TECHNICAL MEMORANDUM

Stanislaus Regional Water Authority Surface Water Supply Project
Historical Water Quality Assessment

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To: Stanislaus Regional Water Authority (SRWA)
Technical Advisory Committee (TAC)

From: Trussell Technologies, Inc. and West Yost Associates

Authors: Sangam K. Tiwari, Ph.D., P.E. (Trussell Technologies)
Elaine W. Howe, P.E. (Trussell Technologies)

Reviewers: Andy Smith, P.E. (West Yost Associates)
R. Rhodes Trussell, Ph.D., P.E. (Trussell Technologies)
Celine C. Trussell, P.E. (Trussell Technologies)

Subject: **Tuolumne River Historical Water Quality Assessment**

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1 INTRODUCTION

The Stanislaus Regional Water Authority (SRWA), a joint powers authority between the Cities of Turlock and Ceres (Cities), is embarking on a new water supply project to provide treated surface water to the Cities to supplement their existing groundwater supply. The source water for this new water treatment plant (WTP) is the Tuolumne River. The proposed intake is an existing infiltration gallery located four to five feet below the river bottom.

As part of the source water characterization process, historical water quality data collected along the Tuolumne River at locations between Don Pedro Reservoir and the confluence of Dry Creek at Modesto were reviewed. These water quality data and any observed temporal or spatial trends in water quality are provided within this technical memorandum (TM). This TM has the following layout:

1. Project Location and Background
2. Applicable State and Federal Drinking Water Regulations
3. Potential Contaminant Sources
4. Review of Historical Water Quality Data
5. Summary of Water Quality Implications on Treatment Options

The historical water quality assessment will be used as a guide to develop a water quality monitoring plan and to select the appropriate treatment process for SRWA's new WTP.

2 PROJECT LOCATION AND BACKGROUND

The source water for this project is the Tuolumne River. The Tuolumne River originates in Yosemite National Park high in the Sierra Nevada mountain range as two streams and converges in Tuolumne Meadows (Figure 1). The River then meanders northwest with spectacular drops through the Tuolumne Canyon and receives flow from various creeks before widening into Hetch Hetchy Reservoir (formed by O'Shaughnessy Dam). The River exits Yosemite National Park and enters the Stanislaus National Forest. The main Tuolumne River tributaries join within the reach between Hetch Hetchy Reservoir and Don Pedro Reservoir (formed by New Don Pedro Dam) (SFPD, 2008). Don Pedro Reservoir impounds the Upper Tuolumne River Watershed flows from the Sierra Nevada and is operated by the Turlock and Modesto Irrigation Districts. The Tuolumne River enters the Lower Tuolumne River Watershed as it enters La Grange Dam, which is two miles downstream of the New Don Pedro Dam. The Lower Tuolumne River Watershed is shaded in light green in Figure 2. The watersheds for Turlock Lake and the Lower Tuolumne River include steep grassland and woodland of the Sierra Nevada foothills on the far eastern side, transitioning to the plains of the Central Valley downstream. Approximately 17% of the watersheds are dedicated to agriculture (Brown and Caldwell, 2008a). At the New Don Pedro Dam, the Tuolumne River is divided into three flow streams – the Turlock Irrigation District (TID) Canal, the Modesto Irrigation District (MID) Canal (flow only diverted during winter months), and about half of the flow is allowed to continue as the Tuolumne River (MID, 2015). Dry Creek is the last major tributary (just north of the City of Modesto) before the Tuolumne River terminates at the San Joaquin River southwest of San Joaquin River National Wildlife Refuge (SFPD, 2008).

The existing infiltration gallery is located in the Lower Tuolumne River watershed, approximately 25 miles upstream of the confluence of the Tuolumne River with the San Joaquin River (Brown and Caldwell, 2008a). The location of this infiltration gallery within the Lower Tuolumne River Watershed is shown in Figure 2. The infiltration gallery location relative to the Cities of Hughson and Waterford is shown in Figure 3, with an enlargement of the site location shown in Figure 4.

The SRWA plans to construct a new 30 mgd surface water treatment plant to provide high quality, treated water to the Cities of Ceres and Turlock, to supplement their current groundwater supplies. The intake for this new WTP is the previously constructed infiltration gallery, with piping already in-place below the riverbed (Figure 4). This piping is comprised of sixteen (16), 45-foot long sections of 24-inch slotted pipe, covered by four to five feet of pea gravel, washed rock and river cobble. The wet well and raw water pump station to which these pipes will ultimately be connected has not yet been constructed.

Since there are no nearby WTPs directly[1] on the Tuolumne River, characterization of the source water quality will be an important part of the design process. The characterization presented in this TM will facilitate selection and construction of a cost-effective and efficient treatment process capable of producing a stable supply of high-quality potable water to the Cities of Ceres and Turlock.

[1] The Modesto Regional Water Treatment Plant, operated by MID, has its intake in the southwest point of Modesto Reservoir. The source water for the Modesto Reservoir is the Tuolumne River which is diverted from La Grange Reservoir at the La Grange Dam and diversion structure. This diversion structure is approximately 26 miles upstream of the location of the infiltration gallery. The Reservoir water quality is different from the River water quality due to long storage time and seasonal stratification and turnover.

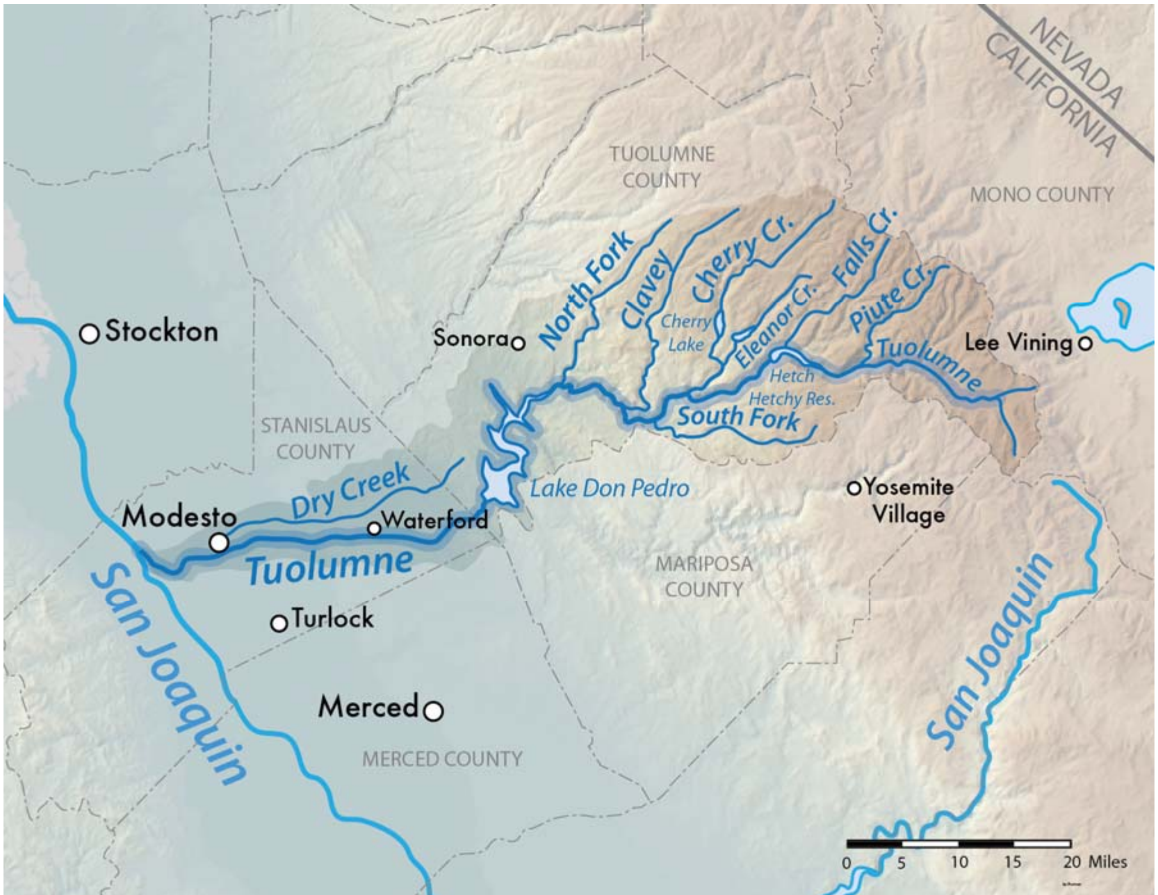

Figure 1. Overall Course of the Tuolumne River (USGS website)

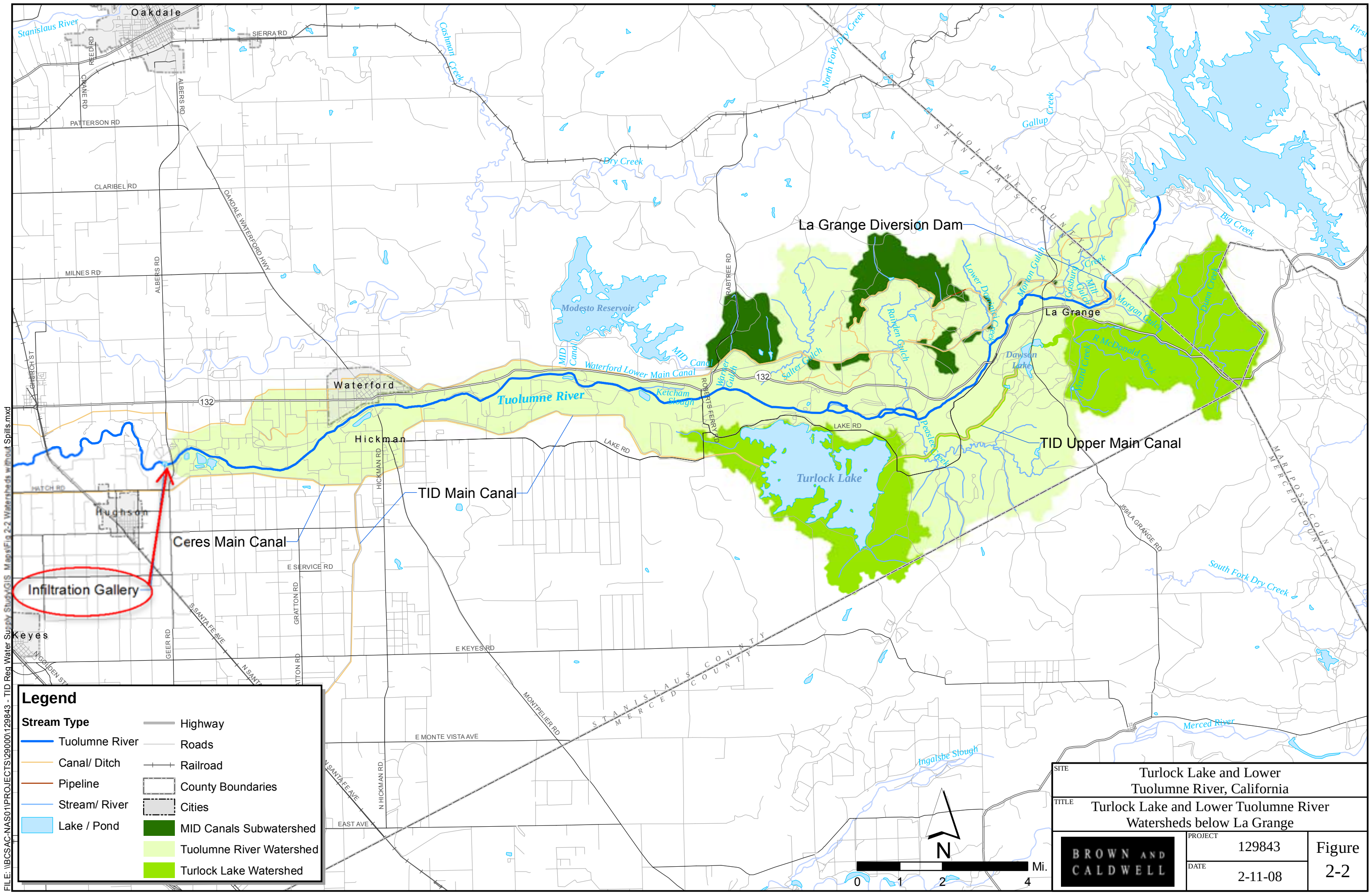

Figure 2. Lower Tuolumne River Watershed (Brown and Caldwell, 2008a)

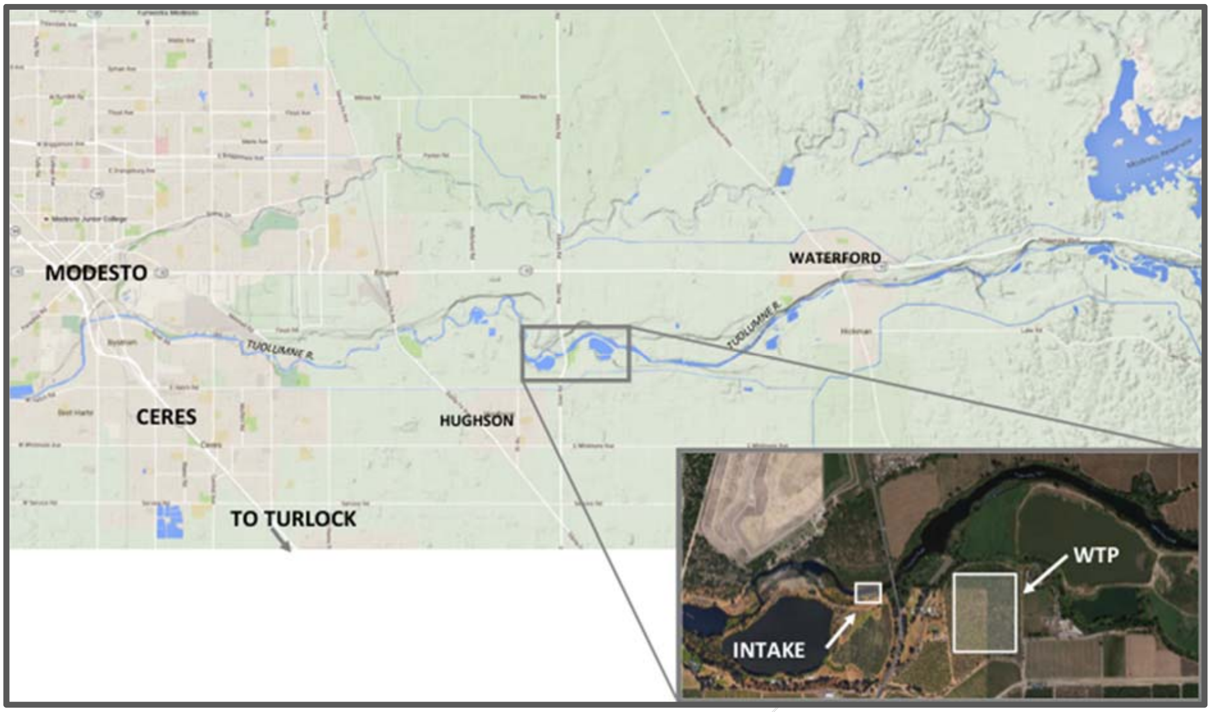

Figure 3. Infiltration Gallery Location on the Tuolumne River

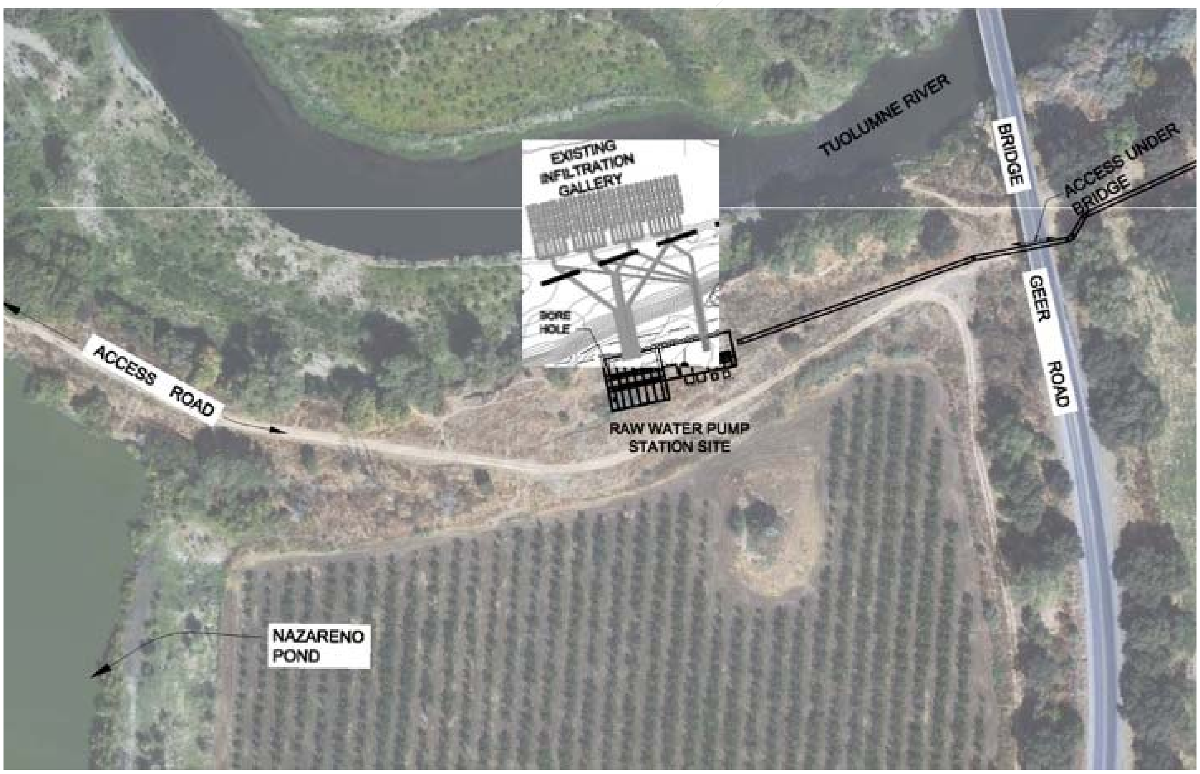

Figure 4. Enlargement of Infiltration Gallery Location on the Tuolumne River

3 STATE AND FEDERAL DRINKING WATER REGULATIONS

The SRWA's future surface water treatment facility will be subject to all applicable state and federal drinking water regulations. The following is a list of standards which define the maximum contaminant levels (MCLs) that the United States Environmental Protection Agency (USEPA) and the State of California (as specified in Title-22 of the California Code of Regulations (CCR)) have legislated for the drinking water industry to ensure the public's health and safety:

§64431	Maximum Contaminant Levels – Inorganic Chemicals
§64442	MCLs and Monitoring - Gross Alpha Particle Activity, Radium-226, Radium-228, and Uranium
§64443	MCLs and Monitoring - Beta Particle and Photon Radioactivity
§64444	Maximum Contaminant Levels – Organic Chemicals
§64449	Secondary Maximum Contaminant Levels and Compliance
§64533	Maximum Contaminant Levels for Disinfection Byproducts
§64426.1	Total Coliform Maximum Contaminant Level
§64674	Lead and Copper – Large Water System Requirements

In addition to the MCLs, treatment techniques have been legislated which regulate microbial removal through filtration and microbial inactivation through disinfection (§64652). The raw water quality will determine how these treatment techniques are applied, and will influence the design of the SRWA's future WTP.

Treatment techniques have also been legislated for removal of DBP precursor material, as measured by Total Organic Carbon (TOC) (§64535). The percentage of TOC to be removed through treatment is determined by source water TOC and alkalinity. Historical river water quality data for these parameters is also discussed in this TM, and potentially will have a large impact on process train selection for the future WTP.

3.1 Primary and Secondary Maximum Contaminant Levels (MCLs)

Primary MCLs (pMCL) are legally enforceable limits that regulate contaminant levels based on toxicity and adverse human health effects. Secondary MCLs (sMCL) are guidelines rather than enforceable limits; they are based on aesthetics and are labeled by the regulations as "consumer acceptance contaminant levels." Tables extracted from the Title 22 CCR for all constituents that have primary and secondary MCLs are provided in Appendix A (CCR, Updated July 16, 2016).

One contaminant that will soon have a MCL is 1,2,3-Trichloropropane (1,2,3-TCP). This contaminant has had a California Division of Drinking Water (DDW) notification level (NL) of 0.005 µg/L since 1999. On July 20, 2016, DDW released a recommendation establishing a MCL for 1,2,3-TCP of 0.005 µg/L—the same as the current NL—because this compound is a known carcinogen.

All contaminants with a pMCL and sMCL, including 1,2,3-TCP, are included in the Draft Source Water Characterization Sampling Plan (Trussell Technologies, July 14 2016) and will be sampled quarterly for one year.

3.2 Surface Water Treatment Rules

There has been a series of four federally mandated Rules that have been promulgated with the intent of preventing waterborne diseases caused by pathogenic microorganisms, starting with the Surface Water Treatment Rule (SWTR). These Rules established treatment techniques to remove and/or inactivate microbial contaminants through effective filtration and disinfection. While they are detailed and complex, the following discussion provides a brief synopsis as it relates to the potential treatment train for the SRWA.

The SWTR was promulgated in 1989. It required that all public water systems (PWS) using surface water or groundwater under the direct influence of surface water, which practice conventional or direct filtration, to:

1. Achieve 4-log (99.99%) removal/inactivation of viruses and 3-log (99.9%) removal/inactivation of *Giardia lamblia*,
2. Maintain a disinfectant concentration of at least 0.2 mg/L at the entrance to the distribution system, and maintain a detectable disinfectant residual throughout the distribution system, and
3. Maintain a combined filter effluent turbidity less than 0.5 NTU.

The Interim Enhanced Surface Water Treatment Rule (IESWTR) was promulgated in 1998 and built on the treatment techniques required by the SWTR. In order to address *Cryptosporidium*, the IESWTR required PWSs that filter to achieve a 2-log removal of *Cryptosporidium* by increasing the stringency of the combined filter effluent turbidity standards to 0.3 NTU. *Cryptosporidium* are highly resistant to traditional disinfection practices using chlorine and/or chloramines, so the required 2-log removal is through filtration and not inactivation.

The Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR), promulgated in 2002, made the 2-log *Cryptosporidium* removal requirement applicable to small systems servicing less than 10,000 people.

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), promulgated in 2006, requires utilities to monitor their source water on a monthly basis for *Cryptosporidium*, *E. coli*, and turbidity. Depending on the maximum running annual average (RAA) *Cryptosporidium* concentration, the water is placed in a “Bin” which dictates the level of treatment required to achieve the required log removal/inactivation of *Cryptosporidium*. Bin classification is summarized below in Table 1.

Table 1. Bin classification for filtered public water systems indicating the *Cryptosporidium* removal required under the LT2ESWTR

Bin	Cryptosporidium Concentration (oocysts/L)	Treatment Requirements for Conventional Filtration	Treatment Requirements for Direct Filtration
1	<0.075	No additional treatment	No additional treatment
2	0.075 to <1.0	1-log	1.5-log
3	1.0 to <3.0	2-log	2.5-log
4	≥3.0	2.5-log	2-log

In addition to stipulating the overall requirements, these rules require a multi-barrier treatment approach to ensure effective microbial treatment. The specific treatment credit awarded for pathogen *removal* depends on the filtration technology applied, and the credit awarded for pathogen *inactivation* depends on the disinfectant type, dose and contact time. As such, regardless of the removal credit attained, at least 0.5-log *Giardia* inactivation and 2-log virus inactivation must be provided through disinfection.

