

Kaweah Project, FERC Project No. 298

AQ 6 – Water Quality Technical Study Report

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List of Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
µS/cm	microSiemens per centimeter
AQ 6 – TSP	AQ 6 – Water Quality Technical Study Plan
Basin Plan	Water Quality Control Plan for the Tulare Lake Basin
cfs	cubic feet per second
CTR	California Toxics Rule
DO	dissolved oxygen
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GPS	Global Positioning System
MDL	method detection limit
mg/L	milligram per liter
mL	milliliter
MRL	method reporting limit
NTU	Nephelometric Turbidity Unit
PDF	Portable Document Format
PQL	practical quantitation limit
Project	Kaweah Project
PSP	Proposed Study Plan
QA	quality assurance
QA/QC	quality assurance/quality control
RL	reporting limit
RSP	Revised Study Plan
SCE	Southern California Edison Company

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1 INTRODUCTION

This Technical Study Report describes the data and findings developed by Southern California Edison Company (SCE) in association with implementation of the AQ 6 – Water Quality Technical Study Plan (AQ 6 – TSP) for the Kaweah Project (Project). The AQ 6 – TSP was included in SCE’s Revised Study Plan (RSP)¹ (SCE 2017a) and was approved by the Federal Energy Regulatory Commission (FERC) on October 24, 2017, as part of its Study Plan Determination for the Project (FERC 2017). Specifically, this report provides a description of the methods and results of the water quality sampling completed in 2018.

2 STUDY OBJECTIVES

The AQ 6 – TSP included one study objective, as follows:

- Characterize physical, chemical, and bacterial water quality conditions in the bypass² river reaches and comparison reaches, and compare to the Water Quality Control Plan for the Tulare Lake Basin (Basin Plan; CVRWQCB 2015) objectives and water quality standards and other applicable Environmental Protection Agency (EPA) national or California Toxics Rule (CTR) standards.

3 EXTENT OF STUDY AREA

The study area included the bypass river reaches associated with the Project and comparison river reaches upstream and downstream of the bypass reaches (Table AQ 6-1, Map AQ 6-1).

It should be noted that the majority of lands along the bypass reaches are privately owned and outside the FERC Project boundary. Prior to beginning the water quality study in 2018, SCE provided notification to landowners about Project relicensing and requested authorization to enter property to conduct the field study. If authorization was obtained, SCE completed sampling as described in the AQ 6 – TSP. If authorization was not obtained, SCE sampled from the nearest location within the reach where permission was granted.

4 STUDY APPROACH

The following describes the water quality sampling field program, which included *in-situ* water quality measurements, general water quality sampling, coliform sampling, and laboratory analysis and reporting. The results from the water quality sampling program were documented in tables and then compared to the Basin Plan (CVRWQCB 2015) water quality objectives, the CTR, and applicable EPA national water quality criteria.

4.1 *In-situ* Field Measurements

In-situ water quality measurements (water temperature, dissolved oxygen [DO], turbidity, conductivity, and pH) were collected at sampling locations listed in Table AQ 6-1 using a YSI® meter. Samples were collected during the spring runoff (May 7 to 9 and May 30 to 31, 2018), and during the summer low-flow or base-flow period (August 20 to 24, 2018). Pre- and post-sampling calibration of *in-situ* instrumentation was conducted following the manufacturer’s instructions.

¹ SCE filed a Proposed Study Plan (PSP) on May 24, 2017 (SCE 2017b). Three comments were filed on the PSP, however, they did not result in revisions to any of the study plans. Therefore, SCE filed an RSP on September 19, 2017 which stated that the PSP, without revision, constituted its RSP. The FERC subsequently issued a Study Plan Determination on October 24, 2017, approving all study plans for the Kaweah Project.

² A bypass reach is a segment of a river downstream of a diversion facility where Project operations result in the diversion of a portion of the water from that reach. Typically the diverted water re-enters the river through a powerhouse at the downstream end of the bypass reach.

The results of the *in-situ* monitoring were documented on field data sheets and then entered into Excel spreadsheets. Quality Assurance/Quality Control (QA/QC) of the data entry was subsequently performed by a separate individual.

4.2 General Water Quality Sampling

General water quality samples (e.g., calcium, chloride, hardness, dissolved metals, etc.) were collected at sampling locations listed in Table AQ 6-1 and depicted on Map AQ 6-1. Samples were collected twice: once during the spring runoff and once during the summer low-flow period to screen for potential water quality issues. Samples were collected using methods consistent with the EPA 1669 sampling protocol Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria. Water quality samples collected from streams were analyzed for the parameters listed in Table AQ 6-2, which include general parameters, a suite of dissolved metals, total mercury, and bacteria.

Water quality samples were decanted into laboratory-supplied sample containers. The sample containers were labeled with the date and time that the sample was collected and the sampling site or identification label. The sample container was preserved (as appropriate), stored, and delivered to a State-certified water quality laboratory for analyses in accordance with maximum holding periods. A chain-of-custody record was maintained with the samples at all times. The sampling site locations were recorded using a Global Positioning System (GPS) unit and the coordinates were recorded on field data sheets.

The results of the analyses were provided by the laboratory in either Portable Document Format (PDF) files or Excel spreadsheets. The PDF results were then entered into an Excel spreadsheet and QA/QC of the data entry was performed by a separate individual.

4.3 Coliform Sampling

Total and fecal coliform, specifically *Escherichia coli* (*E. coli*), sampling was conducted to determine if study waters met objectives for contact recreational activities identified by EPA (2012). The Basin Plan includes the older fecal coliform standard, rather than the newer recommended *E. coli* standard (CVRWQCB 2015). Samples were collected at a near-shore location immediately above and below the river access area near Kaweah No. 2 Powerhouse (“Edison Beach”) where contact recreation (e.g., swimming) occurs. Coliform samples were collected five times between July 5 and July 31, 2018, which is within the thirty-day period mandated by the Basin Plan. Samples were generally collected in the afternoon when the access area was open (Monday – Thursday; 8 am – 7 pm).

Samples were decanted into laboratory supplied sample vials that contained preservative. The samples were placed on ice and delivered to the laboratory immediately after sampling.

The results of the analyses were provided by the laboratory in PDF files. The PDF results were then entered into an Excel spreadsheet and QA/QC of the data entry was performed by a separate individual.

4.4 Laboratory Analysis and Reporting

Water quality samples collected during the field program were analyzed by State-certified laboratories approved by the State Water Resources Control Board for chemical analysis. The laboratories attempted to attain reporting and detection limits that were at or below the applicable regulatory criteria. The parameters analyzed by the laboratories are provided in Table AQ 6-2 and described in Appendix A. The laboratories reported each chemical parameter with an associated method detection limit (MDL), method reporting limit (MRL or RL), and/or practical quantitation limit (PQL). The MDL is the minimum measured concentration of a substance that can be reported with 99 percent confidence that the measured concentration is distinguishable from method blank result (EPA 2016). MRL and PQL are laboratory specific measures of the lowest concentration the laboratory could reliably reproduce (usually 3 to 10 times the MDL). One laboratory used MRL and PQL interchangeably and the other laboratories reported

a MRL (or RL). A detailed definition of MDL, MRL, and PQL is provided in Appendix B along with a glossary of laboratory terminology, the units of measure used by the laboratories, and water quality criteria calculation methods.

4.5 Quality Assurance/ Quality Control Procedures

Water quality samples were collected using methods consistent with the EPA 1669 sampling protocol Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria. At each station, all samples were collected by the same person, wearing ultra-trace sampling gloves. In-stream water samples were collected just below the water surface in areas of steady flow. Water quality samples were collected using the designated collection bottle supplied by the appropriate laboratory. Upon collection, each sample was immediately labeled with the date and time and logged on a chain-of-custody form and placed into a cooler filled with ice. Sampling equipment was cleaned with a cleaning solution and distilled water prior to sample collection.

Water quality samples were delivered to the analytical laboratory within the appropriate holding times. Coliform samples were delivered to the laboratory on the same day of collection, while all other samples were delivered between 24 to 48 hours of the sample collection time by courier. A chain-of-custody form accompanied all samples from the time of collection to delivery and submittal to the analytical laboratory.

Standard quality assurance (QA) procedures were performed by the laboratories during analyses of water samples. These included matrix and laboratory spikes and spike duplicates, matrix duplicates, and method blanks as appropriate. A summary of the QA measures were included with each certified laboratory report. A QA/QC screening level review was conducted on all of the laboratory analytical reports.

5 STUDY RESULTS

Results of the spring and summer 2018 *in-situ* field measurements, general water quality sampling, and coliform sampling are discussed below. A summary of the water quality tests performed, analysis methods, detection and reporting limits, water quality criteria, and holding time and preservative requirements is included in Table AQ 6-2. Sampling occurred from May 7 to 9 and May 30 to 31, 2018, for the spring sampling period and from August 20 to 23, 2018, for the summer sampling period. A description of the sampling locations, GPS coordinates, and sampling dates is included in Table AQ 6-1. Table AQ 6-3 shows that most results met the Basin Plan water quality objectives, the CTR, and EPA national water quality criteria. All *in-situ* field measurements and coliform parameters are discussed below, but only two general water quality parameters (ammonia and alkalinity) that had unique issues related to Basin Plan water quality objectives, the CTR, and/or the EPA national water quality criteria are discussed. Results of the QA/QC of the laboratory reports are also discussed at the end of this section.

5.1 Water Quality Objectives and Criteria

The Basin Plan identifies specific water quality objectives of allowable limits or levels of water quality constituents. These objectives are established for the protection of beneficial uses of the waters in the Tulare Lake Basin, which is comprised of the drainage area of the San Joaquin Valley south of the San Joaquin River and includes the Kaweah River upstream of Lake Kaweah (CVRWQCB 2015). If water quality is maintained at levels that meet these objectives, the beneficial uses of the waters are considered to be protected. The beneficial uses identified in the Basin Plan for the Kaweah River upstream of Lake Kaweah include: (1) municipal and domestic supply; (2) hydropower generation; (3) water contact recreation; (4) non-contact water recreation; (5) warm freshwater habitat; (6) cold freshwater habitat; (7) wildlife habitat; (8) rare, threatened, or endangered species; (9) spawning, reproduction, and / or early development; (10) freshwater replenishment. The definition of each of these beneficial uses is provided in Table AQ 6-4.

Water quality objectives include both numeric and narrative objectives (Table AQ 6-2). The Basin Plan provides specific numeric objectives for *in-situ* measurements, chemical constituents, metals, and bacteria. The Basin Plan water quality objectives for chemical constituents are derived from the maximum contaminant levels that are provided in Title 22 of the California Code of Regulations. Table AQ 6-2 also includes the CTR and EPA national water quality criteria (65 FR 31682, EPA 2019). The most stringent objectives were used for this study.

Several of the parameters analyzed do not have established water quality criteria. Various literature sources were reviewed for each parameter to identify guidelines or ranges that might be expected for the Project area. The ranges are described in Appendix A.

5.2 **In-Situ Field Measurements**

In-situ field measurements are presented in Table AQ 6-5 for the spring sampling period and in Table AQ 6-6 for the summer sampling period. Each *in-situ* parameter is discussed below.

5.2.1 **Water Temperature**

The Basin Plan water quality objective for water temperature states that elevated temperature wastes shall not cause the temperature of waters designated COLD³ or WARM⁴ to increase by more than 5 degrees Fahrenheit (°F) (2.78 degrees Celsius [°C]) above natural receiving water temperature (CVRWQCB 2015). There are no water temperature criteria in the CTR or in the EPA's national water quality criteria.

During the spring 2018 sampling period (May 7 to 9 and May 30 to 31, 2018) water temperatures ranged from 9.31°C to 16.56°C and during the summer sampling period (August 20 to 23, 2018) water temperatures ranged from 18.19°C to 26.90°C. *In-situ* field measurements consisted of a single point measurement taken at each site during each site visit, and the time of day at which measurements were taken varied across sites. Both temperature and streamflow can fluctuate over the course of a day and both (temperature and flow) fluctuated during the sampling periods. Figure AQ 6-1 shows continuous flow and water temperature data in the bypass reaches. The continuous water temperature data was collected as part of the AQ 4 Water Temperature Modeling Technical Study. Tables AQ 6-5 and AQ 6-6 also show the flow in the flowlines or stream reaches when the *in situ* sampling was conducted.

During the spring sampling period, water temperature in all locations was less than 17°C and significant flow existed in the river reaches and the flowlines (Figure AQ 6-1). During the summer sampling period some high water temperatures were present (>25°C), but these were natural occurrences in the system. No significant Project flow diversions were occurring. The powerhouses were not operating during the summer low flow period. Kaweah No. 1 Flowline was diverting only 0.48 to 0.56 cubic feet per second (cfs) (for water delivery requirements), Kaweah No. 2 Flowline was diverting 2.6 cfs (for water delivery requirements), and Kaweah No. 3 Flowline was not diverting water.

The AQ 4 Water Temperature Modeling Technical Study includes continuous water temperature data collected in the bypass reaches and water temperature modeling that will be used to identify if there are

³ The Basin Plan defines the beneficial use Cold Freshwater Habitat (COLD) as uses of water that support cold water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. The Basin Plan indicates that waters designated as COLD are present in Kaweah River above Lake Kaweah and notes that the beneficial uses of any specifically identified water body generally apply to its tributary streams. In some cases a beneficial use may not be applicable to the entire body of water, and in these cases the Regional Water Board's judgement will be applied.

⁴ The Basin Plan defines the beneficial use Warm Freshwater Habitat (WARM) as uses of water that support warm water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. WARM includes support for reproduction and early development of warm water fish. The Basin Plan indicates that waters designated as WARM are present in Kaweah River above Lake Kaweah and notes that the beneficial uses of any specifically identified water body generally apply to its tributary streams. In some cases a beneficial use may not be applicable to the entire body of water, and in these cases the Regional Water Board's judgement will be applied.

potential effects of the Project on water temperature during the late spring or early summer period in year types when the hydrology provides enough water for the Project powerhouses to operate.

5.2.2 Dissolved Oxygen

The Basin Plan water quality objectives for DO are a minimum of 5.0 milligrams per liter (mg/L) for water designated WARM and a minimum of 7.0 mg/L for waters designated COLD or SPWN⁵ (CVRWQCB 2015). The EPA's DO criterion was established in the 1986 Gold Book, which recommends a 1-day minimum DO value of 8.0 mg/L in cold waters for early life stages of fish (EPA 1986). There are no water temperature criteria in the CTR.

During the *in situ* water sampling, DO exceeded the minimum criteria in the Basin Plan and the EPA's 1986 Gold Book during both the spring and summer 2018 sampling periods: during the spring 2018 sampling period DO ranged from 9.1 to 10.05 mg/L and during the summer 2018 sampling period DO ranged from 8.3 to 9.61 mg/L.

