHP	36.996653	-121.583167	Uvas Creek at Christmas Hill Park
SBC	36.971858	-121.501578	Pajaro River on Frazier Lake Rd.-San Benito County Line
WLC	37.095889	-121.600858	WLL near Corrallitos Creek confluence
UTN	37.082494	-121.587003	Unnamed Tributary North at Columbet Ave

LLA	36.975984	-121.512218	Llagas Creek at Bloomfield Avenue
ELC	37.096756	-121.599742	ELL near Corrallitos Creek confluence
UVA	36.965092	-121.531981	Uvas Creek at Bloomfield Avenue
PAJ	36.915894	-121.549916	Pajaro River at Betabel Road
FUF	36.976164	-121.511836	Furlong (Jones) Creek near confluence w/ Llagas Creek at Bloomfield Avenue

Water sampling was planned to begin a few days after the last major rainfall event in March 2015. However, due to the California drought, little precipitation occurred and many of the creeks remained dry. To not miss the 2015 sampling season, SCVWD staff decided to continue the study as a pilot for 2015. A preliminary visit to all the sites on March 10, 2015 revealed only five (MON, CHP, PAJ, LLA, and FUF see table 3) with flowing water. An additional site (SBC) was identified during the site visit near LLA and FUF and was subsequently added to the study. Site SBC lies on the Santa Clara-San Benito County border and merges with Llagas Creek 0.75 mile downstream of the SBC sampling site. The site once connected San Felipe Lake to the Pajaro River until the creation of Henry-Miller Canal diverted water from its natural path. Only during high water level and rainfall events does San Felipe Lake discharge water into the Pajaro River at SBC. The site contained mostly near-stagnant water and was adjacent to agriculture fields and cattle. During the first sampling trip on April 7, 2015, site CHP was nearly dry and was consequently removed from the pilot study, leaving the following five sampling sites: MON, PAJ, LLA, FUF and SBC for the pilot study. Sampling ended on May 7, 2015.

After the pilot study was conducted, SCVWD staff collaborated with EOA Inc., who was representing the County of Santa Clara, to expand the study's scope for 2016. The number of sampling sites increased to seventeen but only twelve were sampled (grey background shading in Table 3) because of stream flow challenges related to the lack of flowing water. Sampling began on March 9, 2016 and ended on April 7, 2016. During this study, site ELL and VIS were dry after the second sampling event and WLL dried after the April 4, 2016 sampling event. Coordinates and a location description of each site is provided in Table 4. A map of the seventeen identified sites is provided in Figure 3.

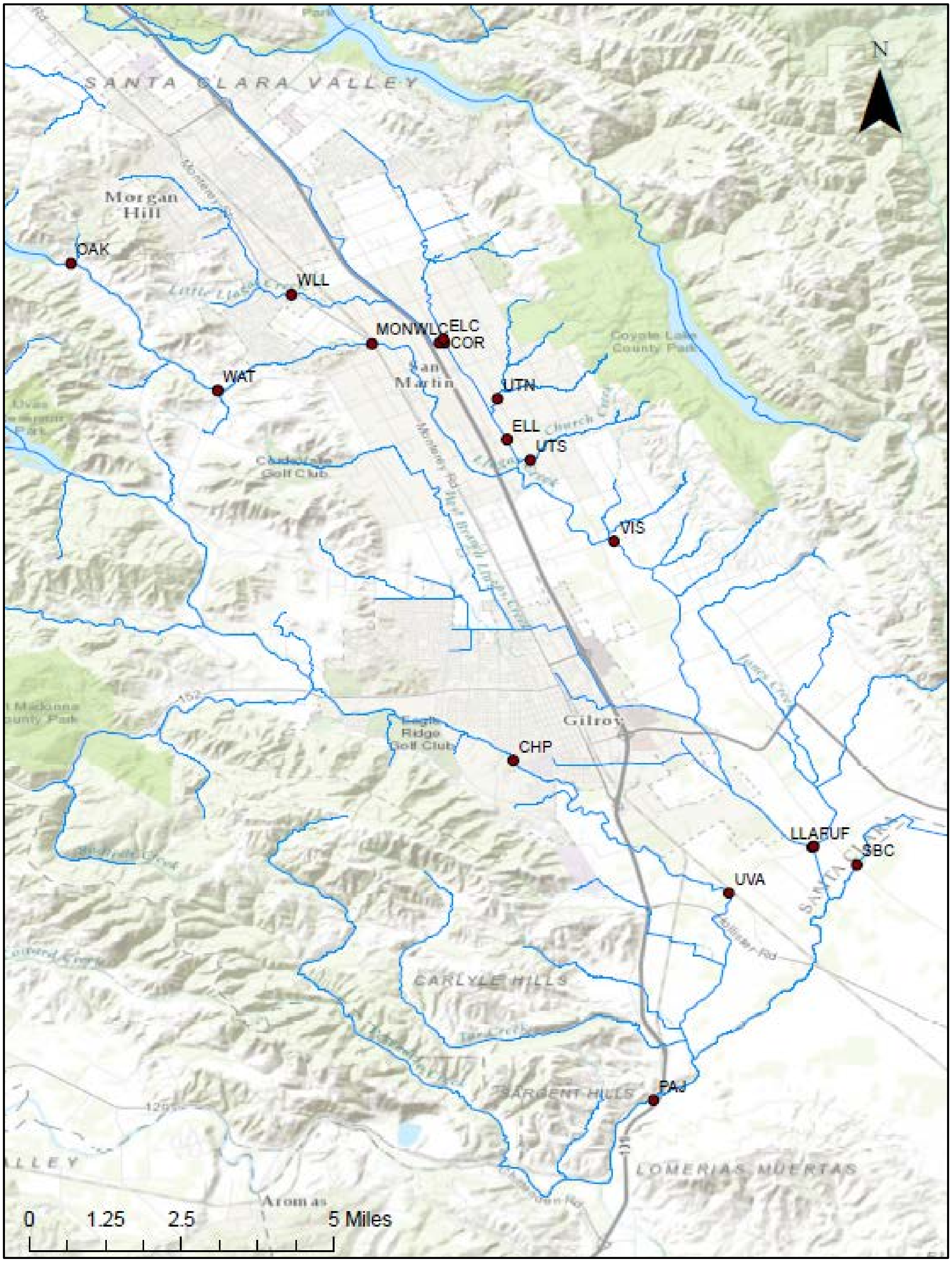

Figure 3. Sites identified for pathogen sampling in the Pajaro Watershed portion of South Santa Clara County.

Sample Collection

In 2015, water samples were collected using a bottle holding sampling rod and an attached glass amber bottle. The contents were poured into 2 sterile plastic containers at each site: one for fecal indicator bacteria and one for microbial source tracking. Before collecting the water sample, the amber bottle was triple rinsed with source water from the sampling site. In between each sampling site, the amber bottle was rinsed first with soap and brushed and then triple rinsed with Millipore water. Additional water quality parameters were collected from each site including dissolved oxygen (DO), pH, conductivity, and temperature using a YSI EXO2 multiparameter sonde (Appendix B). Water samples were collected weekly for 30 days to calculate the Geometric Mean (GM). Site SBC was not collected on week 3 because of roadway safety concerns but was collected twice during week 5.

After the 2015 pilot study, District staff consulted with the District's Water Quality Lab regarding observed variability in duplicate sampling. Our discussion revealed that water sample collections were highly and inherently variable due to the nature of bacteria in the water. Staff at the Water Quality Lab recommended using sterilized amber bottles (1L) to collect a larger volume of sample. A larger sample would allow lab personnel to homogenize the sample to get a more accurate representation of the bacteria concentration in the water. Aliquots were also taken from the 1L bottle for MST analysis. No field blanks were collected in 2016 as the amber bottles were sterilized in-house and duplicates were only collected at EOA sites (OAK, WAT, WLL, ELL, MON and VIS) based on their study plan. Results of duplicates will not be discussed in this report.

In 2016, water samples were collected about 1 meter from the water's edge. Staff wore nitrile gloves while collecting samples. A sterilized 1L amber bottle was used to capture a representative water sample. Samples were collected with the bottle and cap fully submerged underwater without disturbing the sediment. At site SBC, a sampling rod was used to collect samples off a creek overpass. Sampling at CHP, UVA, LLA, SBC, FUF and PAJ were conducted by the District while sampling at OAK, WAT, WLL, ELL, MON and VIS were conducted by EOA. During the study, water quality parameters (D.O, conductivity, pH, etc.) were measured at all the District's sites and only once on 3/16/2016 at EOA's sites (Appendix D).

Sample Analysis

<u>Fecal Indicator Bacteria Analysis</u>

Fecal indicator bacteria samples were analyzed in-house at the Santa Clara Valley Water District Water Quality Lab using the following methods:

- Enterococci by ENTEROLERT (ASTMD6503-99)
- Total Coliforms and *E. Coli* by COLILERT Quanti-Tray (AM 9223 B)

Results are presented in most probable number (MPN) units. The MPN method of bacterial analysis provides a probability estimate for Colony Forming Units (CFU). The MPN units are considered equivalent to CFU in this evaluation.

<u>Microbial Source Tracking Analysis</u>

Microbial source tracking samples (2015) and aliquots (2016) were filtered through a 0.4 µm membrane filter (Pall MicroFunnel PN FMFNL1050) and stored in a -20°C freezer. The filters were then sent to Source Molecular Corporation for analysis based on staff interpretation of FIB results and/or potential fecal sources in the area.

In 2015, MST samples were sent to Source Molecular Corporation for analysis only when FIB levels exceeded EPA Rec- 1 threshold. MST samples collected during the first two weeks were tested initially for Human, Cow and Bird biomarkers. Horse testing was added to week 3, 4 and 5 testing after reviewing aerial photos on Google Earth that indicated a potential that upstream horse presence could be FIB sources. The phylum Bacteroidetes was used to test for Human (EPA method), Cows, and Horses whereas the genus Helicobacter was used in birds. Source Molecular Corporation's methods mostly involve analyzing 16S ribosomal RNA of Bacteroidales.

After attending an information sharing luncheon hosted by SMC and GeoSyntec in February 2016, District staff learned that although FIB may not have exceeded recommended thresholds, it would still be beneficial to know what fecal sources are present in the water. Therefore, MST samples collected in spring of 2016 were sent for analysis based on the potential upstream sources, via field site visits and reviewing aerial images on Google Earth, and not solely on FIB results. In addition, new research by the Source Identification Protocol Project (SIPP) indicates that testing two human markers may provide better detection of human fecal matter (personal communication with SMC). Considering this new information, water samples tested for human fecal bacteria were analyzed using the recommended combination of the Dorei biomarker and the EPA developed biomarker.

Sampling Conditions

In 2015, Santa Clara County experienced below average rainfall. Apart from a section of creek downstream of Uvas Reservoir, the Uvas sub-watershed was mostly dry when sampling began on 4/7/2015. Sampling occurred later than anticipated because of continued optimism for rain. Water released from the reservoir infiltrated into the creek bed and did not reach CHP and UVA. Thus, water from the Uvas sub-watershed did not contribute directly to any of the observed FIB and MST results at PAJ. Only one small rain event occurred during the study. On the morning of April 7th, 2015, the first day of sampling, 0.5'' of rain fell in South Santa Clara County. The rain had little impact as most of the water quickly infiltrated into the ground because of the dry winter.

In 2016, Santa Clara County experienced average rainfall overall, which provided staff the opportunity to sample more sites. However, before sampling occurred in March, February had little to no rain for the entire month. Sampling also occurred one month earlier than in 2015. Water released from Uvas Reservoir made its way through CHP and UVA and the surface water remained connected to the Llagas sub-watershed throughout the sampling period. Thus, surface water from the Uvas sub-watershed contributed directly to the observed FIB and MST results at PAJ. In addition, three rainfall events occurred within a few days of the sampling day. The amount and date of precipitation of each event are shown in table 4.

Table 4: March 2016 Precipitation Events

Date	Precipitation
3/7/2016	0.7"
3/13/2016	1.7"
3/21/2016	0.1"

Results

<u>Fecal Indicator Bacteria</u>

Some *E. coli* and Enterococci lab results were reported with a higher than or less than value because the samples exceeded the initial screening test limits. Values used to calculate the geometric mean, the N-th root of the product of N numbers, were the values reported without the greater or less than sign. For the GM, a (*) or (**) symbol is used to indicate values that should be less than or greater than the calculated value (Table 2). Duplicate samples were not used in any calculations.

The Statistical Threshold Value is derived from the water quality distribution as defined by the Geometric Mean. Because our study used the minimum sample number for calculating Geometric Mean (5 samples within a 30-day period), the small sample size causes the <10% STV to be exceeded if only 1/5 samples exceeds the EPA Rec. 1 values for *E. coli* and Enterococci. Due to this factor, sample sites with 40% or greater of samples exceeding the EPA Rec. 1 values will be focused on when interpreting STV exceedance results.

During the sampling period in 2015, Site PAJ and MON exceeded the Rec-1 GM value for Entero. while site SBC, FUF, and LLA exceeded the Rec-1 GM threshold for both FIBs (Table 5). STV was exceeded at SBC and FUF for both FIBs and for Entero at LLA. During the sampling period in 2016, PAJ, SBC, LLA, UVA and OAK exceeded the Rec-1 threshold for Entero, while FUF, MON, and WAT exceeded the Rec-1 GM threshold for both FIBs (Table 6). STV was exceeded at FUF, MON, and WAT for both FIBs and for Entero. at SBC, LLA, and OAK.