DDW has authority to require greater levels of pathogen treatment based on source water quality. DDW has stated it plans to follow the DDW Surface Water Treatment Rule (SWTR) guidance document[2] with regard to log treatment requirements for *Giardia* and viruses:

Total coliform (monthly median):

- If <1000 /100 mL, then 3-log or 4-log treatment requirements for *Giardia* and viruses, respectively
- If >1000 /100 mL, then 4-log or 5-log treatment requirements for *Giardia* and viruses, respectively

E. coli (monthly median):

- If <200 /100 mL, then 3-log or 4-log treatment requirements for *Giardia* and viruses, respectively
- If >200 /100 mL, then 4-log or 5-log treatment requirements for *Giardia* and viruses, respectively

The minimum microbial reduction requirements, as mandated by DDW and the USEPA are summarized in Table 2.

[2] "Appendix B, Guidelines for Determining when Surface Waters will Require More than the Minimum Levels of Treatment Defined in the Surface Water Treatment Regulations"

Table 2. Overall regulatory pathogen removal/inactivation requirements

Pathogen	DDW Removal/Inactivation Requirements
Cryptosporidium (Bin 1)	2-log
Giardia	3-log
Viruses	4-log

3.3 Disinfectants and Disinfection Byproducts Rule

The Disinfectants and Disinfection Byproducts Rule (D/DBPR) was legislated to minimize the public's exposure through drinking water to potentially carcinogenic disinfection byproducts (DBPs). The rule was promulgated in two parts. The Stage 1 D/DBP Rule, promulgated in 1999, established:

- MCLs for two groups of organic DBPs—total trihalomethanes (TTHMs) and haloacetic acids (HAA_5);
- MCLs for two inorganic DBPs—bromate and chlorite;
- Treatment techniques for the effective removal of DBP precursor material, measured as TOC; and,
- Maximum residual disinfectant levels (MRDLs) for chlorine, chloramines, and chlorine dioxide.

The Stage 1 D/DBP Rule MCLs are summarized in Table 3. Compliance is based on a system-wide running annual average (RAA).

Table 3. MCLs for the Disinfection Byproducts

Disinfection By-Product	MCL (mg/L)
Total Trihalomethanes (TTHM)	0.08
- Chloroform	
- Bromodichloromethane	
- Dibromochloromethane	
- Bromoform	
Haloacetic Acids (HAA5)	0.06
- Mono-, di-, and trichloroacetic acids	
- Mono- and dibromoacetic acids	
Chlorite	1.0
Bromate	0.010
Disinfectants	**MRDL (mg/L)**
Chlorine	4.0 (as Cl2)
Chloramine	4.0 (as Cl2)
Chlorine Dioxide	0.8 (as ClO2)

The treatment technique for TOC removal is referred to as “enhanced coagulation”. The amount of TOC removal required by the D/DBP Rule is a function of the source water TOC concentration and alkalinity, as summarized in Table 4. The D/DBP Rule also provides “alternative compliance criteria” which systems have the option of meeting for compliance in lieu of the TOC removal requirement. These alternative compliance criteria are:

1. System’s source water TOC is <2.0 mg/L
2. System’s treated water TOC is <2.0 mg/L
3. System’s source water TOC is <4.0 mg/L and alkalinity is >60 mg/L (as $CaCO_3$), and the system’s TTHM and HAA5 compliance samples are <40 µg/L and <30 µg/L, respectively.
4. System’s TTHM concentration is <40 µg/L and HAA5 concentration is <30 µg/L, with only free chlorine for primary disinfection and residual maintenance.
5. System’s source water Specific Ultraviolet Absorption (SUVA) prior to any treatment is ≤2.0 L/mg-m; and
6. System’s treated water SUVA is ≤2.0 L/mg-m.

Meeting any of the above six requirements permits the utility to avoid the enhanced coagulation TOC removal requirement.

Direct filtration systems are not required to comply with the Enhanced Coagulation treatment requirements, but the System must still comply with the DBP MCLs.

The Stage 2 D/DBP Rule requires each system to conduct an “initial distribution system evaluation (IDSE)” to determine locations within their distribution system that represent the highest concentrations of DBPs, and to modify their monitoring and reporting requirements to include these locations. The Stage 2 D/DBP Rule requires calculation of locational running annual averages (LRAA) rather than system-wide RAA as had been used in the Stage 1 Rule. The RAA allowed some areas of the system to have higher DBP concentrations, while still complying with the regulations. The LRAA is more stringent because it ensures all locations in the distribution system are in compliance with the MCLs.

Table 4. TOC Removal Required Under the Stage 1 D/DBP Rule

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0-60	>60-120	>120
>2.0 – 4.0	35%	25%	15%
>4.0 – 8.0	45%	35%	25%
>8.0	50%	40%	30%

3.4 Total Coliform Rule

The Total Coliform Rule (TCR) was published in 1989 and became effective in 1990. The Revised Total Coliform Rule (RTCR) was published on February 13, 2013. PWSs were required to comply with requirements of the RTCR by April 1, 2016. The TCR requires public water systems to collect a specific number of samples from their distribution system (based on the size of their system) to monitor for total coliform. Compliance is based on the presence or absence of total coliform. If a sample tests positive for total coliform, it must also be tested for fecal coliform or *E. coli*. A sample that tests positive for fecal coliform or *E. coli* is considered an acute violation.

The RTCR introduces an MCL goal (MCLG) of zero for *E. coli,* and an MCL for *E. coli* based on monitoring results for total coliforms and *E. coli*. The RTCR also eliminates the MCLs and MCLGs for total coliforms (and fecal coliforms) included in the TCR. The measurement of Total Coliform was developed at the turn of the century as an indicator of the presence of fecal contamination (Smith, 1893). From the beginning it was clear that some members of the coliform group (the organisms that test positive as coliform organisms) are not actually fecal in origin. The fecal coliform test was developed in the 1960s as a test that more narrowly targeted members of the coliform group that are of fecal origin, but even that test was not still specific for the main organism found in human feces, namely *Escherichia coli* (*E. coli*). In recent decades a specific test for the *E. coli* organism, itself, has been developed and has seen widespread use. Under the TCR, total coliform-positive samples trigger an assay for either fecal coliforms or *E. coli*. The RTCR eliminates fecal coliform tests, replacing them with direct measurement of *E. coli* as an indicator of fecal contamination.

Perhaps the most significant change in the RTCR is the requirement of corrective action and a coliform treatment technique. Under the coliform treatment technique, total coliforms serve as an indicator of a potential pathway of contamination. It requires a system to conduct an assessment of their system when monitoring results indicate the system may be vulnerable to contamination, based on exceeding a specified frequency of total coliform occurrence. A simple Level 1 self-assessment or a more detailed Level 2 assessment may be required depending on how severe and how frequent the contamination. Any sanitary defects identified in the Level 1 or Level 2 assessments must be corrected. Example sanitary defects include cross-connection and backflow issues; operator issues; distribution system issues; storage issues; and disinfection issues like failure to maintain the disinfectant residual throughout the distribution system.

The RTCR also makes changes to the public notification requirements. Under the TCR, public notification is required for detection of total coliforms. Under the RTCR, public notification would no longer be required upon detection of total coliforms. Instead, a Tier 1 public notification (PN) is required when the *E. coli* MCL is violated. A Tier 2 PN is required when there is a treatment technique violation. A Tier 3 PN is required in the case of monitoring or reporting violations.

3.5 Lead and Copper Rule

The lead and copper rule (LCR), promulgated by the USEPA in 1991, established action levels for lead and copper concentrations in potable water. The four basic requirements of this rule for water suppliers are (1) to optimize treatment to control corrosion in the distribution system and in customers' plumbing, (2) determine concentrations of lead and copper at the taps of customers with lead service lines or lead solder in their plumbing, (3) rule out the source water as a source of significant lead levels, and (4) provide public education about lead if action levels are exceeded. The LCR requires PWS to monitor for lead and copper at the entry to their distribution system and at taps throughout the distribution system (the number of monitoring points is based on system size and the monitoring should target taps in homes/buildings that are at high risk of lead and copper contamination). The action level for lead is 0.015 mg/L and the action level for copper is 1.3 mg/L, both based on 90th percentile levels. If 90th percentile concentrations exceed these action levels, the utility must evaluate and implement one of the prescribed corrosion control treatment strategies, which include alkalinity and pH adjustment, calcium hardness adjustment, and the addition of a phosphate or silicate based corrosion inhibitor.

In 2007, the USEPA promulgated seven short-term regulatory revisions and clarifications to the LCR, which targeted monitoring, treatment processes, public education, customer awareness, and lead service line replacement (USEPA, 2007). These minor revisions did not change the action levels, MCLG, or basic requirements of the LCR.

In July 2016, EPA published a memo providing recommendations on how public water systems should address lead and copper sampling details in a comprehensive document, *The Optimal Corrosion Control Treatment Evaluation Technical Recommendations Document,* which provides technical recommendations that both systems can use to comply with Lead and Copper Rule (LCR) corrosion control treatment requirements and effective evaluation and designation of optimal corrosion control treatment (OCCT). The technical recommendations in the new document are based on new science and implementation experience. Key topics covered are:

1. Influence of oxidation-reduction potential (ORP) on lead and copper release, and importance of Pb(IV) compounds for systems with lead service lines (LSLs).
2. Importance of aluminum, manganese, and other metals on formation of lead scales and lead release.
3. Impact of physical disturbances on lead release.
4. Mechanisms and limitations of using blended phosphates for corrosion control.
5. Target water quality parameters (WQPs) for controlling copper corrosion.
6. Impacts of treatment changes, particularly disinfectant changes, on corrosion and corrosion control.

3.6 Water Quality Criteria for Unregulated Contaminants

Monitoring may be necessary for certain unregulated contaminants. Both the DDW and the EPA maintain lists of unregulated contaminants that may be on the regulatory horizon. These lists are: (a) DDW's list of compounds with Notification Levels (NL) or Archived Notification Levels (aNLs) and (b) EPA's current Contaminant Candidate List (CCL) with the associated Unregulated Contaminant Monitoring Rule (UCMR).

3.6.1 DDW Notification Levels and Archived Notification Levels

DDW has established health-based notification levels for certain chemicals associated with actual contamination of drinking water supplies. Contaminants with notification levels currently lack MCLs, but may be regulated in the future. If, after several years, an MCL is not adopted for a specific chemical, its notification level is then archived. Notification levels are advisory in nature and not legally enforceable standards. Nevertheless, if a contaminant is detected in a finished water above the NL then DDW recommends consumer notification, and if the measured contaminant concentration exceeds the NL response level, then further action is recommended by DDW.

3.6.2 Candidate Contaminant List (CCL)

The EPA is mandated by the Safe Drinking Water Act (SDWA) to publish a list of candidate contaminants being considered for regulation every five years. This list is referred to as the Candidate Contaminant List (CCL). Candidates on this list are not currently regulated, but are either known or suspected to occur in PWSs. After being listed on a CCL, supporting data is evaluated to determine whether or not it is sufficient for regulatory determination. Data needs are evaluated in three categories—health effects, occurrence, and analytical methods. If insufficient occurrence data exist and regulation seems probable, candidates can be added to the list of constituents monitored under the Unregulated Contaminant Monitoring Rule (UCMR).

The EPA has published three CCLs and a draft of the fourth CCL which was published February 2015. Monitoring for non-UCMR CCL constituents is not required.

3.6.3 Unregulated Contaminant Monitoring Rule (UCMR)

The EPA uses the UCMR to collect occurrence data for contaminants known or suspected to exist in source waters and which pose a human health risk. Most of the contaminants on the UCMR list were initially on a CCL, and were selected due to a lack of occurrence data. The EPA can require PWS to monitor for as many as 30 contaminants under the UCMR, and the monitoring list is reevaluated every 5 years. Information gathered under the UCMR is used in establishing future contaminant MCLGs and MCLs. EPA proposed the fourth UCMR list in December 2015, with a proposed sampling time frame between March 2018 and November 2020.

4 POTENTIAL CONTAMINATING SOURCES

The following potential sources of contamination were identified in the TID Watershed Sanitary Survey (WSS) of the Lower Tuolumne River and Turlock Lake (Brown and Caldwell, 2008a), online visual searches using Google Earth (US Dept. of State Geographer © 2016 Google) between La Grange Dam and the infiltration gallery, and correspondence with Terry Scanlan of SPF Water Engineers on June 17, 2016. A land use map is provided in Figure 6 (extracted from the 2008 TID WSS). Locations of the main potential contaminating activities are shown in Figure 7, and discussed below:

- City of Waterford Wastewater Treatment Plant (WWTP). This is the only municipal WWTP in this reach of the River that could impact water quality at the infiltration gallery site; the remainder of the study area uses septic systems for wastewater disposal. The location of the aeration ponds and percolation basins are shown in Figure 8. The WWTP has a capacity of 1 mgd and an average flow of approximately 0.585 mgd. The facility uses four reinforced concrete aeration ponds (128,000 ft^2) on the North side of the River, followed by storage ponds. The effluent from the storage ponds is pumped to four drying beds/percolation basins across (South side) the Tuolumne River. As of 2006, the facility met existing requirements of the Central Valley Regional Water Quality Control Board, but upgrades were needed to meet secondary treatment standards and future discharge standards (City of Waterford, 2006).

- Dairy, Poultry and Ranch Operations[3]. There are a number of dairy, poultry, and ranch operations near the bank of the River: J & T Cattle Co. Bret Warner Ranch, Right Fork Cattle Co., Golding Farms, Hayes Ranch, Donald & Patricia Mason Farm, Sunset Farms, Alberto Dairy, Michel Ranch and Dairy, Foster Poultry Farms, and Jeg Ranch. Only the larger operations are shown in Figure 7.

- Geer Road Landfill. The Geer Road Landfill, which is closed now, is located ¼ mile north of, and directly across the river from the infiltration gallery. The extent of this inactive landfill is shown in Figure 9. As discussed in the 2008 TID WSS, although there are no active solid waste or hazardous waste disposal facilities within the study area, this closed landfill continues to be regulated by Regional Water Quality Control Board (RWQCB) waste discharge requirements during its closure (Brown and Caldwell, 2008a). SPF Water Engineering completed a preliminary investigation of the potential impact of this closed landfill on

[3]According to the United States Department of Agriculture (USDA, 2012), Stanislaus County ranks 7th among California's 58 counties in total value of agricultural products sold, 4th in value of livestock, poultry, and their products, and 3rd in value of sales for both poultry and eggs, as well as milk from cows (4th overall in the United States). In addition to livestock, the top three crops, in terms of land area, grown locally include almonds (3rd in the state and U.S.), forage land (hay and haylage, grass silage, and greenchop; 10th in the state and 84th in the U.S.), and corn for silage (3rd in the state and 4th in the U.S.). In terms of land use, approximately 50% of the county's farmland is pastureland and 44% is cropland.

Tuolumne River water quality (Scanlan, 2016). This landfill is under close surveillance with on-going groundwater remediation and monitoring. Based on the Second Semiannual and Annual 2015 Detection, Evaluation and Corrective Action Monitoring Report, "The 2015 analytical results do not indicate degradation to the Tuolumne River water quality from the landfill" (Tetra Tech BAS, 2016 – Page 23). The sampling locations on the Tuolumne River and the monitoring wells (shallow and deep) in the project vicinity are provided in Figure 5. The shallow groundwater flows southwest to west and the deep groundwater flows west, so the flow path of the groundwater beneath the landfill is towards the Tuolumne River, but downstream of the infiltration gallery site. Toluene was the only VOC detected in the River samples. One detection was upstream of the infiltration gallery (Sampling Location TR-1, 0.11 µg/L laboratory estimate) and the other was downstream of the infiltration gallery (Sampling Location TR-3, 0.096 µg/L laboratory estimate) and were both collected in November 2015. The two detections (out of 20 total samples) were j-flagged because the concentration was above the method detection limit but below the practical quantitation limit, so the reported concentrations are estimates. Additionally, Toluene was not present in the duplicate sample taken at TR-3 and the levels observed were substantially below the pMCL of 150 µg/L (Tetra Tech BAS, 2016).

- Groundwater influences. SPF Water Engineering completed a preliminary investigation of the groundwater quality in the vicinity of the infiltration gallery in June 2016. Using the GeoTracer website, SPF Water Engineers identified the following sites of interest in the vicinity of the infiltration gallery: Western Stone Products (T060990234), multiple contamination sites within the City of Hughson, and the Geer Road Landfill. The Western Stone Products is a leaking underground storage tank site with a closed cleanup status. This site is 1.25 miles east and up gradient of the infiltration gallery. The closed cleanup status suggests low potential for impacts near the infiltration gallery. The contamination sites with the City of Hughson are all located 1.5 to 2.0 miles southwest of the infiltration gallery. The groundwater flows in a westerly direction in this area, so the risk of these contaminants entering the River near the infiltration gallery is low (Scanlan, 2016). See previous bullet for a discussion about the Geer Road Landfill.

- Recreational Areas: There are several recreational areas nearby and in the upper reaches of the Lower Tuolumne watershed, including La Grange Off-Highway Vehicle Use, Basso Bridge River Access, Turlock Lake State Recreational Area, and Fox Grove County Park.

- Pesticide and Herbicide Application to Agricultural Areas[1]: Given the large percentage of the watershed dedicated to agriculture, stormwater and irrigation runoff from these areas is a known source of contamination to the River. The Lower Tuolumne River, downstream of Don Pedro Reservoir, is listed as an impaired water body under USEPA Clean Water Act Section 303(d) (California State Water Resources Control Board, 2010). This designation is largely due to the presence of several pesticides, including chlopyrifos, diazinon, Group A pesticides (aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane - including lindane, endosulfan, and toxaphene), as well as pollution from mercury, water temperature, and an unknown toxicity.

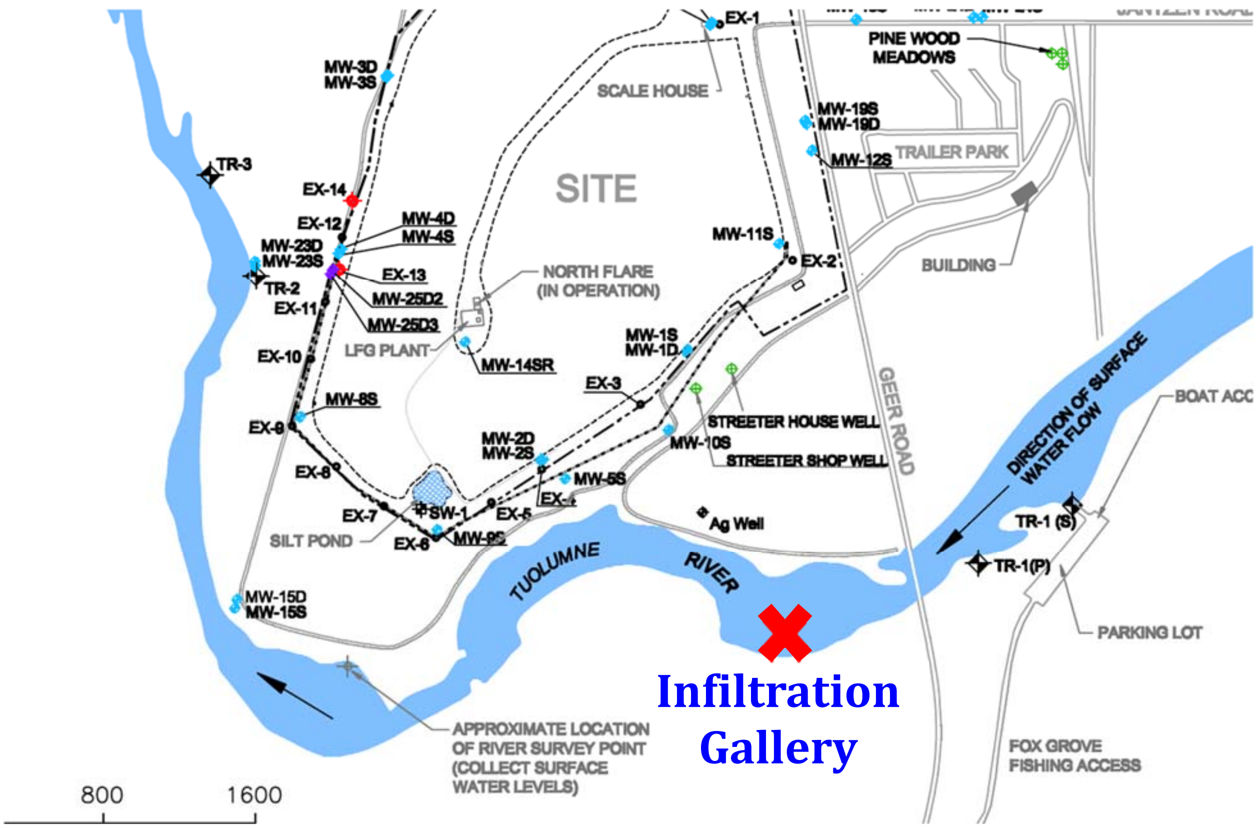

Figure 5. Sampling Locations to Monitor the Closed Geer Road Landfill in Project Vicinity

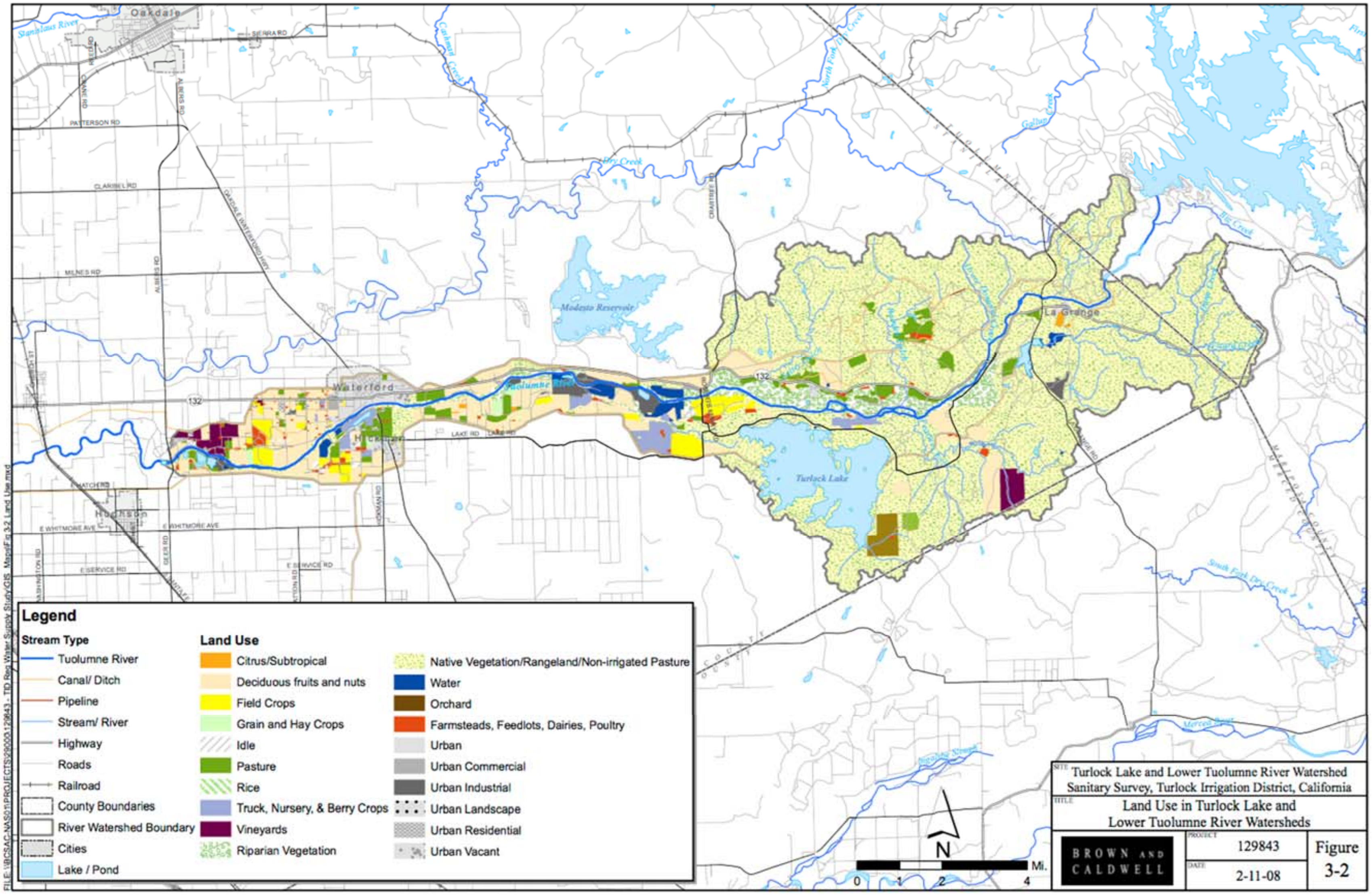

Figure 6. Land Use in Project Vicinity (Brown and Caldwell, 2008a – Screen Capture of Figure 3-2 from 2008 TID WSS)

Figure 7. Potential Sources of Contamination in Project Vicinity

Figure 8. City of Waterford WWTP Aeration Basins and Percolation Ponds

Figure 9. Inactive Geer Road Landfill Highlighted in Yellow

5 REVIEW OF HISTORICAL WATER QUALITY DATA

As part of the source water characterization process, historical water quality data collected on the Tuolumne River at locations between Don Pedro Reservoir and the confluence of Dry Creek at Modesto were reviewed. There are a number of monitoring locations along the Tuolumne River. This summary focuses on the reach between La Grange Dam and the confluence with Dry Creek. This portion of the River includes the infiltration gallery, which will serve as the intake for SRWA's new WTP. The historical data from this reach of the Tuolumne River are expected to be representative of WTP source water, as there are no major influences along this portion. Sampling locations upstream of La Grange Dam and downstream of the Dry Creek confluence are not included due to the influence of dams, reservoirs, inflowing water bodies, and major cities along these portions of the Tuolumne River.