5.2.3 Turbidity

The Basin Plan water quality objective for turbidity states that, “where natural turbidity is between 0 and 5 Nephelometric Turbidity Units (NTUs), increases shall not exceed 1 NTU. Where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent. Where natural turbidity is equal to or between 50 and 100 NTUs, increases shall not exceed 10 NTUs. Where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent” (CVRWQCB 2015). There are no turbidity criteria in the CTR or in the EPA's national water quality criteria.

For the *in situ* sampling, turbidity measured using a YSI meter ranged from 0.1 to 5.5 NTUs during the spring 2018 sampling period and from 1.2 to 4.0 NTUs during the summer 2018 sampling period. Turbidity was also measured in the laboratory as part of the general water quality parameters. Turbidity measured in the laboratory ranged from 0.42 to 2.7 NTUs during the spring 2018 sampling period and from 0.31 to 0.53 NTUs during the summer 2018 sampling period. Turbidity measured in the study area was very low. The Project consists of concrete diversions and lined flowlines and is unlikely to alter turbidity as a result of normal Project operations.

5.2.4 Conductivity

The Basin Plan water quality objective for conductivity is a maximum of 175 microsiemens per centimeter ($\mu\text{S}/\text{cm}$) (CVRWQCB 2015). There are no conductivity criteria in the CTR or in the EPA's national water quality criteria. Conductivity was below the maximum $\mu\text{S}/\text{cm}$ criterion during both the spring and summer 2018 sampling periods: conductivity ranged from 15 to 50 $\mu\text{S}/\text{cm}$ during the spring 2018 sampling period and from 92 to 139 $\mu\text{S}/\text{cm}$ during the summer 2018 sampling period (Tables AQ 6-5 and AQ 6-6).

5.2.5 pH

The Basin Plan water quality objective for pH states that, “the pH of water shall not be depressed below 6.5, raised above 8.3, or changed at any time more than 0.3 units from normal ambient pH” (CVRWQCB 2015). The national EPA pH criterion is 6.5 to 9 for chronic exposure in fresh water (EPA 2019). There is no pH criterion in the CTR.

During the spring sampling period (May 7 to 9 and May 30 to 31, 2018), pH values ranged from 7.32 to 7.88 and during the summer sampling period (August 20 to 23, 2018), pH values were generally higher,

⁵ The Basin Plan defines the beneficial use Spawning, Reproduction, and/or Early Development (SPWN) as uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish. SPWN is limited to cold water fisheries. The Basin Plan indicates that waters designated as SPWN are present in Kaweah River above Lake Kaweah and notes that the beneficial uses of any specifically identified water body generally apply to its tributary streams. In some cases a beneficial use may not be applicable to the entire body of water, and in these cases the Regional Water Board's judgement will be applied.

ranging from 7.82 to 8.57. All sites were within the EPA pH criteria. A single site, K2 Flowline Above PH2, had a pH of 8.57, slightly outside of the 6.5 to 8.3 “depression range” identified in the Basin Plan (Tables AQ 6-5 and AQ 6-6). Flow in the K2 Flowline in August was very low (2.6 cfs) as water was only being diverted to meet consumptive water deliveries for water users and not for hydropower generation (Table AQ 6-6). Likely the combination of low flow and daytime photosynthesis by attached algae in the flowline and the general low alkalinity (soft water) in the Kaweah River watershed resulted in the slightly higher pH value. During the day, photosynthesis results in the removal of CO_2 and/or HCO_3^- from the water and consequently pH values increase, particularly in waters with low alkalinity (low buffering capacity) (e.g., Hem 1989; Boyd 2015). Because the flow in the flowline was being used by consumptive water users, very little would have potentially returned to the Kaweah River and, therefore, the slightly elevated pH water would not have affected the Kaweah River.

5.3 General Water Quality Sampling

Results of the general water quality sampling are presented in Table AQ 6-7 for spring and in Table AQ 6-8 for summer. Table AQ 6-9 and Table AQ 6-10 contain the calculated criteria and results for ammonia, which has criteria based on temperature and pH and therefore must be calculated on a location-by-location basis. Table AQ 6-11 and Table AQ 6-12 contain calculated criteria and results for cadmium, copper, lead, and nickel, which have hardness-based criteria. For each of these metals, the water quality criterion decreases with decreasing water hardness (see Appendix B for equations). All general water quality sampling parameters were within the Basin Plan water quality objectives and the CTR and EPA national water quality criteria. With respect to ammonia, 4 of 29 samples were greater than the Basin Plan ammonia “waste discharge” objective. The samples were not “waste discharge,” they were natural conditions; nevertheless, ammonia is discussed below. Also, because of the naturally low alkalinity in the Kaweah River watershed, 9 of 29 samples were below the EPA total alkalinity criterion. The EPA criterion also has an “unless the low alkalinity is natural,” which is the case for the Kaweah River samples; nevertheless, alkalinity is also discussed below. General water quality sampling parameters that were within the Basin Plan water quality objectives and CTR and EPA national water quality criteria or that have no criteria defined are not discussed below.

5.3.1 Ammonia

The Basin Plan water quality objective for ammonia is that discharge of waste shall not cause concentrations of ammonia to exceed 0.025 mg/L (CVRWQCB 2015). The national EPA ammonia criteria are dependent on ambient pH and temperature conditions and were calculated using both the acute and chronic criterion calculations (see Appendix B for equations) in the EPA’s Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater (EPA 2013). There are no ammonia criteria in the CTR.

The calculated ammonia criteria and laboratory ammonia concentration results are presented in Table AQ 6-9 for the spring sampling period and Table AQ 6-10 for the summer sampling period. Ammonia was detected in four samples: K2 Flowline Below PH3 during the spring 2018 sampling period; and KR Upstream of PH1, KR Upstream of PH2, and KR Downstream of PH2 during the summer sampling period. The ammonia concentration in two samples (KR Upstream of PH1 and KR Upstream of PH2) fell below the PQL and above the MDL, and therefore the ammonia concentration values at these sites are considered estimates. All four samples are above the “waste discharge” values in the Basin Plan; however, Project operations do not produce any “waste discharge.” One sample (KR Downstream of PH2 during the summer 2018 sampling period) exceeded the EPA calculated ammonia chronic criterion, but not the acute criterion.

There are no known Project related activities, facilities, or operations that have the potential to affect ammonia concentrations and cause the slightly elevated ammonia levels at a few places in the Project area. Ammonia can be produced from septic systems (decomposing organic matter) and there are many

homes and the Sequoia National Park Visitor Center that are adjacent to the Kaweah River and could potentially be a source for ammonia.

5.3.2 Total Alkalinity

The EPA national water quality criterion for total alkalinity states that a continuous concentration, “of 20 mg/L is a minimum value except where alkalinity is naturally lower, in which case the criterion cannot be lower than 25 percent of the natural level” (EPA 2019). There is no alkalinity criterion in the Basin Plan water quality objectives or in the CTR.

During the spring sampling period, alkalinity was below 20 mg/L at 9 of the 16 sites (Table AQ 6-7). All of the other sites also had relatively low alkalinity (<24.1 mg/L) except for one likely anomalous measurement (369 mg/L, KR Downstream of the Conf. with EF). Low alkalinity is a natural condition of the Kaweah River watershed during spring high flow conditions. Snowmelt and rainfall runoff have little opportunity to pick up calcium carbonate from the basin geology. During the summer, low flow sampling period, alkalinity was higher (ranging from 38.8 to 63.5 mg/L at 12 of the 13 sites sampled) (Table AQ 6-8). During the summer there was also one site that had an apparently anomalous high reading (645 mg/L, EF Upstream of K1 Div.). There are no known mechanisms through which the Project would affect alkalinity. Alkalinity of natural waters in the range observed in the Kaweah River is considered low (Boyd 2015), but is generally a product of the underlying geology and land use of a watershed.

5.4 Coliform Sampling

The Basin Plan water quality objective for bacteria states that, “in water designated REC-1⁶, the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200/100 milliliters (mL), nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100 mL” (CVRWQCB 2015). *E. coli* is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA now recommends *E. coli* as the best indicator of health risk from water contact in recreational waters rather than fecal coliform (i.e., fecal coliform concentrations are composed of some species of bacteria that are not necessarily fecal in origin). The EPA’s criterion for *E. coli* is that it should not exceed a geometric mean of 126/100 mL, nor more than ten percent of samples exceed 410/100 mL in waters used for freshwater contact recreation (EPA 2012). Neither the Basin Plan nor the EPA have criteria for total coliform.

Water samples were collected for total coliform and *E. coli* analysis five times between July 5 and July 31, 2018, at one location upstream of Edison Beach, a public recreational beach, and one location downstream of the beach (Map AQ 6-2). The results of the total coliform and *E. coli* analysis are presented in Table AQ 6-13. *E. coli* concentrations ranged from 14.5 to 69.7/100mL upstream of Edison Beach and from 14.8 to 76.9/100mL downstream of Edison Beach. All samples were less than the EPA criteria for human health risk for contact recreation. Total coliform was greater than 2,419.6/100mL in all samples collected. There is no contact recreation criteria for total coliform, because much of total coliform can be from natural sources (total coliform is primarily used in drinking water analyses to indicate the potential contamination from outside water sources).

⁶ The Basin Plan defines the beneficial use Water Contact Recreation (REC-1) as uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfacing, white water activities, fishing, or use of natural hot springs. The Basin Plan indicates that waters designated as REC-1 are present in Kaweah River above Lake Kaweah and notes that the beneficial uses of any specifically identified water body generally apply to its tributary streams. In some cases a beneficial use may not be applicable to the entire body of water, and in these cases the Regional Water Board’s judgement will be applied.

5.5 Laboratory Analysis and Reporting

Eighteen analytes were tested by APPL Labs, three analytes were tested by BSK Associates Labs, and nine analytes were tested by Brooks Applied Labs. The laboratories provided reports of each parameter analyzed and the associated MDL, MRL, and/or PQL. All of the laboratory reports are available upon request.

5.6 Quality Assurance/ Quality Control Procedures

Appendix C contains a detailed QA/QC summary of the reports received from the water quality testing laboratories. The QA/QC review of reports from APPL Labs, BSK Associates Labs, and Brooks Applied Labs indicated that most of the samples were acceptable (i.e., holding times, preservation, sample containers, etc. were appropriate). The labs flagged four samples with qualifiers: (1) Sample 21 Total Kjeldahl Nitrogen and; (2) Sample 12 Total Alkalinity the analyte was found in a method blank as well as in the sample; (3) Sample 28 Total Organic Carbon was received without chemical preservation; (4) and Sample 21 Turbidity was subcontracted to BSK Associates Labs after equipment failure at APPL Labs prevented analysis of the sample, and the sample was received at BSK Associates Labs past the holding time limit and above the mandated temperature.

Numerous samples had results that were less than or equal to the MDL, and therefore were considered non-detects, or were greater than the MDL but less than or equal to the PQL/MRL, and therefore were considered estimates (see Appendix B for a discussion of MDL, PQL and MRL). Samples with analyte concentrations that were less than or equal to the MDL were included as “<MDL” in Tables AQ 6-7 through AQ 6-12. Samples with analyte concentrations that were greater than the MDL but less than or equal to the PQL or MRL are reported in Tables AQ 6-7 through AQ 6-12 and flagged with footnotes indicating that they should be considered estimates.

6 LITERATURE CITED

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TABLES

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Table AQ 6-1. Water Quality Monitoring and Sampling Locations.

Sampling Location	Sampling Location Description	Sample ID	GPS Coordinates		Sampled in Spring? (May 7 – 31, 2018)	Sampled in Summer? (Aug 20 – 23, 2018)
			UTM11_ NAD 83 E	UTM11_ NAD 83 N		
Kaweah River						
K3 Flowline Above PH3	Kaweah No. 3 Flowline Upstream of the Kaweah No. 3 Powerhouse	6, 19	336315	4039197	Y	N ¹
KR Upstream of PH3	Kaweah River Upstream of the Kaweah No. 3 Powerhouse	8, 25	335524	4039460	Y	Y
K2 Flowline Below PH3	Kaweah No. 2 Flowline Downstream of the Kaweah No. 3 Powerhouse	9	335446	4039333	Y	N ¹
KR Downstream of PH3	Kaweah River Downstream of the Kaweah No. 3 Powerhouse	7, 26	335549	4039215	Y	Y
KR Upstream of the Conf. with EF	Kaweah River Upstream of the East Fork Kaweah River Confluence	10, 27	335382	4038784	Y	Y
KR Downstream of the Conf. with EF	Kaweah River Downstream of the East Fork Kaweah Confluence	11, 32	335161	4038695	Y	Y
KR Upstream of PH1	Kaweah River Upstream of the Kaweah No. 1 Powerhouse	14, 23, 34	333144	4037224	Y	Y
K1 Flowline Above PH1	Kaweah No. 1 Flowline Upstream of the Kaweah No. 1 Powerhouse	12, 16	333867	4036565	Y	N ²
KR Downstream of PH1	Kaweah River Downstream of the Kaweah No. 1 Powerhouse	13, 22, 33	333049	4037206	Y	Y
K2 Flowline Above PH2	Kaweah No. 2 Flowline Upstream of the Kaweah No. 2 Powerhouse	5, 18, 36	331832	4037037	Y	Y
KR Upstream of PH2	Kaweah River Downstream of the Kaweah No. 1 Powerhouse and Upstream of the Kaweah No. 2 Powerhouse	4, 17, 35	331593	4036687	Y	Y
KR Downstream of PH2	Kaweah River Downstream of the Kaweah No. 2 Powerhouse	15, 24, 37	331240	4036770	Y	Y
East Fork Kaweah River						
EF Upstream of K1 Div.	East Fork Kaweah River Upstream of the Kaweah No. 1 Diversion	2, 28	339661	4035539	Y	Y
EF Downstream of K1 Div.	East Fork Kaweah River Downstream of the Kaweah No. 1 Diversion	3, 20, 29	339590	4035507	Y	Y
K1 Flowline Below K1 Div.	Kaweah No. 1 Flowline Downstream of the Kaweah No. 1 Diversion	1, 30	339450	4035266	Y	Y
EF Upstream of the Conf. with KR	East Fork Kaweah River Upstream of the Confluence with Kaweah River	21, 31	335383	4038647	Y	Y

Notes:

¹ The water level in the K3 Flowline above PH3 and the K2 Flowline below PH3 was so low during the summer sampling period that it could not be reached without entering the flowlines. Since entering the flowlines is prohibited, water quality samples could not be collected.

² The K1 Flowline above PH1 was dry during the summer sampling period and therefore water quality samples could not be collected.

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Table AQ 6-2. Summary of Water Quality Analytical Tests, Including Laboratory Methods and Detection Limits, and Chemical Water Quality Objectives.