Table 5. 2015 Fecal Indicator Bacteria Results – Geometric Mean and Statistical Threshold Value Recommendation 1

2015 Fecal Indicator Bacteria Results- Geometric Mean and Statistical Threshold Value					
Site	Test	GM Value (MPN/100mL)	EPA Recommendation 1 GM (cfu/100mL)	STV	EPA Recommendation 1 STV (< 10 %)
PAJ	*E. coli*	100	126	1/5	*E. Coli* = 410 cfu/100ml, Enterococci =130 cfu/100mL
	Enterococci	81*	35	0/5	
SBC	*E. coli*	720**	126	2/5	
	Enterococci	1829**	35	5/5	
FUF	*E. coli*	1976**	126	4/5	
	Enterococci	1748**	35	5/5	
LLA	*E. coli*	302	126	1/5	
	Enterococci	225	35	4/5	
MON	*E. coli*	38*	126	0/5	
	Enterococci	40	35	0/5	

** GM should be > than based on reported results (exceeded test limit), red indicates an exceeded value.

Table 6. 2016 Fecal Indicator Bacteria Results – Geometric Mean and Statistical Threshold Value Recommendation 1

2016 Fecal Indicator Bacteria Results- Geometric Mean and Statistical Threshold Value					
Site	Test	GM Value (MPN/100mL)	EPA Recommendation 1 GM (cfu/100mL)	STV	EPA Recommendation 1 STV (< 10 %)
PAJ	*E. coli*	96	126	0/5	*E. Coli* = 410 cfu/100ml, Enterococci =130 cfu/100mL
	Enterococci	89	35	1/5	
SBC	*E. coli*	121	126	0/5	
	Enterococci	570**	35	4/5	
FUF	*E. coli*	259	126	2/5	
	Enterococci	508	35	5/5	
LLA	*E. coli*	125	126	0/5	
	Enterococci	124	35	2/5	
MON	*E. coli*	306	126	3/5	
	Enterococci	424	35	3/5	
CHP	*E. coli*	50	126	0/5	
	Enterococci	30	35	1/5	
UVA	*E. coli*	124	126	0/5	
	Enterococci	93	35	2/5	
WAT	*E. coli*	183	126	1/5	
	Enterococci	148	35	2/5	
OAK	*E. coli*	39	126	1/5	
	Enterococci	103	35	2/5	

** GM should be > than based on reported results (exceeded test limit), red indicates an exceeded value

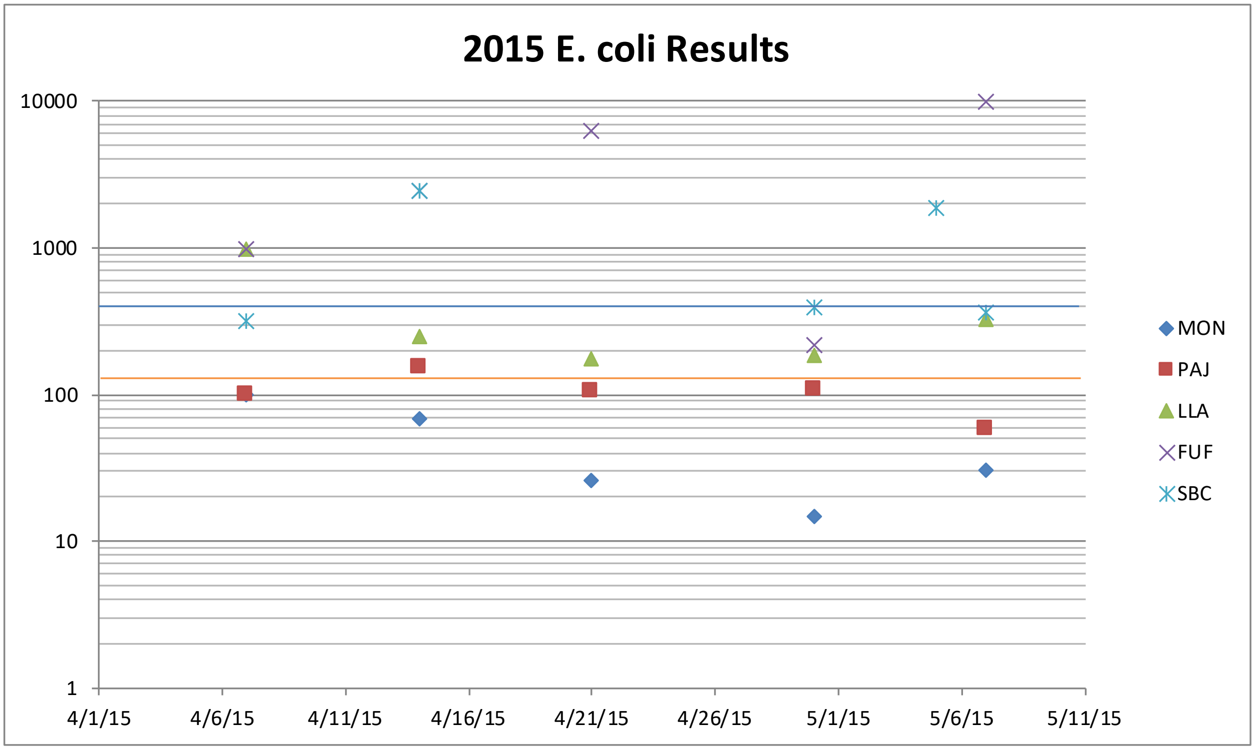

Figure 4. 2015 E. coli Results. Blue line indicates Rec-1 STV value and Orange line Rec-1 Geometric Mean.

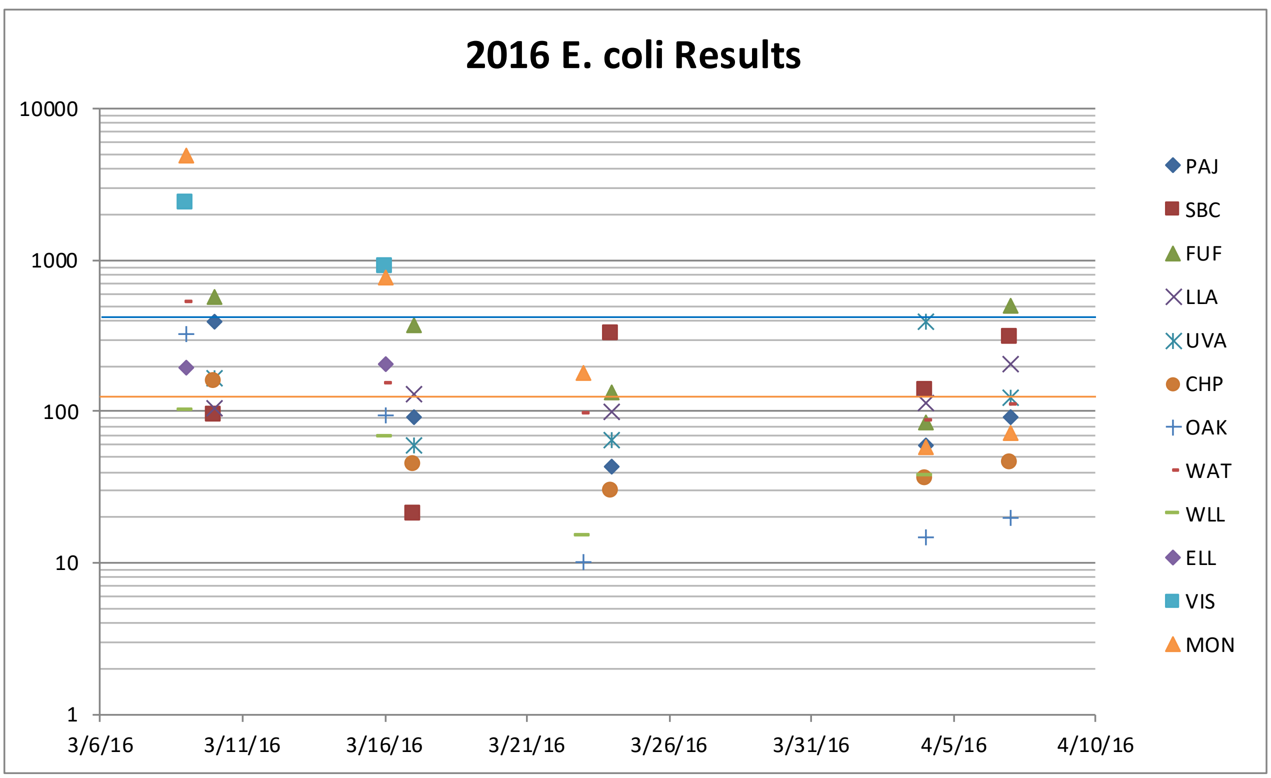

Figure 5. 2016 E. coli Results. Blue line indicates Rec-1 STV value and Orange line Rec-1 Geometric Mean.

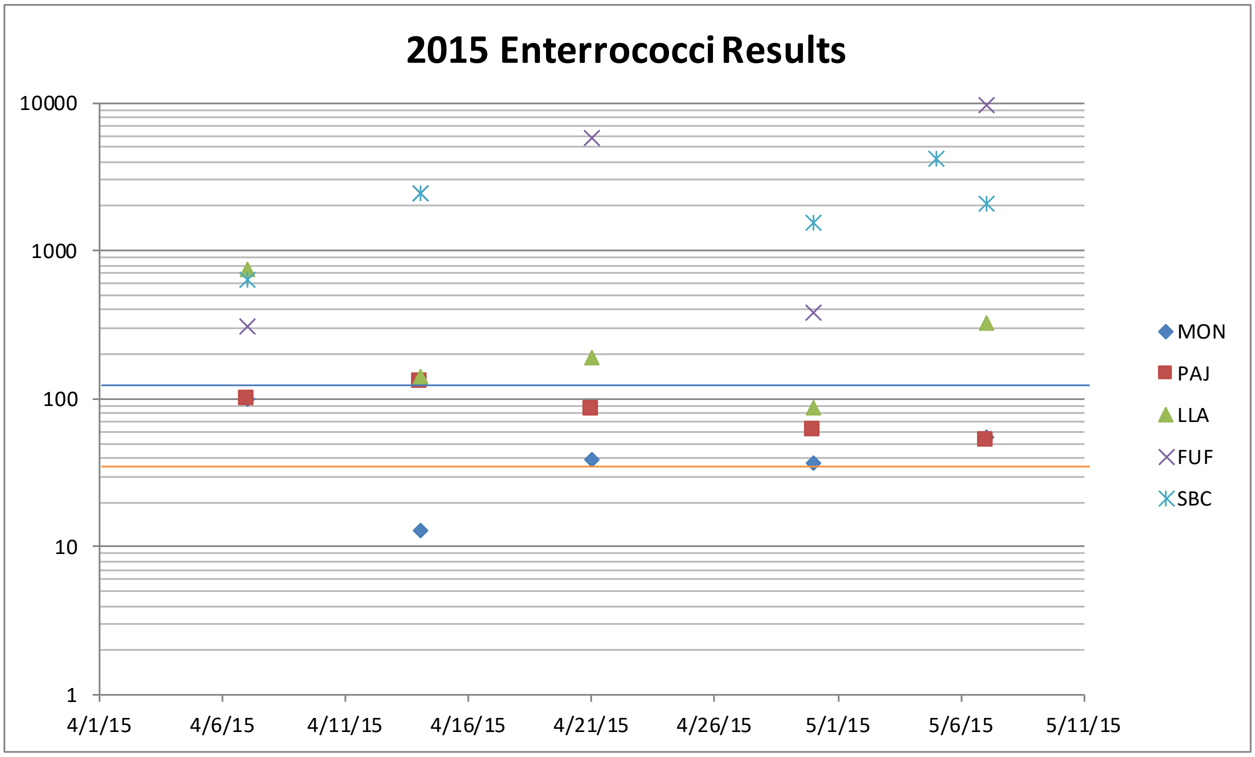

Figure 6. 2015 Enterococci Results. Blue line indicates Rec-1 STV value and Orange line Rec-1 Geometric Mean.