5.1 Sources of Data

Various agencies were contacted and an online search was completed for the compilation of historical data covering the past ten years (2005 through 2015). The majority of the historical data collected were dated prior to 2005. The most substantial data sets were available through watershed sanitary surveys (WSS) generated by Turlock Irrigation District during the original efforts to implement this surface water supply project and their sampling efforts during the 2007-2008 pilot investigation of treatment alternatives (Brown & Caldwell, 2008a; Brown & Caldwell, 2008b). Historical water quality data for the past ten years between La Grange Dam and the confluence of Dry Creek were available from the following sampling efforts:

1. The United States Geological Survey (USGS) collects water quality data nationwide, which are available online via the National Water Information System[4]. The only data available within the last 10 years and within the river reach of interest are 15-minute temperature and river flow data that continues to be collected.
2. MID owns and operates the Modesto Regional WTP, located adjacent to and just to the southwest of Modesto Reservoir. Every five years they prepare a WSS for their water source, which is diverted from La Grange Dam to Modesto Reservoir. MID provided their WSS covering a four-year period from 2009 through 2012. The water quality of their plant intake is somewhat representative of the water quality expected at the infiltration gallery since La Grange Dam is on the Tuolumne River and approximately 20 miles upstream of the infiltration gallery (HDR, 2014).
3. TID prepared a WSS for the Lower Tuolumne River and Turlock Lake in 2008, prior to the formation of the SRWA. The proposed water supply project is now headed by SRWA and water is purchased from TID via a Water Sales Agreement entered by the two agencies in July 28, 2015. These data are most relevant to the proposed project as the monitoring locations were most proximate to the source water. One year of data are provided from May 2006 to May 2007 (Brown and Caldwell, 2008a).
4. The *Turlock Irrigation District Regional Surface Water Supply Pilot Study Report* was prepared by Brown and Caldwell in 2008. This pilot study assessed various treatment options for the purification of Tuolumne River water near the Hughson

[4] http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11289650&agency_cd=USGS

WWTP in the vicinity of the infiltration gallery. This study report included raw water quality data collected between September 2006 to March 2007 (Brown and Caldwell, 2008b).

5. *Technical Memorandum Number 3: Treatment Process Evaluation Memorandum* was prepared for TID by Brown and Caldwell in 2007. The data presented in this TM were incorporated into the 2008 TID WSS by Brown and Caldwell (2008a)—listed as item 3 above.
6. TID's extended Monitoring Program, which was conducted as part of the WSS effort from May 2007 to October 2008 (data were provided to SRWA by TID)
7. The State Water Resources Control Board (SWRCB) created the California Environmental Data Exchange Network (CEDEN) in an effort to consolidate water quality data in a central location online[5]. Data for the area and time frame of interest were available through the Statewide Perennial Streams Assessment 2009 and the RWQCB Region 5 Surface Water Ambient Monitoring Program Safe to Swim 2011-2012 and Safe to Swim Annual 2013-2014.
8. The State Water Project Watershed Sanitary Survey (Volume 1 - covering the San Joaquin River Watershed) included some historical water quality data from the Tuolumne River, about 10 miles downstream from the infiltration gallery. These data were and continue to be generated by the City of Modesto's Stormwater Management Program[6] (DWR, 2015). Data were supplied by the City of Modesto from 2004-2016.

5.2 Monitoring Locations

Historical water quality was assessed from the sampling locations described below. Each of the listed locations is shown in Figure 10, and the monitoring agencies and corresponding unique ID associated with the locations are listed in Table 5.

1. USGS California Water Science Center National Water Information System
   ID: A - Upstream of infiltration gallery near Old La Grange Bridge
   (USGS Station Code: 11289650)

2. MID Modesto Regional Water Treatment Plant (MRWTP) Watershed Sanitary Survey
   ID: B - Inlet to Modesto Reservoir from La Grange Dam
   ID: C - Raw intake from Modesto Reservoir for MRWTP

3. TID Watershed Sanitary Survey of the Lower Tuolumne River and Turlock Lake, as well as data from additional monitoring completed from May 2007 to April 2008 at infiltration gallery
   ID: D - Upstream of infiltration gallery near Basso Bridge

[5] http://ceden.waterboards.ca.gov/AdvancedQueryTool
[6] http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/san_joaquin/r5-2009-0119_swmp.pdf

ID: E - Upstream of infiltration gallery near Roberts Ferry Bridge
ID: I - At infiltration gallery near Geer Road

4. TID Regional Surface Water Supply Pilot Study Report
   ID: J - Tuolumne River at Hughson WWTP

5. SWRCB CEDEN
   ID: F - Upstream of infiltration gallery, 4 miles upstream of Hickman Road (SWRCB Station Code: 535PS0265)
   ID: G - Upstream of infiltration gallery at Waterford Road (SWRCB Station Code: 535TR5xxx)
   ID: H - Slightly upstream of infiltration gallery at Fox Grove (SWRCB Station Code: 535STC218)
   ID: K - Downstream of infiltration gallery at Ceres River Bluff Park (SWRCB Station Code: 535STC217)
   ID: M - Downstream of infiltration gallery near Modesto City-County Airport at Legion Park (SWRCB Station Code: 535STC216)

6. City of Modesto – Stormwater Management Program
   ID: L - Downstream of infiltration gallery, near Mitchell Road

Figure 10. Historic Sampling Locations in Relation to Potential Contaminating Activities

Table 5. Historic Sampling Locations in the Lower Tuolumne River Watershed

Monitoring Agency or Reference Document	Site ID	Approx. Miles from infiltration gallery[1]	Location Description	Monitored Parameters	Monitoring Dates
USGS California Water Science Center National Water Information System	A	+ 23.9	USGS Station Code 11289650; Upstream of infiltration gallery near Old La Grange Bridge	Temperature, Flow from La Grange Dam	Oct 2007 – April 2016
MID Modesto Regional Water Treatment Plant (MRWTP) WSS	B	+ 13.90	Inlet to Modesto Reservoir from La Grange Dam	*Cryptosporidium, Giardia*	May 2009 – Sept 2012
	C	--	MRWTP raw water intake in Modesto Reservoir	General, Turbidity, TOC, Microbiological, *Cryptosporidium, Giardia*, Metals,	Jan 2009 – Dec 2012
TID WSS of the Lower Tuolumne River and Turlock Lake, plus additional monitoring data collected May 2007 to October 2008	D	+ 21.7	Near Basso Bridge	General, Turbidity, Bromide, Nutrients, Fe, Mn, TOC, DOC, DO, Chlorophyll, Microbiological, Pesticides, SOCs	May 2006 - Oct 2008
	E	+ 13.90	Near Roberts Ferry Bridge	General, Turbidity, Bromide, Nutrients, Fe, Mn, TOC, DOC, DO, Chlorophyll, Microbiological, Pesticides, SOCs	May 2006 - Oct 2008
SWRCB California Environmental Data Exchange Network (CEDEN)	F	+ 9.45	SWRCB Station Code 535PS0265; Four miles upstream of Hickman Rd.	General, Turbidity, Nutrients (1 data point)	Aug 2009
	G	+ 5.71	SWRCB Station Code 535TR5xxx; Waterford Road	Field data, Microbiological, *Cryptosporidium, Giardia*	Aug 2010 – Jun 2014
	H	+ 0.1	SWRCB Station Code: 535STC218; Fox Grove	Field data, Microbiological, *Cryptosporidium, Giardia*	Aug 2010 – Jun 2014
TID WSS of the Lower Tuolumne River and Turlock Lake, plus additional monitoring data collected May 2007 to April 2008	I	0	At infiltration gallery near Geer Road	General, Turbidity, Bromide, Nutrients, Fe, Mn, TOC, DOC, DO, Chlorophyll, Microbiological, Pesticides, SOCs	May 2006 - Oct 2008
TID Regional Surface Water Supply Pilot Study Report	J	- 2.54	Tuolumne River at Hughson WWTP	General, Fe, Mn, TOC, Turbidity	Sept 2006 – April 2007
SWRCB California Environmental Data Exchange Network (CEDEN)	K	- 6.96	SWRCB Station Code: 535STC217; Ceres River Bluff Park	Field data, Microbiological, *Cryptosporidium, Giardia*	Aug 2010 – Jun 2014
City of Modesto – Stormwater Management Program	L	- 7.74	Near Mitchell Road	General, Turbidity, Nutrients, Fe, TOC, DO, Microbiological, Pesticides, SOCs	Jan 2005 – Apr 2016
SWRCB California Environmental Data Exchange Network (CEDEN)	M	- 9.86	SWRCB Station Code: 535STC216; Modesto City-County Airport at Legion Park	Field data, Microbiological, *Cryptosporidium, Giardia*	Aug 2010 – Jun 2014

5.3 Tuolumne River Flow Rate near Project Area

River flow rate and rainfall can influence river water quality. Total suspended solids (TSS), turbidity, microbiological parameters and nutrients typically fluctuate throughout the year and are often correlated with rainfall and river flow.

River flows and rainfall data in the project vicinity were characterized using:

- USGS[7] daily flow data from Site A (USGS 11289650, upstream of infiltration gallery near Old La Grange Bridge, just below La Grange Dam)
- NOAA[8] daily rainfall data from Modesto Airport (approximately one mile downstream from the infiltration gallery)

As illustrated in Figure 11, peak stream flows correlate with rainfall events, with rainfall events preceding releases. The following observations are based on the State Water Project WSS San Joaquin Valley water year hydrologic classification indices[9] for runoff:

- 2008 and 2013 were critical dry years
- 2009 was below average
- 2010 was above normal
- 2011 was a wet year
- 2012 was a dry year

[7] http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11289650&agency_cd=USGS
[8] https://www.ncdc.noaa.gov/cdo-web/orders?email=sangamt@trusselltech.com&id=764481
[9] Water year classification based on an index for the sum of unimpaired flow the San Joaquin Valley from the SWRCB's Water Rights Decision 1641 (California Department of Water Resources, June 2015).

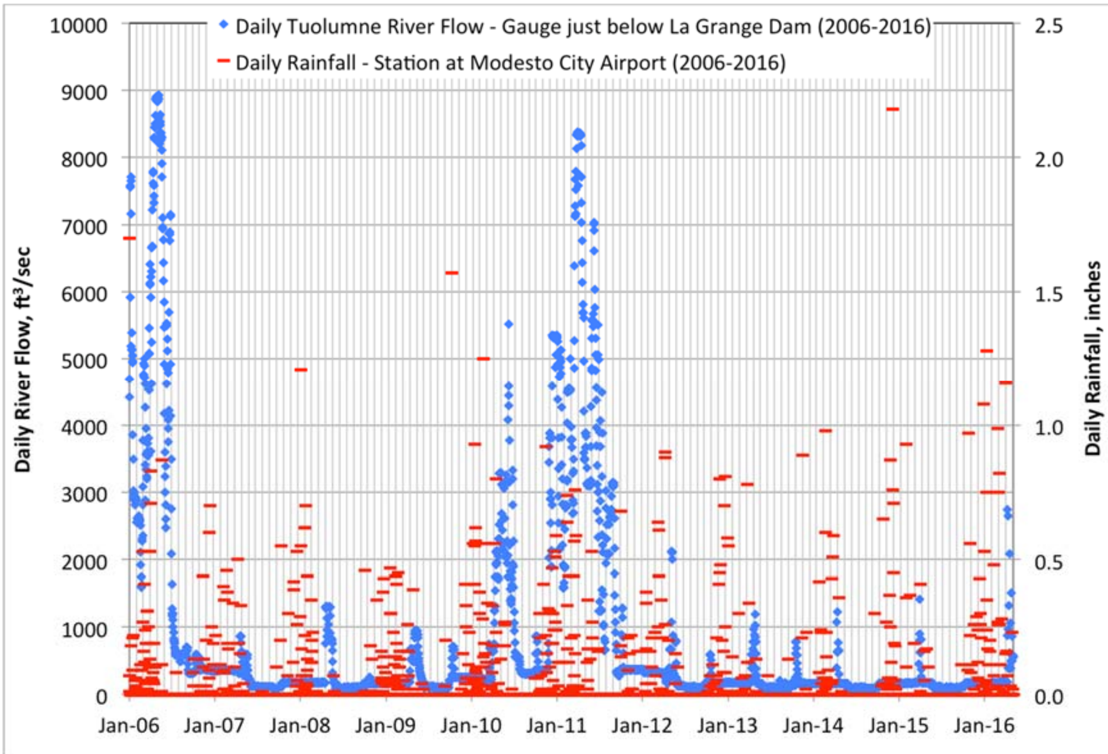

Figure 11. Tuolumne River Flow Rate just Below La Grange Dam and Rainfall at Modesto Airport[10] (2006-2016).

5.4 Water Quality Data

The following section includes a summary of relevant water quality data in the following categories:

- General Parameters
- Nutrients
- DBP-Related Parameters
- Metals
- Microbial Parameters
- Pesticides and other Synthetic Organics Compounds (SOCs)
- Asian Clams (an invasive mollusk)

For each category, tables with statistical summaries and figures with available water quality trends are provided for the infiltration gallery location and other nearby monitoring sites.

[10] (http://nwis.waterdata.usgs.gov/ca/nwis/inventory/?site_no=11289650&agency_cd=USGS) and NOAA (https://www.ncdc.noaa.gov/cdo-web/orders?email=sangamt@trusselltech.com&id=764481)

5.4.1 General Parameters

General water quality parameters are summarized in Table 6. The general parameters are typical of river water quality. Noteworthy observations are provided below:

- **Alkalinity & pH.**
  - The alkalinity of the Tuolumne River at the infiltration gallery location (Site I) is moderately low and ranged from 23 to 80 mg/L as $CaCO_3$, with an average alkalinity of 37 mg/L as $CaCO_3$ (Figure 12). Finished water will likely require stabilization using chemicals such as lime or caustic to adjust the pH and/or increase the finished water buffering capacity in the distribution system.
  - The Modesto Regional WTP intake (Site C) alkalinity is plotted in Figure 13 and has lower alkalinity (averaging 12 mg/L as $CaCO_3$) than that at the infiltration gallery (Site I) (averaging 37 mg/L as $CaCO_3$). (Note: These datasets are from two different time periods.) This difference indicates that the Modesto Regional WTP intake is potentially not representative of the Tuolumne River water quality in the project vicinity, even though the Modesto Region WTP's source water is from the Modesto Reservoir, which is Tuolumne River water diverted from La Grange Dam. The difference is likely caused by differing influences on the reservoir and river systems, such as the reservoir having a greater potential for algal blooms and reservoir stratification/turnover from lateral temperature gradients.
  - The alkalinity generally increases as the water moves downstream, averaging 17 mg/L as $CaCO_3$ at the upstream-most sampling location (Site D – Basso Bridge) and 37 mg/L $CaCO_3$ at the downstream-most sampling location (Site L – Mitchell Rd). This is not an expected trend for the Tuolumne River.
  - The pH at the infiltration gallery location (Site I) ranged from 6.7 to 8.3, with an average of 7.4 (Figure 14). Raw water pH has large fluctuations due to the relatively low alkalinity, which results in limited buffering capacity. Low alkalinity can also be the result of algal blooms.
  - The addition of either alum or ferric coagulants depresses pH, as both of these coagulants are acidic (i.e., coagulants consume 0.5 mg of alkalinity per mg of alum and 0.92 mg of alkalinity per mg of ferric chloride.). With a lower pH, TOC removal is enhanced, thereby reducing DBP formation. However, given the low buffering capacity of the water, if the pH of coagulation is too low, addition of caustic (or other alkalinity source) may be necessary for effective clarification. This possibility can be evaluated by conducting jar tests.

- **Chloride, Conductivity, & Total Dissolved Solids (TDS).**
  - The chloride concentrations of the Tuolumne River at the infiltration gallery (Site I) were very low, ranging from 2.1 to 11.0 mg/L and average 9.2 mg/L. The measurements at the infiltration gallery concur with the single measurement at the Site F (3.3 mg/L), which is 9.5 miles upstream of the

infiltration gallery. These concentrations are substantially below the secondary MCL of 250 mg/L.
  - The conductivity of the Tuolumne River at the infiltration gallery (Site I) is low, ranging from 33 to 201 uS/cm and averaging 90 uS/cm (Figure 15). The average concentration is 10-fold lower than the secondary MCL of 900 uS/cm. All sampling locations had similar conductivity, with an overall average of 89 uS/cm.
  - TDS gradually increases as the river moves downstream, likely due to increasing human activities (such as agriculture and urbanized areas) downriver. TDS averaged 25 mg/L at the upstream-most sampling location (Site D – Basso Bridge) and 75 mg/L at the downstream-most sampling location (Site L – Mitchell Rd). At the infiltration gallery, the TDS ranged from non-detect (<30 mg/L) to 150 mg/L and averaged 61 mg/L (Figure 16). All historical TDS data assessed for this effort were well below the secondary MCL of 500 mg/L.
  - At the infiltration gallery the ratio of TDS to conductivity (using the mean TDS and mean conductivity) is 0.68, which is within the typical range of 0.55 to 0.7 (Eaton et al. 2005). The correlation between TDS and conductivity (Figure 17) is very poor, but is likely skewed by an outlier TDS value (approximately 150 mg/L). Ideally, conductivity can be used as a surrogate for TDS, as conductivity has the advantages of being a more sensitive measurement, and can be measured continuously with online instruments.

- **<u>Hardness.</u>**
  - The hardness of the Tuolumne River at infiltration gallery (Site I) is low, ranging from 23 to 53 mg/L as $CaCO_3$ and averaging 39 mg/L as $CaCO_3$. This is classified as soft water. Approximately half of the hardness is from calcium (average 9.2 mg/L as Ca or 23 mg/L as $CaCO_3$) and the other half from magnesium (average 4.4 mg/L as Mg or 18 mg/L as $CaCO_3$).

- **<u>Dissolved Oxygen.</u>**
  - The dissolved oxygen (DO) concentration of the Tuolumne River at the infiltration gallery location (Site I) ranged from 7.9 to 14.5 mg/L, with an average concentration of 10.6 mg/L. Seasonal fluctuations are apparent in Figure 18. The coldest temperature measured that also had a corresponding DO measurement was 8.4 deg C and the corresponding DO was 12.9 mg/L; the oxygen saturation at 8.4 deg C is 11.7 mg/L (Tchobanoglous et al., 2003). The warmest temperature measured was 27.7 deg C and the corresponding DO was 9.02 mg/L; the oxygen saturation at 27.7 deg C is 7.9 mg/L (Tchobanoglous et al., 2003). The DOs for both the low- and high-temperature days are higher than the saturation concentration, meaning that the system is super-saturated—more evidence of algal blooms. If the water has a DO that is substantially

below the oxygen solubility at a corresponding temperature, this can result in anoxic conditions, which has water quality implications such as naturally occurring iron and manganese converting from solid to the dissolved form.

- Overall, the Tuolumne River in the project vicinity is well-oxygenated. Well-oxygenated water sources ensure that naturally occurring metals in the solid form, such as iron and manganese, are not reduced and released in the soluble form, which is more difficult to treat. Iron and manganese often occur together in surface water sources. In reducing environments (e.g., anaerobic conditions were ions gain electrons), these metals are relatively soluble, however in well-oxygenated environments, the iron should be present in its oxidized state, Fe(III), and the manganese may be in its oxidized state, Mn(IV). Iron is oxidized by oxygen quickly, on the order of minutes to hours, whereas manganese oxidizes slowly, on the order of days to weeks, so manganese is often found in reduced form (soluble) in natural systems even when iron is not.

- **<u>Total Suspended Solids (TSS) & Turbidity.</u>**
  - Turbidity at the infiltration gallery site is low—consistently less than 7.5 NTU—and does not seem to exhibit seasonal fluctuations (Figure 19). It is difficult to tell, however, if or by how much the turbidity increases in response to a significant storm event. Additionally, filtration through the rock and gravel media above the infiltration gallery is expected to reduce storm related turbidity spikes should they occur in the River. Raw water turbidity will be measured twice per month during the Source Water Monitoring Program.
  - As shown in Figure 20, the turbidity of the River water remains low even during high River flows and periods of rain[11]. Water from Modesto Reservoir at the Modesto Regional WTP intake measured higher turbidities than the other sites assessed along the Tuolumne River. The difference is likely caused by reservoir influences (e.g., algae and potential reservoir turnover).
  - TSS measured low at all sites. All TSS measurements taken by TID were below the 5 mg/l detection limit except one sample taken at the infiltration gallery location (Site I) on February 6, 2008, which measured 62 mg/L.
  - The solids loading at the WTP is expected to be low based on the low TSS and low turbidity historically recorded in the project vicinity. The solids loading can be estimated from jar tests designed to determine the optimal coagulation/flocculation configuration.

- **<u>Temperature.</u>**

[11] River flow rates are correlated with rain events – shown in Figure 11

- There are substantial historical temperature data available. These data indicate temperature tends to vary considerably from site to site without an apparent trend as the River moves downstream.
- At the infiltration gallery, large seasonal temperature changes were observed, falling to as low as 4 deg C (39.2 deg F) and peaking at 28 deg C (82.4 deg F).

- Figure 21 shows seasonal temperature fluctuations.