Analyte	Units ¹	Analysis Method ²	Method Detection Limit (MDL)	Practical Quantitation Limit (PQL)/ Method Reporting Limit (MRL)	Water Quality Criteria			Sample Container	Hold Time	Preservative/ Comment
					Basin Plan ³	CA Toxics Rule (CTR) ⁴	EPA Criteria ⁵			
In-Situ Measurements					PQL/MRL					
Water Temperature	Celsius (°C)	Water Quality Meter	Not Applicable	Not Applicable	≤ +5°F ⁶	NS	NS	Not Applicable	Not Applicable	None
Dissolved Oxygen (DO)	mg/L	Water Quality Meter	Not Applicable	Not Applicable	5.0 - 7.0 ⁷	NS	3.0 - 8.0 ⁸	Not Applicable	Not Applicable	None
Turbidity	NTU	Water Quality Meter	Not Applicable	Not Applicable	Depends on natural turbidity ⁹	NS	NS	Not Applicable	Not Applicable	None
Conductivity	µS/cm at 25°C	Water Quality Meter	Not Applicable	Not Applicable	175	NS	NS	Not Applicable	Not Applicable	None
pH	unitless	Water Quality Meter	Not Applicable	Not Applicable	6.5 – 8.3 ¹⁰	NS	6.5 – 9.0	Not Applicable	Not Applicable	None
General Parameters					PQL/MRL					
Calcium	µg/L	EPA 200.7	10.79	50.0	NS	NS	NS	500mL plastic	180 days	HNO ₃ , maintain at ≤6°C
Chloride	mg/L	EPA 300.0	0.08	1.0	250 ¹¹	NS	230/860 ¹²	250mL plastic	28 days	Maintain at ≤6°C
Hardness (as CaCO ₃)	mg/L	EPA 200.7/SM 2340B	1.00	1.0	NS	NS	NS	500mL plastic	180 days	HNO ₃ , maintain at ≤6°C
Magnesium	µg/L	EPA 200.7	3.48	25.0	NS	NS	NS	500mL plastic	180 days	HNO ₃ , maintain at ≤6°C
Nitrate	mg/L	EPA 300.0	0.01	0.2	10	NS	NS	500mL plastic	48 hours	H ₂ SO ₄ , maintain at ≤6°C
Nitrite	mg/L	EPA 300.0	0.01	0.1	1	NS	NS	500mL plastic	48 hours	H ₂ SO ₄ , maintain at ≤6°C
Nitrate/Nitrite (NO ₃)	mg/L	EPA 353.2	0.028	0.10	10	NS	NS	500mL plastic	48 hours	H ₂ SO ₄ , maintain at ≤6°C
Ammonia as N	mg/L	EPA 350.1	0.012	0.5	0.025	NS	Depends on pH & temperature	500mL plastic	28 days	H ₂ SO ₄ , maintain at ≤6°C
Total Kjeldahl Nitrogen (TKN)	mg/L	EPA 351.2	0.267	0.50	NS	NS	NS	500mL plastic	28 days	H ₂ SO ₄ , maintain at ≤6°C
Total Phosphorus	µg/L	SM 4500	24.0	100	NS	NS	NS	500mL plastic	28 days	H ₂ SO ₄ , maintain at ≤6°C
Ortho-phosphate	mg/L	SM 4500-P E	0.016	0.05	NS	NS	NS	500mL amber glass	48 hours	Maintain at ≤6°C
Potassium	µg/L	EPA 200.7	93.9	500	NS	NS	NS	500mL plastic	180 days	HNO ₃ , maintain at ≤6°C
Sodium	µg/L	EPA 200.7	82.9	500	NS	NS	NS	500mL plastic	180 days	HNO ₃ , maintain at ≤6°C
Sulfate (SO ₄)	mg/L	EPA 300.0	0.09	1.0	250 ¹¹	NS	NS	250mL plastic	180 days	Maintain at ≤6°C
Total Dissolved Solids	mg/L	SM 2540C	4.4	10	500 ¹¹	NS	NS	500mL plastic	7 days	Maintain at ≤6°C
Total Suspended Solids	mg/L	SM 2540D	5.6	10	NS	NS	NS	500mL plastic	7 days	Maintain at ≤6°C
Turbidity	NTU	EPA 180.1/SM 2130B	0.035	0.10	Depends on natural turbidity ⁹	NS	NS	1L amber glass	Not Applicable	Maintain at ≤6°C
Organic Carbon, Total (TOC)	mg/L	SM 5310C	Not Applicable	0.2	NS	NS	NS	250mL amber glass	28 days	H ₂ SO ₄ , maintain at ≤6°C
Total Alkalinity	mg/L	SM 2320B	0.85	2.0	NS	NS	>20 ¹³	250mL plastic	14 days	Maintain at ≤6°C
Metals-Dissolved					MRL					
Arsenic	µg/L	EPA 1638	0.056	0.204	10	150/340 ¹²	150/340 ¹² , 0.018 ¹⁴ , 0.14 ¹⁵	125mL plastic	48 hours	Maintain at ≤6°C
Cadmium	µg/L	EPA 1638	0.031	0.092	5	2.2/4.3 ^{12, 16}	0.72/1.8 ^{12, 16}	125mL plastic	48 hours	Maintain at ≤6°C
Copper	µg/L	EPA 1638	0.112	0.337	1,000 ¹¹	9.0/13 ^{12, 16} , 1,300 ¹⁴	9.0/13 ^{12, 16, 17}	125mL plastic	48 hours	Maintain at ≤6°C

Analyte	Units ¹	Analysis Method ²	Method Detection Limit (MDL)	Practical Quantitation Limit (PQL)/ Method Reporting Limit (MRL)	Water Quality Criteria			Sample Container	Hold Time	Preservative/ Comment
					Basin Plan ³	CA Toxics Rule (CTR) ⁴	EPA Criteria ⁵			
Iron	µg/L	EPA 1638	1.43	4.34	300 ¹¹	NS	1,000 ¹⁸ , 300 ¹⁹	125mL plastic	48 hours	Maintain at ≤6°C
Lead	µg/L	EPA 1638	0.026	0.077	15	2.5/65 ^{12, 16}	2.5/65 ^{12, 16}	125mL plastic	48 hours	Maintain at ≤6°C
Manganese	µg/L	EPA 1638	0.107	0.321	50 ¹¹	NS	50 ²⁰	125mL plastic	48 hours	Maintain at ≤6°C
Nickel	µg/L	EPA 1638	0.117	0.352	100	52/470 ^{12, 16} , 610 ¹⁴ , 4,600 ¹⁵	52/470 ^{12, 16} , 610 ¹⁴ , 4,600 ¹⁵	125mL plastic	48 hours	Maintain at ≤6°C
Chromium-Total	µg/L	EPA 1638	0.128	0.383	50	NS	NS	125mL plastic	48 hours	Maintain at ≤6°C
Metals-Total				MRL						
Mercury	ng/L	EPA 1631E	0.13	0.40	2,000	50 ¹⁴ , 51 ¹⁵	770/1,400 ¹²	125mL plastic	48 hours	Maintain at ≤6°C
Bacteria				MRL						
Total Coliform	MPN/100 mL	EPA SM9223B	Not Applicable	1	NS	NS	NS	100 mL plastic	24 hours	Maintain at ≤6°C
<i>E. coli</i>	MPN/100 mL	EPA SM9223B	Not Applicable	1	NS	NS	126	100 mL plastic	24 hours	Maintain at ≤6°C

Notes:

- MDL - Method Detection Limit: The minimum measured concentration of a substance that can be reported with 99 percent confidence that the measured concentration is distinguishable from method blank results.
- MPN - Most probable number of bacterial colonies per 100 mL of water.
- MRL - Method Reporting Limit: The lowest concentration of a substance that can be reliably reported under current laboratory operating conditions.
- NS - no standard available
- PQL - Practical Quantitation Limit: The concentration that can be reliably measured within specified limits and accuracy during routine laboratory operating conditions.

Footnotes:

- ¹ Units follow listed criterion standards. If standards were not available, laboratory supplied units were used. (Note: µg/L=ppb and mg/L=ppm)
- ² Analysis methods are periodically updated by the EPA. The most recent methods available were used for the water quality analysis.
- ³ The Water Quality Control Plan for the Tulare Lake Basin Second Edition relies on California primary and secondary Maximum Concentration Level objectives as criteria for water quality to be used as a municipal and domestic supply for human consumption.
- ⁴ California Toxics Rule (CTR) criteria are based primarily on EPA standards developed under the Clean Water Act for human consumption of water and aquatic organisms with an adult risk for carcinogens estimated to be one in one million as contained in the Integrated Risk Information System (IRIS) as of October 1, 1996.
- ⁵ Federal water quality criteria are from the EPA's website unless otherwise noted in the footnotes.
Aquatic Life Criteria: <https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table#table>
Human Health Criteria: <https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table>
- ⁶ Elevated temperature wastes shall not cause the temperature of waters designated COLD or WARM to increase by more than 5°F above natural receiving water temperature.
- ⁷ 5.0 mg/L for waters designated WARM, 7.0 mg/L for waters designated COLD or SPWN.
- ⁸ The 1-day minimum warmwater criteria are 5.0 mg/L for early life stages, which includes all embryonic and larval stages and all juveniles forms to 30 days following hatching, and 3.0 mg/L for other life stages. The 1-day minimum coldwater criteria are 8.0 mg/L to achieve required intergravel DO concentrations for early life stages, 5.0 mg/L for early life stages exposed directly to the water column, and 4.0 mg/L for other life stages (EPA's 1986 'Gold Book').
- ⁹ Where natural turbidity is between 0 and 5 NTUs, increases shall not exceed 1 NTU. Where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent. Where natural turbidity is equal to or between 50 and 100 NTUs, increases shall not exceed 10 NTUs. Where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent.
- ¹⁰ pH shall not be depressed below 6.5, raised above 8.3, or changed at any time more than 0.3 units from normal ambient pH.
- ¹¹ The criteria listed are secondary Maximum Concentration Levels for California drinking water quality objectives that do not necessarily indicate a toxic amount of contaminate. Rather these standards dictate water quality objectives designed to preserve taste, odor, or appearance of drinking water.
- ¹² Freshwater aquatic life protection, continuous concentration (4-day average)/maximum concentration (1-hour average).
- ¹³ The CCC of 20 mg/L is a minimum value except where alkalinity is naturally lower, in which case the criterion cannot be lower than 25 percent of the natural level.
- ¹⁴ Human health criterion (30-day average) for drinking water sources (consumption of water and aquatic organisms).
- ¹⁵ Human health criterion (30-day average) for other waters (consumption of aquatic organisms only).
- ¹⁶ Criterion is hardness dependent which is expressed as a function of hardness and decreases as hardness decreases. The actual criteria are calculated based on the hardness (as CaCO₃) of the sample water. Values displayed above correspond to a total hardness of 100mg/L.
- ¹⁷ Criteria values are from the EPA's 2004 National Recommended Water Quality Criteria.
- ¹⁸ Criterion for freshwater aquatic life protection (EPA's 1986 'Gold Book').
- ¹⁹ Criterion for domestic water supplies (EPA's 1986 'Gold Book').

Table AQ 6-3. Results that Met Water Quality Criteria.

Analyte	Result Completely Consistent With Criteria ¹
<i>In-Situ Measurements</i>	
Water Temperature	Yes
Dissolved Oxygen (DO)	Yes
Turbidity	Yes
Conductivity	Yes
pH	No (Discussed in Text)
General Parameters	
Calcium	No Standard Available (NS)
Chloride	Yes
Hardness (as CaCO ₃)	NS
Magnesium	NS
Nitrate	Yes
Nitrite	Yes
Nitrate/Nitrite (NO ₃)	Yes
Ammonia as N	No (Discussed in Text)
Total Kjeldahl Nitrogen (TKN)	NS
Total Phosphorus	NS
Ortho-phosphate	NS
Potassium	NS
Sodium	NS
Sulfate (SO ₄)	Yes
Total Dissolved Solids	Yes
Total Suspended Solids	NS
Turbidity	Yes
Organic Carbon, Total (TOC)	NS
Total Alkalinity	No (Discussed in Text)
Metals-Dissolved	
Arsenic	Yes
Cadmium	Yes
Copper	Yes
Iron	Yes
Lead	Yes
Manganese	Yes
Nickel	Yes
Chromium-Total	Yes

Analyte	Result Completely Consistent With Criteria ¹
Metals-Total	
Mercury	Yes
Bacteria	
Total Coliform	NS
<i>E. coli</i>	Yes

Notes:

NS - No standard available

¹ Applicable water quality criteria come from The Water Quality Control Plan for the Tulare Lake Basin Second Edition, the California Toxics Rule, and the EPA's Federal water quality criteria.

Table AQ 6-4. Water Quality Control Plan for the Tulare Lake Basin - Beneficial Uses Above Lake Kaweah.

Beneficial Use	Definition
Municipal and Domestic Supply (MUN)	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
Hydropower Generation (POW)	Uses of water for hydropower generation.
Water Contact Recreation (REC-1)	Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.
Non-contact Water Recreation (REC-2)	Uses of water for recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
Warm Freshwater Habitat (WARM)	Uses of water that support warm water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates. WARM includes support for reproduction and early development of warm water fish.
Cold Freshwater Habitat (COLD)	Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Wildlife Habitat (WILD)	Uses of water that support terrestrial or wetland ecosystems, including, but not limited to, preservation and enhancement of terrestrial habitats or wetlands, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.
Rare, Threatened, or Endangered Species (RARE)	Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened or endangered.
Spawning, Reproduction and/or Early Development (SPWN)	Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish. SPWN shall be limited to cold water fisheries.
Freshwater Replenishment (FRSH)	Uses of water for natural or artificial maintenance of surface water quantity or quality.

Source: Water Quality Control Plan for the Tulare Lake Basin Second Edition revised January 2015.

Table AQ 6-5. Summary of *In-Situ* Water Quality Measurements, Spring 2018.