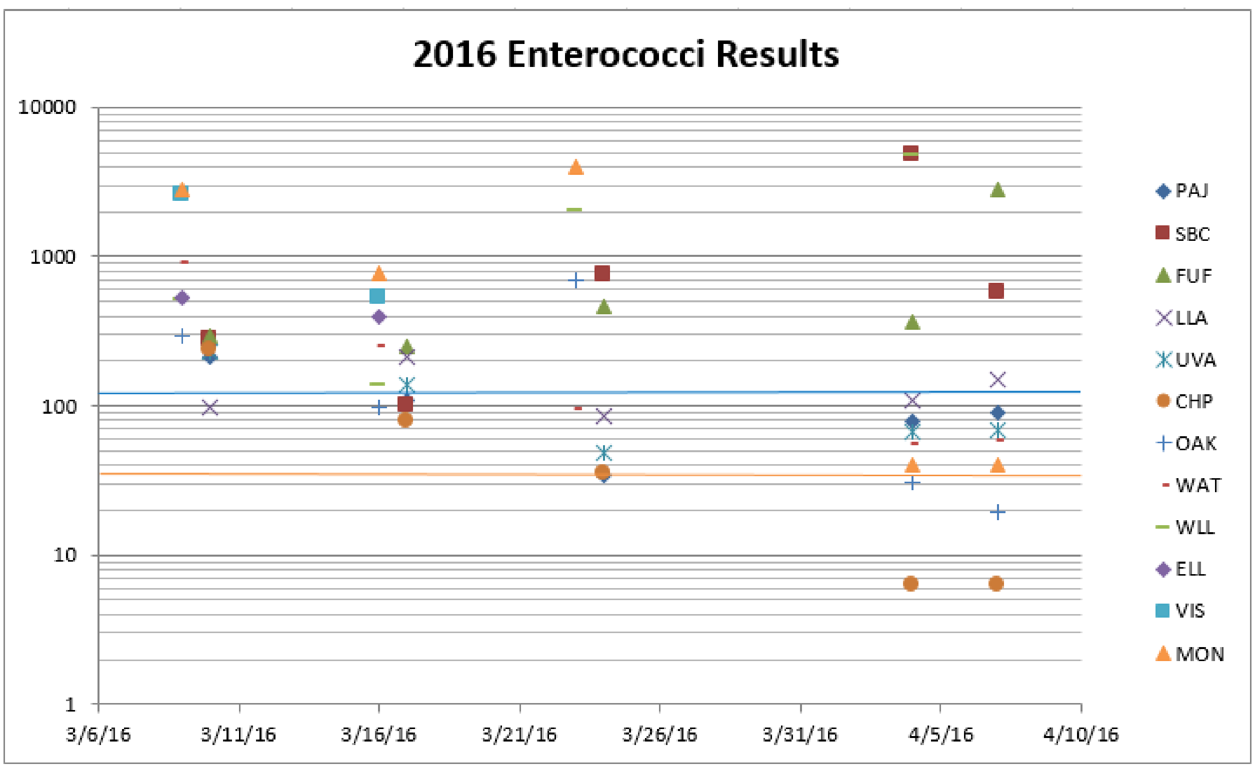

Figure 7. 2016 Enterococci Results. Blue line indicates Rec-1 STV value and Orange line Rec-1 Geometric Mean.

2015 Microbial Source Tracking Results Map

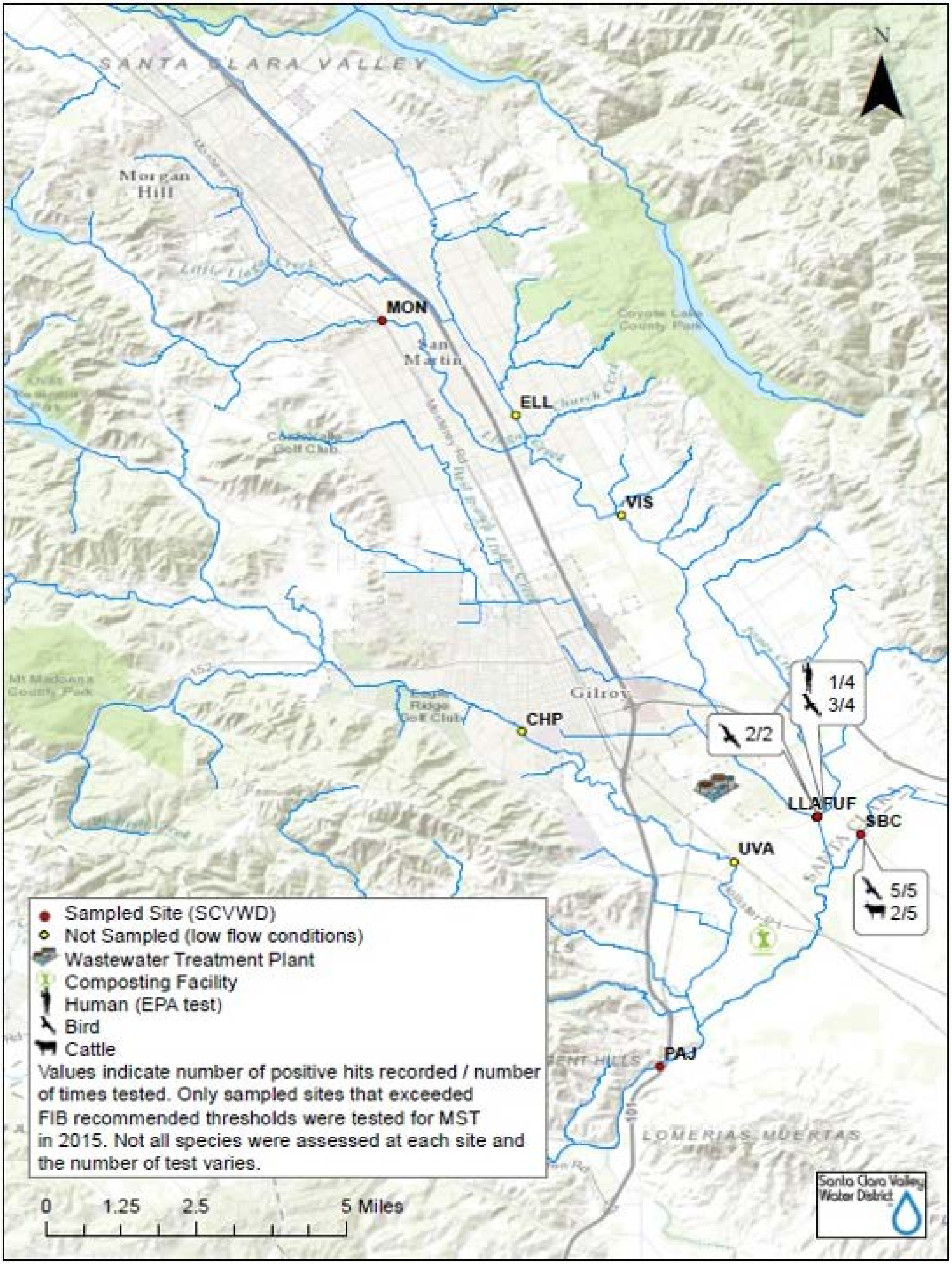

Figure 8. 2015 Microbial Source Tracking Results

2016 Microbial Source Tracking Results Map

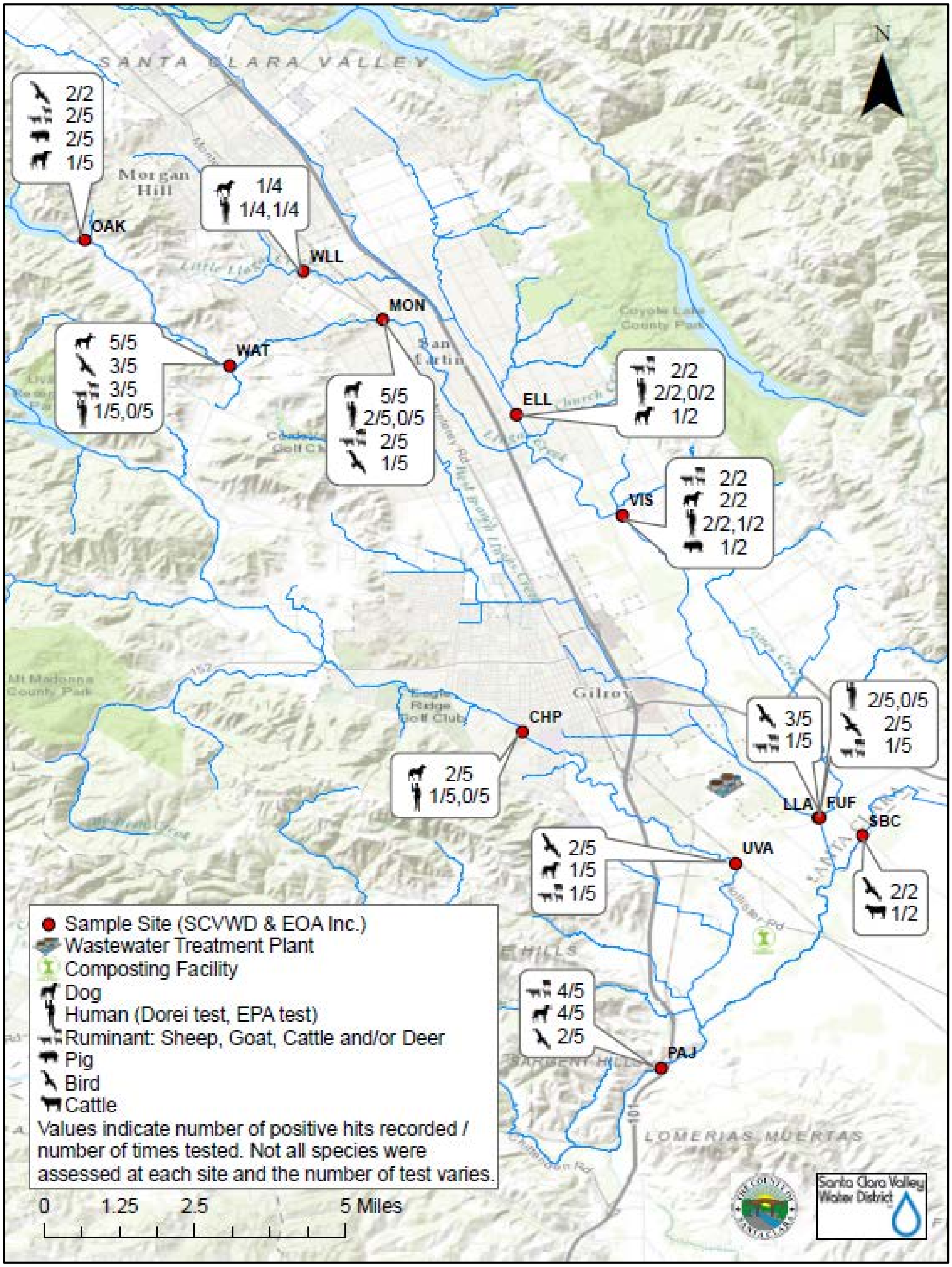

Figure 9. 2016 Microbial Source Tracking Results.

Discussion

2015 vs. 2016 Approach

The MST approaches for 2015 and 2016 differed in several ways. In the 2015 MST analysis, only one human biomarker was used (EPA), while 2016 used both EPA and Dorei. The EPA biomarker is an EPA-patented target for *Bacteriodales*-like bacteria, while the Dorei biomarker focuses on specific strains of *Bacteroides dorei*, a species common in the gut microbiome of warm blooded animals. After using both the EPA and Dorei test in 2016, it was clear that the Dorei test was more sensitive in detecting human fecal material than the EPA test. In 2016, the Dorei biomarker received a total of 11 hits, while the EPA test received 2 when both were tested for at the same sites. Due to these factors, it is possible that 2015 human MST results may have been higher than what the EPA test alone revealed.

In 2015 the MST study focused on detecting cow biomarkers, due to the human health risks associated with pathogens from cow feces such as Cryptosporidia, Giardia, Salmonella, and E. coli O157 (Rosen, 2000). In 2015 there were 2/5 hits for cow biomarkers at site SBC, 0/2 at LLA, and 0/4 at FUF. 2016 MST analysis expanded to include the ruminant biomarker that targets sources from sheep, goat, cattle, and/or deer, but cannot conclude specifically what ruminant made up each measurable result. Use of ruminant biomarker in 2016 along with field reconnaissance was useful for gaining a view of other animal sources that may be contributing to fecal contamination in the watershed, and helped to interpret 2015 sites that had non-detects for cow, but still had high FIB values. Other MST biomarkers added during the 2016 data collection included dog and pig.

The blanket approach used in 2016 to identify sources of fecal pollution had positive results. MST testing detected Dog and Bird at PAJ, Cow and Bird at SBC, Bird at FUF, UVA and LLA, Bird and Human at CHP, Dog at MON, Bird, Dog and Ruminant at WAT, and Bird, Pig Ruminant at OAK when associated E. coli and/or Entero concentrations were below the recommended threshold (when comparing the individual FIB concentration to the recommended GM concentration). These fecal sources would not have been identified if the study had followed the 2015 approach of testing host species only when FIB concentration exceeded recommended threshold levels. Tradeoffs to this approach include higher laboratory cost and a lower chance of host detection because of lower FIB concentration.

In December 2016, the SCVWD sent coyote scat samples to Source Molecular for fecal identification analysis. Coyote scat samples were identified and collected by District staff biologists while in the field. In addition to the scat identified in the field, the District sent coyote feces from a coyote at the Wildlife Center of Silicon Valley.

Table 7: Locations and Dates for Tested Coyote Scat

Sample ID	Location	Time of Collection
SCVWD-1	Coyote Canal at Bailey	11/17/2016, 3:39 PM
SCVWD-2	HWY 101 culvert to golf course	11/29/2016, 11:30 AM
SCVWD-3	HWY 101 culvert to golf course	11/29/2016, 12:00 PM
SCVWD-4	HWY 101 culvert to golf course	11/29/2016, 11:34 AM
SCVWD-5	Culvert 10 East Coyote Ridge	11/29/2016, 12:45 PM
SCVWD-6	Culvert 10 East Coyote Ridge	11/29/2016, 12:50 PM
WCSV 1 through 5	Wildlife Center of Silicon Valley	11/23/2016, 12:00 PM

A composite was created from the samples and tested against the Source Molecular dog biomarker. The coyote fecal sample composite analysis tested positive for dog biomarker. This result indicates several study locations that are considered to have contributions from domestic dogs could potentially be contributions from coyote or other native canines.