Table 6. General Water Quality Parameter Statistics

		Sampling Location on Tuolumne River (in order of upstream to downstream, with sample location ***I*** = Infiltraiton Gallery)												
Label on Map in Figure 3-6 >>>		*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*
Analytes General Water Quality	**Statistics**	Near Old La Grange Bridge[1]	Modesto Reservoir Inlet[2]	MRWTP Intake[2,3]	At Basso Bridge[4]	At Robert Ferry Bridge[4]	4 miles upstream of Hickman Rd.[5]	At Waterford Rd.[6]	At Fox Grove[7]	At Infiltration Gallery near Geer Rd.[4]	TID Pilot Study; At Hughson WWTP[3,8]	At Ceres River Bluff Park[9]	Near Mitchell Rd.[3, 10]	At Legion Park[11]
Sampling Period		Oct 2007-Apr 2016	May 2009-Sep 2012	Jan 2009-Dec 2012	May 2006-Oct 2008	May 2006-Oct 2008	Aug 2009	Aug 2010-Jun 2014	Aug 2010-Jun 2014	May 2006-Oct 2008	Sep 2006 - Apr 2007	Aug 2010-Jun 2014	Jan 2005-Feb 2016	Aug 2010-Jun 2014
Sampled By		USGS	Modesto Irrigation District	Modesto Irrigation District	Turlock Irrigation District	Turlock Irrigation District	CEDEN	CEDEN	CEDEN	Turlock Irrigation District	Turlock Irrigation District	CEDEN	City of Modesto/State Water Project	CEDEN
Alkalinity, Total mg/L as $CaCO_3$	Min			8	13	15	36			23	27		18	
	Max			16	34	28	36			80	36		67	
	Median			12	16	20	n/a			37	32		39	
	Mean			12	17	20	36			37	32		37	
	N			1415	17	17	1			40			28	
Calcium mg/L	Min			6.0						5.0				
	Max			13.0						11.0				
	Median			8.0						9.2				
	Mean			8.2						9.2				
	N			1411						23				
Chloride mg/L	Min						3.29			2.10				
	Max						3.29			11.00				
	Median						n/a			4.80				
	Mean						3.29			5.12				
	N						1			5				
Chlorophyll a mg/L	Min				0	0				0				
	Max				0	0				4.1				
	Median				0	0				0				
	Mean				0	0				0.4				
	N				23	23				23				
Color [12] Color units	Min									<1	2			
	Max									10	10			
	Median									5				
	Mean									4	5.8			
	N									14				
Conductivity uS/cm	Min				33	35	65	30	30	33		40	8	40
	Max				162	68	65	70	190	201		170	1060	160
	Median				67	45	n/a	47	110	77		100	103	100
	Mean				78	46	65	49	95	90		96	131	101
	N				24	24	1	8	15	67		9	30	9
Hardness mg/L as $CaCo_3$	Min			9.1	14	17	21.6			23			12	
	Max			13.0	18	22	21.6			53			53	
	Median			12.0	17	21	n/a			40			39	
	Mean			11.6	16	20	22			39			34	
	N			7	11	11	1			34			27	
Magnesium mg/L	Min			0.89						2.2				
	Max			1.30						5.6				
	Median			1.20						4.3				
	Mean			1.16						4.4				
	N			7						23				
Odor[13] TON	Min									<1				
	Max									4				
	Median									<1				
	Mean									1				
	N									13				
Oxygen, Dissolved mg/L	Min				10.32	9.87	4.08	7.05	7.09	7.93		7.40	6.81	7.00
	Max				12.88	12.11	4.08	7.27	17.60	14.49		18.50	11.18	14.48
	Median				11.14	11.27	n/a	7.16	7.64	10.53		7.71	9.14	7.14
	Mean				11.26	11.32	4.08	7.16	8.97	10.60		10.33	9.07	8.94
	N				24	24	1	2	9	66		4	30	4

Table 6. General Water Quality Parameters Statistics (*continued*)

Analytes General Water Quality	Statistics	Sampling Location on Tuolumne River (in order of upstream to downstream, with sample location *I* = Infiltraiton Gallery)												
Label on Map in Figure 3-6 >>>		*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*
		Near Old La Grange Bridge[1]	Modesto Reservoir Inlet[2]	MRWTP Intake[2,3]	At Basso Bridge[4]	At Robert Ferry Bridge[4]	4 miles upstream of Hickman Rd.[5]	At Waterford Rd.[6]	At Fox Grove[7]	At Infiltration Gallery near Geer Rd.[4]	TID Pilot Study; At Hughson WWTP[3,8]	At Ceres River Bluff Park[9]	Near Mitchell Rd.[3,10]	At Legion Park[11]
Sampling Period		Oct 2007-Apr 2016	May 2009-Sep 2012	Jan 2009-Dec 2012	May 2006-Oct 2008	May 2006-Oct 2008	Aug 2009	Aug 2010-Jun 2014	Aug 2010-Jun 2014	May 2006-Oct 2008	Sep 2006 - Apr 2007	Aug 2010-Jun 2014	Jan 2005-Feb 2016	Aug 2010-Jun 2014
Sampled By		USGS	Modesto Irrigation District	Modesto Irrigation District	Turlock Irrigation District	Turlock Irrigation District	CEDEN	CEDEN	CEDEN	Turlock Irrigation District	Turlock Irrigation District	CEDEN	City of Modesto/State Water Project	CEDEN
pH pH units	Min			6.51	6.56	6.86	8.6	7.4	7.4	6.73		7.0	6.1	7.5
	Max			7.33	8.54	8	8.6	8.3	11.4	8.29		11.1	8.8	10.1
	Median			6.97	7.75	7.55	n/a	7.96	7.9	7.41		7.9	7.3	8.0
	Mean			6.94	7.72	7.52	8.60	7.93	8.1	7.41		8.2	7.2	8.1
	N			1420	24	23	1	9	16	68		10	30	10
Silica[13] mg/L as SiO_2	Min				6	7	16			8				
	Max				22	26	16			26				
	Median				8	9	n/a			11				
	Mean				8	9	16			11				
	N				24	24	1			24				
Sodium mg/L	Min			1.3										
	Max			1.6										
	Median			1.4										
	Mean			1.4										
	N			5										
Solids, Total Dissolved mg/L	Min			13.3	<10	13				<30			28	
	Max			28.8	42	61				150			135	
	Median			18.0	25	30				64			71	
	Mean			18.6	25	31				61			75	
	N			1206	24	24				54			30	
Solids[12], Total Suspended mg/L	Min				<5	<5	< 0.9			<5			2	
	Max				<5	<5	< 0.9			62			17	
	Median				<5	<5	n/a			<5			6	
	Mean				<5	<5	< 0.9			7			7	
	N				4	4	1			37			31	
Sulfate mg/L	Min						1.47			2.3				
	Max						1.47			6.5				
	Median						n/a			3.0				
	Mean						1.47			3.5				
	N						1			5				
Temperature deg C	Min	9.0		6.5	10.8	9.9	22.6	13.0	12.8	4.4		14.4	9.6	15.0
	Max	18.7		21.4	13.7	15.7	22.6	25.0	27.5	27.7		27.7	27.2	28.7
	Median	11.4		15.4	12.6	13.4	n/a	19.8	24.3	15.2		21.7	14.8	22.6
	Mean	11.6		14.4	12.3	13.2	22.6	19.5	22.0	16.0		21.3	15.9	21.9
	N	218821		1419	23	24	1	8	15	70		10	30	10
Turbidity NTU	Min			2.0	0.45	0.79	0.89	0.70	0.72	0.62	0.75	1.02	0.6	0.75
	Max			23.3	2.01	1.85	0.89	1.48	3.56	7.32	8.70	3.74	9.5	2.10
	Median			5.0	0.96	1.22	n/a	0.90	1.62	2.01		1.59	1.7	1.26
	Mean			6.6	0.98	1.26	0.89	0.99	2.13	2.25	2.80	1.81	2.3	1.26
	N			1420	24	24	1	7	11	72		7	31.0	7

[1] USGS California Water Science Center National Water Information System. USGS Station Code: 11289650.
[2] MID Modesto Regional Water Treatment Plant (MRWTP) Watershed Sanitary Survey.
[3] Minimum and maximum estimated from a graph or extracted from text in which data are discussed (indicated by gray cells).
[4] TID Watershed Sanitary Survey of the Lower Tuolumne River and Turlock Lake & data from additional monitoring completed from May 2007 to April 2008.
[5] SWRCB CEDEN. Station Code: 535PS0265.
[6] SWRCB CEDEN. Station Code: 535TR5xxx.
[7] SWRCB CEDEN. Station Code: 535STC218.
[8] TID Regional Surface Water Supply Pilot Study Report
[9] SWRCB CEDEN. Station Code: 535STC217.
[10] State Water Project WSS. Data source: City of Modesto – Stormwater Management Program.
[11] SWRCB CEDEN. Station Code: 535STC216.
[12] When data set contained a mix of non-detect and detected values, the MRL was used in calculating statistics.
[13] Dissolved was measured for location F, otherwise it is not specificied.
[14] Some coliform concentrations were reported as >2419.6 MPN/100mL. In determining the statistics, this value was used.
[15] Range given since report provided average for differnet treatment schemes tested
[16] When calculating the statistic, if a value was non-detect, the value was assumed to be equal to zero.
[17] During pilot testing, total iron was tested. Other data sources do not specifiy dissolved versus total.

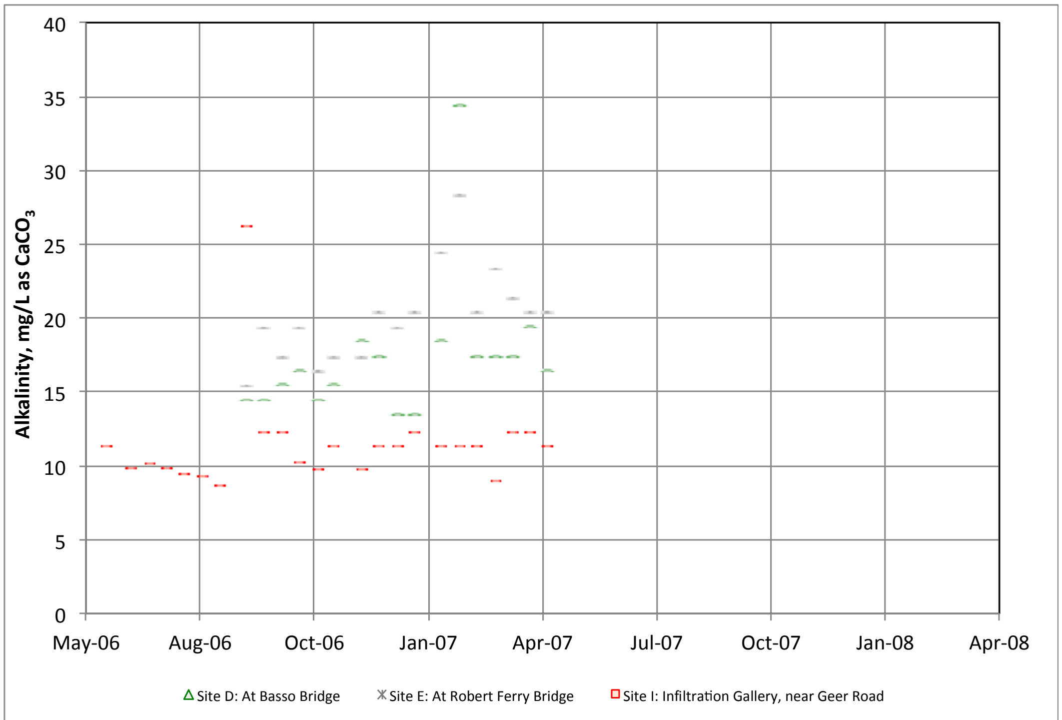

Figure 12. Alkalinity of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

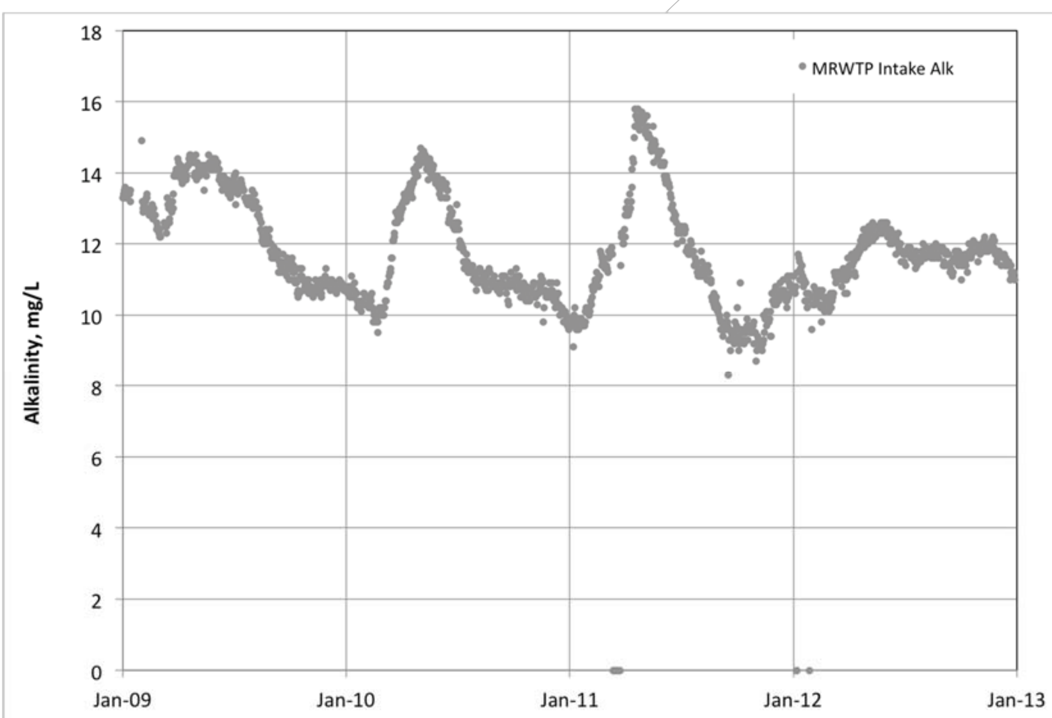

Figure 13. Alkalinity from MID MRWTP Intake from Modesto Reservoir

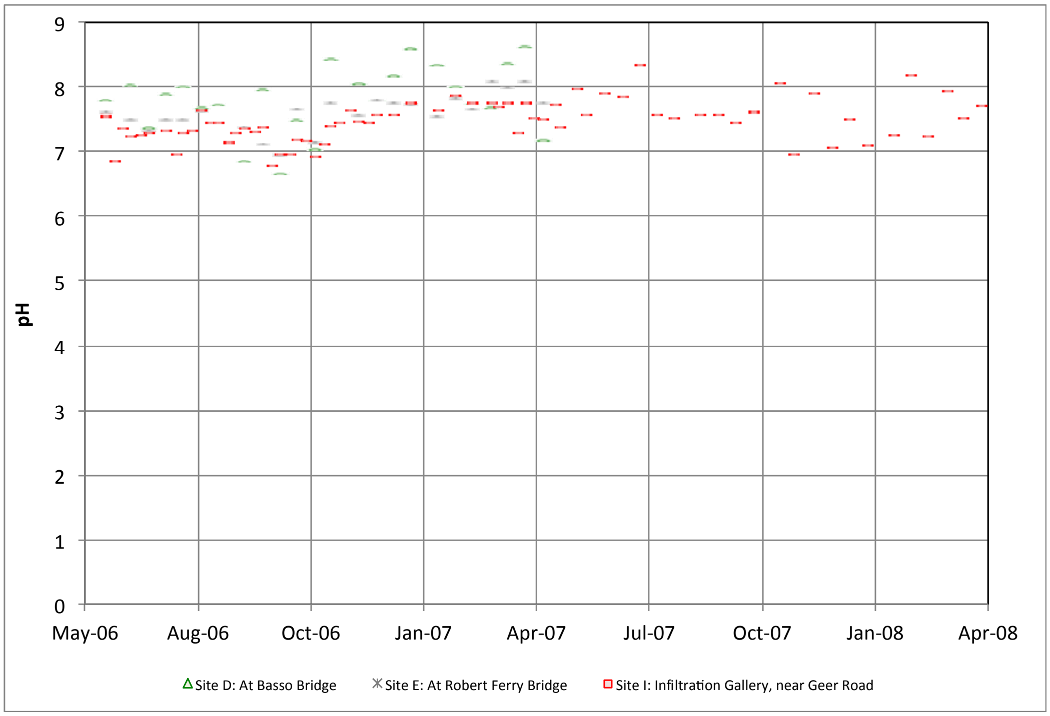

Figure 14. pH of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

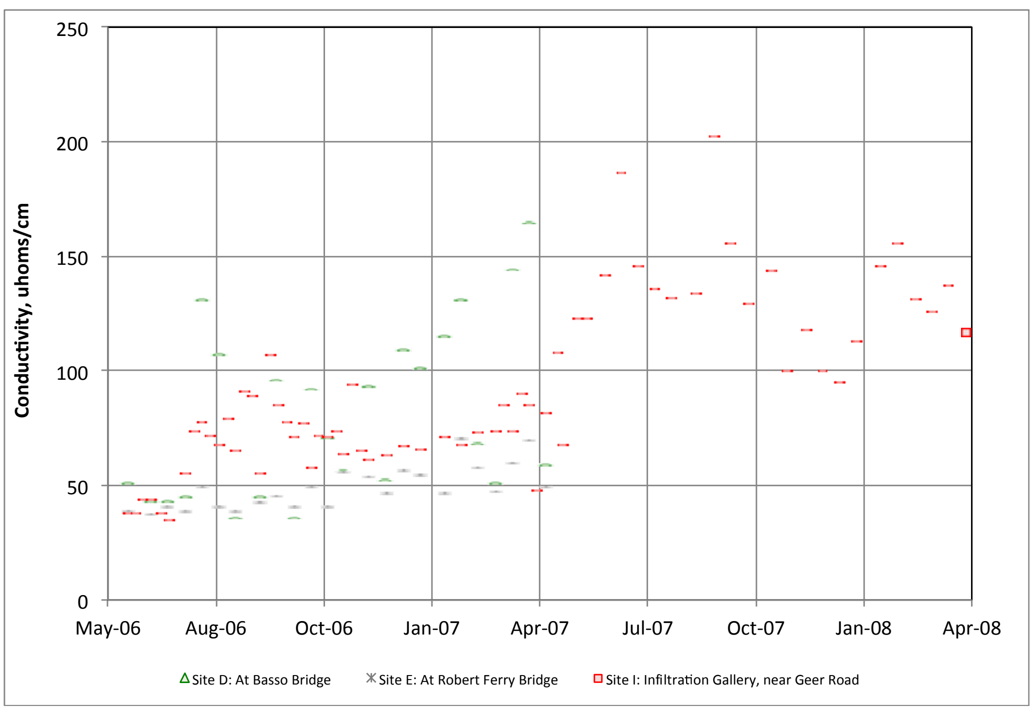

Figure 15. Conductivity of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

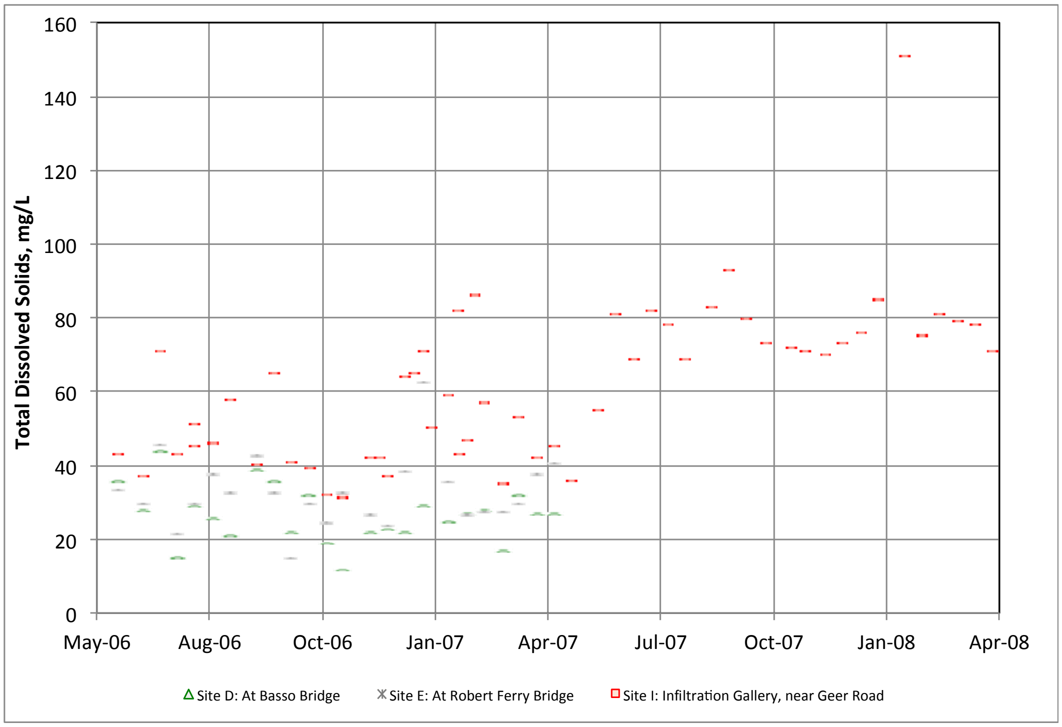

Figure 16. TDS of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

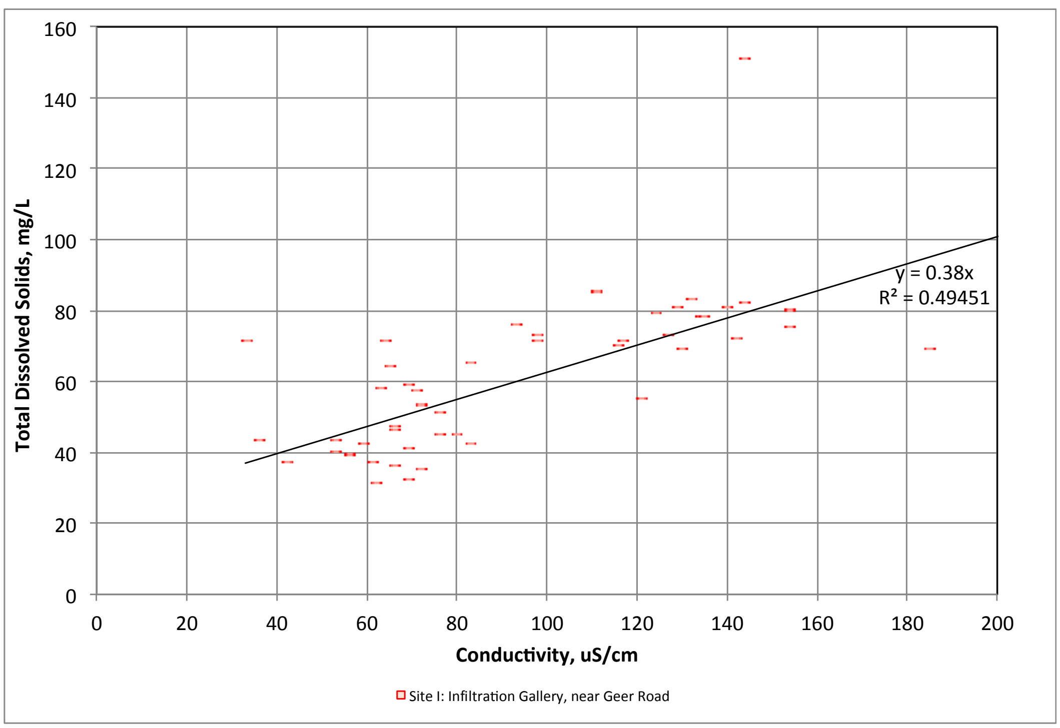

Figure 17. Correlation between TDS and Conductivity Using Paired Data Collected by TID at Site I