Sampling Location	Sample ID	Date	Time	Flow (cfs)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Conductivity (µS/cm)	pH
K3 Flowline Above PH3	6	5/8/2018	825	90	10.82	9.33	3.7	15	7.32
	19	5/30/2018	1145	88	13.53	10.05	1.8	17	7.68
KR Upstream of PH3	8	5/8/2018	1000	841	11.88	9.44	2.0	16	7.35
K2 Flowline Below PH3	9	5/8/2018	1045	68	12.16	9.31	3.1	16	7.36
KR Downstream of PH3	7	5/8/2018	930	773	11.75	9.46	2.2	15	7.35
KR Upstream of the Conf. with EF	10	5/8/2018	1200	773	12.75	9.1	2.3	16	7.4
KR Downstream of the Conf. with EF	11	5/8/2018	1310	1073	13.49	9.21	2.9	23	7.55
KR Upstream of PH1	14	5/9/2018	1110	1088	12.1	9.48	3.6	22	7.51
	23	5/31/2018	845	531	13.56	9.77	0.9	28	7.64
K1 Flowline Above PH1	12	5/9/2018	830	16	9.38	9.3	5.5	38	7.69
	16	5/30/2018	835	16	14.02	9.22	0.5	49	7.46
KR Downstream of PH1	13	5/9/2018	1000	1104	12.05	9.26	3.9	23	7.5
	22	5/31/2018	820	547	13.51	10.04	0.1	29	7.51
K2 Flowline Above PH2	5	5/7/2018	1405	65	14.78	9.35	1.7	19	7.75
	18	5/30/2018	1035	69	15.37	9.87	0.8	18	7.75
KR Upstream of PH2	4	5/7/2018	1250	880	14.05	9.27	2.5	26	7.56
	17	5/30/2018	1015	627	15.37	9.55	1.1	27	7.6
KR Downstream of PH2	15	5/9/2018	1150	1171	13.12	9.15	3.8	23	7.51
	24	5/31/2018	930	616	13.95	9.9	2.8	29	7.76
EF Upstream of K1 Div.	2	5/7/2018	1015	276	9.34	9.57	1.5	41	7.74
EF Downstream of K1 Div.	3	5/7/2018	1100	258	9.59	9.8	2.0	40	7.7
	20	5/30/2018	1300	158	13.63	9.39	0.8	50	7.88
K1 Flowline Below K1 Div.	1	5/7/2018	840	18	9.31	9.71	2.1	40	7.7
EF Upstream of the Conf. with KR	21	5/30/2018	1430	158	16.56	9.31	0.6	50	7.84

Table AQ 6-6. Summary of *In-Situ* Water Quality Measurements, Summer 2018.

Sampling Location	Sample ID	Date	Time	Flow (cfs)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Conductivity (µS/cm)	pH
KR Upstream of PH3	25	8/20/2018	1100	23.6	23.07	8.51	4.0	93	7.86
KR Downstream of PH3	26	8/20/2018	1315	21	24.03	8.43	3.5	92	8.07
KR Upstream of the Conf. with EF	27	8/20/2018	1400	21	25.03	8.44	2.5	92	8.16
KR Downstream of the Conf. with EF	32	8/23/2018	1031	29.2	21.93	8.9	2.2	110	8.04
KR Upstream of PH1	34	8/23/2018	1155	29.2	23.03	8.9	2.4	110	8.14
KR Downstream of PH1	33	8/23/2018	1123	29.68	22.42	8.71	2.3	110	8.12
K2 Flowline Above PH2	36	8/23/2018	1254	2.6	26.9	9.61	2.1	95	8.57
KR Upstream of PH2	35	8/23/2018	1325	29.68	23.8	8.3	1.3	113	8.21
KR Downstream of PH2	37	8/23/2018	1400	32.28	24.64	8.69	1.2	113	8.17
EF Downstream of K1 Div.	29	8/22/2018	900	9.1	18.19	8.97	3.2	136	7.84
EF Upstream of the Conf. with KR	31	8/23/2018	938*	9.2	21.04	8.85	1.9	139	7.82

Notes:

* *In-situ* water quality measurements were taken in the morning and water quality samples were collected in the afternoon.

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Table AQ 6-7. Summary of Analytical Results for Water Quality Samples Collected during the Spring 2018 Sampling Event.

					Sample ID	6, 19	8	9	7	10	11	14, 23	12, 16	13, 22	5, 18	4, 17	15, 24	2	3, 20	1	21
					Sample Location	K3 Flowline Above PH3	KR Upstream of PH3	K2 Flowline Below PH3	KR Downstream of PH3	KR Upstream of the Conf. with EF	KR Downstream of the Conf. with EF	KR Upstream of PH1	K1 Flowline Above PH1	KR Downstream of PH1	K2 Flowline Above PH2	KR Upstream of PH2	KR Downstream of PH2	EF Upstream of K1 Div.	EF Downstream of K1 Div.	K1 Flowline Below K1 Div.	EF Upstream of the Conf. with KR
					Date	5/8/2018 ¹ , 5/30/2018 ¹	5/8/2018	5/8/2018	5/8/2018	5/8/2018	5/8/2018	5/9/2018 ¹ , 5/31/2018 ¹	5/9/2018 ¹ , 5/30/2018 ¹	5/9/2018 ¹ , 5/31/2018 ¹	5/7/2018 ¹ , 5/30/2018 ¹	5/7/2018 ¹ , 5/30/2018 ¹	5/9/2018 ¹ , 5/31/2018 ¹	5/7/2018	5/7/2018 ¹ , 5/30/2018 ¹	5/7/2018	5/30/2018
					Time	0825, 1145	1000	1045	0930	1200	1310	1110, 0845	0830, 0835	1000, 0820	1405, 1035	1250, 1015	1150, 0930	1015	1100, 1300	0840	1430
General Parameters	Units	MDL	PQL/MRL	WQ Criteria																	
Calcium	µg/L	10.79	50.0	NS	1740	2040	2010	1930	2040	3120	3300	6410	3260	2850	3660	3190	6660	6270	6590	7350	
Chloride	mg/L	0.08	1.0	250 ²	0.6 ^J	0.7 ^J	0.7 ^J	0.7 ^J	0.7 ^J	0.7 ^J	<MDL	0.7 ^J	<MDL	0.7 ^J	0.8 ^J	<MDL	0.8 ^J	0.7 ^J	0.7 ^J	0.8 ^J	
Hardness (as CaCO ₃)	mg/L	1.00	1.0	NS	5.4	6.4	6.4	6.1	6.3	9.2	9.7	17.9	9.6	8.6	10.8	9.4	18.6	17.5	18.5	20.5	
Magnesium	µg/L	3.48	25.0	NS	266	316	341	303	298	334	346	468	343	366	400	346	487	456	485	519	
Nitrate	mg/L	0.01	0.2	10 ²	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Nitrite	mg/L	0.01	0.1	1 ²	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Nitrate/Nitrite (NO ₃)	mg/L	0.028	0.10	10 ²	<MDL	<MDL	<MDL	<MDL	<MDL	0.16	0.34	0.36	0.24	<MDL	<MDL	0.08 ^J	<MDL	<MDL	<MDL	1.50	
Ammonia as N	mg/L	0.012	0.5	0.025 ³	<MDL	<MDL	1.6	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Total Kjeldahl Nitrogen (TKN)	mg/L	0.267	0.50	NS	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Total Phosphorus	µg/L	24.0	100	NS	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	39 ^J	<MDL	<MDL	49 ^J	<MDL	<MDL	<MDL	<MDL	53 ^J	<MDL	
Ortho-phosphate	mg/L	0.016	0.05	NS	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Potassium	µg/L	93.9	500	NS	370 ^J	413 ^J	418 ^J	401 ^J	401 ^J	420 ^J	415 ^J	493 ^J	434 ^J	419 ^J	463 ^J	408 ^J	504	468 ^J	484 ^J	473 ^J	
Sodium	µg/L	82.9	500	NS	884	1060	1020	999	1050	1120	1230	1420	1200	1220	1390	1200	1570	1490	1570	1740	
Sulfate (SO ₄)	mg/L	0.09	1.0	250 ²	0.7 ^J	0.7 ^J	0.8 ^J	0.7 ^J	0.8 ^J	1.0	1.1	1.7	1.1	0.8 ^J	1.1	1.1	1.9	1.8	1.8	2.0	
Total Dissolved Solids	mg/L	4.4	10	500 ²	30	33	34	25	26	35	33	49	41	36	40	35	51	49	48	58	
Total Suspended Solids	mg/L	5.6	10	NS	9 ^J	11	10	14	11	10	<MDL	<MDL	<MDL	7 ^J	7 ^J	<MDL	11	8 ^J	16	<MDL	
Turbidity	NTU	0.035	0.10	Depends on natural turbidity ⁴	1.30	1.40	1.40	1.10	0.80	1.00	2.10	2.70	2.10	0.42	0.60	1.40	1.10	0.77	0.72	0.61 ^{H,T}	
Organic Carbon, Total (TOC)	mg/L	Not Applicable	0.2	NS	1.6	1.5	1.5	1.5	1.6	1.7	1.6	2.1	1.7	1.5 ^B	1.8 ^B	1.6	2.2 ^B	2.1 ^B	2.1 ^B	1.6	
Total Alkalinity	mg/L	0.85	2.0	>20 ⁵	5.9	6.6	1.0 ^J	6.5	2.8	369	9.4	22.4 ^B	11.6	7.8	20.3	9.7	23.6	23.7	24.1	20.4	

					Sample ID	6, 19	8	9	7	10	11	14, 23	12, 16	13, 22	5, 18	4, 17	15, 24	2	3, 20	1	21
					Sample Location	K3 Flowline Above PH3	KR Upstream of PH3	K2 Flowline Below PH3	KR Downstream of PH3	KR Upstream of the Conf. with EF	KR Downstream of the Conf. with EF	KR Upstream of PH1	K1 Flowline Above PH1	KR Downstream of PH1	K2 Flowline Above PH2	KR Upstream of PH2	KR Downstream of PH2	EF Upstream of K1 Div.	EF Downstream of K1 Div.	K1 Flowline Below K1 Div.	EF Upstream of the Conf. with KR
					Date	5/8/2018 ¹ , 5/30/2018 ¹	5/8/2018	5/8/2018	5/8/2018	5/8/2018	5/8/2018	5/9/2018 ¹ , 5/31/2018 ¹	5/9/2018 ¹ , 5/30/2018 ¹	5/9/2018 ¹ , 5/31/2018 ¹	5/7/2018 ¹ , 5/30/2018 ¹	5/7/2018 ¹ , 5/30/2018 ¹	5/9/2018 ¹ , 5/31/2018 ¹	5/7/2018	5/7/2018 ¹ , 5/30/2018 ¹	5/7/2018	5/30/2018
					Time	0825, 1145	1000	1045	0930	1200	1310	1110, 0845	0830, 0835	1000, 0820	1405, 1035	1250, 1015	1150, 0930	1015	1100, 1300	0840	1430
Metals-Dissolved	Units	MDL	MRL	WQ Criteria																	
Arsenic	µg/L	0.056	0.204	10 ²	0.124 ^J	0.223 ^J	0.210	0.215	0.233	0.435	0.564	1.250	0.589	0.269, 0.305	0.566	0.585	0.894	1.200	0.951	1.365	
Cadmium	µg/L	0.031	0.092	Hardness dependent ⁶	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Copper	µg/L	0.112	0.337	Hardness dependent ⁶	0.239 ^J	0.261 ^J	0.290 ^J	0.299 ^J	0.283 ^J	0.383	0.260 ^J	0.573	0.228 ^J	0.268 ^J , 0.271 ^J	0.254 ^J	0.236 ^J	0.224 ^J	0.192 ^J	0.322 ^J	0.233 ^J	
Iron	µg/L	1.43	4.34	300 ²	65.5	50.7	47.1	45.4	48.2	55.5	37.7	44.0	47.2	166.7, 29.3	48.1	38.6	40.1	47.3	38.4	71.1	
Lead	µg/L	0.026	0.077	Hardness dependent ⁶	0.041 ^J	0.044 ^J	0.031 ^J	0.028 ^J	0.027 ^J	0.046 ^J	<MDL	0.032 ^J	0.029 ^J	<MDL	0.028 ^J	<MDL	<MDL	0.037 ^J	<MDL	0.062 ^J	
Manganese	µg/L	0.107	0.321	50 ²	2.30	1.74	1.74	1.65	1.95	2.32	1.60	2.05	1.96	3.29, 1.19	2.06	1.80	1.57	2.21	1.65	3.21	
Nickel	µg/L	0.117	0.352	Hardness dependent ⁶	<MDL	<MDL	<MDL	<MDL	<MDL	0.133 ^J	<MDL	0.120 ^J	<MDL	<MDL, 0.236 ^J	<MDL	<MDL	0.206 ^J	<MDL	0.187 ^J	<MDL	
Chromium-Total	µg/L	0.128	0.383	50 ²	<MDL	0.132 ^J	<MDL	0.134 ^J	<MDL	0.136 ^J	<MDL	0.151 ^J	<MDL	<MDL, 0.464	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Metals-Total	Units	MDL	MRL	WQ Criteria																	
Mercury	ng/L	0.13	0.40	1,400 ⁷	0.66	0.97	1.12	1.04	0.94	0.94	0.65	0.81	0.70	0.84, 0.72	0.95	0.67	1.29	1.29	1.35	1.28	

Note: Bold results do not meet the listed criteria

Acronyms

MRL (Method Reporting Limit): The lowest concentration of a substance that can be reliably reported under current laboratory operating conditions.

PQL (Practical Quantitation Limit): The concentration that can be reliably measured within specified limits and accuracy during routine laboratory operating conditions.

<MDL: Analyte was not detected above the method detection limit and is therefore considered a non-detect.

NS: No standard

Footnotes

^B The analyte was found in a method blank, as well as in the sample.

^J Detected by the instrument, the result is greater than the method detection limit but less than or equal to the method reporting limit. Result is reported and considered an estimate.

^H Holding time exceeded. Due to equipment failure at the primary lab, the sample was subcontracted to another lab and the analysis was completed one day past holding time.

^T Sample was received above the mandated temperature. Due to equipment failure at the primary lab, the sample was subcontracted to another lab and was received above the mandated temperature. The lab did not indicate by how much temperature was exceeded.

¹ Some locations were sampled twice because samples were missed or because holding times were exceeded during the first sampling effort. Sample results where holding times were exceeded were omitted from this results table except one instance (see "H" flag) where holding time was exceeded due to lab equipment failure.

² Water quality objective from the 2015 Water Quality Control Plan for the Tulare Lake Basin Second Edition.

³ Basin Plan water quality objective is 0.025 mg/L. EPA criterion is pH, temperature, and life cycle dependent. See Table AQ 6-9 for EPA criteria and results.

⁴ Where natural turbidity is between 0 and 5 NTUs, increases shall not exceed 1 NTU. Where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent. Where natural turbidity is equal to or between 50 and 100 NTUs, increases shall not exceed 10 NTUs. Where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent.

⁵ EPA criterion. The CCC of 20 mg/L is a minimum value except where alkalinity is naturally lower, in which case the criterion cannot be lower than 25 percent of the natural level.

⁶ Criterion is hardness dependent which is expressed as a function of hardness and decreases as hardness decreases. The actual criterion is calculated based on the hardness (as CaCO₃) of the sample water. Refer to Table AQ 6-11 for sample site criteria and results.