Site Level Analysis

OAK is located ¼ mile downstream of Chesbro Reservoir at the corner of Oak Glen Ave and Llagas road. Water from the reservoir is released year-round into Llagas Creek ranging from 1 to 12 cubic feet per second. On the southern end of the creek is Chesbro Lake Drive which lies parallel to the creek and separates the surrounding rural neighborhood from the creek. On the northern end of the creek are three to four properties that border the creek's riparian zone.

<u>2015:</u> Samples were not collected at OAK in 2015 because it was added by EOA as a reference site for 2016.

<u>2016:</u> Fecal indicator bacteria results at OAK were initially high (*E. coli* at 321 MPN/100 mL and Entero at 290 MPN/100 mL). However, the four subsequent FIB analyses (except week 3 Entero) were a magnitude lower than the first sampling event indicating that a phenomenon likely occurred to cause the large difference. The sampling event coincided with the lack of rain in February and the first major rain event on 3/7/16 (0.7'' of rain). Precipitation likely contributed to observed high FIB concentration at week 1 (3/9/16) by producing runoff of surrounding fecal matter into the creek. Additional precipitation occurred on 3/13/16 (1.7'' of rain) before the second sampling event on 3/16 and resulted in an *E. Coli* value of 92.4 MPN/100 mL and Entero. of 97 MPN/100 mL. Fecal runoff likely decreased after the first rain event and the increase in rainfall (1.7'') would have reduced the FIB concentration further.

Aerial photos and field reconnaissance of the properties bordering the creek reveal that dogs, ruminant species, and horses were present. A specific ruminant source of sheep was observed on property adjacent to the creek. Detection of four fecal sources (dog, ruminant, bird, and pig) during the first sampling event is consistent with the high FIB concentrations. By week 2, dog was no longer present, and the concentration of ruminant and pig decreased. For weeks three to five, no animals were detected, and FIBs were in low concentration, except for an anomaly in week 3 (Entero. 688 cfu/100mL).

The presence of dog and ruminant on the adjacent properties combined with rainfall events may have been the source and cause of fecal pollution at OAK. Dog and ruminant were both detected in water samples collected during week 1 and ruminant again in week 2. Cows were tested to determine if it was the source of the ruminant hit, however no cow biomarkers were detected from the samples, making the sheep that were observed during reconnaissance, or an alternate ruminant species, the likely source of pollution. Horse was also not detected during the first two weeks. Trace amounts of bird were detected in the first two weeks, but these appear to be from natural sources as no anthropogenic related bird source was observed.

Figure 10. Sheep observed on a property upstream of OAK

Although pig was not observed during the reconnaissance trip or in aerial photos, it was detected in samples from weeks 1 and 2. Sources for pig fecal pollution may have been from a natural source, as wild pigs are likely residing around the reservoir, using it as a source of water, or from adjacent properties with domesticated pigs hidden out of view. No human fecal biomarkers were detected at OAK.

WAT is located approximately 3 miles downstream from OAK on Llagas Creek where it crosses Watsonville Road. Oak Glen Avenue borders most of the creek upstream of WAT to the west, and a private driveway borders along the southern portion. Residential properties border the creek to the northeast directly upstream of WAT, while the further upstream portions are intermittently bordered by open space and residential property on the eastern side.

2015: Samples were not collected at WAT in 2015 due to dry conditions in Llagas Creek.

2016: Fecal indicator bacteria results at WAT were highest in week 1 (*E. coli* 526 MPN/ mL, Entero. 920 MPN/ mL on 3/9/2016) following the precipitation event on 3/7/2016 (0.7”), and lower in the subsequent weeks. The initial high FIB values followed by a decline are similar to the FIB results further upstream at OAK. High values in week 1 followed by lower FIB values in the following weeks are likely a result of first flush runoff deposits of fecal matter following a dry period in February, and later dilution from the subsequent rain events on 3/13/2016 (1.7”) and 3/21/2016 (0.1”). Geometric mean values at WAT exceeded EPA recommendations for both E. coli and Enterococci (*E. coli* at 183 MPN/100 mL, Entero. at 148 MPN/100 mL). At WAT 40% of Enterococci samples exceeded the EPA STV compared to 20% of *E. coli* samples.

Aerial photos and field reconnaissance surrounding the creek revealed two potential sources on properties adjacent to the creek just north of the W Edmundson Ave crossing. Goats (ruminant) were observed on the eastern creek side property and horses were observed on the west side property. While no horse was detected, the observed goats are a probable ruminant source detected in weeks 1, 2, and 5, consistent in value with the FIB results. Additional potential sources were found during field reconnaissance near WAT at Sycamore Drive. Multiple cattle were observed in a fenced area adjacent to the creek, along with multiple hand-drawn slow down signs for deer. It is possible that the deer and cattle contributed to the ruminant hits at WAT in the three out of five tested weeks. Furthermore, cattle were not tested for individually, but could be present in the ruminant detection.

Dog biomarkers were present in all 5 weeks, with quantifiable values in weeks 1 and 2 and trace amounts in weeks 3-5. Dog is a probable source of fecal pollution at WAT because of the many residential properties between WAT and OAK adjacent to the creek, that are likely a result of improperly disposed pet waste or due to coyotes using the creek as a wildlife corridor. Bird was detected in trace amounts in weeks 1,2, and 4 and are presumed to be from natural sources as anthropogenic bird sources were not identified. A trace amount of human marker was detected in week 1, and it is unclear where the potential source may be, as no encampments were observed. Leaking septic tank is an unlikely source, because human was only detected once during the sampling period. Pig were not tested for at this site and not found during the field reconnaissance.

Figure 11. Fenced cattle observed upstream of WAT.

Figure 12. Warning signs indicating deer upstream of WAT

MON is located on Llagas creek downstream of WAT at the Monterey Highway crossing. Upstream of MON the creek flows through Atherton Way Hidden Pond (also known as Lake Silveria) and further upstream above the pond, the creek is bordered by residential property to the north. Residential streets

Atherton Way and Easy Street are to the south. Between Atherton Pond and MON are open space areas to the north and open space and riparian habitat to the south.

2015: In 2015, fecal indicator bacteria at MON was highest in week 1 (*E. coli* at <100 MPN/100 mL, Entero. 100 MPN/100 mL on 4/7/2015) following a rain event on the morning of the sampling day (0.5" on 4/7/2015). FIB values then decreased in the next three sample weeks but rose slightly in the final sample week on 5/7/2015 with *E. coli* at 29.9 MPN/ 100mL and Enterococci at 37.3 MPN/100 mL, corresponding to the highest flow release at Chesbro Reservoir outlet of 4.8 cfs compared to a constant 2.8 cfs in the preceding four sample weeks. The geometric mean values at MON for the 2015 sample year show the EPA Rec. 1 for geometric mean was exceeded for Enterococci at 40 MPN/100 mL. *E. coli* at site MON did not exceed the EPA Rec. 1 GM.

MST analysis was not conducted at MON for sample year 2015.

2016: In the 2016 sample year MON had the highest fecal indicator bacteria result for *E. coli* out of all the tested sites in week 1 on 3/9/2016 at 4810 MPN/100 mL, with Entero. at 2800 (precipitation 0.7" on 3/7/2016). Week 2 fecal indicator bacteria collected on 3/16/2016 then declined (*E. coli* at 762 MPN/100 mL, Entero. 770 MPN/100 mL). Fecal laden runoff from the first major rain event on 3/7/2016 following a dry period is the likely cause of the high FIB values. FIB values were much lower in the remaining sample weeks excluding one anomaly (Entero. 3970 MPN/100 mL 3/23/2016). The EPA recommended geometric means for *E. coli* and Enterococci were both exceeded at site MON in 2016 (*E. coli* at 306 MPN/100 mL, Entero. at 424 MPN/ 100 mL). Additionally, the EPA recommended statistical threshold values were exceeded by three of the five samples for both *E. coli* and Enterococci.

Aerial reconnaissance revealed two properties that had potential animal sources. The first was found to have horses, while the second is unknown as the suspected source area is in the back of private property adjacent to the creek. No other properties appeared to house animals based on aerial images.

The trail adjacent to the creek that begins at the end of Easy St and goes along Atherton Way Hidden Pond was investigated for potential sources by foot. Fecal material was found along the trail and multiple people were seen walking dogs. The fecal material seen on the trail looked to come from horse and dogs (or possibly coyote). Dog, deer, human, and bird tracks were also observed on a dried mud bank adjacent to the creek.

In the 2016 sample year, ruminant markers were detected for weeks 1 and 2, but not observed aerially with google images. However, deer tracks were seen in the mud banks adjacent to the creek upstream of site MON during a site visit. It is possible that there are ruminants present on private property out of view contributing to the fecal pollution at MON. MON also had trace bird markers in week 2, and trace human markers in weeks 1 and 2. No evidence was found for anthropogenic related bird presence, and no encampments were observed near MON. Dog biomarkers were detected at MON in all five of the sample weeks. Due to the prevalence of fecal material along the creek side trail coupled with dog tracks and visible dog walkers, it is likely that improperly disposed of dog waste contributed to fecal pollution at the MON sample site for weeks 1-5. This site is also likely a location visited by native canines due to the presence of water. Although there was visible horse fecal material also along the trail, and horses observed on property adjacent to the creek, horse marker was not detected in weeks 1 and 2 and not tested for in the remaining weeks.

Figure 13. Dog tracks observed adjacent to Llagas Creek upstream of site MON

CHP is located on Miller Avenue crossing above Uvas creek. The creek is bordered by Debell Uvas Creek Park Preserve trails as well as portions of Eagle Ridge Golf Course and residential homes. CHP receives water from Uvas Reservoir, approximately 15 km (approximately 9 miles) upstream, and various Uvas Creek tributaries during major storm events.

<u>2015:</u> CHP was not sampled in 2015 due to low flow conditions.

<u>2016:</u> In 2016 CHP had notably lower fecal indicator bacteria concentrations for week 1 than other sampled sites (*E. coli* 154 MPN/100 mL, Entero 240 MPN/100 mL on 3/10/2016). CHP fecal indicator bacteria concentrations continued to decline in the sample weeks 2-5 after the first large rain event about the time of the week 1 sample, (0.7" on 3/7/2016) likely a result of first flush runoff effects that carried fecal material into the creek. CHP was the only site to meet EPA recommended GM mean values for both *E. coli* and Enterococci during the 2016 sampling season.

Aerial reconnaissance did not reveal potential source locations near CHP. This reinforces the lower FIB concentration data and MST findings. Dog was only found in weeks 1 and 2 in trace amounts at CHP with week 3-5 results being non-detects. The field team visually observed a woman with three dogs walking along a trail adjacent to the stream which supports the detection of dogs at CHP. Cattle and bird were not detected in weeks 1 and 2 and not tested in weeks 3-5. Horse, pig, and ruminant were not tested at CHP. Human biomarker was found in trace amounts in week 2 and not detected in the other four weeks.

UVA is located downstream of CHP on Uvas Creek at Bloomfield Avenue crossing. The site is bordered by agricultural fields to the west and south and Bolsa Road to the east and north. The creek itself is lined with a small riparian zone on both sides of the bank.

2015: UVA was not sampled in 2015 due to low flow conditions.

2016: Fecal indicator bacteria concentration at UVA was highest in week 1 (*E. coli* 162 MPN/100 mL, Entero. 230 MPN/100 mL on 3/10/2016). FIB concentrations were lower in weeks 2 and 3 for both *E. coli* and Enterococci (*E. coli* 58.4MPN/100 mL, Entero. 140 MPN/100 mL on 3/17/2016; *E. coli* 64.6 MPN/100 mL, Entero. 48 MPN/100 mL on 3/24/2016). Then week 4 *E. coli* increased greatly (*E. coli* 387 MPN/100 mL on 4/4/2016) while Enterococci increased slightly (Entero. 67 MPN/100 mL on 4/4/2016) despite not having precipitation for two weeks (0.1" on 3/21/2016), possibly from some source event that increased fecal loading directly into the creek. The last sample for *E. coli* on 4/7/2016 decreased (*E. coli* 122 MPN/100 mL), while Enterococci remained almost the same (Entero 68.2 MPN/100 mL). The EPA geometric mean was not exceeded at UVA for *E. coli*. However, the geometric mean for Enterococci exceeded the EPA recommended value (GM Entero. at 93 MPN/100 mL) and the STV was exceeded two out of five samples.

Aerial reconnaissance did not reveal a large amount of possible fecal sources. Private property just upstream of UVA may contain animal structures in the back of the property, but this was not confirmed as access was restricted.

Dog, and ruminant biomarkers were found in trace amounts at UVA in week 1, while bird biomarkers were found in trace amounts in weeks 1 and 3. Horse and Pig were not tested for, while human and cattle biomarkers were not detected in weeks 1 and 2 and not tested for in the remaining weeks. Due to the low biomarker concentrations, bird is likely a natural source, while ruminant and dog may be from scattered small scale anthropogenic sources from livestock or pets on private property near the sample site.