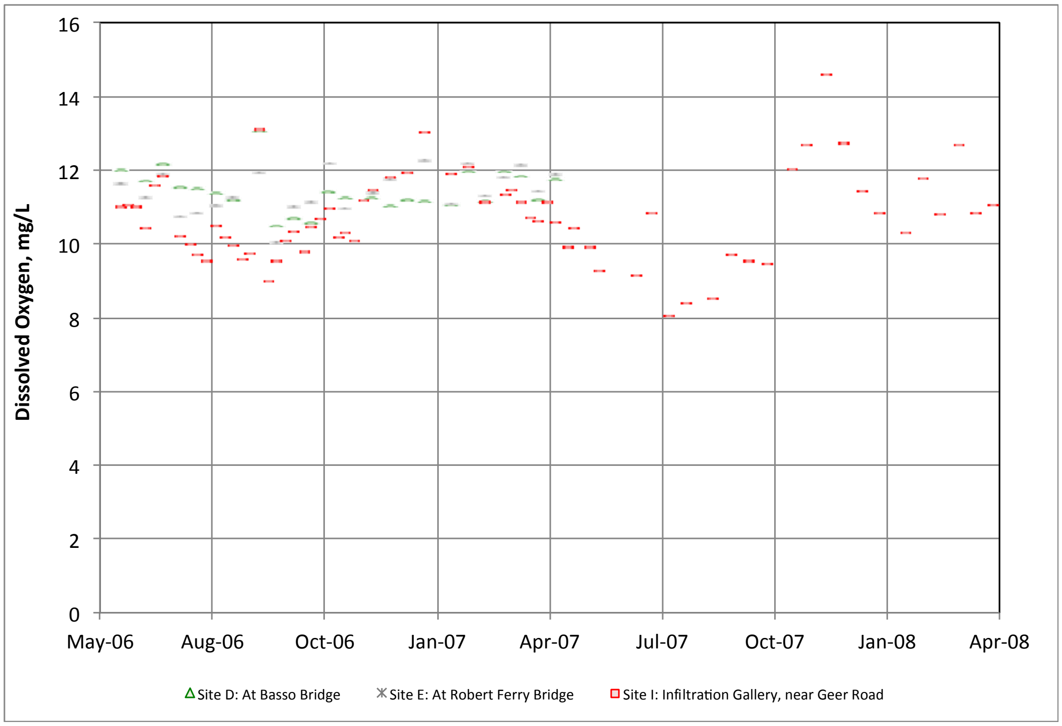

Figure 18. Dissolved Oxygen of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

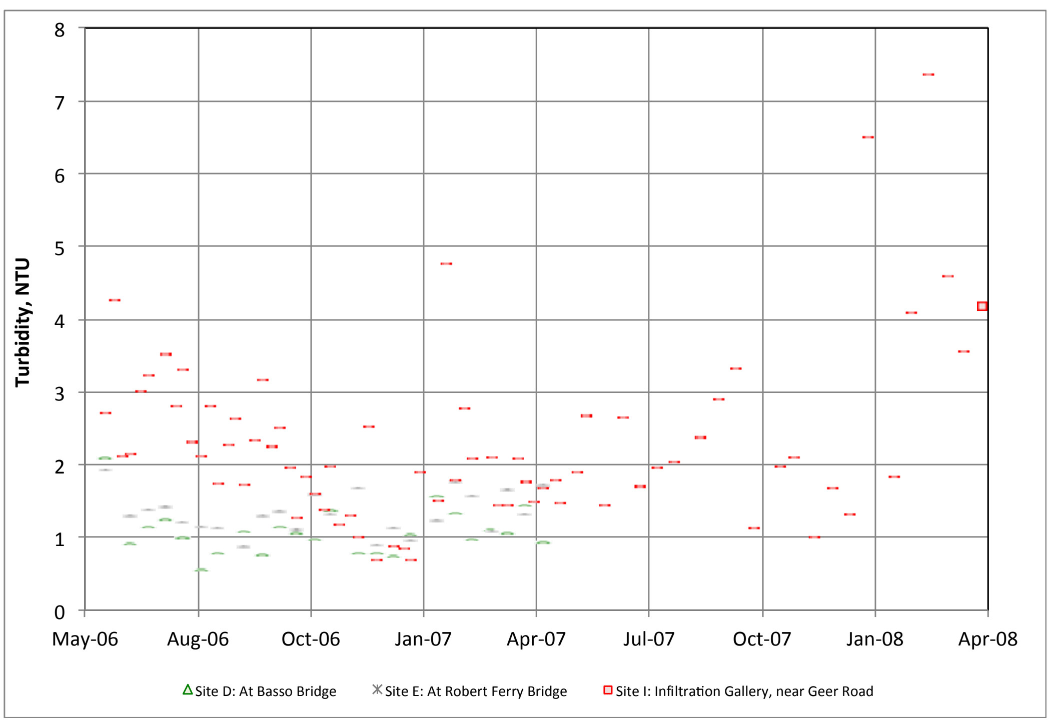

Figure 19. Turbidity of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

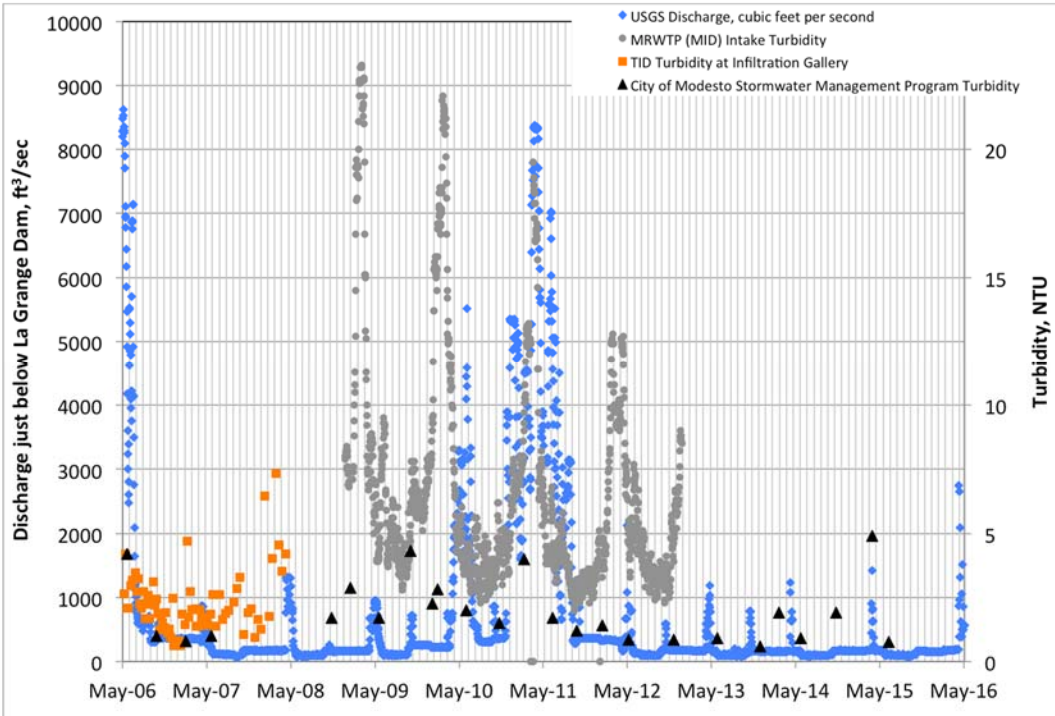

Figure 20. Flow Rate and Turbidity from MID MRWTP Intake, TID Tuolumne River at infiltration gallery, City of Modesto Stormwater Management Program

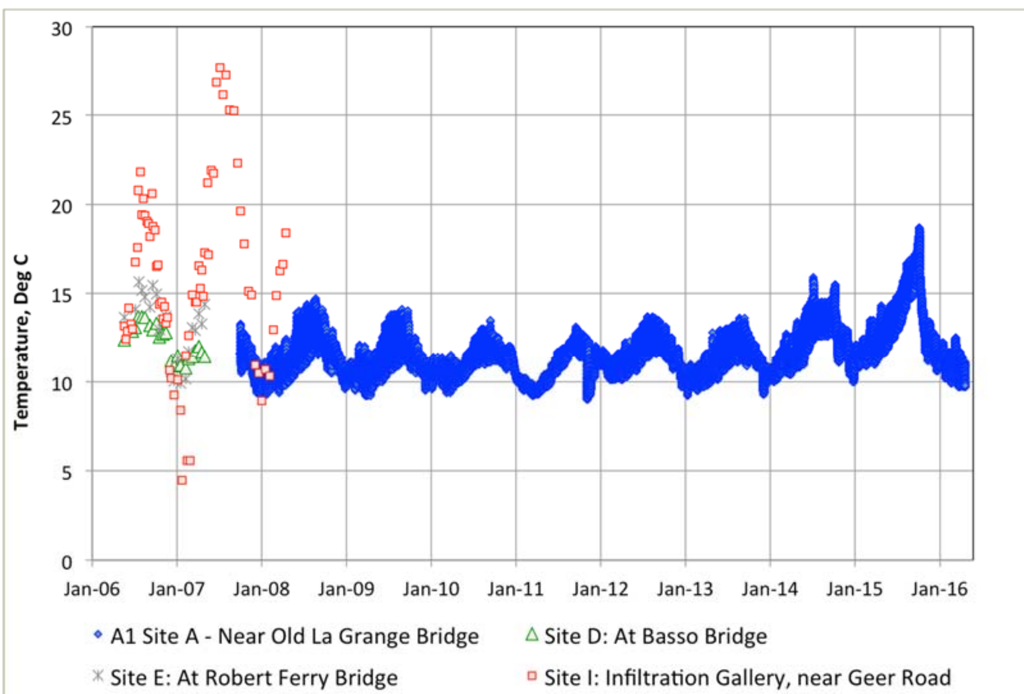

Figure 21. Seasonal Temperature Fluctuations of the Tuolumne River from Site A, Sites D, E and I (infiltration gallery)

5.4.2 Nutrients

Nutrient concentrations are summarized in Table 7. Noteworthy observations are provided below:

- **Nitrogen Species.**
  - All ammonia measurements taken by TID were below the 0.1 mg/L detection limit except one sample taken at Basso Bridge (Site D) on April 18, 2007, which measured 0.1 mg/L – right at the detection limit. The absence of ammonia at the infiltration gallery was expected, since the River is well-oxygenated and ammonia-oxidizing-bacteria (AOBs) are likely converting ammonia to nitrate. The absence of ammonia is beneficial for chlorine disinfection, because there will be no additional chlorine demand exerted.
  - Ammonia was not detected upstream of the infiltration gallery, at either Site D (Basso Bridge) or Site E (Robert Ferry Bridge), but was detected downstream of the infiltration gallery at Site L (near Mitchell Rd.) where concentrations ranged from non-detect (<0.02 mg/L) to 0.30 mg/L and averaged 0.07 mg/L.
  - All six nitrite samples taken at the infiltration gallery were below the method reporting limit (MRL) of 0.1 mg/L as N, and most of the samples at Site L (near Mitchell Rd. – about 7.7 miles downstream of the infiltration gallery) were also below the MRL of 0.1 mg/L as N. Nitrite exerts a substantial ozone demand—3.4 mg/L of ozone for every 1 mg/L of nitrite—which is an important consideration if the selected process train for the new WTP includes ozone. Hence, no ozone demand is expected from nitrite.
  - Nitrate levels are not a regulatory concern since they are well below MCL of 10 mg/L-N at all sites with available historical data. Nitrate was measured below the MRL of 0.1 mg/L-N upstream of the infiltration gallery. At the infiltration gallery, nitrate was detected at concentrations between 0.3 to 0.9 mg/L-N, with an average of 0.5 mg/L-N. Nitrate may correlated with rainfall due to stormwater runoff. However, these data indicate no obvious correlation at the infiltration gallery (Figure 22). The presence of nitrate is indicative of the potential for algae in stagnant areas and in turn the potential for associated taste and odor (T&O) events. At the SRWA's June 29th, 2016 meeting with DDW, DDW staff mentioned that in recent years algae has been observed in locations where it previously had not. So, the selected treatment train may need to include treatment for algae related T&O compounds.

- **Phosphorous.**
  - All phosphorous measurements taken by TID were below the 0.05 mg/L detection limit. High levels of phosphorus could indicate potential wastewater or fertilizer contamination, and the potential for algae blooms.

Table 7. Nutrient Statistics

		Sampling Location on Tuolumne River (in order of upstream to downstream, with sample location *I* = Infiltraiton Gallery)												
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*
Analytes Nutrients	**Statistics**	Near Old La Grange Bridge[1]	Modesto Reservoir Inlet[2]	MRWTP Intake[2,3]	At Basso Bridge[4]	At Robert Ferry Bridge[4]	4 miles upstream of Hickman Rd.[5]	At Waterford Rd.[6]	At Fox Grove[7]	At Infiltration Gallery near Geer Rd.[4]	TID Pilot Study; At Hughson WWTP[3,8]	At Ceres River Bluff Park[9]	Near Mitchell Rd.[3,10]	At Legion Park[11]
Sampling Period		Oct 2007-Apr 2016	May 2009-Sep 2012	Jan 2009-Dec 2012	May 2006-Oct 2008	May 2006-Oct 2008	Aug 2009	Aug 2010-Jun 2014	Aug 2010-Jun 2014	May 2006-Oct 2008	Sep 2006 - Apr 2007	Aug 2010-Jun 2014	Jan 2005-Feb 2016	Aug 2010-Jun 2014
Sampled By		USGS	Modesto Irrigation District	Modesto Irrigation District	Turlock Irrigation District	Turlock Irrigation District	CEDEN	CEDEN	CEDEN	Turlock Irrigation District	Turlock Irrigation District	CEDEN	City of Modesto/State Water Project	CEDEN
Ammonia[13] mg/L as N	Min				<0.1	<0.1	< 0.02			<0.1			<0.02	
	Max				0.1	<0.1	< 0.02			<0.1			0.30	
	Median				<0.1	<0.1	n/a			<0.1			0.04	
	Mean				<0.1	<0.1	< 0.02			<0.1			0.07	
	N				11	11	1			11			30	
Nitrate[12] mg/L as N	Min				<0.1	<0.1				0.3			0.09	
	Max				<0.1	<0.1				0.9			1.68	
	Median				<0.1	<0.1				0.4			0.38	
	Mean				<0.1	<0.1				0.5			0.60	
	N				11	11				19			11	
Nitrite mg/L as N	Min						< 0.005			<0.1			<0.01	
	Max						< 0.005			<0.1			0.20	
	Median						n/a			<0.1			<0.01	
	Mean						< 0.005			<0.1			0.03	
	N						1			6			20	
Nitrate + Nitrite mg/L as N	Min						0.0177						0.09	
	Max						0.0177						1.23	
	Median						n/a						0.41	
	Mean						0.0177						0.47	
	N						1						31	
Nitrogen, Total mg/L	Min						0.223							
	Max						0.223							
	Median						n/a							
	Mean						0.223							
	N						1							
Phosphate[13], Ortho mg/L as P	Min						0.0249			<0.05				
	Max						0.0249			<0.05				
	Median						n/a			<0.05				
	Mean						0.0249			<0.05				
	N						1			4				
Phosphorus, Total mg/L as P	Min				<0.05	<0.05	0.0303			<0.05			<0.01	
	Max				<0.05	<0.05	0.0303			<0.05			0.25	
	Median				<0.05	<0.05	n/a			<0.05			0.02	
	Mean				<0.05	<0.05	0.0303			<0.05			0.03	
	N				11	11	1			11			30	

[1] USGS California Water Science Center National Water Information System. USGS Station Code: 11289650.
[2] MID Modesto Regional Water Treatment Plant (MRWTP) Watershed Sanitary Survey.
[3] Minimum and maximum estimated from a graph or extracted from text in which data are discussed (indicated by gray cells).
[4] TID Watershed Sanitary Survey of the Lower Tuolumne River and Turlock Lake & data from additional monitoring completed from May 2007 to April 2008.
[5] SWRCB CEDEN. Station Code: 535PS0265.
[6] SWRCB CEDEN. Station Code: 535TR5xxx.
[7] SWRCB CEDEN. Station Code: 535STC218.
[8] TID Regional Surface Water Supply Pilot Study Report
[9] SWRCB CEDEN. Station Code: 535STC217.
[10] State Water Project WSS. Data source: City of Modesto – Stormwater Management Program.
[11] SWRCB CEDEN. Station Code: 535STC216.
[12] When data set contained a mix of non-detect and detected values, the MRL was used in calculating statistics.
[13] Dissolved was measured for location F, otherwise it is not specificied.
[14] Some coliform concentrations were reported as >2419.6 MPN/100mL. In determining the statistics, this value was used.
[15] Range given since report provided average for differnet treatment schemes tested
[16] When calculating the statistic, if a value was non-detect, the value was assumed to be equal to zero.
[17] During pilot testing, total iron was tested. Other data sources do not specifiy dissolved versus total.

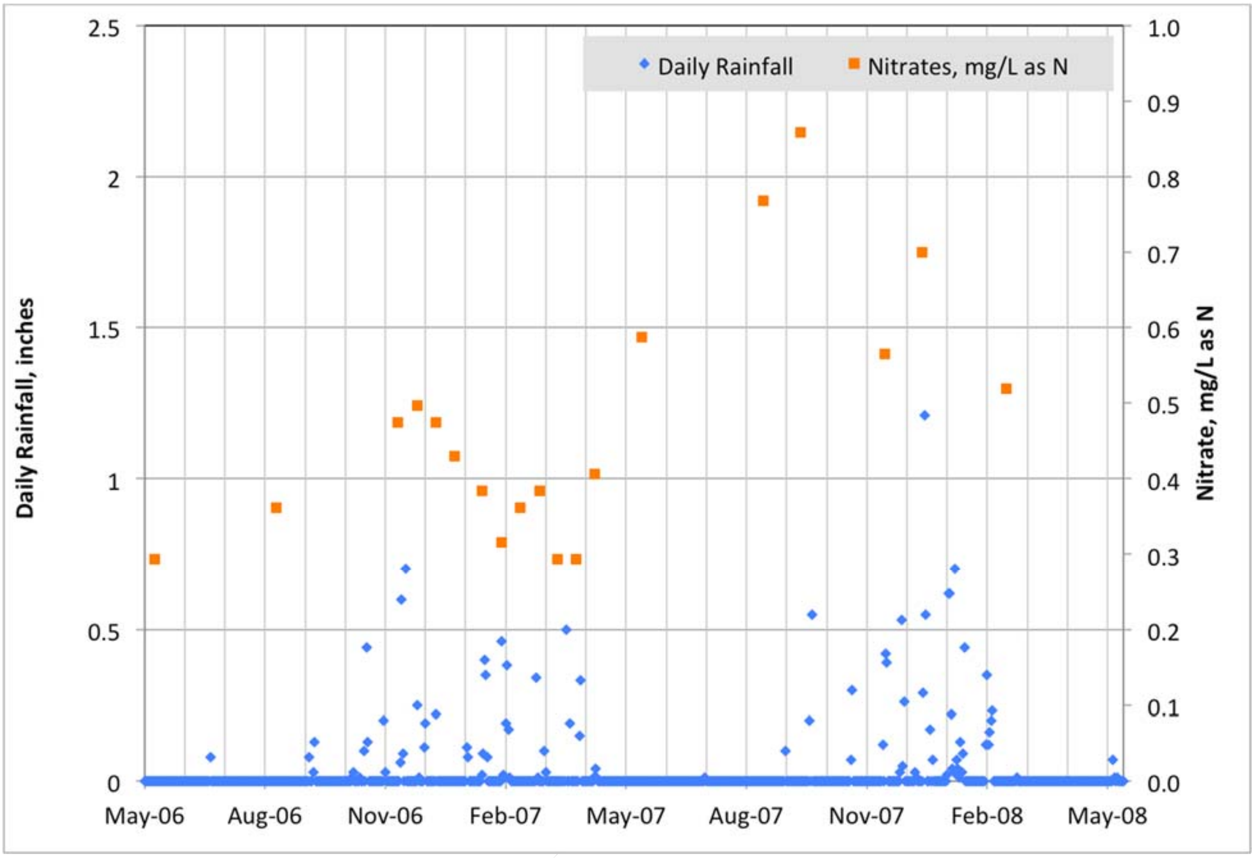

Figure 22. Rainfall and Nitrate of the Tuolumne River at infiltration gallery (Values Plotted At 0.5 mg/L Are Non-Detects)

5.4.3 DBP-Related Parameters

DBP-related parameters are summarized in Table 8. Noteworthy observations are provided below:

- **<u>Bromide</u>**
    - o Bromate is a regulated DBP (with an MCL of 0.010 mg/L) that forms during ozonation of a water containing bromide. The formation of bromate is pH-dependent, and less bromate is formed at lower pHs (i.e., < 8.8). So, what is a reasonable raw water bromide limit in order to stay below the bromate MCL? Based solely on stoichiometry, if 100% of the bromide were converted to bromate, 0.006 mg/L of bromide would be needed to form 0.010 mg/L bromate (i.e., its MCL). This is a worst case scenario because in surface waters there would be competition by natural organic matter to form brominated THMs and HAAs. Based on experience, the bromide limit for exceeding the bromate MCL with ozone is typically 0.1 to 0.3 mg/L. The historical data showed bromide was always measured

below the detection limit in the raw water (<0.1 mg/L). Thus, bromate formation in conjunction with ozonation should not be a treatment issue of concern for this water.

- **<u>Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC).</u>**
  DOC and TOC are important parameters because they are DBP precursors and therefore affect coagulation and disinfection approaches. Higher levels of chlorination DBPs (i.e., THMs and HAAs) form when free chlorine is used compared with chloramines. The point in the process train where chlorine is applied has a significant impact on the level of DBPs formed. If chlorine is added prior to TOC removal, much higher levels of DBPs form compared to adding chlorine after coagulation/sedimentation (i.e., clarification). Free chlorine is a much more powerful disinfectant than chloramines, so a much longer contact time with a disinfectant is required with chloramines to achieve the required disinfection credit, even though fewer DBPs may form.

  Review of the historical Tuolumne River data, along with review of the DBP formation data presented in the 2008 TID pilot study report (Brown and Caldwell, 2008), indicate the following regarding TOC and DOC:

  - Based on data collected by TID as a part of the WSS effort in 2007-2008, the majority of the TOC is in the dissolved form. The DOC to TOC ratio of time-paired samples was 80% on average with a standard deviation of 18%.
  - TOC concentrations reported at the infiltration gallery location are relatively high and quite variable, as shown in Figure 23. The average TOC concentration at the infiltration gallery site is somewhat higher than upstream and downstream locations (Figure 24). The average concentration at the infiltration gallery was 3.3 mg/L (ranging from 1.4 mg/L – 6.5 mg/L) versus 2.9 mg/L at Robert Ferry Bridge (Site E) approximately 14 river miles upstream, versus 2.0 mg/L at Mitchell Road (Site L) approximately 8 miles downstream near Modesto. The concentrations at the infiltration gallery are high enough that DBP formation will be a concern with free chlorine disinfection, unless significant TOC reduction is achieved during treatment. In order to obtain a better understanding of the TOC levels at this location, and potentially to characterize seasonal and storm-related influences, TOC will be measured monthly for two years as part of the upcoming monitoring program. These data will aid in evaluating TOC removal requirements under the Enhanced Coagulation component of the D/DBP Rule.
  - Based on the mean TOC concentration of 3.3 mg/L and the mean alkalinity of 37 mg/L as $CaCO_3$ at the infiltration gallery, the Stage 1 D/DBP Rule will require that treatment remove at least 35% TOC.

- As a part of the pilot testing completed by TID, percent TOC removal was quantified for three proprietary High Rate Clarifier (HRC) systems alongside a conventional plate settler, using four different coagulants (Brown and Caldwell, 2008). (Note: The plate settler did not operate appropriately possibly due to construction issues, so the percentage TOC removal was not useful.) High-rate clarifiers are designed to operate at a higher loading rate (gpm/sf) and therefore a smaller footprint than conventional sedimentation, often by providing more surface area for settling using inclined plates or tubes. Surface loading rate for conventional rectangular clarifiers is 0.5 to 1.0 gpm/sf, and 2.5 to 6.25 gpm/sf for tube settlers (Crittenden, et al., 2008). The proprietary systems that were pilot tested have proprietary features that allow enhanced settling or floating—as in the case of dissolved air flotation (DAF—of the floc. Each of the HRC systems provided significant TOC removal, although performance varied. TOC removals through clarification ranged from 21% to 51%. From this study, the dissolved air flotation systems (DAF) outperformed the sand ballasted clarification (SBC) system.