⁷ EPA maximum concentration (1-hour average) criterion for freshwater aquatic life protection. Basin Plan water quality objective is less stringent (2,000 ng/L).

Table AQ 6-8. Summary of Analytical Results for Water Quality Samples Collected during the Summer 2018 Sampling Event.

					Sample ID	25	26	27	32	34	33	36	35	37	28	29	30	31
					Sample Location	KR Upstream of PH3	KR Downstream of PH3	KR Upstream of the Conf. with EF	KR Downstream of the Conf. with EF	KR Upstream of PH1	KR Downstream of PH1	K2 Flowline Above PH2	KR Upstream of PH2	KR Downstream of PH2	EF Upstream of K1 Div.	EF Downstream of K1 Div.	K1 Flowline Below K1 Div.	EF Upstream of the Conf. with KR
					Date	8/20/2018	8/20/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/21/2018	8/21/2018	8/21/2018	8/23/2018
					Time	1100	1315	1400	1031	1155	1123	1254	1325	1400	1250	0900	1415	0938
General Parameters	Units	MDL	PQL	WQ Criteria														
Calcium	µg/L	10.79	50.0	NS	8350	8690	9670	13700	13100	14200	10000	14100	13500	21200	21000	20800	21100	
Chloride	mg/L	0.08	1.0	250 ¹	3.0	3.0	3.0	2.8	2.9	2.7	3.2	3.3	3.4	1.4	1.4	1.3	1.8	
Hardness (as CaCO ₃)	mg/L	1.00	1.0	NS	26.7	27.9	31.0	41.2	39.3	42.6	32.0	42.2	40.7	59.2	58.9	58.2	59.5	
Magnesium	µg/L	3.48	25.0	NS	1430	1500	1670	1680	1620	1730	1690	1730	1680	1540	1540	1550	1650	
Nitrate	mg/L	0.01	0.2	10 ¹	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Nitrite	mg/L	0.01	0.1	1 ¹	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Nitrate/Nitrite (NO ₃)	mg/L	0.028	0.10	10 ¹	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Ammonia as N	mg/L	0.012	0.5	0.025 ²	<MDL	<MDL	<MDL	<MDL	0.3^J	<MDL	<MDL	0.1^J	0.9	<MDL	<MDL	<MDL	<MDL	
Total Kjeldahl Nitrogen (TKN)	mg/L	0.267	0.50	NS	<MDL	<MDL	<MDL	0.50	<MDL	0.27 ^J	0.44 ^J	0.72	<MDL	<MDL	<MDL	<MDL	<MDL	
Total Phosphorus	µg/L	24.0	100	NS	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Ortho-phosphate	mg/L	0.016	0.05	NS	<MDL	<MDL	0.03 ^J	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Potassium	µg/L	93.9	500	NS	1180	1210	1360	1320	1310	1430	1410	1470	1400	1230	1270	1270	1350	
Sodium	µg/L	82.9	500	NS	5340	5580	6160	6280	6030	6520	6400	6830	6650	5240	5200	5180	6220	
Sulfate (SO ₄)	mg/L	0.09	1.0	250 ¹	2.0	2.0	2.0	3.0	3.0	3.0	2.1	2.9	2.9	4.6	4.7	4.6	4.7	
Total Dissolved Solids	mg/L	4.4	10	500 ¹	66	66	70	83	87	77	66	78	75	89	90	91	105	
Total Suspended Solids	mg/L	5.6	10	NS	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Turbidity	NTU	0.035	0.10	Depends on natural turbidity ³	0.37	0.39	0.36	0.32	0.31	0.35	0.38	0.40	0.33	0.37	0.41	0.34	0.53	
Organic Carbon, Total (TOC)	mg/L	Not Applicable	0.2	NS	1.2	1.3	1.3	1.2	1.2	1.2	1.5	1.2	1.2	0.9 ^C	0.9	1.1	1.2	
Total Alkalinity	mg/L	0.85	2.0	>20 ⁴	38.8	40.5	41.0	49.4	49.1	49.6	39.2	49.2	48.8	645	62.9	63.2	63.5	
Metals-Dissolved	Units	MDL	MRL	WQ Criteria														
Arsenic	µg/L	0.056	0.204	10 ¹	3.265	3.190	3.210	3.340	3.120	3.215	3.330	2.950	2.995	2.442	2.450	2.465	3.475	
Cadmium	µg/L	0.031	0.092	Hardness dependent ⁵	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Copper	µg/L	0.112	0.337	Hardness dependent ⁵	0.150 ^J	0.174 ^J	0.182 ^J	0.171 ^J	0.280 ^J	0.154 ^J	0.208 ^J	0.141 ^J	0.137 ^J	0.120 ^J	0.125 ^J	0.125 ^J	0.137 ^J	
Iron	µg/L	1.43	4.34	300 ¹	26.7	27.2	28.1	35.1	36.0	37.0	35.7	47.4	48.8	30.2	33.5	30.7	40.7	
Lead	µg/L	0.026	0.077	Hardness dependent ⁵	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	

					Sample ID	25	26	27	32	34	33	36	35	37	28	29	30	31	
					Sample Location	KR Upstream of PH3	KR Downstream of PH3	KR Upstream of the Conf. with EF	KR Downstream of the Conf. with EF	KR Upstream of PH1	KR Downstream of PH1	K2 Flowline Above PH2	KR Upstream of PH2	KR Downstream of PH2	EF Upstream of K1 Div.	EF Downstream of K1 Div.	K1 Flowline Below K1 Div.	EF Upstream of the Conf. with KR	
					Date	8/20/2018	8/20/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/21/2018	8/21/2018	8/21/2018	8/23/2018	
					Time	1100	1315	1400	1031	1155	1123	1254	1325	1400	1250	0900	1415	0938	
Manganese	µg/L	0.107	0.321	50 ¹		1.34	1.2	1.10	1.82	1.51	1.55	1.36	2.245	2.25	3.415	3.75	3.26	2.92	
Nickel	µg/L	0.117	0.352	Hardness dependent ⁵		0.140 ^J	<MDL	0.123 ^J	0.121 ^J	0.121 ^J	<MDL	0.120 ^J	0.121 ^J	0.119 ^J	0.122 ^J	0.138 ^J	0.142 ^J	0.124 ^J	
Chromium-Total	µg/L	0.128	0.383	50 ¹		<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	
Metals-Total	Units	MDL	MRL	WQ Criteria															
Mercury	ng/L	0.13	0.40	1,400 ⁶		0.30 ^J	0.26 ^J	0.31 ^J	0.30 ^J	0.31 ^J	0.30 ^J	0.33 ^J	0.25 ^J	0.28 ^J	0.43	0.45	0.46	0.50	

Notes: Bold results do not meet the listed criteria

Acronyms:

<MDL: Analyte was not detected above the method detection limit and is therefore considered a non-detect.

MRL (Method Reporting Limit): The lowest concentration of a substance that can be reliably reported under current laboratory operating conditions.

NS: No standard

PQL (Practical Quantitation Limit): The concentration that can be reliably measured within specified limits and accuracy during routine laboratory operating conditions.

Footnotes:

^C Sample was received without chemical preservation.

^J Detected by the instrument, the result is greater than the method detection limit but less than or equal to the method reporting limit. Result is reported and considered an estimate.

¹ Water quality objective from the 2015 Water Quality Control Plan for the Tulare Lake Basin Second Edition.

² Basin Plan water quality objective is 0.025 mg/L. EPA criterion is pH, temperature, and life cycle dependent. See Table AQ 6-10 for EPA criteria and results.

³ Where natural turbidity is between 0 and 5 NTUs, increases shall not exceed 1 NTU. Where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent. Where natural turbidity is equal to or between 50 and 100 NTUs, increases shall not exceed 10 NTUs. Where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent.

⁴ EPA criterion. The CCC of 20 mg/L is a minimum value except where alkalinity is naturally lower, in which case the criterion cannot be lower than 25 percent of the natural level.

⁵ Criterion is hardness dependent which is expressed as a function of hardness and decreases as hardness decreases. The actual criterion is calculated based on the hardness (as CaCO₃) of the sample water. Refer to Table AQ 6-12 for sample site criteria and results.

⁶ EPA maximum concentration (1-hour average) criterion for freshwater aquatic life protection. Basin Plan water quality objective is less stringent (2,000 ng/L).

Table AQ 6-9. Basin Plan Ammonia Waste Discharge Exceedance Criteria and Calculated Ammonia Concentration Criteria for the Spring 2018 Sampling Event.

Sample Site, Date, Time, and Parameters						Basin Plan Waste Discharge Exceedance Criteria mg/L	EPA Ammonia Chronic Criteria ¹ mg/L	EPA Ammonia Acute Criteria ¹ mg/L	Ammonia Concentration mg/L
Sample ID	Location Name	Date	Time	pH	Temperature (°C)				
6	K3 Flowline Above PH3	5/08/2018	0825	7.3	10.82	0.025	2.89	17.07	<MDL
8	KR Upstream of PH3	5/08/2018	1000	7.4	11.88	0.025	2.65	16.41	<MDL
9	K2 Flowline Below PH3	5/08/2018	1045	7.4	12.16	0.025	2.58	16.20	1.6
7	KR Downstream of PH3	5/08/2018	0930	7.4	11.75	0.025	2.67	16.41	<MDL
10	KR Upstream of the Conf. with EF	5/08/2018	1200	7.4	12.75	0.025	2.41	15.34	<MDL
11	KR Downstream of the Conf. with EF	5/08/2018	1310	7.6	13.49	0.025	2.03	12.31	<MDL
14	KR Upstream of PH1	5/09/2018	1110	7.5	12.1	0.025	2.30	13.09	<MDL
12	K1 Flowline Above PH1	5/09/2018	0830	7.7	9.38	0.025	2.29	9.81	<MDL
13	KR Downstream of PH1	5/09/2018	1000	7.5	12.05	0.025	2.33	13.28	<MDL
5	K2 Flowline Above PH2	5/07/2018	1405	7.8	14.78	0.025	1.51	8.85	<MDL
4	KR Upstream of PH2	5/07/2018	1250	7.6	14.05	0.025	1.94	12.12	<MDL
15	KR Downstream of PH2	5/09/2018	1150	7.5	13.12	0.025	2.15	13.09	<MDL
2	EF Upstream of K1 Div.	5/07/2018	1015	7.7	9.34	0.025	2.17	9.01	<MDL
3	EF Downstream of K1 Div.	5/07/2018	1100	7.7	9.59	0.025	2.24	9.64	<MDL
1	K1 Flowline Below K1 Div.	5/07/2018	0840	7.7	9.31	0.025	2.28	9.64	<MDL
21	EF Upstream of the Conf. with KR	5/30/2018	1430	7.8	16.56	0.025	1.21	6.98	<MDL

Notes: Bold results do not meet the listed criterion.

<MDL: Analyte was not detected above the method detection limit (MDL) and is therefore considered a non-detect. The MDL for ammonia is 0.012 mg/L.

¹ Ammonia criterion calculated using guidelines from the EPA's 2013 Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater, which is based on ambient pH and temperature conditions.

Table AQ 6-10. Basin Plan Ammonia Waste Discharge Exceedance Criteria and Calculated EPA Ammonia Concentration Criteria for the Summer 2018 Sampling Event.

Sample Site, Date, and Parameters						Basin Plan Waste Discharge Exceedance Criteria mg/L	EPA Ammonia Chronic Criteria ¹ mg/L	EPA Ammonia Acute Criteria ¹ mg/L	Ammonia Concentration mg/L
Sample ID	Location Name	Date	Time	pH	Temperature (°C)				
25	KR Upstream of PH3	8/20/2018	1100	7.86	23.07	0.025	0.77	3.92	<MDL
26	KR Downstream of PH3	8/20/2018	1315	8.07	24.03	0.025	0.54	2.45	<MDL
27	KR Upstream of the Conf. with EF	8/20/2018	1400	8.16	25.03	0.025	0.44	1.89	<MDL
32	KR Downstream of the Conf. with EF	8/23/2018	1031	8.04	21.93	0.025	0.65	3.08	<MDL
34	KR Upstream of PH1	8/23/2018	1155	8.14	23.03	0.025	0.52	2.32	0.3 ^J
33	KR Downstream of PH1	8/23/2018	1123	8.12	22.42	0.025	0.56	2.54	<MDL
36	K2 Flowline Above PH2	8/23/2018	1254	8.57	26.9	0.025	0.20	0.74	<MDL
35	KR Upstream of PH2	8/23/2018	1325	8.21	23.8	0.025	0.44	1.90	0.1 ^J
37	KR Downstream of PH2	8/23/2018	1400	8.17	24.64	0.025	0.45	1.92	0.9
28	EF Upstream of K1 Div.	8/22/2018	0900	7.83 ²	18.08 ³	0.025	1.11	6.26	<MDL
29	EF Downstream of K1 Div.	8/22/2018	0900	7.84	18.19	0.025	1.09	6.10	<MDL
30	K1 Flowline Below K1 Div.	8/22/2018	0900	7.83 ²	18.15 ³	0.025	1.10	6.23	<MDL
31	EF Upstream of the Conf. with KR	8/23/2018	0938	7.82	21.04	0.025	0.93	4.99	<MDL

Notes: Bold results do not meet the listed criterion.

<MDL: Analyte was not detected above the method detection limit (MDL) and is therefore considered a non-detect. The MDL for ammonia is 0.012 mg/L.

¹ Ammonia criterion calculated using guidelines from the EPA's 2013 Aquatic Life Ambient Water Quality Criteria for Ammonia - Freshwater, which is based on ambient pH and temperature conditions.

² pH was not measured at this site on this date. The pH value was estimated by averaging the pH values at the other sites on the East Fork Kaweah River (EF Downstream of K1 Div. and EF Upstream of the Conf with KR).

³ Temperature was not measured with a YSI at this site on this date. Temperature values were obtained from the temperature logger reading at this site at 0900 on 8/22/2018.

^J Detected by the instrument, the result is greater than the method detection limit but less than or equal to the reporting limit (RL). Result is reported and considered an estimate. The RL for ammonia is 0.5 mg/L.

Table AQ 6-11. Hardness-based Water Quality Criteria for Cadmium, Copper, Lead, and Nickel for the Spring 2018 Sampling Event.