WLL is located at the Watsonville Road and Monterey Road crossing on West Little Llagas Creek. Edmundson Creek flows in to West Little Llagas creek from the west from a residential area, and the western side of West Little Llagas creek is mostly residential area. Monterey Road borders West Little Llagas creek to the east and is dominated by commercial areas.

2015: WLL was not sampled in 2015 due to low flow conditions.

2016: Fecal indicator bacteria results at WLL were high during week one (*E. coli* 101 MPN/100 mL and Entero. 520MPN/ 100 mL on 3/9/2016) following 0.7" of rain on 3/7/2016. FIB values then declined in the remaining three sample weeks except for Entero on week 4 and 5(Entero. 2020MPN/ 100 mL, and Entero. >4840 MPN/100 mL, respectively). WLL was not sampled for a fifth week due to low flow conditions. WLL did not have five sampling events due to low flow conditions and therefore a GM was not calculated.

Aerial reconnaissance did not display possible sources for fecal pollution near WLL. MST results showed trace biomarkers for both types of human tests and dog in week 1. Bird was not detected at WLL in weeks 1 or 2, and horse, pig, cattle, and ruminant were not tested for. Results suggest possible fecal contamination from improperly disposed pet waste or from native canines as this area could be a wildlife corridor. A homeless encampment was observed 1.5 miles upstream of site WLL four months after the last sampling event to verify homeless documented by the City of Morgan Hill in the area. The presence of homeless encampments in the area suggests they may be a source of the trace human fecal pollution as the area is not known to have septic systems. There were no biomarkers for human or dog detected in the samples collected that had the highest values for Enterococci (3/23/2016, 4/4/2016), and there were also no recent precipitation events, except for 0.1" in on 3/21/2016.

LLA is located on Llagas Creek at the Bloomfield Avenue crossing. Agricultural lands border the creek on the east and west. A wastewater facility is also located two kilometers northwest of LLA (Figure 8).

2015: Fecal indicator bacteria results at LLA from 2015 revealed highest levels during week 1 (*E. coli* at 980 MPN/100 mL, Entero. 750 MPN/100 mL on 4/7/2015) following the same day rain event (0.5" precipitation on 4/7/2015). Fecal indicator values declined by sample week 2 (*E. coli* 248 MPN/100 mL, Entero. 140 MPN/100 mL on 4/14/2015). In week 3 Enterococci values rose slightly (Entero. at 190 MPN/100 mL on 4/21/2015) while *E. coli* continued to decline (*E. coli* at 172 MPN/100 mL on 4/21/2015). In sample week 4 *E. coli* increased slightly (*E. coli* at 185 MPN/100mL on 4/20/2015) while Enterococci declined (Entero. at 88 MPN/100mL on 4/20/2015). In sample week 5 both *E. coli* and Enterococci levels increased to 326 MPN/100mL on 5/7/2015. The geometric mean values at site LLA exceeded EPA recommendations for both *E. coli* and Enterococci (*E. coli* GM value 302 MPN/100 mL, Entero. GM value at 225 MPN/100 mL). Statistical threshold values were exceeded at LLA 2/5 times for *E. coli* and 4/5 times for Enterococci. Sample year 2015 MST analysis revealed bird biomarkers in weeks 1 and 5 and negative results for human, cow, and horse biomarkers.

2016: In 2016 fecal indicator bacteria results at LLA showed highest concentrations during weeks 2 and 5 (*E. coli* 129 MPN/100 mL, Entero. 210 MPN/100 mL on 3/17/2016 and (*E. coli* 204 MPN/100 mL, Entero. 152 MPN/100 mL on 4/7/2016). Week 3 showed a decrease in bacteria concentrations (*E. coli* at 97.4 MPN/100mL, Entero. at 86 MPN/100mL on 3/24/2016) followed by a slight increase in concentrations in week 4 (*E. coli* at 113 MPN/100 mL, Entero. at 110 MPN/100 mL). The geometric mean and STV was only exceeded for Enterococci (Entero. GM value at 124 MPN/100 mL).

Aerial reconnaissance did not reveal potential fecal sources as the area surrounding the creek is primarily agricultural, and animal housing structures were not evident.

In sample year 2016 trace biomarkers for bird were detected in weeks 3-5, and bird nests (swallows) were noted beneath the bridge near the sample site, indicating a possible natural bird source. Ruminant was detected in week 2 in trace amount, while it was a non-detect in the other four sample weeks. Cattle biomarkers were tested for during weeks 1 and 2 but were not detected. Human biomarkers were not detected during in any of the five weekly samples. Dog, horse, and pig were not tested for at LLA.

Figure 14. Swallow nests observed under a bridge at LLA

FUF is located northeast of sample site LLA on Jones Creek adjacent to Bloomfield Avenue before its convergence with Llagas Creek. Most the creek is surrounded by agricultural land.

2015: Fecal indicator bacteria at site FUF were inconsistent throughout the five sample weeks, despite consistent stream flow and precipitation conditions. Week 1 sample concentrations with 0.5" of precipitation in the early morning of the sample day on 4/7/2015 were *E. coli* at 980 MPN/100 mL, Entero at 310 MPN/ 100mL. Week 2 samples then show a drastic increase in fecal indicator bacteria (*E. coli* at >2420 MPN/100mL, Entero. at >2420 MPN/100 mL on 4/14/3015). Concentrations again increased in week 3 despite not having any recent precipitation (*E. coli* at 6130 MPN/100 mL, Entero. at 5800 MPN/100 mL on 4/21/2015). Week 4 show concentrations decreasing (*E. coli* 214 MPN/100 mL, Entero. 387 MPN/100 mL on 4/30/2015) and then increasing to the highest concentrations in week 5 (*E. coli* 9680 MPN/100 mL, Entero. >9680 MPN/ 100 mL on 5/7/2015). Site FUF greatly exceeded EPA recommended geometric mean values (*E. coli* GM value at 1976 MPN/100 mL, Entero. GM value at 1748 MPN/100 mL). The statistical threshold values were exceeded by four of the five of *E. coli* samples and all five of Enterococci samples.2015 MST analysis revealed trace biomarkers for human and bird in week 1, and trace bird again in weeks 3 and 5. Horse and cattle were not detected at FUF in 2015.

<u>2016:</u> *E. coli* were found to be high in week 1 (*E. coli* 573 MPN/100 mL n 3/10/2016) and then declined during each sample week until week 5 where the concentration increased (*E. coli* 498 MPN/ 100 mL). Contrastingly, Enterococci was lower in week 1 and 2 (Entero. 290 MPN/100mL on 3/10/2016, 250 MPN/100 mL on 3/17/2016), but still relatively high in terms of fecal load, than in week 3 and 4 (Entero. 460 MPN/100 mL on 3/24/2016, Entero. 360 MPN/100 mL on 4/4/2016). A large increase in concentration was also observed at week 5 (Entero. 2830 MPN/ 100 mL). Both *E. coli* and Enterococci exceeded the EPA recommended means at site FUF in 2016 (*E. coli* GM value at 259 MPN/100 mL, Entero. GM value at 508 MPN/100 mL). The statistical threshold values were exceeded by two of the five *E. coli* samples and all five Enterococci samples. Aerial reconnaissance revealed potential ruminant fecal sources on upstream private properties near tributaries of Jones Creek. Potential sources were not verified on ground due to difficult access.

In 2016 trace ruminant biomarker was detected in week 1 at FUF and not detected in the other four weeks. Human was detected in trace amounts in weeks 1 and 2 while trace bird was detected in weeks 1 and 4. Human sources are unlikely to be derived from leaking septic system because it was only detected within the first two weeks. Dog and horse were not detected in any of the weeks, while cattle were only tested for during weeks 1 and 2 and both were non- detects. Pig biomarkers were not tested for at FUF.

SBC is located on the Pajaro River where it crosses Frazier Lake Road. SBC is bordered entirely by agricultural and grazing land.

<u>2015:</u> At site SBC fecal indicator bacteria were lowest in week 1 following recent precipitation of 0.5" on 4/7/2015 (*E. coli* at 310 MPN/100 mL, Entero. at 630 MPN/100 mL on 4/7/2015). Concentration levels increased during week 2 (*E. coli* >2420 MPN/100 mL, Entero. >2420 MPN/100 mL on 4/14/2015), decreased in week 3 (*E. coli* 387 MPN/100 mL, Entero. 1550 MPN/100 mL on 4/30/2015), and then increased again in week 4 (*E. coli* 1840 MPN/100 mL, Entero. 4180 MPN/100 mL on 5/5/2015) and decreased again in week 5 (*E. coli* 363 MPN/100 mL, Entero. 2070 MPN/100 mL on 5/7/2015). The geometric means at site SBC exceeded the EPA recommended geometric mean values for both *E. coli* and Enterococci, and exceeded the statistical threshold values in two of the five of samples for *E. coli* and all five samples for Enterococci.

2015 microbial source tracking results for SBC showed that bird biomarker was detected in all five weeks, while cattle was detected in trace amount in week 2 and greater than trace amount in week 4. During one of the earlier sampling trips, a cow was observed in the adjacent lot next to the sampling site. It is likely fecal matter from the adjacent parcel is the source of cattle biomarker in the creek. Horse and human biomarkers were not detected at SBC. High FIB values correspond to when both cattle and bird were detected in sample weeks 2 (4/14/2015) and 4 (5/5/2015). Lower observed flow and high amounts of aquatic vegetation at SBC may have contributed to the high concentration of Enterococci by providing more suitable habitat for the bacteria to grow.

<u>2016:</u> Sample analysis for fecal indicator bacteria showed *E. coli* at 93.2 MPN/100 mL and Entero. at 280 MPN/100 mL during week 1 (3/10/2016). Week 2 saw lower levels for both *E. coli* and Entero, while week 3 revealed an increase for both *E. coli* at 321 MPN/100 mL and Entero. at 760 MPN/100 mL during week 3 (3/17/2016). Week 4 shows contrasting results for *E. coli* and Enterococci as *E. coli* decreased from the previous week (*E. coli* at 137 MPN/100 mL on 4/4/2016) while enterococci rose drastically (Entero. >4840 MPN/100 mL on 4/4/2016) with the most recent rain 0.1" on 3/21/2016. The high

increase in Enterococci on 4/4/2016 may be attributed to algae growth near the sample site. Field notes indicate water was stagnant and visual confirmation of algae presence was noted. Enterococci has been shown to grow and persist in the presence of algae (Byappanahalli et al., 2003; Byappanahalli et al., 2012). 2016 SBC samples exceeded the EPA recommended geometric mean and statistical threshold value for Enterococci only.

Aerial reconnaissance surrounding SBC showed possible ruminant fecal sources across Frazier Lake Road near the sample site and further upstream from the sample site towards highway 152.

2016 microbial source tracking analysis resulted in trace bird biomarkers in weeks 1 and 2, and trace cattle biomarkers in week 1 and non-detect in week 2. Although cattle were not observed during the sampling days, the adjacent parcel did have cattle in 2015 and is possibly contributing to fecal bacteria in the creek. Ruminant was tested for in weeks 3-5 and resulted in non-detects. Human biomarkers were tested for each week and not found. Dog, horse, and pig were not tested for at SBC.

Figure 15. Sampling at SBC

ELL is located on Little Llagas Creek at Church Ave. The creek receives most of its water from rain events and therefore is intermittently wet in the winter and spring. The upstream and surrounding areas are dominated by farmland, rural homes, and small livestock operations (goat, sheep and horse).
2015: Samples were not collected at ELL in 2015 due to dry conditions at Little Llagas Creek.

2016: Fecal indicator bacteria samples were only sampled during the first two weeks of the study because of dry conditions. In both instances, *E. coli* and Entero. concentrations were high and above the recommended GM (*E. coli* at 195 and 205 MPN/100 mL, Entero. at 205 and 400 MPN/100 mL). Both *E. coli* values were above the STV (Table 5). Rainfall during the first two weeks of sampling contributed to the water flow at ELL and likely washed fecal matter from surrounding upstream areas into the creek.

Microbial source tracking analysis detected trace amounts of dog and low concentration of ruminant in the week 1 sample and low concentration of ruminant again in week 2. Trace amount of human fecal matter was also detected in both sampling events using the Dorei biomarker test but not with the EPA test. No birds, cattle or horses were detected. Aerial photos and field reconnaissance showed many goats, sheep and horses present in the surrounding area. The goats and sheep are therefore the likely contributor to fecal pollution observed at WAT. In addition, bags of butchered animal carcasses, believed to be sheep and/or goats, were discovered in the creek by concerned citizens that reported the issue to the District in January 2016. The animal's remains were found near Church Ave which would indicate the bags were simply tossed into the creek from the side of road. The animal's remains likely impacted the creek's water quality and contributed fecal pollution to ELL. Unfortunately, the magnitude of such pollution discharge is unknown.

Figure 16. Disposed bags of Animal Carcasses

VIS is located on Llagas Creek at Buena Vista Ave. It is located approximately three kilometers downstream of MON. Although site MON on Llagas Creek flows year-round because of water released from Chesbro Reservoir, this water does not reach the VIS site due to infiltration. When water does flow at VIS, it comes primarily from the surrounding tributaries during rain events and increased flow from Llagas Creek. Like ELL, VIS is also surrounded by farmland, rural homes and small livestock operations (goat, sheep, and horse).