- **Disinfection By-Products.**
  - DBP formation is water-specific and highly influenced by the presence of organic carbon and pH. As a part of the pilot testing completed by TID, DBP formation potential was analyzed on the raw water and clarifier effluent. A modified Simulated Distribution System (SDS) procedure was used to simulate DBP formation in a distribution system in terms of applied chlorine dose, pH and sample holding time[12]. According to the 2008 TID pilot report, TTHM and HAA5 formation in samples of raw water (using a 3 mg/L chlorine dose) ranged from approximately 55 to 100 µg/L and 30 to 75 µg/L, respectively – both above the regulatory limit. After high rate clarification, TTHM and HAA5 formation potential never exceeded 50 µg/L and 30 µg/L, respectively, for all HRC systems tested. All measured DBP concentrations were below the pMCL of 80 µg/L for TTHM and 60 µg/L for HAA5 after HRC.
  - Bromate is an ozonation DBP which can form when bromide is present. During the TID pilot study, source water bromide concentrations were non-detect (ND). Bromate formation was not observed during pilot testing, with either pre- or post-ozone disinfection (Brown and Caldwell, 2008).

[12] "Samples were collected after each pilot process, dosed with 3 mg/L Cl_2 and held at approximately 13 degrees (deg) C for five or seven days to assess the DBP formation potential. The pH value of the samples was raised to 8 with calcium bi-carbonate to more closely simulate the pH in the finished water of the full-scale facility. Samples were collected at all locations on the same day to observe the change in the water on those days. After the five and seven day incubation period, chlorine residual, organic carbon, and pH were measured at the site lab and samples were quenched with sodium thiosulfate and sent to the analytical laboratory for analysis of trihalomethane (TTHM) and five regulated halo-acetic acid (HAA5)" (TID Pilot Report, Brown and Caldwell, 2008b).

Table 8. DBP-Related Parameter Statistics

		Sampling Location on Tuolumne River (in order of upstream to downstream, with sample location *I* = Infiltraiton Gallery)												
Label on Map in Figure 3-6 >>>		*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*
Analytes DBP-Related Parameters	**Statistics**	Near Old La Grange Bridge[1]	Modesto Reservoir Inlet[2]	MRWTP Intake[2,3]	At Basso Bridge[4]	At Robert Ferry Bridge[4]	4 miles upstream of Hickman Rd.[5]	At Waterford Rd.[6]	At Fox Grove[7]	At Infiltration Gallery near Geer Rd.[4]	TID Pilot Study; At Hughson WWTP[3,8]	At Ceres River Bluff Park[9]	Near Mitchell Rd.[3, 10]	At Legion Park[11]
	Sampling Period	Oct 2007-Apr 2016	May 2009-Sep 2012	Jan 2009-Dec 2012	May 2006-Oct 2008	May 2006-Oct 2008	Aug 2009	Aug 2010-Jun 2014	Aug 2010-Jun 2014	May 2006-Oct 2008	Sep 2006 - Apr 2007	Aug 2010-Jun 2014	Jan 2005-Feb 2016	Aug 2010-Jun 2014
	Sampled By	USGS	Modesto Irrigation District	Modesto Irrigation District	Turlock Irrigation District	Turlock Irrigation District	CEDEN	CEDEN	CEDEN	Turlock Irrigation District	Turlock Irrigation District	CEDEN	City of Modesto/State Water Project	CEDEN
Bromide [12] mg/L	Min				<0.1	<0.1				<0.1				
	Max				<0.1	<0.1				<0.1				
	Median				<0.1	<0.1				<0.1				
	Mean				<0.1	<0.1				<0.1				
	N				13	13				30				
Organic carbon, Dissolved mg/L	Min				1.4	1.2	1.48			1.3	1.5			
	Max				4.1	3.2	1.48			4.0	2.3			
	Median				2.0	2.0	n/a			2.4				
	Mean				2.2	2.0	1.48			2.5				
	N				24	24	1			47				
Organic carbon, Total mg/L	Min			1.2	1.7	1.8				1.4	1.5		1.1	
	Max			3.3	7.7	5.4				6.5	2.3		6.6	
	Median			1.6	2.7	2.6				3.0			1.7	
	Mean			1.7	3.2	2.9				3.3	1.8		2.0	
	N			965	24	24				47			30.00	

[1] USGS California Water Science Center National Water Information System. USGS Station Code: 11289650.
[2] MID Modesto Regional Water Treatment Plant (MRWTP) Watershed Sanitary Survey.
[3] Minimum and maximum estimated from a graph or extracted from text in which data are discussed (indicated by gray cells).
[4] TID Watershed Sanitary Survey of the Lower Tuolumne River and Turlock Lake & data from additional monitoring completed from May 2007 to April 2008.
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[7] SWRCB CEDEN. Station Code: 535STC218.
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[10] State Water Project WSS. Data source: City of Modesto – Stormwater Management Program.
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[12] When data set contained a mix of non-detect and detected values, the MRL was used in calculating statistics.
[13] Dissolved was measured for location F, otherwise it is not specificied.
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[15] Range given since report provided average for differnet treatment schemes tested
[16] When calculating the statistic, if a value was non-detect, the value was assumed to be equal to zero.
[17] During pilot testing, total iron was tested. Other data sources do not specifiy dissolved versus total.

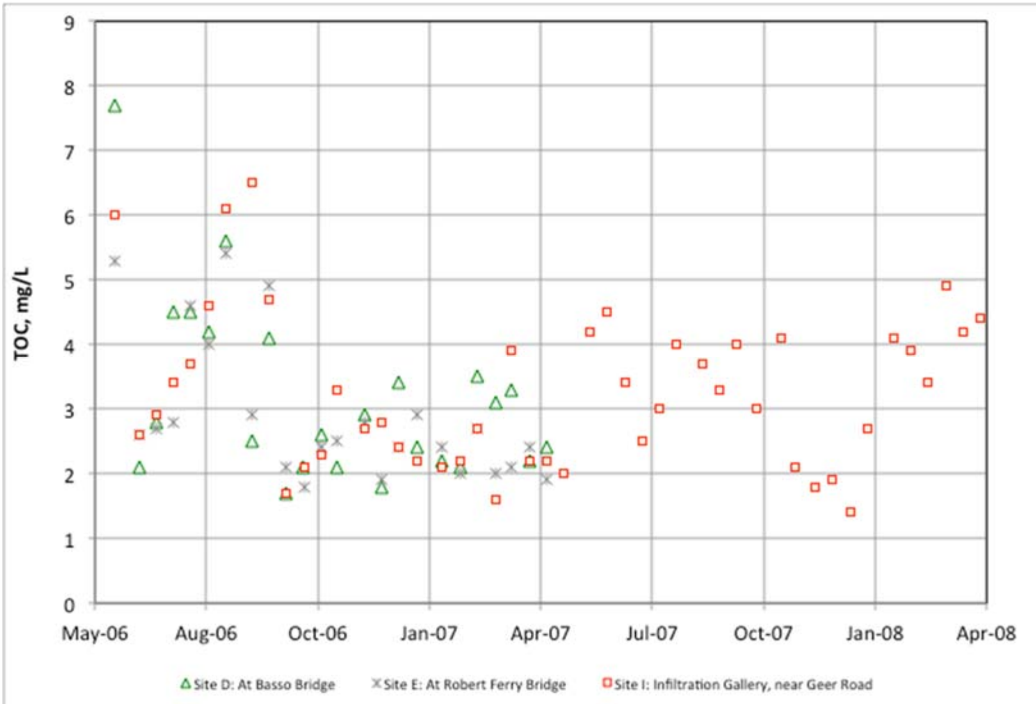

Figure 23. TOC of the Tuolumne River Sites D (Basso Bridge), E (Robert Ferry Bridge), and I (infiltration gallery)

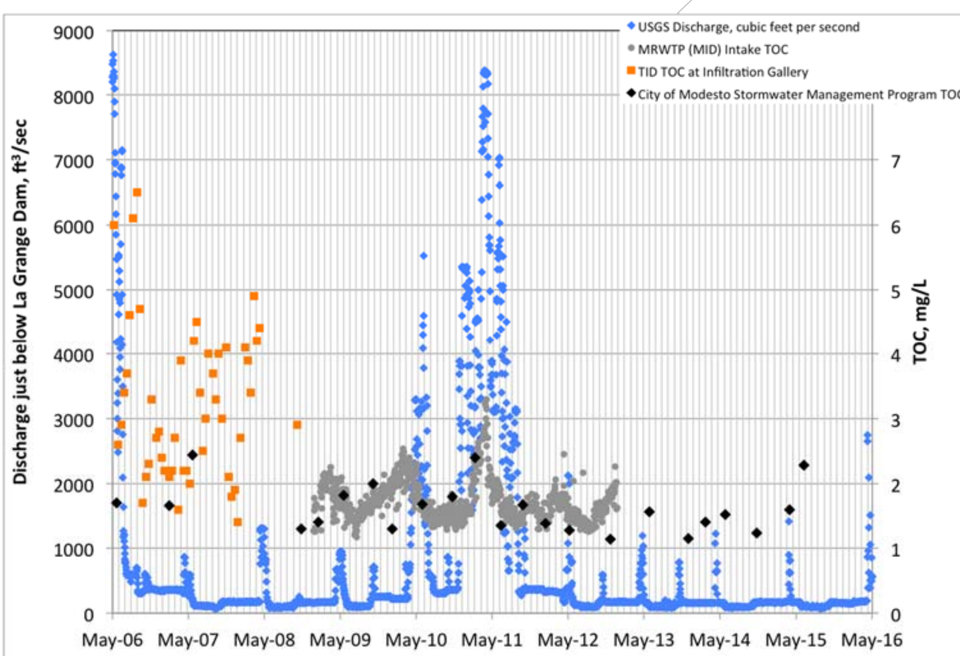

Figure 24. TOC of Modesto Reservoir at MID MRWTP Intake and Tuolumne River at the infiltration gallery and Downstream in Modesto Near Mitchell Road

5.4.4 Metals

Select metals are summarized in Table 9. Noteworthy observations are provided below:

- **Aluminum.**
  - The average total aluminum concentration measured at the infiltration gallery (0.091 mg/L) was slightly lower than that measured downstream of the infiltration gallery near Mitchell Rd (0.124 mg/L). All concentrations measured at both sites were below the 1 mg/L pMCL, but one of the five samples at the infiltration gallery and seven of the 32 samples from the site near Mitchell Road were above the sMCL of 0.2 mg/L. The City of Modesto also measured dissolved aluminum, measuring between non-detect (the dataset did not specify MRL) to 0.015 mg/L. Based on City of Modesto data, most of the aluminum is in the particulate form and should be readily filtered out though conventional treatment (clarification and filtration) to achieve aluminum concentrations that are substantially below both pMCL and sMCL levels. Given the well-oxygenated environment of the Tuolumne River, aluminum should be predominantly in particulate form.

- **Iron.**
  - At the infiltration gallery, total iron concentrations ranged from <0.050 to 6.5 mg/L, with three of these 94 samples above the sMCL of 0.3 mg/L (iron does not have a pMCL). Given that the Tuolumne River in the vicinity of the project is well-oxygenated, the maximum value measured (6.5 mg/L) may be an outlier. In support of this supposition are the facts that the next highest value was 0.380 mg/L, the majority of the data were below the detection limit, and a duplicate sample taken on the same day as the extremely high value (February 6, 2008) was much lower, measuring at 0.130 mg/L.

- **Manganese.**
  - At the infiltration gallery, total manganese concentrations ranged from <0.010 to 0.850 mg/L, with two of the 94 samples above the sMCL of 0.05 mg/L (manganese currently has no pMCL). The maximum value measured may be an outlier because the next highest value was 0.110 mg/L and a duplicate sample taken on the same day as the extremely high value (March 22, 2007) was much lower, measuring at 0.025 mg/L. Nonetheless, these levels are high enough that manganese removal will have to be considered during process train selection.
  - The dissolved fraction of manganese was not available in the historical dataset. Dissolved manganese can be difficult to oxidize and then filter, unlike aluminum and iron. If not removed, this can lead to colored water, staining, and a buildup of manganese on the pipe walls of the distribution system. Additionally, both dissolved and particulate manganese can lead to irreversible fouling of the membrane filtration membranes.

- o Because of potential neurological effects in children and infants, manganese has been included on the latest Contaminant Candidate List (CCL4) and Unregulated Contaminant Monitoring Rule (UCMR4) lists.

Table 9. Metals Statistics

Label on Map in Figure 3-6 >>>		A	B	C	D	E	F	G	H	I	J	K	L	M
		Sampling Location on Tuolumne River (in order of upstream to downstream, with sample location *I* = Infiltraiton Gallery)												
Analytes Metals	**Statistics**	Near Old La Grange Bridge[1]	Modesto Reservoir Inlet[2]	MRWTP Intake[2,3]	At Basso Bridge[4]	At Robert Ferry Bridge[4]	4 miles upstream of Hickman Rd.[5]	At Waterford Rd.[6]	At Fox Grove[7]	At Infiltration Gallery near Geer Rd.[4]	TID Pilot Study; At Hughson WWTP[3,8]	At Ceres River Bluff Park[9]	Near Mitchell Rd.[3,10]	At Legion Park[11]
	Sampling Period	Oct 2007-Apr 2016	May 2009-Sep 2012	Jan 2009-Dec 2012	May 2006-Oct 2008	May 2006-Oct 2008	Aug 2009	Aug 2010-Jun 2014	Aug 2010-Jun 2014	May 2006-Oct 2008	Sep 2006 - Apr 2007	Aug 2010-Jun 2014	Jan 2005-Feb 2016	Aug 2010-Jun 2014
	Sampled By	USGS	Modesto Irrigation District	Modesto Irrigation District	Turlock Irrigation District	Turlock Irrigation District	CEDEN	CEDEN	CEDEN	Turlock Irrigation District	Turlock Irrigation District	CEDEN	City of Modesto/State Water Project	CEDEN
Aluminum[12] mg/L	Min			0.0001						<0.020			0.015	
	Max			0.0009						0.290			0.310	
	Median			0.0003						0.046			0.105	
	Mean			0.0004						0.091			0.124	
	N			5						5			32	
Barium mg/L	Min									0.02				
	Max									0.10				
	Median									not reported				
	Mean									0.04				
	N									4				
Iron[12, 17] mg/L	Min			0.07	<0.050	0.078				<0.050	0.11		0.091	
	Max			0.79	<0.100	0.130				6.500	0.35		1.100	
	Median			0.27	<0.100	<0.100				<0.100			0.230	
	Mean			0.33	<0.100	0.100				0.188	0.17		0.281	
	N			5	48	48				94			32	
Manganese[12] mg/L	Min			0.007	<0.010	<0.010				<0.010	0.014			
	Max			0.009	0.018	0.019				0.850	0.085			
	Median			0.009	<0.010	<0.010				0.017				
	Mean			0.008	<0.010	0.011				0.029	0.04			
	N			3	48	48				95				

[1] USGS California Water Science Center National Water Information System. USGS Station Code: 11289650.
[2] MID Modesto Regional Water Treatment Plant (MRWTP) Watershed Sanitary Survey.
[3] Minimum and maximum estimated from a graph or extracted from text in which data are discussed (indicated by gray cells).
[4] TID Watershed Sanitary Survey of the Lower Tuolumne River and Turlock Lake & data from additional monitoring completed from May 2007 to April 2008.
[5] SWRCB CEDEN. Station Code: 535PS0265.
[6] SWRCB CEDEN. Station Code: 535TR5xxx.
[7] SWRCB CEDEN. Station Code: 535STC218.
[8] TID Regional Surface Water Supply Pilot Study Report
[9] SWRCB CEDEN. Station Code: 535STC217.
[10] State Water Project WSS. Data source: City of Modesto – Stormwater Management Program.
[11] SWRCB CEDEN. Station Code: 535STC216.
[12] When data set contained a mix of non-detect and detected values, the MRL was used in calculating statistics.
[13] Dissolved was measured for location F, otherwise it is not specificied.
[14] Some coliform concentrations were reported as >2419.6 MPN/100mL. In determining the statistics, this value was used.
[15] Range given since report provided average for differnet treatment schemes tested
[16] When calculating the statistic, if a value was non-detect, the value was assumed to be equal to zero.
[17] During pilot testing, total iron was tested. Other data sources do not specifiy dissolved versus total.

5.4.5 Microbial Parameters

Microbial parameters are summarized in Table 10. Noteworthy observations are provided below:

- **Coliforms.**
  - The median total coliform concentration at the infiltration gallery location (between May 2006 and October 2008) was 130 MPN/100mL, based on 73 data points. The CEDEN data had higher total coliform concentrations for both upstream and downstream locations, but with substantially smaller datasets. The median concentrations at Waterford Road (5.7 miles upstream) and Ceres River Bluff Park (7 miles downstream) were >2,417 MPN/100mL, whereas TID data from Basso Bridge (21.7 miles upstream) and Robert Ferry Bridge (13.9 miles upstream) were 17 and 40 MPN/100mL, respectively.
  - Fecal coliform concentrations generally increase as the water moves downstream. Site D (Basso Bridge) had a median of 4 MPN/100mL and Site L (Mitchell Rd.) had a median of 23 MPN/100mL. At the infiltration gallery location, the median was 22 MPN/100mL.
  - The median *E. coli* concentration was 12.7 MPN/100mL. Higher *E. coli* levels were measured upstream and downstream of the infiltration gallery location. A plot of the median, maximum and minimum *E. coli* concentrations between Waterford Road (5.7 miles upstream) and Mitchell Road (7.7 miles downstream) are shown in Figure 26. The same plot would have been provided for total coliform, but there were no data available at the Mitchell Road site and the majority of the CEDEN data at Waterford Road were reported as >2,420 MPN/100mL, because of limited sample volume.
  - Fecal coliform levels were plotted with rainfall to assess the impact of runoff on River water quality. There is a general trend showing increased fecal coliform concentrations after rain events (Figure 25).
  - As discussed in the Proposed RTCR (U.S. EPA 2010), while total coliform bacteria are abundant in the feces of warm-blooded animals, they are also found in soil, aquatic environments and elsewhere, and their presence does not necessarily imply fecal contamination. Fecal coliform bacteria are a subgroup of the total coliform bacteria. While fecal coliform bacteria have traditionally been associated with fecal contamination, the test used to measure these bacteria often includes bacteria that do not originate in the human or mammal gut ((Edberg et al. 2000) as referenced in (U.S. EPA 2010)). *E. coli* are a subset of the fecal coliforms. *E. coli* bacteria almost always originate in the human or mammal gut, and thus are a better indicator of fecal contamination than the fecal coliforms. The median total coliform/fecal coliform and total coliform/*E. coli* ratios

measured for this water are 6 and 10, respectively. These ratios suggest that a small fraction of the coliforms are of fecal origin.

- The SWTR Guidance Manual (USEPA, 1990) provides general guidelines for selecting an appropriate filtration technology based on raw water microbial conditions. According to these guidelines, conventional filtration without pre-disinfection should be effective for a source water with a total coliform concentration <5,000/100 mL, and direct filtration with flocculation should be effective for a source water total coliform concentration <500/100 mL. Regulatory guidelines and requirements were first set using total coliform and were later translated into fecal coliform/*E. coli*, assuming a ratio of five-to-one. Thus a criterion of 5,000 total coliform/100 mL is considered equivalent to 1000 fecal coliform/100 mL, which is considered equivalent to 1000 *E. coli*/100 mL (NRC, 2004). Based on these guidelines and the average total coliform, fecal coliform, and *E. coli* concentrations of this source water at the infiltration gallery (282/100 mL, 62/100mL, and 24/100mL, respectively), conventional filtration and direct filtration should be effective technologies.

- ***Cryptosporidium*.**
  - Twenty-three of the 24 *Cryptosporidum* measurements were zero at the infiltration gallery (sampled between May 2006-Oct 2008). On June 21, 2006, *Cryptosporidum* was detected at the detection limit of 0.09 oocysts/L. This results in the highest 12-month mean concentraiton of 0.0075 oocysts/L, which places this water souces in "Bin 1," thus requiring no additional treatment beyond the 2-log removal required under the IESWTR. MID also has "Bin 1" classification. Thus it seems the new treatment facility will be required to achieve at least 3-log removal/inactivation of *Giardia*, 4-log removal/inactivation of virus and 2-log removal of *Cryptosporidium*.
  - Higher *Cryptosporidium* concentrations were detected at Fox Grove (Site H), just upstream of the infiltration gallery, with samples ranging from 0 to 0.258 oocysts/L and averaging 0.055 oocysts/L. However, these data still place the source water in "Bin 1," since the average is <0.075 oocysts/L.

- ***Giardia*.**
  - *Giardia* concentrations observed at the infiltration gallery ranged from 0 to 0.80 cysts/L, with a geometric mean of 0.08 cysts/L. (Note: Because several measurements were zero, which cannot be used in the computation of a geometric mean, zeros were replaced with the method reporting limit divided by 2.) A 3-log *Giardia* removal/inactivation is recommended when the average (i.e., geometric mean) cyst concentration is ≤ 0.01 cyst/L. When the source water concentration is between 0.01 and 0.10 cysts/L, the SWTR Guidance Manual (USEPA, 1990) recommends 4-log removal/inactivation. For the water quality at the

infiltration gallery, the Guidance Manual recommends 4-log removal/inactivation. It should be noted that this additional level of treatment (i.e., above the required 3-log removal/inactivation), is not a requirement of either the Federal or State (DDW) regulations—it is only guidelines within the Guidance Manual.

Table 10. Microbiological Parameter Statistics

		Sampling Location on Tuolumne River (in order of upstream to downstream, with sample location *I* = Infiltraiton Gallery)												
Label on Map in Figure 3-6 >>>		***A***	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***	***K***	***L***	***M***
Analytes Microbial	**Statistics**	Near Old La Grange Bridge[1]	Modesto Reservoir Inlet[2]	MRWTP Intake[2,3]	At Basso Bridge[4]	At Robert Ferry Bridge[4]	4 miles upstream of Hickman Rd.[5]	At Waterford Rd.[6]	At Fox Grove[7]	At Infiltration Gallery near Geer Rd.[4]	TID Pilot Study; At Hughson WWTP[3,8]	At Ceres River Bluff Park[9]	Near Mitchell Rd.[3,10]	At Legion Park[11]
Sampling Period		Oct 2007-Apr 2016	May 2009-Sep 2012	Jan 2009-Dec 2012	May 2006-Oct 2008	May 2006-Oct 2008	Aug 2009	Aug 2010-Jun 2014	Aug 2010-Jun 2014	May 2006-Oct 2008	Sep 2006 - Apr 2007	Aug 2010-Jun 2014	Jan 2005-Feb 2016	Aug 2010-Jun 2014
Sampled By		USGS	Modesto Irrigation District	Modesto Irrigation District	Turlock Irrigation District	Turlock Irrigation District	CEDEN	CEDEN	CEDEN	Turlock Irrigation District	Turlock Irrigation District	CEDEN	City of Modesto/State Water Project	CEDEN
Coliform, Fecal MPN/100 mL	Min			0	0	2				0			0	
	Max			56.0	50	80				900			540	
	Median			1.0	4	8				22			23	
	Mean			2.5	8	15				62			73	
	N			1415	24	24				73			32	
Coliform[14], Total MPN/100 mL	Min		43.5	0.0	0	8		866.4	816.4	4		913.9		1732.9
	Max		4106.0	2420.0	240	500		> 2419.6	> 2419.6	>1600		> 2419.6		> 2419.6
	Median		410.6	56.0	17	40		> 2419.6	> 2419.6	130		> 2419.6		> 2419.6
	Mean		733.1	113.6	34	85		2035.6	2148.2	282		2131.69		2350.9
	N		50	1415	24	24		9	16	73		10		10
Cryptosporidium[16] oocysts/L	Min		0	0				0	0	0		0		0
	Max		0	0.10				0	0.258	0.09		0		0
	Median		0	0				n/a	0	0		n/a		n/a
	Mean		0	0				0	0.055	0		0		0
	N		30	48				1	7	24		1		1
E. coli MPN/100 mL	Min		0	0				4.1	3	0		5.2	0	18.7
	Max		134.0	33.8				172.3	461.1	160.0		204.6	500	653.9
	Median		12.0	2.0				23.3	18.5	12.7		22.0	23	47.5
	Mean		26.0	3.8				42.3	53.4	24.0		40.8	53	121
	N		50	50				9	16	24		10	32	10
Giardia cysts/L	Min		0	0				0.195	0	0		0.293		0
	Max		0.10	0.10				0.195	0.129	2.00		0.293		0
	Median		0	0				n/a	0	0		n/a		n/a
	Mean		0.01	0.00				0.195	0.018	0.33		0.293		0
	N		30	48				1	7	12		1		1
Heterotrophic Plate Count cfu/mL	Min			0										
	Max			6800.00										
	Median			33.00										
	Mean			79.60										
	N			587										
Salmonella MPN/100 mL	Min								0					
	Max								0.055					
	Median								0					
	Mean								0.011					
	N								6					

[1] USGS California Water Science Center National Water Information System. USGS Station Code: 11289650.
[2] MID Modesto Regional Water Treatment Plant (MRWTP) Watershed Sanitary Survey.
[3] Minimum and maximum estimated from a graph or extracted from text in which data are discussed (indicated by gray cells).
[4] TID Watershed Sanitary Survey of the Lower Tuolumne River and Turlock Lake & data from additional monitoring completed from May 2007 to April 2008.
[5] SWRCB CEDEN. Station Code: 535PS0265.
[6] SWRCB CEDEN. Station Code: 535TR5xxx.
[7] SWRCB CEDEN. Station Code: 535STC218.
[8] TID Regional Surface Water Supply Pilot Study Report
[9] SWRCB CEDEN. Station Code: 535STC217.
[10] State Water Project WSS. Data source: City of Modesto – Stormwater Management Program.
[11] SWRCB CEDEN. Station Code: 535STC216.
[12] When data set contained a mix of non-detect and detected values, the MRL was used in calculating statistics.
[13] Dissolved was measured for location F, otherwise it is not specificied.
[14] Some coliform concentrations were reported as >2419.6 MPN/100mL. In determining the statistics, this value was used.
[15] Range given since report provided average for differnet treatment schemes tested
[16] When calculating the statistic, if a value was non-detect, the value was assumed to be equal to zero.
[17] During pilot testing, total iron was tested. Other data sources do not specifiy dissolved versus total.