Sample ID	6, 19	8	9	7	10	11	14, 23	12, 16	13, 22	5, 18	4, 17	15, 24	2	3, 20	1	21
Sample Location	K3 Flowline Above PH3	KR Upstream of PH3	K2 Flowline Below PH3	KR Downstream of PH3	KR Upstream of the Conf. with EF	KR Downstream of the Conf. with EF	KR Upstream of PH1	K1 Flowline Above PH1	KR Downstream of PH1	K2 Flowline Above PH2	KR Upstream of PH2	KR Downstream of PH2	EF Upstream of K1 Div.	EF Downstream of K1 Div.	K1 Flowline Below K1 Div.	EF Upstream of the Conf. with KR
Date Sampled	5/08/2018 5/30/2018	5/08/2018	5/08/2018	5/08/2018	5/08/2018	5/08/2018	5/09/2018 5/31/2018	5/09/2018 5/30/2018	5/09/2018 5/31/2018	5/07/2018 5/30/2018	5/07/2018 5/30/2018	5/09/2018 5/31/2018	5/07/2018	5/07/2018 5/30/2018	5/07/2018	5/30/2018
Time Sampled	0825, 1145	1000	1045	0930	1200	1310	1110, 0845	0830, 0835	1000, 0820	1405, 1035	1250, 1015	1150, 0930	1015	1100, 1300	0840	1430
Hardness (CaCO ₃) (mg/L)	5.4	6.4	6.4	6.1	6.3	9.2	9.7	17.9	9.6	8.6	10.8	9.4	18.6	17.5	18.5	20.5
Cadmium (Cd)																
Laboratory Result (µg/L)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Maximum Criterion (µg/L)	0.12	0.14	0.14	0.13	0.13	0.19	0.20	0.36	0.20	0.18	0.22	0.20	0.37	0.35	0.37	0.41
Continuous Criterion (µg/L)	0.08	0.09	0.09	0.09	0.09	0.12	0.12	0.20	0.12	0.11	0.13	0.12	0.20	0.19	0.20	0.22
Copper (Cu)																
Laboratory Result (µg/L)	0.239 ^J	0.261 ^J	0.290 ^J	0.299 ^J	0.283 ^J	0.383	0.260 ^J	0.573	0.228 ^J	0.268 ^J , 0.271 ^J	0.254 ^J	0.236 ^J	0.224 ^J	0.192 ^J	0.322 ^J	0.233 ^J
Maximum Criterion (µg/L)	0.86	1.01	1.01	0.96	0.99	1.42	1.49	2.66	1.48	1.33	1.65	1.45	2.75	2.60	2.74	3.02
Continuous Criterion (µg/L)	0.74	0.86	0.86	0.82	0.84	1.17	1.22	2.06	1.21	1.10	1.34	1.19	2.13	2.02	2.12	2.31
Lead (Pb)																
Laboratory Result (µg/L)	0.041 ^J	0.044 ^J	0.031 ^J	0.028 ^J	0.027 ^J	0.046 ^J	<MDL	0.032 ^J	0.029 ^J	<MDL	0.028 ^J	<MDL	<MDL	0.037 ^J	<MDL	0.062 ^J
Maximum Criterion (µg/L)	2.42	2.94	2.94	2.78	2.89	4.46	4.74	9.52	4.68	4.13	5.36	4.57	9.94	9.28	9.88	11.10
Continuous Criterion (µg/L)	0.09	0.11	0.11	0.11	0.11	0.17	0.18	0.37	0.18	0.16	0.21	0.18	0.39	0.36	0.39	0.43
Nickel (Ni)																
Laboratory Result (µg/L)	<MDL	<MDL	<MDL	<MDL	<MDL	0.133 ^J	<MDL	0.120 ^J	<MDL	<MDL, 0.236 ^J	<MDL	<MDL	0.206 ^J	<MDL	0.187 ^J	<MDL
Maximum Criterion (µg/L)	39.63	45.76	45.76	43.94	45.16	62.21	65.05	109.24	64.49	58.76	71.24	63.35	112.84	107.17	112.33	122.52
Continuous Criterion (µg/L)	4.40	5.08	5.08	4.88	5.02	6.91	7.23	12.13	7.16	6.53	7.91	7.04	12.53	11.90	12.48	13.61

Notes: Bold results do not meet the calculated criteria

<MDL: Analyte was not detected above the method detection limit (MDL) and is therefore considered a non-detect. The MDL for cadmium is 0.031 µg/L, the MDL for lead is 0.026 µg/L, and the MDL for nickel is 0.117 µg/L.

^J Detected by the instrument, the result is greater than the MDL but less than or equal to the method reporting limit (MRL). Result is reported and considered an estimate. The MRL for copper is 0.337 µg/L, the MRL for lead is 0.077 µg/L, and the MRL for nickel is 0.352 µg/L.

California Toxics Rule (CTR) and EPA standard was used for Cu, Pb, and Ni. EPA standard was used for Cd as it is more stringent than the CTR standard.

Formulas used are provided in Appendix B.

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Table AQ 6-12. Hardness-based Water Quality Criteria for Cadmium, Copper, Lead, and Nickel for the Summer 2018 Sampling Event.

Sample ID	25	26	27	32	34	33	36	35	37	28	29	30	31
Sample Location	KR Upstream of PH3	KR Downstream of PH3	KR Upstream of the Conf. with EF	KR Downstream of the Conf. with EF	KR Upstream of PH1	KR Downstream of PH1	K2 Flowline Above PH2	KR Upstream of PH2	KR Downstream of PH2	EF Upstream of K1 Div.	EF Downstream of K1 Div.	K1 Flowline Below K1 Div.	EF Upstream of the Conf. with KR
Date Sampled	8/20/2018	8/20/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/23/2018	8/21/2018	8/21/2018	8/21/2018	8/23/2018
Time Sampled	1100	1315	1400	1031	1155	1123	1254	1325	1400	1250	0900	1415	0938
Hardness (CaCO3) (mg/L)	26.7	27.9	31	41.2	39.3	42.6	32	42.2	40.7	59.2	58.9	58.2	59.5
Cadmium (Cd)													
Laboratory Result (µg/L)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Maximum Criterion (µg/L)	0.52	0.54	0.60	0.78	0.75	0.81	0.62	0.80	0.77	1.10	1.09	1.08	1.10
Continuous Criterion (µg/L)	0.27	0.27	0.30	0.37	0.36	0.38	0.30	0.38	0.37	0.48	0.48	0.48	0.49
Copper (Cu)													
Laboratory Result (µg/L)	0.150 ^J	0.174 ^J	0.182 ^J	0.171 ^J	0.280 ^J	0.154 ^J	0.208 ^J	0.141 ^J	0.137 ^J	0.120 ^J	0.125 ^J	0.125 ^J	0.137 ^J
Maximum Criterion (µg/L)	3.87	4.04	4.46	5.83	5.57	6.01	4.59	5.96	5.76	8.20	8.16	8.07	8.24
Continuous Criterion (µg/L)	2.90	3.01	3.29	4.20	4.03	4.32	3.38	4.28	4.15	5.72	5.70	5.64	5.75
Lead (Pb)													
Laboratory Result (µg/L)	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Maximum Criterion (µg/L)	14.95	15.71	17.68	24.30	23.05	25.22	18.32	24.96	23.97	36.33	36.13	35.66	36.54
Continuous Criterion (µg/L)	0.58	0.61	0.69	0.95	0.90	0.98	0.71	0.97	0.93	1.42	1.41	1.39	1.42
Nickel (Ni)													
Laboratory Result (µg/L)	0.140 ^J	<MDL	0.123 ^J	0.121 ^J	0.121 ^J	<MDL	0.120 ^J	0.121 ^J	0.119 ^J	0.122 ^J	0.138 ^J	0.142 ^J	0.124 ^J
Maximum Criterion (µg/L)	153.21	159.02	173.84	221.14	212.48	227.48	178.58	225.67	218.87	300.50	299.21	296.20	301.79
Continuous Criterion (µg/L)	17.02	17.66	19.31	24.56	23.60	25.27	19.83	25.07	24.31	33.38	33.23	32.90	33.52

Notes: Bold results do not meet the calculated criteria

<MDL: Analyte was not detected above the method detection limit (MDL) and is therefore considered a non-detect. The MDL for cadmium is 0.031 µg/L, the MDL for lead is 0.026 µg/L, and the MDL for nickel is 0.117 µg/L.

^J Detected by the instrument, the result is greater than the MDL but less than or equal to the method reporting limit (MRL). Result is reported and considered an estimate. The MRL for copper is 0.337 µg/L and the MRL for nickel is 0.352 µg/L.

California Toxics Rule (CTR) and EPA standard was used for Cu, Pb, and Ni. EPA standard was used for Cd as it is more stringent than the CTR standard.

Formulas used are provided in Appendix B.

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Table AQ 6-13. Edison Beach Coliform Sampling Upstream/Downstream Comparison.

Sample Location	Test	Sample Date				
		7/05/2018	7/12/2018	7/19/2018	7/26/2018	7/31/2018
Upstream of Edison Beach	Total Coliform (MPN/100mL)	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6
	<i>E. coli</i> (MPN/100mL)	69.7	52.9	41.4	14.5	14.5
Downstream of Edison Beach	Total Coliform (MPN/100mL)	>2419.6	>2419.6	>2419.6	>2419.6	>2419.6
	<i>E. coli</i> (MPN/100mL)	30.1	76.9	45.7	18.7	14.8

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FIGURES

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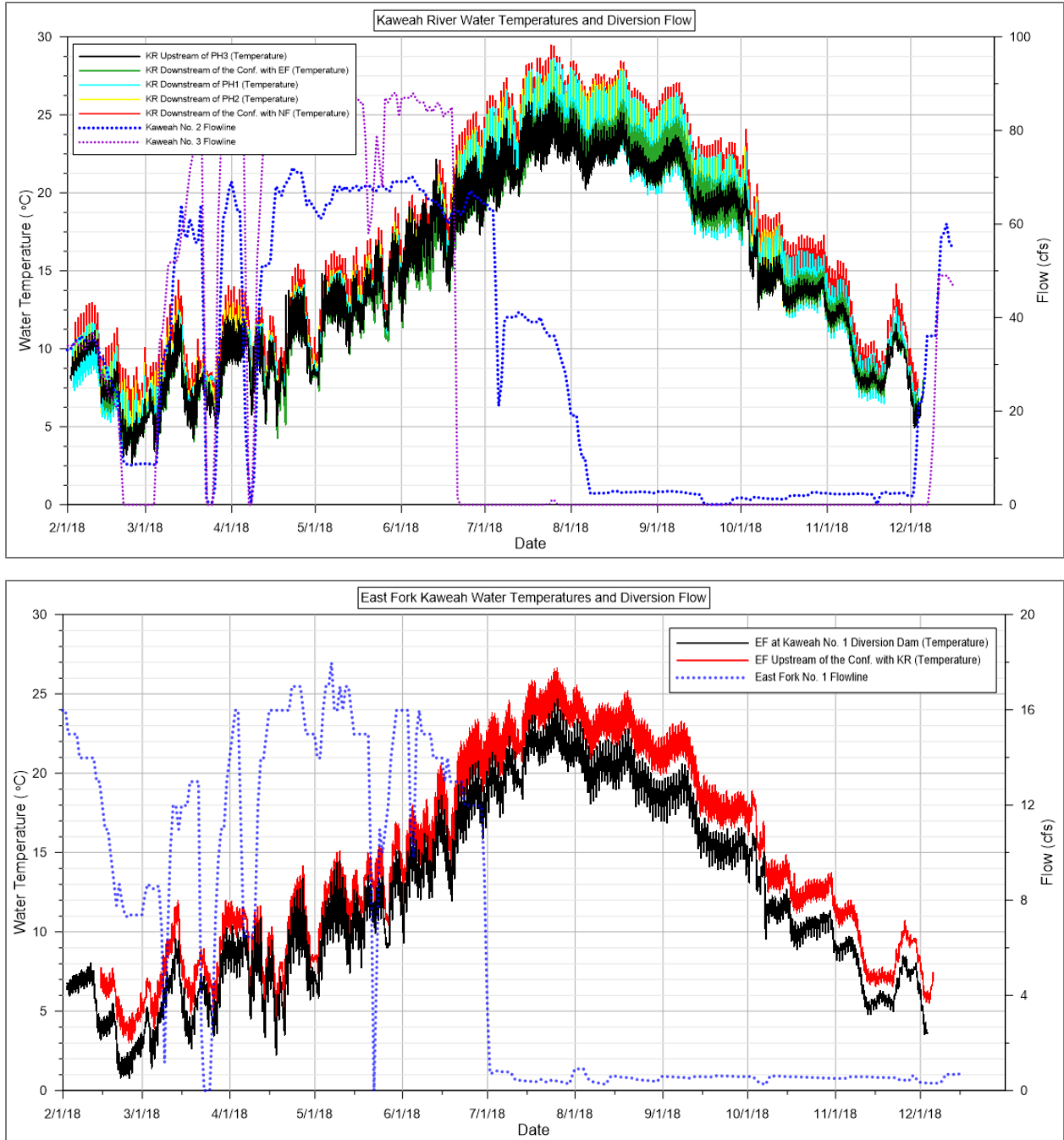
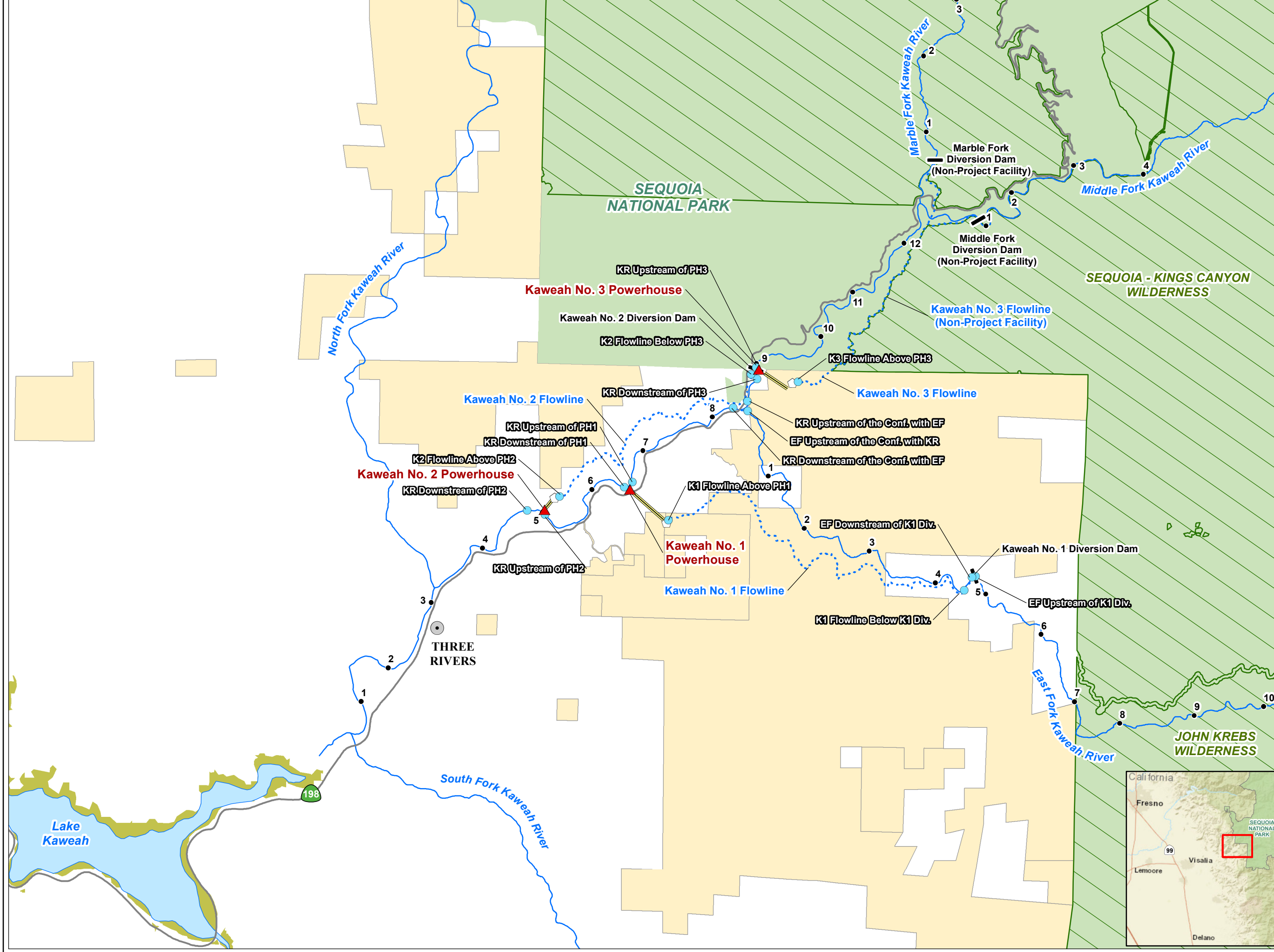


Figure AQ 6-1. 2018 Water Temperature and Flow in Kaweah River and East Fork Kaweah River.