2015: Samples were not collected at VIS in 2015 due to dry conditions in Llagas Creek.

2016: Fecal indicator bacteria samples were only sampled during the first two weeks of the study because of dry conditions. In both instances, *E. coli* and Entero. concentrations were very high and above the recommended GM and STV values (*E. coli* at 2380 and 882 MPN/ 100 mL, Entero. at 2600 and 530 MPN/ 100 mL. Rainfall during the first two weeks of sampling contributed to the water flow at VIS and likely washed fecal matter from surrounding upstream areas into the creek.

Microbial source tracking analysis detected trace amount of human, dog, and pig and low concentration of ruminant in week 1. All markers were detected again in week 2 except for pig. Human fecal matter was detected in both sampling events using the Dorei biomarker test but only once with the EPA test. No birds, cattle, or horses were detected. Aerial photos and field reconnaissance showed upstream and nearby horse and chicken pens but these animals were not detected. Ruminants, such as goats and sheep, are likely present in the area but not visible to staff given most the surrounding area is dominated by farmland and rural homes. Domesticated pig may also be hidden out of sight as wild pigs are not known to inhabit the rural area around VIS.

PAJ is located at the southern end of Santa Clara County (SCC), in the unincorporated community of Sargent, along Betabel road. The site is approximately 170 meters south of the intersection between the Pajaro River and Highway 101. Agricultural land use dominates the southern portion of the River while the portion north of the River and west of Highway 101 are open grazing land. The portion east of Highway 101 is composed of open space and agriculture. Approximately 1500 meters (~1 mile) north of PAJ is the confluence between Uvas sub-watershed and the Pajaro. An additional 4,000 meters north is the confluence between the Pajaro River and Miller Canal. The canal, measuring 5400 meters (3 ¼ miles), was created to divert floodwater from San Felipe Lake which originally flowed through the Pajaro River at site SBC. Llagas sub-watershed also meets with the Pajaro River about 1500 meters north of the Pajaro-Miller Canal confluence and supplies most of the water to the Pajaro River. The Uvas sub-watershed is susceptible to infiltration and typically disconnects from the Pajaro River by the beginning of summer. In addition, 2775 meters north of Uvas-Pajaro confluence is Z-Best Composting which compost yard trimmings, municipal solid waste, food waste and manure (Figure 8).

2015: *E. coli* levels were generally low during the five-week sampling period, exceeding the recommended GM value once but remained below the STV. On the other hand, Entero. concentrations were above the GM value all five times while the STV was exceeded once. The only relevant rain event occurred on the morning of 4/7, during the first sampling event, and may have impacted the bacteria concentration. However, it is unclear whether the bacteria concentration increased or decreased because no sampling occurred before the first event. Fecal indicator bacteria concentration showed a decreasing trend over the sampling period.

No MST analysis was conducted at PAJ in 2015 because FIB concentrations were relatively low, although Entero. values were all above the recommended GM.

2016: Like other sites, FIB levels at PAJ were highest during the first sampling event (*E. coli* 384 MPN/100mL, Entero. 210 MPN/100mL), presumably because of rainfall. Subsequent bacteria levels in the remaining samples were 2-3 times lower, likely due to dilution by subsequent rainfall events and fewer fecal sources being washed into the creek, than the first sample. *E coli* concentrations did not exceed the EPA's recommended STV value in any of the five samples and only once with Entero.

Positive MST analysis at PAJ included bird (week 1 and 3), dog (week 1 - 4) and ruminant (week 1, 2, 4 and 5). No humans (week 1 – 5 for both tests), horses (week 1 – 5) or cattle (week 1 & 2) were detected. Bird detection is likely the result of natural source as PAJ has a large riparian zone. The detection of dogs is likely from coyote sources, as the site and the upstream areas are dominated by riparian habitat and large agricultural fields. Dogs are unlikely to be found in the agricultural fields and riparian zone whereas coyotes may be using the creek as corridors to other upstream habitats. Aerial photos and field reconnaissance showed cattle present in the adjacent grazing area. This may partially explain the presence of ruminant at PAJ. However, cattle were not detected in week 1 and 2 when ruminant was also present. Sheep and goats does not appear to be present upstream of PAJ based on aerial photos. Other potential sources include deer that may be using upstream habitat, although none were seen, and Z-Best compositing as they compost manure and are located near the Pajaro River.

Sub-watershed Level Analysis

Uvas sub-watershed (UVA and CHP)
2015: Uvas sub-watershed was not sampled.

2016: Site CHP and UVA were both sampled five times. Fecal indicator bacteria results from the two sites indicated the sub-watershed is less impaired in the upstream area. Site CHP had *E. coli* and Entero. values that were below the Rec-1 GM and STV (*E. coli* GM 50 MPN/100 mL, Entero. GM 30 MPN/100 mL). As the water moves further downstream towards UVA, FIB concentration increased. *E. coli* GM value was 124 MPN/100 mL just slightly below the recommended GM value of 126 MPN/100 mL and Entero. was 93 MPN/ 100 mL, about three times the Rec-1 GM concentration of 35 MPN/100 mL.

Fecal sources were detected three times at CHP comprising of two dogs and one human. At UVA, fecal sources were detected four times and include two birds, one dog, and one ruminant. To reduce fecal pollution at the sub-watershed level for Uvas, efforts should be directed towards controlling human, dog and ruminant sources. Bird appears to be derived from natural sources and therefore more difficult to control.

Llagas sub-watershed (BSC, FUF, LLA, MON, WAT, OAK, ELL, VIS, and WLL)
2015: Of the five sites that were sampled for FIB in 2015, two had *E. coli* GM values below the recommended level. The two sites were MON (GM 38 MPN/100 mL), which was furthest upstream and PAJ (GM 81 MPN/100 mL), where surface water leaves the County. All five sites had Entero. GM values that were higher than the Rec-1 threshold of 35 MPN/100 mL. Site PAJ was 81 MPN/100 mL, SBC 1829** MPN/100 mL, FUF 1748** MPN/100 mL, LLA 225 MPN/100 mL and MON 40 MPN/100 mL (** GM should be > than based on reported results). Within the Llagas sub-watershed, high concentrations of FIBs are originating from areas upstream and/or adjacent to SBC, FUF and LLA. Apart from LLA's *E. coli* STV, the three sites exceeded the STV multiple times for *E. coli* and Entero. Microbial source tracking at these three sites showed bird, cow and human to be contributor of fecal pollution, although ruminant was not tested in 2015. Birds were consistently detected at all three sites and observed during field sampling. Swallows were overwhelmingly present at FUF and LLA. Site SBC was near stagnant during the last two sampling events which may have contributed to the high FIB concentration.

Fecal indicator bacteria within Llagas sub-watershed are exceedingly high and birds appear to be major contributor to fecal pollution at SBC, FUF, and LLA in 2015.

2016: Of the nine sites sampled in Llagas sub-watershed (excluding site PAJ), six were sampled five times. The three that weren't were ELL, WLL, and VIS. The six sites that were sampled had the GM calculated for *E. coli* and Entero. All six sites either exceeded the Rec-1 GM for both the *E. coli* and Entero. or only Entero. Site SBC, OAK, and LLA had *E. coli* GM below the Rec-1 threshold (SBC 121 MPN/ 100 mL, OAK 39 MPN/ 100 mL, LLA 125 MPN/ 100 mL). The Entero. GM value for all sites were two to 16 times greater than the Rec-1 threshold. *E. coli* GM for FUF and MON were more than two times greater than the Rec-1 threshold (259 MPN/ 100 mL and 306 MPN/ 100 mL, respectively) while WAT was above at 183 MPN/ 100 mL.

Within the Llagas sub-watershed, high concentrations of FIBs are originating from areas upstream and/or adjacent to all the sites sampled. For *E. coli*, the STV was exceeded on two or more occasions at FUF, MON, and WAT. For Entero., the STV was exceeded on two or more occasions at all Llagas sub-watershed sites.

Microbial source tracking results indicated human, bird, ruminant, dog, pig, and cattle as sources of fecal pollution. Human fecal matter was detected in all sites, except OAK, SBC and LLA, but these detections were in trace amounts. Homeless encampments were also not present at any of the sites except for WLL. Because many of the human hits were detected only one or two times at each site, a leaking septic system is not likely the source of human fecal matter in the water. Instead, human hits were found only in weeks 1 and 2 which would correlate with first flush events where human waste are washed into the creeks during rain events.

Birds were also detected throughout the area, except at WLL, ELL and VIS, and are believed to be derived from natural source as all the sites where birds were detected have a moderate or large riparian zone. Ruminants were detected at all sites except WLL which is an urban parkway. Ruminant west of highway 101 are likely derived from cattle, goats, sheep and possibly deer. Although cattle were detected at SBC, ruminant sources east of highway 101 are likely from goats and sheep. Dog fecal matter was detected throughout upper Llagas sub-watershed and upstream of VIS. At ELL, VIS, and WLL, the dog fecal detections are likely derived from domestic dogs. At MON, dogs were observed on several occasions and what appear to be dog scat was found throughout the site. The detection of dogs at OAK and WAT are less clear as domestic dogs, coyotes and gray fox are present in the area. Pigs were detected at VIS and OAK. The detection at VIS is likely derived from domesticated pig(s) as the surrounding and upstream area is comprised of mostly agriculture field and rural houses. At VIS, the pig detection may have been the result of wild boars in the area or from unseen domesticated pig. Lastly, cattle fecal bacteria were detected once at SBC where a known small cattle pen operation was observed in 2015.

Fecal indicator bacteria within Llagas sub-watershed are exceedingly high at all sites. Both natural (birds and possibly coyote, deer and pig) and anthropogenic control sources (human and farm animal waste) contribute to the fecal pollution in Llagas sub-watershed. As natural sources of fecal pollution will be difficult to control, efforts should be directed towards controlling domesticated animal waste to reduce fecal pollution in Llagas sub-watershed.

Water Leaving Santa Clara County

Water leaving Santa Clara County at PAJ was below the Rec-1 threshold for *E. coli* but not Entero. in both 2015 and 2016. The GM for Entero. in 2015 and 2016 were 81 MPN/ 100 mL and 89 MPN/ 100 mL. In most studies, *E. coli* is often used as the primary indicator for fecal pollution in freshwater system while Entero. can be used in both freshwater and saltwater, but more often in the latter. The difference in one group of bacteria exceeding the threshold may be attributed to the different characteristic and survival rates of the bacteria under various environmental conditions. Byappanahalli et al., (2012) point out that Entero. bacteria are widely distributed and may be present in high densities, even when there is "little or no input from human and/or animal fecal source." This may be the case in certain portions of the Pajaro Watershed (within Santa Clara County limits), where only Entero. GM exceeded Rec-1 threshold and not *E. coli* (i.e. SBC, LLA, UVA and OAK in 2016). Factors such as presence of aquatic and terrestrial vegetation, soil, suspended sediments, and sand can impact Entero. concentrations by providing suitable conditions for the bacteria to reproduce outside the host. The reproduction of such bacteria may lead to false conclusion of high fecal contamination in the waterway from human and/or animal sources.

Though there remains some uncertainty regarding how to best evaluate scenarios where one group of bacteria exceed recommended threshold, particularly when the bacteria themselves can survive and reproduce outside the host, it appears that if one solely looks at *E. coli*, water leaving Santa Clara County is within the recommended threshold for recreational water body contact. However, if looking at both *E. coli* and Entero., it is more difficult to make a sound conclusion. Therefore, we can only conclude that water leaving the County have *E. coli* levels that were below the Rec-1 threshold while Entero. exceeded the threshold by two to three-fold.

Conclusion and Recommendations

Conclusion

High concentrations of fecal indicator bacteria were observed throughout the Pajaro watershed in Santa Clara County, particularly within Llagas sub-watershed when compared to US EPA Recommendation 1 illness rate for primary contact with water to protect REC-1 beneficial uses. Uvas sub-watershed appears to be less polluted than the Llagas watershed, at the time of this study. As surface water from Llagas and Uvas mixes and leaves the County, fecal pollution likely becomes less concentrated. *E. coli* concentration leaving the county was within accepted limits for recreational water body contact, but Enterococci was not. Enterococci bacteria also appears to be able to find more suitable habitat within the sampling sites as they were generally found in higher concentration than *E. coli*. Reproduction outside the host species by Enterococci bacteria may explain the large differences between the species concentrations.

First flush phenomena were also observed at several sampling sites and likely explain the increase in FIB concentrations and fecal source detection during the first two weeks of the study. Sources of fecal pollution within the county are derived from a variety of sources including dog (domestic and potentially wild) ruminant, bird, human, pig, and cattle.

The 2012 US EPA thresholds used to assess illness rates in this study are specific to primary contact uses of water. The primary contact designations include "*swimming, bathing, surfing, water skiing, tubing water play by children, and similar water contact activities where a high degree of bodily contact with the water, immersion and ingestion are likely" (USEPA, 2012).* These activities are not common in creeks of South Santa Clara County, and therefore the risk to human health is low**.**

Recommendations

To improve surface water quality within the Pajaro River watershed, the following approach is recommended:

1. focus fecal pollution control efforts in Llagas sub-watershed,
2. investigate possible point source fecal pollution contributions from existing sanitary sewer systems,
3. focus on anthropogenic sources- ex. dogs at MON,
4. implement broad outreach to educate domestic livestock owners regarding fecal pollution
    a. focus on removing animal waste near drainage systems,
    b. removal and/or cover of animal waste piles, and
    c. encourage establishments of buffer zones via setbacks and vegetation barriers.