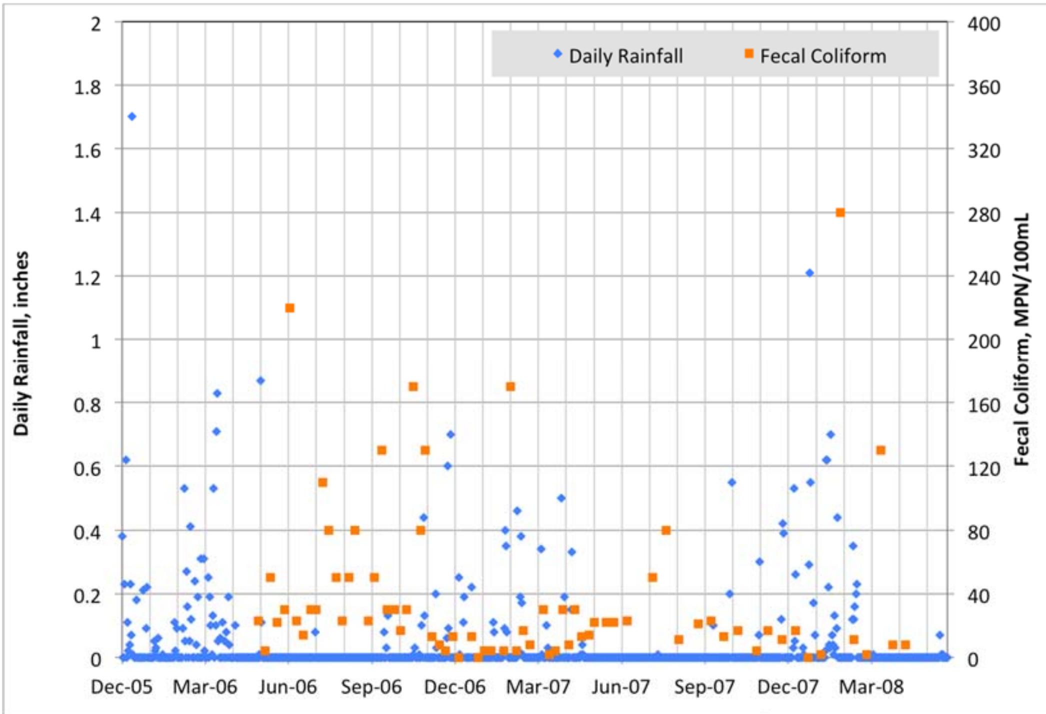

Figure 25. Fecal Coliform at infiltration gallery Location and Daily Rainfall

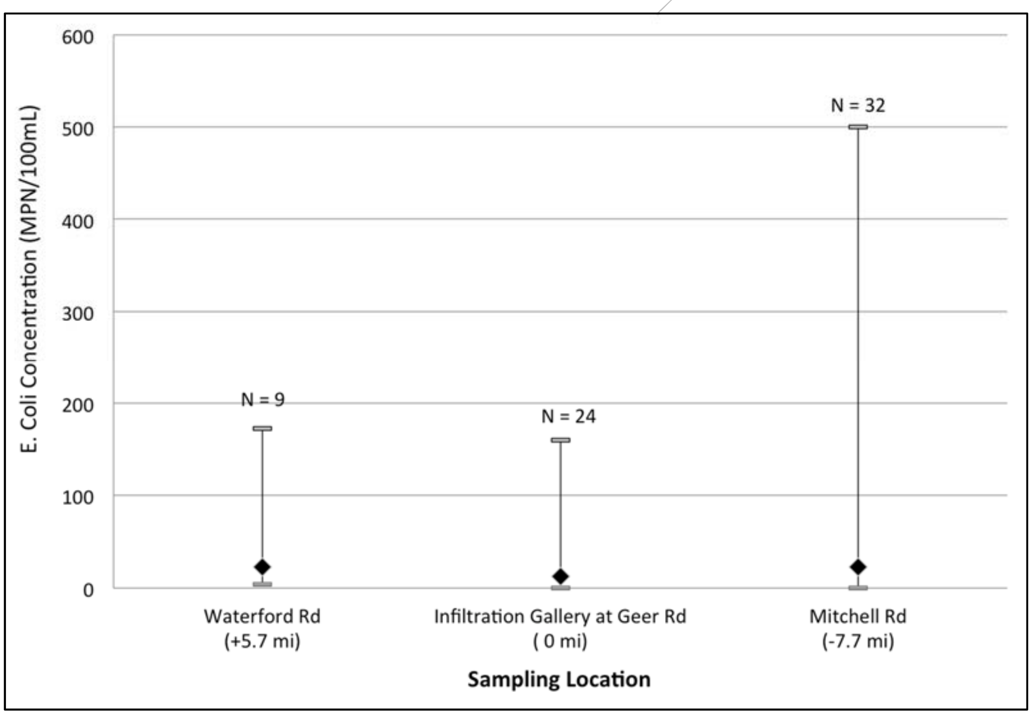

Figure 26. E. Coli Concentrations Measured at the infiltration gallery Location and Upstream and Downstream Locations

5.4.6 Pesticides and other Synthetic Organics Compounds

As stated in the previous section, the Lower Tuolumne River (downstream of Don Pedro Reservoir) is listed as an impaired water body under USEPA Clean Water Act Section 303(d) (California State Water Resources Control Board, 2010). This designation is largely due to the presence of several pesticides, including chlopyrifos, diazinon, Group A pesticides (aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane - including lindane, endosulfan, and toxaphene), as well as pollution from mercury, water temperature, and an unknown toxicity. As of 2014, total maximum daily loads (TMDLs) were established by the RWQCB Central Valley Region to limit diazinon and chlorpyrifos in the San Joaquin River and Sacramento River basins.

The pesticides of local concern for this project were determined through an evaluation of pesticide usage in the local watersheds. CDPR maintains a Pesticide Use Reporting (PUR) database and the most recent available dataset for the project area was from 2014 (CDPR, 2016). The project area was defined using geographic information system (GIS) software (ArcMap 10.3, 2016) to include the Lower Tuolumne River downstream of Don Pedro Reservoir to the confluence with Dry Creek on the east side of Modesto, as well as Turlock Lake, and the Modesto Reservoir. The location information from GIS was used to filter the pesticide use data from the PUR database (CDPR, 2016), from which the top pesticides applied within the project area were determined on the basis of mass (lbs/yr) using a threshold of 5,000 lbs applied per year. These top pesticides are presented in Table 11. The top 5 pesticides used in the project area on a mass basis are further defined by use for specific crops in Table 12. A summary of the detected pesticides and SOCs on the Tuolumne River between La Grange Dam and Modesto are summarized in Table 13. Of the pesticides and SOCs detected, only eight have pMCLs or NLs and of those only diazinon and tert-butyl alcohol were detected above their NL (CDPR and TID Pilot Study and WSS Database). No pesticides were detected above a pMCL. Residential use of Diazinon was outlawed in 2005[13] but is still legal to use on some crops.

The following limited organic- and pesticide-related data were provided by the City of Modesto from their Stormwater Monitoring Program site, downstream of the infiltration gallery:

- Chlorinated Herbicides was ND – sampled on 2/17/16
- Chlorinated Pesticides-PCBs was ND – sampled on 2/17/16
- Organophosphate Pesticides was ND – sampled on 4/8/15
- Regulated Organics was ND – sampled on 4/8/15
- Semi-volatile Organics + PAHs was ND – sampled on 2/17/16
- Volatile Organics was ND – sampled on 4/8/15
- Chlorpyrifos (Dursban) was ND for all samples – 30 samples collected between 1/7/05 to 6/16/15

[13] http://articles.latimes.com/2005/jan/01/nation/na-pest1

- Diazinon was ND for all samples – 30 samples collected between 1/7/05 to 6/16/15

Table 11. Top Pesticides Applied in the Tuolumne River Watershed by Mass (CDPR, 2016)

Chemical Name	Mass Applied (lbs/year)	Area Treated (acres)	Drinking Water Regulations
Mineral Oil [2]	220,210	27,311	N/A
Sulfur [2]	113,438	10,443	N/A
1,3-Dichloropropene	98,091	319	CA PHG: 0.0002 mg/L
Methyl Bromide	90,452	286	CCL4
Glyphosate, Isopropylamine Salt	48,081	31,209	Glyphosate: pMCL: 0.7 mg/L CA PHG: 0.9 mg/L
Copper Hydroxide	47,160	14,212	N/A
Kaolin [2]	34,514	1,105	N/A
Petroleum Oil, Unclassified [2]	33,353	3,283	N/A
Glyphosate, Potassium Salt	31,311	14,160	Glyphosate: pMCL: 0.7 mg/L CA PHG: 0.9 mg/L
Chlorothalonil	20,133	6,826	1-day EPA HA 0.2 mg/L
Mancozeb [1]	10,373	5,219	N/A
Pendimethalin	9,867	4,048	N/A
Oxyfluorfen	8,989	28,536	CCL4
Paraquat Dichloride	8,982	12,122	N/A
2,4-D, Dimethylamine Salt	6,932	7,603	N/A
Chloropicrin	6,753	125	aNL 0.05 mg/L
Copper Sulfate (Basic) [2]	5,167	1,508	N/A
Copper Oxide (Ous) [2]	5,101	1,036	N/A

[1] No method available at Eurofins Eaton Analytical Laboratory

[2] Not considered a synthetic organic chemical

Table 12. Top Five Pesticides Used in the Tuolumne River Watershed by Weight

Pesticide	CAS #	Application	Chemical Used (lbs)	Area Treated (acres)	Drinking Water Regulations
Mineral Oil	64741-56-9	Almond	179,884	21,624	N/A
		Walnut	29,872	4,842	
		Peach	5,545	438	
		Cherry	3,635	292	
		Apple	698	50	
		Other	1,274	116	
Sulfur	7704-34-9	Grape, wine	97,388	8,508	N/A
		Peach	9,363	1,172	
		N-Outdoor Transplants	6,320	692	
		Other	366	72	
1,3-Dichloropropene	542-75-6	Almond	33,783	102	CA PHG: 0.0002 mg/L
		Walnut	29,793	113	
		N-Outdoor Plants in Containers	18,181	54	
		N-Outdoor Transplants	10,657	33	
		Peach	5,677	17	
Methyl Bromide	74-83-9	N-Outdoor Plants in Containers	88,858	273	CCL4
		Almond	1,177	13	
		Walnut	338	–	
		Cherry	40	–	
		Peach	39	–	
Glyphosate, Isopropylamine salt	38641-94-0	Almond	31,726	21,039	Glyphosate: pMCL: 0.7 mg/L CA PHG: 0.9 mg/L
		Walnut	6,636	4,954	
		Corn (Forage - fodder)	2,757	2,146	
		N-Outdoor Plants in Containers	1,982	537	
		Grape, wine	1,488	581	
		Other	3,491	1,952	

Table 13. Summary of Detected Pesticides and SOCs on the Tuolumne River, between La Grange Dam and Modesto

Location	Year	Pesticides & SOCs Detected	Concentration (µg/L)	Regulatory List	MCL/NL (µg/L)	Reference
Between La Grange Dam and Modesto	1995	Diazinon Napropamide Simazine Chlorpyrifos (Dursban) Chlorthal-dimethyl Trifluralin	0.003 – 0.04 0.024 0.069 – 0.22 0.007 – 0.021 0.003 – 0.013 0.007	- NL - None - Primary MCL - UCMR4 - EPA HA - EPA HA	1.2 -- 4 -- -- --	California Department of Pesticide Regulation (CDPR)
Waterford LM Spill; Regional Board Irrigation Lands Monitoring site code: 535MIDWFS	2005 - 2008	Diuron Glyphosate Isoxaben Norflurazon Oryzalin Prodiamine	1.2 – 860 8.1 – 20 5.5 – 9.7 0.084 – 1.4 24 – 170 0.47 – 1.3	- EPA HA; CCL3 - Primary MCL - None - None - None - None	-- 700 -- -- -- --	California Department of Pesticide Regulation (CDPR)
Between La Grange Dam and Modesto	?	Chlorpyrifos (Dursban) Chlorthal-dimethyl Diazinon Malathion Metolachlor Napropamide Simazine	0.04 – 0.032 0.002 – 0.012 0.003 – 2.9 0.031 – 0.16 0.003 – 0.02 0.017 – 0.059 0.038 – 2.2	- UCMR4 - EPA HA - NL - aNL - UCMR2 - None - Primary MCL	-- -- 1.2 160 -- -- 4	CDPR and reported in 2007 TID Treatment Process Evaluation TM
Fox Grove County Park	2007-2008	2,4-Dichlorophenylacetic acid 3,4-Dinitrotoluene Bis(2-Ethylhexyl) Phthalate EPN (ENT) N-Nitrosopyrrolidine Tert-Butyl alcohol (TBA)	0.634 – 3.6 12.2 – 24.2 3.7 1.26 – 3.01 0.009 150	- None - None - Primary MCL - None - None - NL	-- -- 4 -- -- 12	TID Pilot Study and WSS Database

5.4.7 Asian Clams

The only invasive mollusk observed in the Lower Tuolumne River is the Asian Clam (*Corbicula fluminea*). This mollusk can be found in nearly every body of freshwater connected to the San Joaquin Delta (Email correspondence with Pat Maloney in June 2016). Communication with Patrick Maloney (Aquatic Biologist with TID), Jason Guignard (Fisheries Biologist with FishBio), and Kelley Aubushon (Environmental Scientist in the Quagga/Zebra Mussel Program for the California Department of Fish and Wildlife) suggested that Asian clams are found throughout the surface waters of California's Central Valley. None of the sources could confirm the presence of Asian clams on the Tuolumne River in the immediate project area, however. Asian Clams do not adhere to rock or other hard surfaces, but are found at sediment surfaces or slightly buried, existing in the upper 7 cm of sediment, which is significantly shallower than the infiltration gallery (Pat Ryan, Personal Communication, June 2016). Larvae and juvenile clams pass through screens and accumulate in intake piping and water treatment structures. The distribution of these mollusks is tracked by USGS and is prevalent in the project vicinity (Figure 27).

Locally, it is established that Asian clams are present in the Modesto Reservoir, which is the source water for the Modesto Regional WTP. Clam shells have also been observed in the ozone contactor of the conventional half of the Modesto Regional WTP, but not downstream of the ozone contactor since the clams are killed by the ozone (Pat Ryan, Personal Communication, May 2016). The membrane filtration half of the Modesto Regional WTP has been in operation only a limited time in part due to concerns over clam shells cutting or damaging the membranes (Pat Ryan, Personal Communication, May 2016). MID plans to clean the pipeline of silt from La Grange Dam soon and to repeat this cleaning every 5 years so the clams do not have the silt necessary to colonize and grow.

It will be helpful to know if the infiltration gallery can be expected to remove the larvae of Asian Clams from the water. This may be evaluated if pilot infiltration gallery filter tests are conducted.

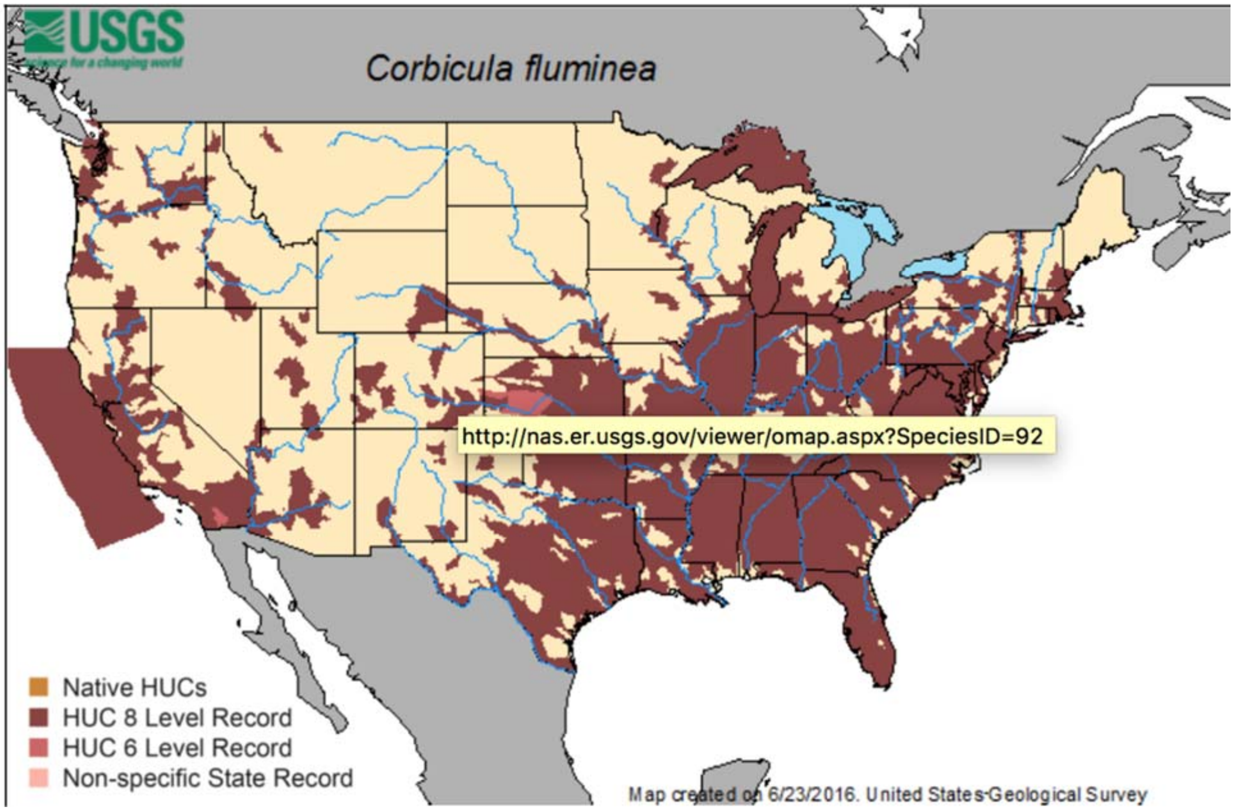

Figure 27. Prevalence of Asian clam (Corbicula fluminea) (Foster et al., 2016)

6 SUMMARY OF WATER QUALITY IMPLICATIONS ON TREATMENT & CONCLUSIONS

Following the May 12, 2016 Treatment Performance Goals Workshop, the TAC identified the following consolidated set of treatment goals for the new WTP. (Note that the goal of meeting all State and Federal drinking water regulations is not explicitly included, as this goal is understood to be a condition for obtaining a drinking water permit):

Employ Reasonably Robust Treatment Train: The treatment train should be robust to accommodate "normal" raw water quality variability, and to accommodate night-time unmanned facility operations. Plant shutdown is acceptable under extreme water quality conditions, since groundwater will remain available.

Use Proven Processes: Choose processes that are successfully operating at other plants. Demonstration testing will be required for membrane filtration, if selected.

Minimize DBP Formation: Choose disinfection and total organic carbon (TOC) removal options that result in lower DBP concentrations. Chloramines will be considered for final disinfection, but only if upstream processes are not expected to sufficiently reduce DBP formation potential.

Design for Unmanned Night Operations: Treatment process complexity and instrumentation and monitoring should be considered in meeting the goal of unmanned facility night operations.

Overall, the Tuolumne River water in the reach where the infiltration gallery is located is of excellent quality. The following parameters were identified as areas that may be treatment issues and must be considered in the upcoming sampling program and design of the SRWA WTP:

- **DBPs.** TOC concentrations indicate potential for DBP formation in excess of MCLs for TTHM (80 µg/L) and HAA5 (60 µg/L) if free chorine is used for disinfection. Additional monitoring will help validate TOC concentrations at the infiltration gallery location. Bench-scale jar testing is recommended to reduce uncertainties and aid in determining the new WTP's optimal coagulation requirements for turbidity removal, TOC removal, and DBP formation potential with both free chlorine and chloramines as possible secondary disinfectants.

- ***Cryptosporidium***. Historical data from the infiltration gallery places the source water in Bin 1. However, there is concern regarding the elevated readings at Fox Grove, immediately upstream of the infiltration gallery. The forthcoming LT2ESWTR 24-month source water monitoring program will define the SRWA's Bin classification. While it is expected the source water will be classified in Bin 1, the WTP should be designed conservatively to provide additional pathogen treatment in case the these or future sampling results place it in Bin 2.

- **Pesticides and SOCs**. Of the pesticides and SOCs detected, only 8 have pMCLs or NLs, and of those, only Diazinon and Tert-Butyl alcohol were detected above their pMCL and NL, respectively. The best treatment process to address low concentrations of pesticides and other SOCs is a combination of ozone and biologically active filtration (i.e., dual media GAC/sand filters).

- **Aesthetics**. There is potential for blue-green algae in the River and the associated taste and odor episodes, or possibly algal toxins, all of which have public acceptance and potential health implications. There are no data to confirm this assumption, however. The forthcoming monitoring plan will investigate algae occurrence. The combination of ozone and biologically active filtration is effective treatment for both T&O and algal toxins.

- **Invasive Mollusks**. While uncertain at this point, mollusks may be an issue based on the presence of Asian Clams in Modesto Reservoir and MID's experience. The potential for mollusks to pass through or accumulate in the infiltration gallery may be researched further through pilot testing.

Based on this review of historical water quality data, a detailed sampling plan was developed to better characterize the quality of the Tuolumne River at the infiltration gallery location. This monitoring data is needed both to facilitate design of the new WTP and for regulatory permitting purposes. The draft Source Water Sampling Plan was submitted to DDW by SRWA on July 21, 2016. After DDW's review, this sampling plan was approved by DDW through email received on July 25, 2016.