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MAPS

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- SCE Facilities**
- Powerhouse
 - Diversion
 - Forebay
 - Flowline
 - Penstock
- Other Features**
- City/Town
 - Highway/Road
 - Watercourse
 - Water Body
 - River Mile
- Land Jurisdiction***
- Bureau of Land Management
 - U.S. Army Corps of Engineers
 - National Park Service
 - Private
- *SOURCE: BLM 2016
- Land Management**
- National Wilderness Area
- Monitoring Locations**
- Water Quality Monitoring Sites



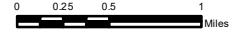
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FERC Project No. 298

Map AQ6-1
Kaweah Project
Water Quality Monitoring
and Sampling Locations



Date: 3/6/2019

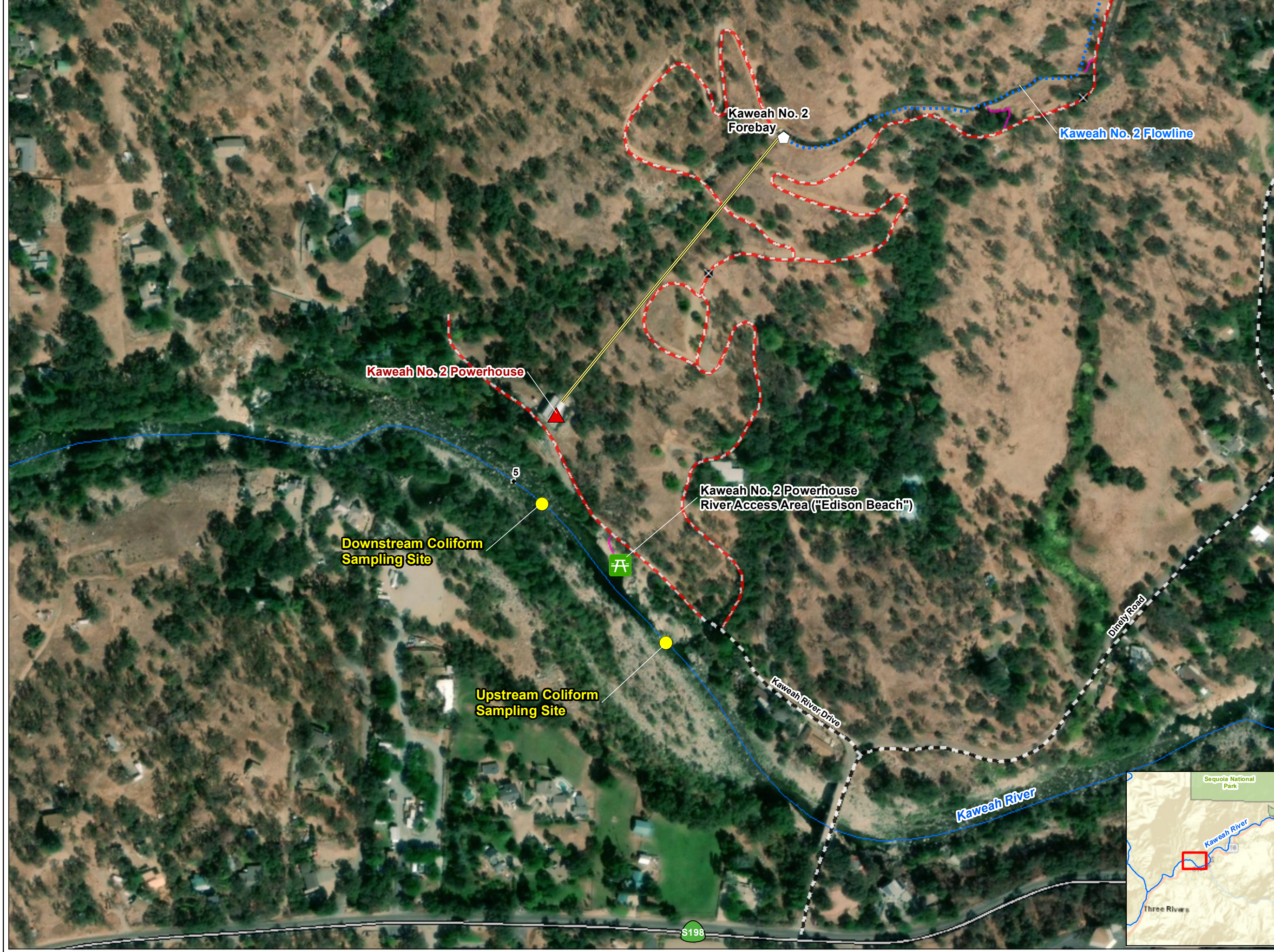


0 0.25 0.5 1 Miles

Projection: UTM Zone 11
Datum: NAD 83

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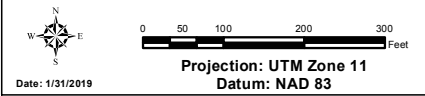


- SCE Facilities**
- Powerhouse
 - Diversion
 - Forebay
 - Flowline
 - Penstock
- Other Features**
- City/Town
 - Highway/Road
 - Watercourse
 - Water Body
 - River Mile
- Transportation**
- Project Road
 - Project Trail
 - Non-Project General Access Road
 - Gate
- Monitoring Locations**
- Coliform Sampling Sites



FERC Project No. 298

**Map AQ 6-2
Kaweah Project
Edison Beach Coliform
Sampling Locations**



Date: 1/31/2019

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Appendix A

Overview of Water Quality Parameters

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A.1 Water Quality Monitoring Parameter

A.1.1 In-situ Measurements

Temperature

Ambient water temperature is a measurement of the intensity of heat stored in a volume of water and is generally reported in degrees Celsius (°C) or Fahrenheit (°F). Natural heat sources include solar radiation, air transfer, condensation of water vapor at the water surface, sediments, precipitation, surface runoff, and groundwater. Anthropogenic sources of heat include industrial effluents, agriculture, forest harvesting, decreases in streamside vegetation coverage, urban development, and mining.

Water temperature has important effects on aquatic biota. Increased water temperature reduces oxygen solubility while elevating metabolic oxygen demand. This causes lower oxygen concentrations that may be detrimental to some aquatic organisms. Reproductive and other biological activities, such as migration, spawning, egg incubation, and fry rearing, are often triggered by water temperature. A rise in water temperature can also provide conditions for the growth of disease-causing organisms. Temperature also influences the solubility of many chemical compounds, thus affecting their toxicity to aquatic life (EPA 1986, MELP 1998).

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in water. Values for DO in water analyses are commonly provided in mg/L, although a percentage of saturation may also be used. The concentration of DO in surface water is usually less than 10 mg/L (MELP 1998). The actual concentration will vary with other parameters such as temperature, elevation, photosynthetic activity, biotic activity, stream discharge, and the concentration of other solutes (Hem 1989, Michaud 1994). The maximum solubility of oxygen (fully saturated) at sea level is 12.75 mg/L at 5°C and 8 mg/L at 25°C. DO concentrations decrease within increasing temperatures or elevation (MELP 1998).

Dissolved oxygen is derived from the atmosphere and photosynthetic production by aquatic plants. Atmospheric oxygen is changed to dissolved oxygen when it enters the water, with more mixing occurring in turbulent waters. Dissolved oxygen is essential for the respiration of fish and other aquatic organisms (Michaud 1994). As water moves past their breathing apparatus (such as gills in fish), oxygen gas bubbles in the water (DO) are transferred from the water to their blood. The transfusion is efficient only above certain concentrations. Oxygen is also used for the decomposition of organic matter and other biological and chemical processes. Anoxic waters have obvious detrimental effects on aerobic organisms. These conditions can also lead to the accumulation of chemically reduced compounds, such as ammonium and hydrogen sulfide, in the bottom sediments that can be toxic to benthic organisms (Michaud 1994).

Nutrient solubility and availability rely partly on DO levels, and thus DO also affects the productivity of aquatic ecosystems. In streams, DO concentrations tend to be higher in faster moving waters. During the summer, in particular, when discharges and velocities decrease in streams, DO concentrations can be quite low. Pollution can cause decreases in average DO concentrations by contributing organic matter that uses oxygen or nutrients and stimulates the growth of algae.

Conductivity

Conductivity is a measurement of the ability of water to conduct an electric current and provides an estimate of the concentration of dissolved solids. This property is related to water temperature and total ion content (e.g. chloride, sulfate, sodium, and calcium), and depends on the concentration of dissolved metals and other dissolved materials. Water carries more current with increased ion content in the water. Conductivity is lower in cooler waters. Conductivity is measured in terms of resistance and reported in

microsiemens per centimeter ($\mu\text{m}/\text{cm}$) at 25°C. Water source and geologic composition of the watershed are important controlling factors of conductivity. Streams that flow through granite bedrock, for example, have lower conductivity than those that flow through limestone or clay soils. The conductivity of pure waters is 0.055 $\mu\text{S}/\text{cm}$. The conductivity of freshwater at 25°C varies between 50 and 1,500 $\mu\text{m}/\text{cm}$ (Hem 1989, MELP 1998). Conductivity measurements in streams flowing through granitic, siliceous, or other igneous rocks usually range between 10 and 50 $\mu\text{S}/\text{cm}$. In comparison, it generally ranges between 150 and 500 $\mu\text{S}/\text{cm}$ in streams that are flowing through limestones. Conductivity itself is not an aquatic health concern, but serves as an indicator of other water quality concerns.

pH

A pH value is a measure of the activity of hydrogen ions in a water sample. Various types of chemical reactions that occur in natural waters produce hydrogen ions, which are then consumed by participating in subsequent chemical reactions in the system. These interrelated chemical reactions that produce and consume hydrogen ions control the pH value of a water body. It is a useful index of the status of equilibrium reactions in which the water participates. A pH of 7 is considered neutral, values less than 7 are acidic, and values greater than 7 are basic. The units of pH are logarithmic; so a difference of one unit represents a 10-fold change in hydrogen ion concentration. The higher the pH, the fewer free hydrogen ions are present in the water. The pH of natural fresh waters ranges from 4.0 to 10.0, with most waters falling between 6.5 and 8.5 (EPA 1986, Hem 1989, MELP 1998).

The pH of water determines the solubility (the amount that can be dissolved in water) and biological availability (the amount that can be used by aquatic biota) of chemical constituents, such as nutrients (e.g. carbon, nitrogen and phosphorus) and heavy metals (e.g. lead, copper). Unusually high or low pH can have adverse effects on aquatic biota. Values above 9.5 and below 4.5 are considered lethal to aquatic organisms (EPA 1996, MELP 1998). For heavy metals, the degree to which they are soluble determines their toxicity. They tend to be more toxic when pH is lower because they are more soluble and bioavailable.

The pH of water is naturally variable, although the amount of change in natural waters tends to be very small due to many chemical reactions. This ability of the water to maintain a stable pH is called buffering capacity. The initial pH of water is influenced by the geology of the watershed and the original source of the water. In particular, alkalinity, which is typically low in granitic drainages, is usually the primary factor that influences pH values. This causes the waters to be more acidic (pH <7.0) in these types of watersheds (Wetzel 2001). The greatest natural cause for variation is the daily and seasonal changes in photosynthesis. Photosynthesis uses up hydrogen molecules and therefore increases the pH. The pH increases during the day (with maximum values up to 9.0) and decreases at night. Respiration and decomposition processes lower pH. The pH also tends to be higher during the growing season when photosynthesis is greater. As a result, most streams that drain coniferous forests tend to be slight acidic (6.5 to 6.8) (Hem 1989, Michaud 1994, Wetzel 2001).

A.2 Laboratory Analysis Parameter

A.2.1 General Parameters

Calcium

Calcium (Ca) is the most abundant of the alkaline-earth metals and is a major constituent of many common rock minerals and of the solutes present in the water (Hem 1989). It is generally the main cation in surface waters. It is most commonly present as the calcium ion (Ca^{2+}) and is generally derived from weathering or dissolution of minerals in soil and rocks. Under conditions of high bicarbonate or sulfate concentration, calcium bicarbonate or calcium sulfate may exist (Hem 1989). It contributes to the total hardness of water. Calcium is reported in $\mu\text{g}/\text{L}$. Water bodies with less than 10,000 $\mu\text{g}/\text{L}$ are considered calcium poor, whereas greater than 20,000 $\mu\text{g}/\text{L}$ are considered calcium rich. Average dissolved

concentration in river waters ranges from 13,400 µg/L to 15,000 µg/L, but can vary substantially due to geology and climate (Hem 1989). Although calcium is an important constituent of igneous rocks, its concentration in associated water bodies is generally low (Hem 1989) (39 µg/L for granitic watersheds, Wetzel 2001) due to slow decomposition rates of igneous rock materials (Hem 1989).