Site specific recommendations to reduce fecal pollution are as follow:

1. MON- Signs for picking up dog waste, provide dog waste baggies and trash bins, fencing to discourage dog encroachment to creek,
2. CHP- Signs for picking up dog waste, no swimming or dogs in creek signs,
3. WLL- Discourage homeless encampments near creek,
4. ELL and VIS- Post Illegal dumping signs along road bridges to discourage dumping of animal waste and trash, and neighborhood outreach to encourage BMPs for livestock waste management, and
5. WAT- Educate livestock (cattle/horse) owners about fecal pollution, encourage owners to not allow livestock near the creek and establish creekside buffer zones.

In addition, future research activities should incorporate monitoring of Miller Canal to determine its fecal pollution contribution, continue long-term monitoring at PAJ to determine the extent of fecal pollution leaving the County on a seasonal and annual basis and monitoring upstream and downstream of Z-best Compost to determine whether the site is impacting the adjacent creek. Furthermore, a better understanding of why Enterococci exceeded the Rec-1 threshold while *E. coli* did not is needed to determine whether surface water leaving Santa Clara County is safe for recreational purposes.

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Appendices

Appendix A: 2015 FIB and MST Results

Llagas Creek at Bloomfield Avenue (LLA)									
	Human EPA	Bird	Horse	Cattle	E. coli	Entero	Flow Estimate	Gage Flow Southside	Precipitation (Current; Most Recent) 1529 Church Ave.
4/7/2015	ND	Trace		ND	980	750	1-5	Stage only	0.5" early 4/7 morning
4/14/2015					248	140	1-5		none
4/21/2015					172	190	0.1-1		none
4/30/2015					185	88	0.1-1		none
5/7/2015	ND	Trace	ND	ND	326	326	1-5		none

Pajaro River Channel at Frazier Lake Road Upstream of Miller Canal Diversion (SBC)									
	Human EPA	Bird	Horse	Cattle	E. coli	Entero	Flow Estimate	Gage Flow at:	Precipitation (Current; Most Recent) 1529 Church Ave.
4/7/2015	ND	Trace		ND	310	630	None		0.5" early 4/7 morning
4/14/2015	ND	Trace		Trace	>2420	>2420	None		none
4/30/2015	ND	Trace	ND	ND	387	1550	None		none
5/5/2015	ND	6.18E+03	ND	6.08E+02	1840	4180	0.1-1		none
5/7/2015	ND	Trace	ND	ND	363	2070	1-5		none

Jones Creek at Llagas Creek Confluence (FUF)									
	Human EPA	Bird	Horse	Cattle	E. coli	Entero	Flow Estimate	Gage Flow at:	Precipitation (Current; Most Recent) 1529 Church Ave.
4/7/2015	Trace	Trace		ND	980	310	1-5		0.5" early 4/7 morning
4/14/2015	ND	ND		ND	>2420	>2420	1-5		none
4/21/2015	ND	Trace	ND	ND	6130	5800	1-5		none
4/30/2015					214	387	1-5		none
5/7/2015	ND	Trace	ND	ND	9680	>9680	1-5		none

Pajaro River at Betabel (PAJ)									
	Human EPA	Bird	Horse	Cattle	E. coli	Entero	Flow Estimate	Gage Flow at:	Precipitation (Current; Most Recent) 1529 Church Ave.
4/7/2015					100	<100	5-20		0.5" early 4/7 morning
4/14/2015					152	130	5-20		none
4/21/2015					105	84	5-20		none
4/30/2015					108	61.7	5-20		none
5/7/2015					57.1	52.8	20-50		none

Llgas Creek at Monterey Hwy (MON)									
	Human EPA	Bird	Horse	Cattle	E. coli	Entero	Flow Estimate	Gage Flow Chestbro Outlet	Precipitation (Current; Most Recent) 1529 Church Ave.
4/7/2015					<100	100	1-5	2.8	0.5" early 4/7 morning
4/14/2015					67	13	1-5	2.8	none
4/21/2015					25.6	39	1-5	2.8	none
4/30/2015					14.6	37.3	1-5	2.8	none
5/7/2015					29.9	55.2	5-20	4.8	none

Appendix B: 2015 Water Quality Data

Station I.D: MON

Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
4/7/2015	13.5	7.49	7.98	76.8	608	3.1	475	-	-	-	Gravel	None	Trash	None	Clear	1-5	Overcast	None	>1''	Colorless
4/14/2015	15.8	8.05	10.79	1.09	624	5.0	514	-	0.04	2.8	Gravel	None	Trash	None	Clear	1-5	Clear	None	None	Colorless
4/21/2015	16.0	8.01	8.57	87	635	1.1	527	413	0.065	0.62	Gravel	None	None	None	Clear	1-5	Overcast	None	None	Colorless
4/30/2015	17.0	8.08	8.25	85.5	639	0.6	542	415	0.02	3.7	Gravel	Sewage	Vascular	None	Clear	1-5	Clear	None	None	Colorless
5/7/2015	16.1	8.11	7.33	7.46	622	2.0	517	405	0.03	8.5	Gravel	Wet Grass	None	None	Clear	5-20	Partly Cloudy	Drizzle	< 1''	Colorless

Notes: 4/21 MON blank time 9:55. 4/30 Algae forming upstream.

Station I.D: LLA

Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
4/7/2015	12.5	7.22	6.98	65.8	1489	6.3	1133	969	-	4.4	Mud/Silt	None	Trash	None	Murky	1-5	Partly Cloudy	None	>1''	Brown
4/14/2015	13.2	7.21	7.66	73.4	1606	3.6	1245	1044	0.21	3.6	Mud	None	Trash	None	Murky	1-5	Partly Cloudy	None	>1''	Brown
4/21/2015	13.2	7.35	7.25	69.5	1616	3.5	1252	1057	0.228	4.44	Mud	None	Trash	None	Clear	0.1-1	Overcast	None	None	Colorless
4/30/2015	13.4	7.47	7.69	74.1	1648	4.1	1285	1072	0.06	3.76	Mud	Mone	scular/Tra	None	Cloudy	0.1-1	Clear	None	None	Brown
5/7/2015	12.6	7.64	7.89	74.8	1298	5.2	1699	1105	0.02	2.98	Sand	None	Trasd	None	Clear	1-5	Partly Cloudy	None	< 1''	Colorless

Notes:

Station I.D: FUF

Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
4/7/2015	11.4	7.8	8.41	77.3	1805	23.8	1337	1176	-	3.36	Mud	None	Trash	None	Murky	1-5	Partly Cloudy	None	>1''	Brown
4/14/2015	11.5	7.84	8.67	80	1592	15.4	1183	1035	0.21	4.87	Mud	None	Vascular	None	Cloudy	1-5	Clear	None	None	Colorless
4/21/2015	12.9	7.97	8.27	78.7	1577	16.0	1214	1026	0.095	5.03	Mud	None	Trash	None	Cloudy	1-5	Overcast	None	None	Yellow
4/30/2015	12.8	8.05	8.86	84.3	1787	7.9	1372	1162	0.097	3.89	Mud	None	Trash	None	Clear	1-5	Clear	None	None	Colorless
5/7/2015	11.9	8.13	8.6	80.1	1522	20.3	1141	989	0.09	5.7	Sand	None	Trash	None	Cloudy	1-5	Partly Cloudy	Drizzle	< 1''	Yellow

Notes:

Station I.D: SBC																			
Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
4/7/2015	13.1	7.8	6.79	65.2	2114	3.8	1633	1374	-	19.8	Mud	None	None	None	Murky	None	Partly Cloudy	None	>1''	Brown
4/14/2015	14.7	7.78	7.43	73.7	1511	7.2	1218	982	0.09	8.11	Mud	None	Vascular	None	Murky	None	Clear	None	None	Colorless
4/30/2015	18.6	7.96	7.45	80.1	1421	27.7	1248	924	-	13.8	Mud	None	Vascular	None	Cloudy	None	Clear	None	None	Colorless
5/5/2015	17.4	7.85	6.13	64.1	803	8.5	687	522	-	2.52	Mud	Manure	Vascular	None	Cloudy	0.1-1	Partly Cloudy	None	None	Brown
5/7/2015	15.0	7.9	6.2	62	771	6.6	625	501	-	2.8	Mud	None	Vascular	None	Cloudy	1-5	Partly Cloudy	Drizzle	< 1''	Colorless

Notes: On 4/30 and later, water quality data was collected from a sampling cup which contained water from the sampling site. Depth readings was not possible. 4/30 Cow seen in area.

5/5 Site has more water than previous visit w/ no recent rain event, likely water came from nearby farming operations.

Station I.D: PAJ																				
Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
4/7/2015	12.9	7.8	8.06	76.8	1817	16.8	1396	1180	-	3.55	Mud	None	None	None	Cloudy/Murky	5-20	Party Cloudy	None	>1''	Slightly brown
4/14/2015	14.6	8.02	7.94	78.6	1815	19.8	1455	1180	0.24	18	Mud	None	Vascular	None	Murky	5-20	Clear	None	None	Green/Brown
4/21/2015	14.3	8.03	5.7	56	1877	15.3	1492	1220	0.137	3.3	Mud	None	Foam	None	Cloudy	5-20	Overcast	None	None	Colorless
4/30/2015	15.6	8.05	6.25	63.2	1866	16.3	1533	1214	0.169	2.88	Mud	None	Wood	None	Murky	5-20	Clear	None	None	Brown
5/7/2015	14.2	8.15	6.76	66.2	1948	15.6	1544	1266	0.09	4.34	Mud	None	None	None	Cloudy	20-50	Partly Cloudy	Drizzle	< 1''	Green

Notes:

Appendix C: 2016 FIB and MST Results

Pajaro River at Betabel (PAJ)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow at:	Precipitation (Current; Most Recent)
3/10/2016	ND	ND	Trace	Trace	ND		ND	1,600	384	>9678	210	50-200		None; 0.7 inches on 3/7/2016
3/17/2016	ND	ND	ND	Trace	ND		ND	665	90.4	>9680	110			None; 1.7 inches on 3/13/2016
3/24/2016	ND	ND	ND	Trace	ND			ND	42.6	>4840	34	50-200		None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND	Trace	Trace	ND			611	59	>4840	79	20-50		None
4/7/2016	ND	ND	ND	ND	ND			1,480	91.4	>4840	89.6	50-200		None

Pajaro River Channel at Frazier Lake Road Upstream of Miller Canal Diversion (SBC)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow at:	Precipitation (Current; Most Recent)
3/10/2016	ND	ND	Trace				Trace		93.2	9680	280	0.1-1		None; 0.7 inches on 3/7/2016
3/17/2016	ND	ND	Trace				ND		20.8	>9680	100	0.1-1		None; 1.7 inches on 3/13/2016
3/24/2016	ND	ND						ND	321	>4840	760	0.1-1		None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND						ND	137	>4840	>4840	0.1-1		None
4/7/2016	ND	ND						ND	308	>4840	582	0.1-1		None

Jones Creek at Llagas Creek Confluence (FUF)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow at:	Precipitation (Current; Most Recent)
3/10/2016	Trace	ND	Trace	ND	ND		ND	Trace	573	>24196	290	1-5		None; 0.7 inches on 3/7/2016
3/17/2016	Trace	ND	ND	ND	ND		ND	ND	364	>24200	250	1-5		None; 1.7 inches on 3/13/2016
3/24/2016	ND	ND	ND	ND	ND			ND	133	>4840	460	0.1-1		None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND	Trace	ND	ND			ND	84.4	>4840	360	0.1-1		None
4/7/2016	ND	ND	ND	ND	ND			ND	498	4840	2830	1-5		None

Llagas Creek at Bloomfield Avenue (LLA)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Southside*	Precipitation (Current; Most Recent)
3/10/2016	ND	ND	ND				ND	ND	104	6930	97	1-5	4.5	None; 0.7 inches on 3/7/2016
3/17/2016	ND	ND	ND				ND	Trace	129	>9680	210	1-5	6.5	None; 1.7 inches on 3/13/2016
3/24/2016	ND	ND	Trace					ND	97.4	>4840	86	0.1-1	6.5	None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND	Trace					ND	113	>4840	110	0.1-1	4.7	None
4/7/2016	ND	ND	Trace					ND	204	>4840	152	0.1-1	4.4	None

Uvas Creek at Bloomfield Avenue (UVA)

	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Luchessa	Precipitation (Current; Most Recent)
3/10/2016	ND	ND	Trace	Trace			ND	Trace	162	>9678	230	20-50	160	None; 0.7 inches on 3/7/2016
3/17/2016	ND	ND	ND	ND			ND	ND	58.4	>9680	140	20-50	275	None; 1.7 inches on 3/13/2016
3/24/2016			Trace	ND				ND	64.6	>4840	48	50-200	75	None; 0.1 inches on 3/21/2016
4/4/2016			ND	ND				ND	387	>4840	67	5-20	31	None
4/7/2016			ND	ND				ND	122	4840	68.2	1-5	25	None