The detailed list of parameters included in the Source Water Sampling Plan is provided in Table B-1 in Appendix B of this TM. Based on the review of historical water quality data presented in this TM, additional monitoring is recommended—beyond what is required by DDW for permitting purposes. Whereas the monitoring defined in the DDW-approved plan will fulfill the requirements of the domestic water supply permit application for the WTP and provide information needed for process train selection and treatment system design, it does not address water quality impacts of local cattle and poultry operations or the potential for algae occurrence in the source water.

As discussed in this TM, dairy, poultry, and ranch operations are potential sources of contamination in the Lower Tuolumne River. The use of antibiotics and hormones is prevalent in animal operations, and these compounds can be flushed into the river via stormwater and irrigation runoff. Ranching operations also may introduce nitrogen compounds (e.g., ammonia, nitrate) which, under more stagnant river conditions, can promote the growth of algae. When present in a surface water supply, algae can be especially problematic due to taste and odor implications. In addition, algae and associated cyanotoxins have been increasingly on the regulatory radar, with the United States Environmental Protection Agency (EPA) including ten cyanotoxin chemical contaminants as part of their fourth and latest Unregulated Contaminant Monitoring Rule (UCMR) for water systems utilizing surface water.

Given the presence of animal operations in the project area and evidence of increased algae occurrence, monitoring for select compounds of interest in the source water is needed to understand the water quality impacts on treatment. The additional recommended parameters are highlighted yellow in Table B-1, provided in Appendix B.

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APPENDIX A – Contaminants with a Primary or Secondary MCL Under Title 22 of the California Code of Regulations

Table 64431-A
Maximum Contaminant Levels
Inorganic Chemicals

Chemical	*Maximum Contaminant Level, mg/L*
Aluminum	1.
Antimony	0.006
Arsenic	0.010
Asbestos	7 MFL*
Barium	1.
Beryllium	0.004
Cadmium	0.005
Chromium	0.05
Cyanide	0.15
Fluoride	2.0
Hexavalent chromium	0.010
Mercury	0.002
Nickel	0.1
Nitrate (as nitrogen)	10.
Nitrate+Nitrite (sum as nitrogen)	10.
Nitrite (as nitrogen)	1.
Perchlorate	0.006
Selenium	0.05
Thallium	0.002

* MFL=million fibers per liter; MCL for fibers exceeding 10 µm in length.

Table 64442
Radionuclide Maximum Contaminant Levels (MCLs)
and Detection Levels for Purposes of Reporting (DLRs)

Radionuclide	*MCL*	*DLR*
Radium-226	5 pCi/L (combined radium-226 & -228)	1 pCi/L
Radium–228		1 pCi/L
Gross Alpha particle activity (excluding radon and uranium)	15 pCi/L	3 pCi/L
Uranium	20 pCi/L	1 pCi/L

Table 64443
Radionuclide Maximum Contaminant Levels (MCLs)
and Detection Levels for Purposes of Reporting (DLRs)

Radionuclide	*MCL*	*DLR*
Beta/photon emitters	4 millirem/year annual dose equivalent to the total body or any internal organ	Gross Beta particle activity: 4 pCi/L
Strontium-90	8 pCi/L (= 4 millirem/yr dose to bone marrow)	2 pCi/L
Tritium	20,000 pCi/L (= 4 millirem/yr dose to total body)	1,000 pCi/L

Table 64444-A
Maximum Contaminant Levels
Organic Chemicals

Chemical	*Maximum Contaminant Level, mg/L*
(a) Volatile Organic Chemicals (VOCs)	
Benzene.	0.001
Carbon Tetrachloride	0.0005
1,2-Dichlorobenzene.	0.6
1,4-Dichlorobenzene.	0.005
1,1-Dichloroethane	0.005
1,2-Dichloroethane	0.0005
1,1-Dichloroethylene	0.006
cis-1,2-Dichloroethylene	0.006
trans-1,2-Dichloroethylene	0.01
Dichloromethane.	0.005
1,2-Dichloropropane.	0.005
1,3-Dichloropropene.	0.0005
Ethylbenzene.	0.3
Methyl-*tert*-butyl ether	0.013
Monochlorobenzene.	0.07
Styrene.	0.1
1,1,2,2-Tetrachloroethane.	0.001
Tetrachloroethylene.	0.005
Toluene.	0.15
1,2,4-Trichlorobenzene	0.005
1,1,1-Trichloroethane.	0.200
1,1,2-Trichloroethane.	0.005
Trichloroethylene.	0.005
Trichlorofluoromethane.	0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane.	1.2
Vinyl Chloride.	0.0005
Xylenes.	1.750*

Table 64444-A (continued)
Maximum Contaminant Levels
Organic Chemicals

Chemical	*Maximum Contaminant Level, mg/L*
(b) Non-Volatile Synthetic Organic Chemicals (SOCs)	
Alachlor	0.002
Atrazine	0.001
Bentazon	0.018
Benzo(a)pyrene	0.0002
Carbofuran	0.018
Chlordane	0.0001
2,4-D	0.07
Dalapon	0.2
Dibromochloropropane	0.0002
Di(2-ethylhexyl)adipate	0.4
Di(2-ethylhexyl)phthalate	0.004
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin	0.002
Ethylene Dibromide	0.00005
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor Epoxide	0.00001
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Lindane	0.0002
Methoxychlor	0.03
Molinate	0.02
Oxamyl	0.05
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated Biphenyls	0.0005
Simazine	0.004
Thiobencarb	0.07
Toxaphene	0.003
2,3,7,8-TCDD (Dioxin)	3×10^{-8}
2,4,5-TP (Silvex)	0.05

*MCL is for either a single isomer or the sum of the isomers.

Table 64449-A
Secondary Maximum Contaminant Levels
"Consumer Acceptance Contaminant Levels"

Constituents	*Maximum Contaminant Levels/Units*
Aluminum	0.2 mg/L
Color	15 Units
Copper	1.0 mg/L
Foaming Agents (MBAS)	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Methyl-*tert*-butyl ether (MTBE)	0.005 mg/L
Odor—Threshold	3 Units
Silver	0.1 mg/L
Thiobencarb	0.001 mg/L
Turbidity	5 Units
Zinc	5.0 mg/L

Table 64449-B
Secondary Maximum Contaminant Levels
"Consumer Acceptance Contaminant Level Ranges"

	Maximum Contaminant Level Ranges		
Constituent, Units	*Recommended*	*Upper*	*Short Term*
Total Dissolved Solids, mg/L	500	1,000	1,500
or			
Specific Conductance, µS/cm	900	1,600	2,200
Chloride, mg/L	250	500	600
Sulfate, mg/L	250	500	600

Table 64533-A
Maximum Contaminant Levels and Detection Limits for Purposes of Reporting
Disinfection Byproducts

Disinfection Byproduct	Maximum Contaminant Level (mg/L)	Detection Limit for Purposes of Reporting (mg/L)
Total trihalomethanes (TTHM)	0.080	
Bromodichloromethane		0.0010
Bromoform		0.0010
Chloroform		0.0010
Dibromochloromethane		0.0010
Haloacetic acids (five) (HAA5)	0.060	
Monochloroacetic Acid		0.0020
Dichloroacetic Acid		0.0010
Trichloroacetic Acid		0.0010
Monobromoacetic Acid		0.0010
Dibromoacetic Acid		0.0010
Bromate	0.010	0.0050 0.0010[1]
Chlorite	1.0	0.020

[1] For analysis performed using EPA Method 317.0 Revision 2.0, 321.8, or 326.0

APPENDIX B – Parameters to be Sampled as Part of the SRWA Source Water Monitoring Program

The following is the list of constituents to be monitored as part of the SRWA source water monitoring program. The monitoring period will be one full year (12 months), with the exception of the required LT2ESWTR parameters (i.e., *Cryptosporidium, E. coli*, turbidity), *Giardia*, total coliform, and TOC which will be sampled monthly for two full years (24 months). Because *Giardia* and total coliform are not required parameters for LT2ESWTR monitoring compliance, the sampling frequency may be reduced during the second year.

The yellow highlighted parameters and/or collection frequencies are above and beyond what was included in the source water sampling plan approved by DDW.

Table B-1. Detailed List of Monitored Constituents

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
General Water Characteristics (Physical and Chemical)						
Alkalinity, total	--	SM 2320B	mg/L	--		m
Ammonia	--	EPA 350.1	mg/L	--		m
Bromide	--	EPA 300.0	mg/L	--		m
Calcium	--	EPA 200.7	mg/L	--		q
Chloride	sMCL	EPA 300.0	mg/L	250		q
Color	sMCL	SM 2120B	units	15		q
Dissolved Oxygen (Field Measurement)	--	--	mg/L	--		m
Foaming Agents (MBAS)	sMCL	SM 5540C	mg/L	0.5		q
Iron (total and dissolved)	sMCL	EPA 200.8	mg/L	0.3		m
Magnesium	--	EPA 200.7	mg/L	--		q
Manganese (total and dissolved)	sMCL/NL	EPA 200.8	mg/L	0.05/0.5		m
Nitrate (as N)	pMCL	EPA 300.0	mg/L	10		m
Nitrate + Nitrite (as N)	pMCL	addition	mg-N/L	10	--	m

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
Nitrite (as N)	pMCL	EPA 300.0	mg-N/L	1	0.4	m
Odor-Threshold	sMCL	SM 6040E	units	3		q
Organic Carbon, Total (TOC)	--	SM5310C	mg/L	TT	0.3	m (24 months)
Organic Carbon, Dissolved (DOC)		SM5310C	mg/L	--		m
pH	--	SM 4500-H+ B	--	--		m
pH (Field Measurement)						m
Phosphorus (total as P)	--	SM 4500-PE/ EPA 365.1	mg/L	--		q
Potassium	--	EPA 200.7	mg/L	--		q
Sodium	--	EPA 200.7	mg/L	--		q
Specific Conductance (field measurement)	sMCL	SM 2510B	µS/cm	900		m
Sulfate	sMCL	EPA 300.0	mg/L	250		q
Temperature	--	--	°C	--		m
Total Dissolved Solids (TDS)	sMCL	SM2540C	mg/L	500		q
Total Suspended Solids (TSS)	--	SM2510D	mg/L	--		q
Turbidity	pMCL/sMCL	EPA 180.1	NTU	TT/5		2x/m (24 months)
Turbidity (field measurement)	pMCL/sMCL	EPA 180.1	NTU	TT/5		m
UV-254	--	SM 5910	cm^{-1}	--		m
Inorganic Contaminants with a primary (p) or secondary (s) MCL (not included in general water characteristics)						
Aluminum	pMCL/sMCL	EPA 200.8	mg/L	1/0.2	0.05	q
Antimony	pMCL	EPA 200.8	mg/L	0.006	0.006	q
Arsenic	pMCL	EPA 200.8	mg/L	0.010	0.002	q
Asbestos	pMCL	EPA 100.2	MFL*	7	0.2	q
Barium	pMCL	EPA 200.8	mg/L	1	0.1	q

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
Beryllium	pMCL	EPA 200.8	mg/L	0.004	0.001	q
Cadmium	pMCL	EPA 200.8	mg/L	0.005	0.001	q
Chromium (Total)	pMCL	EPA 200.8	mg/L	0.05	0.01	q
Chromium-6 (Hexavalent)	pMCL	EPA 218.6	mg/L	0.010	0.001	q
Copper	pMCL/sMCL	EPA 200.8	mg/L	1.3/1.0	0.05	q
Cyanide	pMCL	SM4500CN-F	mg/L	0.15	0.1	q
Fluoride	pMCL	SM4500F-C	mg/L	2.0	0.1	q
Lead	pMCL	EPA 200.8	mg/L	0.015	0.005	q
Mercury (inorganic)	pMCL	EPA 245.1	mg/L	0.002	0.001	q
Nickel	pMCL	EPA 200.8	mg/L	0.1	0.01	q
Perchlorate	pMCL	EPA 314.0	mg/L	0.006	0.004	q
Selenium	pMCL	EPA 200.8	mg/L	0.05	0.005	q
Silver	sMCL	EPA 200.8	mg/L	0.1	0.01	q
Thallium	pMCL	EPA 200.8	mg/L	0.002	0.001	q
Zinc	sMCL	EPA 200.8	mg/L	5	0.05	q
* MFL = million fibers per liter; MCL for fibers exceeding 10 µm in length						
Organic Contaminants with a primary or secondary MCL (excludes DBPs)						
1,1,1-Trichloroethane (1,1,1-TCA)	pMCL	EPA 524.2	mg/L	0.200	0.0005	q
1,1,2,2-Tetrachloroethane	pMCL	EPA 524.2	mg/L	0.001	0.0005	q
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	pMCL	EPA 524.2	mg/L	1.2	0.01	q
1,1,2-Trichloroethane (1,1,2-TCA)	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
1,1-Dichloroethane (1,1-DCA)	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
1,1-Dichloroethylene (1,1-DCE)	pMCL	EPA 524.2	mg/L	0.006	0.0005	q
1,2,4-Trichlorobenzene	pMCL	EPA 524.2	mg/L	0.005	0.0005	q

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
1,2-Dichlorobenzene	pMCL	EPA 524.2	mg/L	0.6	0.0005	q
1,2-Dichloroethane (1,2-DCA)	pMCL	EPA 524.2	mg/L	0.0005	0.0005	q
1,2-Dichloropropane	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
1,3-Dichloropropene [1]	pMCL	EPA 524.2	mg/L	0.0005	0.0005	q
1,4-Dichlorobenzene (p-DCB)	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
2,3,7,8-TCDD (Dioxin)	pMCL	EPA 1613	mg/L	3.E-08	5. E-09	q
2,4,5-TP (Silvex)	pMCL	EPA 515.4	mg/L	0.05	0.001	q
2,4-Dichlorophenoxyacetic acid (2,4-D) [1]	pMCL	EPA 515.4	mg/L	0.07	0.01	q
Alachlor	pMCL	EPA 505	mg/L	0.002	0.001	q
Atrazine	pMCL	EPA 525.2	mg/L	0.001	0.0005	q
Bentazon	pMCL	EPA 515.4	mg/L	0.018	0.002	q
Benzene	pMCL	EPA 524.2	mg/L	0.001	0.0005	q
Benzo(a)pyrene	pMCL	EPA 525.2	mg/L	0.0002	0.0001	q
Carbofuran	pMCL	EPA 531.2	mg/L	0.018	0.005	q
Carbon Tetrachloride	pMCL	EPA 524.2	mg/L	0.0005	0.0005	q
Chlordane	pMCL	EPA 505	mg/L	0.0001	0.0001	q
cis-1,2-Dichloroethylene	pMCL	EPA 524.2	mg/L	0.006	0.0005	q
Dalapon	pMCL	EPA 515.4	mg/L	0.2	0.01	q
Di(2-ethylhexyl)adipate	pMCL	EPA 525.2	mg/L	0.4	0.005	q
Di(2-ethylhexyl)phthalate (same as Bis (2-ethylhexyl)phthalate [2])	pMCL	EPA 525.2	mg/L	0.004	0.003	q
Dibromochloropropane (DBCP)	pMCL	EPA 551.1	mg/L	0.0002	0.00001	q
Dichloromethane (Methylene chloride)	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
Dinoseb	pMCL	EPA 515.4	mg/L	0.007	0.002	q
Diquat	pMCL	EPA 549.2	mg/L	0.02	0.004	q

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
Endothall	pMCL	EPA548.1	mg/L	0.1	0.045	q
Endrin	pMCL	EPA 508	mg/L	0.002	0.0001	q
Ethylbenzene	pMCL	EPA 524.2	mg/L	0.3	0.0005	q
Ethylene Dibromide (EDB)	pMCL	EPA 551.1	mg/L	0.00005	0.00002	q
Glyphosate [1]	pMCL	EPA 547	mg/L	0.7	0.025	q
Heptachlor	pMCL	EPA 505	mg/L	0.00001	0.00001	q
Heptachlor Epoxide	pMCL	EPA 505	mg/L	0.00001	0.00001	q
Hexachlorobenzene	pMCL	EPA 505	mg/L	0.001	0.0005	q
Hexachlorocyclopentadiene	pMCL	EPA 505	mg/L	0.05	0.001	q
Lindane	pMCL	EPA 505	mg/L	0.0002	0.0002	q
Methoxychlor	pMCL	EPA 505	mg/L	0.03	0.01	q
Methyl tert butyl ether (MTBE)	pMCL/sMCL	EPA 524.2	mg/L	0.013/0.005	0.003	q
Molinate	pMCL	EPA 525.2	mg/L	0.02	0.002	q
Monochlorobenzene	pMCL	EPA 524.2	mg/L	0.07	0.0005	q
Oxamyl	pMCL	EPA 531.2	mg/L	0.05	0.02	q
Pentachlorophenol	pMCL	EPA 515.4	mg/L	0.001	0.0002	q
Picloram	pMCL	EPA 515.4	mg/L	0.5	0.001	q
Polychlorinated Biphenyls (PCBs)	pMCL	EPA 505	mg/L	0.0005	0.0005	q
Simazine [2]	pMCL	EPA 525.2	mg/L	0.004	0.001	q
Styrene	pMCL	EPA 524.2	mg/L	0.1	0.0005	q
Tetrachloroethylene (PCE)	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
Thiobencarb	pMCL/sMCL	EPA 525.2	mg/L	0.07/0.001	0.001	q
Toluene	pMCL	EPA 524.2	mg/L	0.15	0.0005	q
Total Xylenes	pMCL	EPA 524.2	mg/L	1.750	0.0005	q
Toxaphene	pMCL	EPA 505	mg/L	0.003	0.001	q

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
trans-1,2-Dichloroethylene	pMCL	EPA 524.2	mg/L	0.01	0.0005	q
Trichloroethylene (TCE)	pMCL	EPA 524.2	mg/L	0.005	0.0005	q
Trichlorofluoromethane (Freon 11)	pMCL	EPA 524.2	mg/L	0.15	0.005	q
Vinyl Chloride	pMCL	EPA 524.2	mg/L	0.0005	0.0005	q
Disinfection By-Products						
Haloacetic acids (HAA5)	pMCL	SM 6251B	mg/L	0.060	--	q
Total Trihalomethanes (TTHMs)	pMCL	EPA 551.1	mg/L	0.080	--	q
Bromate	pMCL	EPA 317.0	mg/L	0.010	0.0010	q
Chlorite	pMCL	EPA 300.0	mg/L	1.0	0.020	q
Radionuclides with an MCL						
Gross Alpha Particle (excluding radon and uranium)	pMCL	EPA 900	pCi/L	15	3	q
Gross Beta Particle	pMCL	EPA 900	mrem/yr	4	4	q
Radium-228 and -226 (combined)	pMCL	GA Method	pCi/L	5	1 for each	q
Strontium-90	pMCL	EPA 905	pCi/L	8	2	q
Tritium	pMCL	EPA 906	pCi/L	20,000	1,000	q
Uranium	pMCL	EPA 200.8	pCi/L	20	1	q
Microbiological						
Cryptosporidium	pMCL	EPA 1623	oocysts/L	TT	--	m (24 months)
E. coli	pMCL	SM 9223F	MPN/100mL	TT	--	2x/m (24 months)
Giardia	pMCL	EPA 1623	cysts/L	TT	--	m (24 months)

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
Total Coliform	pMCL	SM 9223B	MPN/100mL	TT	--	2x/m (24 months)
Applied in Watershed - Unregulated, High-Use Pesticides (>5,000 lbs/yr)						
Chloropicrin	aNL	551.1	mg/L	0.05	--	q
Chlorothalonil	HA (1-day)	525.2	mg/L	0.2	--	q
Methyl Bromide	CCL3, CCL4	524.2	--	--	--	q
Oxyfluorfen	CCL3, CCL4	525.2	--	--	--	q
Paraquat Dichloride	HA (1-day)	549.2	mg/L	0.1	--	q
Pendimethalin	none	525.2	mg/L			q
Additional Unregulated Pesticides Applied in the Watershed, with a Health Advisory Level or Considered for Future Regulation						
Acephate	CCL3, CCL4	LCMS-MS		--	--	q
Carbaryl	aNL	531.2	mg/L	0.7	--	q
Dimethoate	aNL	525.2	mg/L	0.001	--	q
Diuron	HA (1-day); CCL4	EPA 532	mg/L	1	--	q
Hexazinone	HA (1-day)	EPA 525.2	mg/L	3	--	q
Methomyl	HA (1-day)	531.2	mg/L	0.3	--	q
Metolachlor [2]	UCMR2; HA (1-day)	525.2	mg/L	2	--	q
Permethrin	CCL3, CCL4	525.2		--	--	q
Tebuconazole	CCL3, CCL4	LCMS-MS		--	--	q
Thiamethoxam	UCMR3	LCMS-MS		--	--	q
Thiophanate-Methyl	CCL4	LCMS-MS		--	--	q
Ziram	CCL4	630.1		--	--	q
Additional SOCs Reported in Historical Data						
Diazinon	aNL; HA	EPA 525.2	mg/L	0.0012	--	q

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]
Tertiary butyl alcohol (TBA)	NL	EPA 524.2	mg/L	0.012	--	q
Chlorpyrifos (Dursban)	UCMR4; HA	525.2	mg/L	0.03	--	q
EPTC	UCMR1	525.2		--	--	q
Malathion	aNL; HA	525.2	mg/L	0.16	--	q
Trifluralin	HA (1-day)	525.2	mg/L	0.08	--	q
Select Additional Unregulated Constituents of Interest						
1,2,3-Trichloropropane (1,2,3-TCP)	Forthcoming pMCL, NL	EPA 524.2	mg/L	5.00E-06	5.00E-06	q
Additional Unregulated Constituents of Interest Related to Dairy, Poultry and Ranch Operations						
17-β-estradiol	UCMR3, List 2	EPA 539	ng/L			q
17-α-ethynylestradiol	UCMR3, List 2	EPA 539	ng/L			q
Estriol	UCMR3, List 2	EPA 539	ng/L			q
Equilin	UCMR3, List 2	EPA 539	ng/L			q
Erythromycin	CCL3, CCL4	LC-MS-MS	ng/L			q
Estrone	UCMR3, List 2	EPA 539	ng/L			q
Testosterone	UCMR3, List 2	EPA 539	ng/L			q
4-androstene-3,17-dione	UCMR3, List 2	EPA 539	ng/L			q
Select Additional Unregulated Constituents of Interest Related to Algae Occurrence						
Algae Identification	--	Flow Cam	ng/L			q
Algae Enumeration	--	Flow Cam	ng/L			q
Chlorophyll A	--		ng/L			q
Microcystins Screen	UCMR4	ELISA	ng/L			2x/y
Cyanotoxins (Microcystins, Nodularin)	UCMR4	EPA 544	ng/L			2x/y
Cyanotoxins (Anatoxin, Cylindrospermopsin)	UCMR4	EPA 545	ng/L			2x/y

Parameter[4]	List	Method	Units	DDW MCL/NL	DDW DLR	Collection Frequency[3,4]

Footnotes:

[1] Also a high-use pesticide in this watershed.

[2] Also measured during prior water sampling.

[3] m=monthly; q-quarterly, 2x/m=twice per month; 2x/y=twice per year

[4] Highlighted constituents represent additional monitoring, either parameter of sampling frequency, beyond what was included in the source water sampling plan submitted to DDW. DDW accepted the proposed sampling plan in an email from Tahir Mansoor to Michael Brinton, dated July 25, 2016.

TT = Treatment Technique

pMCL = Primary Maximum Contaminant Level

sMCL = Secondary Maximum Contaminant Level

NL = DDW Notification Level

aNL = DDW Archived Notification Level

UCMR = Unregulated Contaminant Monitoring Rule

CCL = EPA's Contaminant Candidate List

HA = EPA Health Advisory Level