Uvas Creek at Christmas Hill Park (CHP)

	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Luchessa	Precipitation (Current; Most Recent)
3/10/2016	ND	ND	ND	Trace			ND		154	>9678	240	50-200	160	None; 0.7 inches on 3/7/2016
3/17/2016	Trace	ND	ND	Trace			ND		44	>9680	78	50-200	275	None; 1.7 inches on 3/13/2016
3/24/2016	ND	ND		ND					29.2	>4840	35	50-200	75	None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND		ND					35	4840	6.2	5-20	31	None
4/7/2016	ND	ND		ND					45.2	3970	6.2	5-20	25	None

Llagas Creek at Monterey Hwy (MON)

	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Chesbro Outlet	Precipitation (Current; Most Recent)
3/9/2016	Trace	ND	ND	3,110	ND			18,000	4810	>9678	2800		3.3	None; 0.7 inches on 3/7/2016
3/16/2016	Trace	ND	Trace	717	ND			11,200	762	>9678	770	5-20	4.2	None; 1.7 inches on 3/13/2016
3/23/2016	ND	ND		1,900				ND	180	197	3970		4.2	None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND		1,200				ND	57	1730	40		4.5	None
4/7/2016	ND	ND		1,640				ND	71.8	1730	40.2		4.5	None

Llagas Creek at Watsonville Road (WAT)

	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Chesbro Outlet	Precipitation (Current; Most Recent)
3/9/2016	Trace	ND	Trace	4,520	ND			2,550	526	>9678	920		3.3	None; 0.7 inches on 3/7/2016
3/16/2016	ND	ND	Trace	1,990	ND			1,410	152	>9678	250	1-5	4.2	None; 1.7 inches on 3/13/2016
3/23/2016	ND	ND	ND	Trace				ND	279	1740	96		4.2	None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND	Trace	Trace				ND	85	3470	55		4.5	None
4/7/2016	ND	ND	ND	Trace				Trace	110	3110	59		4.5	None

Llagas Creek at Oak Glen Ave (OAK)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Chesbro Outlet	Precipitation (Current; Most Recent)
3/9/2016	ND	ND	Trace	973	ND	684	ND	10,100	321	7950	290		3.3	None; 0.7 inches on 3/7/2016
3/16/2016	ND	ND	Trace	ND	ND	Trace	ND	669	92.4	2450	97	1-5	4.2	None; 1.7 inches on 3/13/2016
3/23/2016				ND		ND	ND	ND	10	46.2	688		4.2	None; 0.1 inches on 3/21/2016
4/4/2016				ND		ND	ND	ND	14.6	412	31		4.5	None
4/7/2016				ND		ND	ND	ND	19.6	428	19.2		4.5	None

East Little Llagas Creek at Church Ave (ELL)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow ELL at Church	Precipitation (Current; Most Recent)
3/9/2016	Trace	ND	ND	Trace	ND		ND	622	195	5790	530		0 (high flow only)	None; 0.7 inches on 3/7/2016
3/16/2016	Trace	ND	ND	ND	ND		ND	Trace	205	5200	400	0.1-1	0 (high flow only)	None; 1.7 inches on 3/13/2016
3/23/2016													0	None; 0.1 inches on 3/21/2016
4/4/2016						Dry							0	None
4/7/2016													0	None

Llagas Creek at Buena Vista Ave (VIS)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow Southside*	Precipitation (Current; Most Recent)
3/9/2016	Trace	Trace	ND	Trace	ND	Trace	ND	1,680	2380	>24196	2600		4.5	None; 0.7 inches on 3/7/2016
3/16/2016	Trace	ND	ND	Trace	ND	ND	ND	2,300	882	>24196	530	0.1-1	6.5	None; 1.7 inches on 3/13/2016
3/23/2016													6.5	None; 0.1 inches on 3/21/2016
4/4/2016						Dry							4.7	None
4/7/2016													4.4	None

West Little Llagas Creek at Watsonville Road (WLL)														
	Human Dorei	Human EPA	Bird	Dog	Horse	Pig	Cattle	Ruminant	E. coli	Total Coliforms	Entero	Flow Estimate	Gage Flow at WLL at Edmondson	Precipitation (Current; Most Recent)
3/9/2016	Trace	Trace	ND	2,700					101	9680	520		0 (high flow only)	None; 0.7 inches on 3/7/2016
3/16/2016	ND	ND	ND	ND					68.4	4810	140		0 (high flow only)	None; 1.7 inches on 3/13/2016
3/23/2016	ND	ND		ND					15	45.6	2020		0 (high flow only)	None; 0.1 inches on 3/21/2016
4/4/2016	ND	ND		ND					37	3970	>4840		0 (high flow only)	None
4/7/2016						Dry							0 (high flow only)	None

Appendix D: 2016 Water Quality Data

Station I.D: CHP

Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
3/10/2016	15.0	7.42	9.03	89.6	318	12.6	257	207	0.36	0.79	143	Concrete/Mud	None	None	None	Cloudy (>4")	50-200	Clear	None	<1"	Colorless
3/17/2016	13.2	7.51	8.96	85.5	294	18.7	228	191	0.228	1.82	112	Concrete/Mud	None	None	None	Murky (<4")	50-200	Clear	None	None	Brown
3/24/2016	13.0	7.39	8.81	83.7	347	6.0	267	225	0.36	0.68	146	Cobble	None	None	None	Cloudy (>4")	50-200	Clear	None	None	Colorless
4/4/2016	15.3	7.3	9.29	92.7	383	1.8	311	249	0.434	-	263	Cobble	None	None	None	Clear	5-20	Clear	None	None	Colorless
4/7/2016	16.1	7.72	9.46	96.6	393	1.5	326	255	0.126	0.54	146	Cobble	None	None	None	Clear	5-20	Partly Cloudy	None	None	Colorless

Notes:

Station I.D: UVA

Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
3/10/2016	14.3	7.65	9.86	96.3	316	16.4	251	205	0.785	2.28	151	Mud	None	None	None	Murky (<4")	20-50	Clear	None	-	Brown
3/17/2016	13.2	7.65	9.91	94.5	294	22.1	228	191	0.31	1.85	11	Mud	None	None	None	Murky (<4")	20-50	Clear	None	None	Brown
3/24/2016	13.2	7.76	10	95.5	350	6.7	270	227	0.35	0.86	152	Gravel	Compost	Trash on Bank	None	Clear	50-200	-	-	-	-
4/4/2016	15.4	7.9	9.96	99.8	393	1.9	321	255	0.383	-	247	Gravel	Compost	None	None	-	5-20	Clear	None	None	Colorless
4/7/2016	17.0	7.98	9.23	95.5	397	2.0	336	258	0.416	0.53	218	Cobble	None	Trash on Bank	None	Clear	1-5	Partly Cloudy	None	None	Colorless

Notes:

Station I.D: FUF

Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
3/10/2016	16.2	7.7	7.27	74.3	1622	13.7	1328	1054	0.33	2.54	115.6	Mud	None	-	None	Cloud (>4")	1-5	Clear	None	None	Brown
3/17/2016	13.3	7.63	7.2	69.2	1560	15.8	1212	1015	0.37	2.2	77.2	Mud	None	-	None	Murky (<4")	1-5	Clear	None	None	Brown
3/24/2016	12.6	7.74	7.9	75	1655	7.4	1261	1076	0.4	1.79	112.2	Mud	None	Vascular/Trash	None	Clear	0.1-1	-	-	-	-
4/4/2016	15.2	7.77	8.78	88	1624	6.2	1321	1055	0.285	0.29	227.3	Mud	Sulfide	Trash	None	Clear	0.1-1	-	-	-	-
4/7/2016	15.4	7.7	6.98	70.1	1642	15.0	1342	1067	0.21	2.76	193.3	Mud	None	Trash	None	Clear	1-5	Partly Cloudy	None	None	Brown

Notes:

Station I.D: LLA																						
Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
3/10/2016	16.1	6.93	5.99	61	1474	4.1	1023	958	0.71	2.9	113.2	Mud	None	-	None	Cloudy (>4'')	1-5	Clear	None	-	-
3/17/2016	13.8	7.04	5.61	54.5	1395	3.3	1098	906	0.413	2.97	93.4	Mud	None	-	None	Murky (<4'')	1-5	Clear	None	None	Brown
3/24/2016	13.8	7.07	6.22	60.3	1454	1.6	1142	945	0.41	2.58	115.1	Mud	None	Vascular/Trash	None	Clear	0.1-1	Clear	None	None	-
4/4/2016	15.9	7.1	6.8	69.2	1475	1.1	1219	958	0.566	0.35	235.4	Mud	Sulfides	-	None	Clear	0.1-1	-	-	-	-
4/7/2016	16.2	7.14	5.36	54.8	1480	3.0	1228	962	0.404	2.88	166	Mud	None	-	None	Clear	0.1-1	Partly Cloudy	None	None	Colorless

Notes: 4/4 Illegal dumping from bridge, numerous swallow nest under bridge

Station I.D: SBC																					
Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
3/10/2016	18.4	7.53	5.88	63.2	2129	311.0	1858	1384	0.325	6.7	34.2	Mud	None	-	None	Murky (<4'')	0.1-1	Clear	None	-	-
3/17/2016	15.4	7.6	5.47	55.2	2149	15.0	1756	1397	0.289	5.08	74.9	Mud	Animal	Vascular	None	Murky (<4'')	0.1-1	Clear	None	None	Brown
3/24/2016	14.8	7.75	9.63	96.2	3766	9.9	3031	2448	0.24	6.8	92.1	Mud	None	Vascular	None	Clear	0.1-1	Clear	None	None	-
4/4/2016	22.4	8.27	14.38	165	5074	16.8	4837	3298	0.165	16	106.5	Mud	Compost	Oily Sheen	None	Cloudy (>4'')	0.1-1	-	-	-	-
4/7/2016	17.1	7.79	12.41	132	8945	28.1	760	5817	0.073	11.34	87.4	Mud	None	Oily Sheen	None	Clear	0.1-1	Partly Cloudy	None	None	Colorless

Notes: 3/24- Approx. 40 field workers upstream of site, no porta potty observed. 4/4: sample collected 10 ft upstream of bridge, 4/7: sample collected under the bridge. Sonde partially in mud during sonde measurements which likely impacted readings.

Station I.D: PAJ																					
Date	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipitation	24 Precipitation	Water Color
3/10/2016	14.8	7.54	7.53	74.5	519	27.4	418	337	0.52	4.31	127.4	Mud	None	-	None	Murky (<4'')	50-200	Partly Cloudy	None	None	Brown
3/17/2016	14.6	7.55	5.83	57.4	397	83.0	318	258	0.324	6.12	106	-	-	-	-	.-	-	-	-	-	-
3/24/2016	14.6	7.67	6.73	66.3	663	12.8	531	431	0.9	4.55	288.9	Mud	Mixed	-	None	Murky (<4'')	50-200	Clear	None	None	-
4/4/2016	16.0	7.83	7.7	78.4	996	15.4	825	648	1.04	0.6	120.2	Mud	None	-	None	Murky (<4'')	20-50	-	-	-	-
4/7/2016	16.6	7.68	6.91	71.2	1078	17.8	907	701	0.805	3.08	208.3	Mud	None	-	None	Murky (<4'')	50-200	Partly Cloudy	None	None	Brown

Notes: 3/17- Water level extremely high and staff unable to sample from original spot. Instead, sample taken from bank. Turbidity level likely lower than actual reading. Illegal encampment was observed on 3/24, 4/4 and 4/7 along the access road and adjacent to the river. Camp consisted of a tarp and a small fire on the last instance. Water level drop considerabily from the first event to the last.

3/16/2016																					
Site I:D	Water Temp (C)	pH	O2 (mg/L)	O2 (%)	SC (us/cm)	Turb. (NTU)	Cond. (us/cm)	TDS (mg/L)	Depth (m)	Chlor (ug/L)	ORP	Substrate	Site Odor	Other presence	Water Odor	Water Clarity	Flow (CFS)	Sky Code	Precipi tation	24 Precipi tation	Water Color
OAK	12.1	7.64	9.38	87.1	392	20.3	265	228	0.237	0.47	120	Mud	None	-	None	Cloudy (>4")	1-5	Clear	None	None	Brown
WAT	12.6	7.59	9.39	88.3	516	10.3	394	335	0.348	0.08	124.5	Mud/Cobble	None	-	None	Cloudy (>4")	1-5	Clear	None	None	Brown
WLL	12.5	7.66	7.32	69.3	525	2.5	400	341	0.356	0.25	119.7	Cobble/Sand	None	Trash	Sulfides	Clear	0	Clear	None	None	Colorless
MON	13.4	7.69	8.48	81.4	428	15.8	334	278	0.215	0.37	108.5	oncrete/Cobbl	None	Vascular	None	Cloudy (>4")	5-20	Clear	None	None	Brown
VIS	12.1	7.93	9.76	91.2	563	23.0	425	366	0.189	0.88	121.7	Concrete	None	Trash	None	Cloudy (>4")	0.1-1	Clear	None	None	Brown
ELL	14.7	7.71	6.97	69	297	10.1	239	193	-	0.37	106.3	Concrete	None	-	None	Clear	0.1-1	Clear	None	None	Colorless
Notes:																					