Calcium is an essential element for metabolism in most plants and animals (Hem 1989). The distribution of many freshwater species, particularly invertebrates, is related to calcium concentration. Significant changes in calcium concentration in a water body can influence the presence or absence of these organisms. Most calcium in surface waters is derived from waters flowing over limestone, dolomite, gypsum, and other calcium-containing sedimentary rocks and minerals.

Chloride

Chloride (Cl⁻) is among the important anions found in natural waters (Hem 1989). Chloride is reported in mg/L. It originates from the dissociation of salts, such as sodium chloride or calcium chloride, in water. Concentrations tend to be low in fresh waters (8.3 mg/L, on average) (Schlesinger 1997, MELP 1998), and essentially zero in granite drainages (Wetzel 2001). Water will taste salty when the chloride concentrations are greater than 250 to 400 mg/L.

Chloride influences osmotic salinity balance and ion exchange in aquatic organisms, thus making it an important ion for metabolic processes. Increased chloride levels may reduce the toxicity of nitrite to aquatic life (MELP 1998). Fish and invertebrates appear to be more sensitive to increases in chloride levels than aquatic plants. High chloride content can adversely affect plant growth. Fairly low concentrations can be lethal to fish (EPA 1986). Chloride is common in areas with limestone deposits. It is uncommon in most other soils, rocks, or minerals (Hem 1989). Anthropogenic sources of chloride include municipal water supplies, sewage plant effluents, urban development, rock salt, agricultural runoff, and industrial effluents (MELP 1998).

Hardness

The hardness of water is based on its content of calcium and magnesium salts, combined with bicarbonate and carbonate (temporary hardness) and with sulfates, chlorides, and other anions of mineral acids (permanent hardness) (MELP 1989). Hardness is expressed in degrees of hardness or mg/L of calcium carbonate (CaCO₃). Values greater than 120 mg/L are considered hard, while values less than 60 mg/L are considered soft (Hem 1989, MELP 1989). The EPA (1986) utilizes the following hardness classification:

Concentration CaCO₃ (mg/L)	Description
<75	Soft Water
75-150	Moderately Hard Water
150-300	Hard Water
>300	Very Hard Water

Water hardness can have indirect effects on aquatic biota, primarily affecting the toxicity of certain metals (MELP 1989). The binding activity of major ions such as calcium and magnesium with metals such as copper, lead, and zinc, will lower the toxicity of these metals by decreasing the bioavailability. Therefore, when water hardness is low, the toxic effects of these metals may increase.

Hardness is influenced by the underlying rock-types, such as limestone. Anthropogenic sources of hardness include the inorganic chemical industry and mines (EPA 1986). The effects of hardness on freshwater fish and other aquatic life appear to be related to the ions causing the hardness rather than

hardness (EPA 1986). For this reason, technical guidance groups recommend providing the concentrations of specific ions, rather than using hardness.

Magnesium

Magnesium (Mg) is a common alkaline-earth metal found in igneous, sedimentary, and other rock types. It contributes to the total hardness of water. Magnesium concentration is reported in mg/L or $\mu\text{g/L}$. It is much more soluble than calcium, with an average concentration of 5,000 $\mu\text{g/L}$ in North American rivers (Schlesinger 1997) and 31 $\mu\text{g/L}$ in granite drainage basins (Wetzel 2001).

Magnesium is an essential nutrient in the metabolic activity of plants and animals. It is commonly present as an ion (Mg^{2+}) and is typically derived from weathering of ferromagnesian minerals in soil and rocks or dissolution of limestone. Similar to calcium, magnesium may exist as magnesium bicarbonate or magnesium sulfate under certain conditions. Magnesium concentrations are not strongly influenced by anthropogenic activities (Hem 1989).

Nitrate/Nitrite

Nitrate (NO_3^-) and nitrite (NO_2^-) ions are produced during nitrification of reduced and organic forms of nitrogen. Nitrate and nitrite are typically reported in mg/L or $\mu\text{g/L}$. Nitrite is usually present in only minute quantities in water (<0.001 mg/L) because it is in an intermediate, unstable form of nitrogen within the nitrogen cycle (MELP 1998). It is formed from nitrate or ammonium ions by certain microorganisms found in soil and water (EPA 1986). Nitrate is formed by the complete oxidation of ammonium by microorganism in the soil and water. It is the most oxidized and stable form of nitrogen in water, and therefore is the principle form of combined nitrogen. Most surface waters contain less than 0.01 mg/L of nitrite and less than 0.2 mg/L nitrate (MELP 1998, Wetzel 2001).

Nitrate is the primary form of nitrogen used during plant growth. Excessive amounts of nitrate may cause phytoplankton or macrophyte outbreaks. Nitrite is toxic to aquatic life at relatively low concentrations (MELP 1998). Although it is an essential plant nutrient, excessive nitrogen can cause proliferation of algae and macrophytes, resulting in eutrophic water conditions. Eutrophication causes decreased oxygen levels which may cause stress or mortality of fish and invertebrates (EPA 1986). Sources of elevated nitrate and nitrite come from municipal and industrial wastewaters, agricultural runoff, urban development, and automobile exhausts.

Ammonia

Ammonia is found in two forms, ammonium (NH_4^+) that is not toxic and NH_3 , which is (EPA 1986). Ammonium is readily adsorbed onto mineral surfaces (Hem 1989). It is reported as mg/L or $\mu\text{g/L}$, with typical surface water values less than 0.1 mg/L (MELP 1998, Wetzel 2001). Ammonia as NH_3 is reported to be toxic to various aquatic organisms over a range of concentrations (0.53 to 22.8 mg/L) (Oram 2007).

Complex nitrogen cycling and processes occur within aquatic systems. Nitrogen is an essential plant nutrient which contributes to the productivity of a water body. However, excessive ammonia overstimulates the growth of algae and other plants, leading to eutrophication of a water body. The resulting decrease of oxygen levels may cause stress and mortality of fish and invertebrates (EPA 1986). High ammonia concentrations are also toxic to aquatic life. The specific concentration at which ammonia is harmful to organism depends upon the temperature and pH of the water. At higher temperatures and pH, a greater proportion of the total ammonia is present as NH_3 , increasing the toxicity of the water (EPA 1986). The distribution of ammonia in surface waters varies spatially and seasonally depending upon productivity and the amount of organic matter. Anthropogenic sources of ammonia include fertilizers, livestock wastes, residential effluents (e.g. cleaning products), mining, sewage treatments plants, and effluent from various types of industries (Oram 2007).

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) is a measure of both the ammonia and organic forms of nitrogen. Organic nitrogen includes organic compounds, such as proteins, polypeptides, amino acids, and urea. TKN is reported in mg/L or $\mu\text{g/L}$ (MELP 1998). In Sierra Nevada rivers and streams, TKN values typically range between 0.025 and 0.65 mg/L (EPA 2000).

High ammonia concentrations can be deleterious to aquatic life, as it contributes to the eutrophication of water bodies. Organic nitrogen is not biologically available. As a result, it does not influence plant growth or water quality condition until it is transformed to the inorganic forms of nitrogen (MELP 1998). Natural sources of TKN include decaying organic material such as plants and animals wastes. Some species of streamside vegetation, such as alders, are nitrogen fixers. Elevated nitrogen concentrations have been measured in waters with decaying alder leaves (Wetzel 2001). Anthropogenic sources of TKN include effluents from sewage treatment plants and industry, agriculture (fertilizers), urban developments, paper plants, recreation, and mining.

Total Phosphorus

Phosphorus (P) is a nutrient that is essential for growth, and is a measure of both organic and inorganic forms of phosphorus. It can be measured as total phosphorus or ortho-phosphate. Total phosphorus is the total amount of phosphorus in the sample. Ortho-phosphate is the portion that is available to organisms for growth. Total phosphorus measurements include phosphorus that is in biological tissue, as well as the insoluble mineral particles (Michaud 1994, MELP 1998). Phosphorus is fairly abundant in sediments, but concentrations are usually less than a few tenths of a milligram per liter in surface waters (Hem 1989). Total phosphorus concentrations in the rivers and streams in the Sierra Nevada typically range between 2.5 and 485 $\mu\text{g/L}$ (EPA 2000). It is usually reported in $\mu\text{g/L}$ or mg/L.

Phosphorus is essential for plant growth and is often the most limiting nutrient for plant growth in surface waters. As a result, inputs of phosphorus into surface waters can cause algal blooms. Anthropogenic sources of phosphorus include effluents from sewage treatment plants and industry, agriculture, and urban developments (EPA 1986, Hem 1989, MELP 1998).

Ortho-phosphate

Ortho-phosphate (PO_4) is a measure of the inorganic oxidized form of soluble phosphorus. It is generally reported in mg/L or $\mu\text{g/L}$. Background concentrations of orthophosphate in surface waters generally average 0.01 mg/L (Hem 1989).

Along with nitrogen, phosphorus is a necessary nutrient for plant growth. Ortho-phosphate is the most readily available form of phosphorus for uptake during photosynthesis. Animals obtain phosphorus through the consumption of plant materials. Excess ortho-phosphate causes prolific algal growth, causing the same detrimental water conditions as described for nitrogen and total phosphorus (MELP 1998). Since phosphorus is typically the most limiting nutrient for plant growth in fresh water, additions of this element are often the primary causes of eutrophication of water bodies. Phosphate ions readily and strongly adsorb onto soils, suspended solids, and streambed sediments. As a result, soil erosion can be a source of ortho-phosphate. Other sources include agricultural, urban, and industrial wastewater effluents.

Potassium

Potassium (K) is a common element in most rock types, but occurs in generally lower concentrations and is less soluble than calcium and magnesium (Hem 1989). Potassium is reported in mg/L or $\mu\text{g/L}$, with an average concentration of 1,400 $\mu\text{g/L}$ in North American rivers and 8 $\mu\text{g/L}$ in granite drainage basins (Wetzel 2001).

Potassium is important in the cellular ion transport and exchange processes of plants and animals, especially for algae growth (Wetzel 2001). Potassium is derived during the weathering of feldspar and mica minerals from rocks and soil. Another potential source of potassium is release through the decay of plant materials (Hem 1989). The alteration of potassium concentration in natural waters is not common, except when effluent from industrial, agricultural, or urban sources exist or runoff from road salts reaches a water body (Wetzel 2001). This type of pollution can cause significant alteration in the ionic composition of water bodies and ultimately change the balance of plant and animal productivity.

Sodium

Sodium (Na) is the most abundant of the alkaline-earth metals and is commonly found in solution (Hem 1989). It generally has lower water concentrations than calcium, except in igneous dominated watersheds (Wetzel 2001). Sodium is typically reported in mg/L, with concentrations that range from less than 1 mg/L to more than 500 mg/L. An average sodium concentration of 9.0 mg/L is found in North American rivers (Schlesinger 1997) and 0.088 mg/L in granite drainage basins (Wetzel 2001).

Sodium is important in the cellular ion transport and exchange processes of plants and animals (Wetzel 2001). Certain species of cyanobacteria require high amounts of sodium for photosynthesis, metabolism, and nitrogen fixation. The enrichment of water with high levels of sodium and phosphorus from domestic effluents can result in large cyanobacteria populations (Wetzel 2001). Sodium is typically present as an ion (Na^+) and is commonly derived from the weathering of rocks and soil or the dissolution of sodium salts (Hem 1989). Similar to potassium, sodium concentrations in natural water bodies are not easily altered, except by pollutants such as road salts, industrial effluent, and agricultural runoff (Hem 1989, Wetzel 2001).

Sulfate

Sulfate (SO_4^{2-}) is a relatively common anion produced during geochemical weathering of sulfides (reduced form) from igneous and sedimentary rocks and soils (Hem 1989, Wetzel 2001). Sulfate is reported in mg/L or $\mu\text{g/L}$, with an average concentration of 20 mg/L in North American rivers (Schlesinger 1997) and 0.031 mg/L in granite drainage basins (Wetzel 2001).

Sulfur is essential for proper metabolic functioning of all organisms. The primary sources of sulfur compounds to water bodies is atmospheric precipitation, which is largely due to the combustion of fossil fuels, oxidation of metallic sulfides, and smelting of ores (Hem 1989, Wetzel 2001). Sulfate is naturally released from volcanic regions, during rock weathering, and through sulfur-reducing bacterial activity (Hem 1989, Wetzel 2001). The most extensive natural occurrence of sulfate is in evaporate sediments and rocks. Sulfate tends to form complex ions with sodium and calcium (Hem 1989). Strong acids associated with sulfate are major contributors to acidifications of lakes and rivers (Hem 1989, Wetzel 2001).

Total Dissolved Solids

Total dissolved solids (TDS) is a measure of the concentration of inorganic salts (e.g. sodium, chloride, potassium, calcium, magnesium, and sulfate), small amounts of organic material, and dissolved materials in the water column and is reported in mg/L. The value of TDS in fresh water naturally ranges from 0 to 1,000 mg/L (EPA 1986, MELP 1998). Concentrations tend to be comparatively low in streams in granitic and sandstone-dominated watersheds than watersheds with abundant limestone.

The effect of elevated TDS levels on aquatic biota depends on the ionic composition of the dissolved material and the extent of the increase in concentration. Under natural conditions, all aquatic life must be able to survive a range of TDS concentrations (EPA 1986). Sources of total dissolved solids include sewage, stormwater and agricultural runoff, salts from roads, and industrial and water treatment plant wastewater discharges. Total dissolved solids can also be derived from natural sources, including carbonate and salt deposits and mineral springs.

Total Suspended Solids

Total suspended solids (TSS) is a measurement of particulate matter suspended in the water column and is typically reported in mg/L (MELP 1998). Nephelometric Turbidity Units (NTUs) correspond approximately to TSS concentrations. Total suspended solids fluctuate with stream flow and may increase significantly during snowmelt and runoff from rain events. Streams in forested watersheds tend to have low TSS concentrations, usually less than 50 mg/L, although concentrations can be naturally much higher in some streams and rivers (Windell 1992). Waters with TSS concentrations less than 20 mg/L are usually considered to be clear. Concentrations between 40 and 80 mg/L are considered to be cloudy. Waters with concentrations greater than 150 mg/L appear dirty.

High TSS concentrations can increase turbidity, resulting in reduced light penetration, reduced primary productivity, damage to fish gills, and impaired fish feeding ability. Once the suspended solids settle on the stream or lake bottom, invertebrate and other benthic organisms and fish spawning can be adversely affected (EPA 1986).

The freshwater aquatic life criterion for TSS set forth in the EPA's *Quality Criteria for Water* (1976) states that 'settable and suspended solids should not reduce the depth of the composition point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.' In other words, light penetration should not be decreased more than 10 percent.

Turbidity

Turbidity is a measurement of the amount of light that is scattered or absorbed from a water sample. It is an indicator of suspended particulate matter in a water body. More suspended particles in the water cause greater scattering. Materials that contribute to turbidity include silt, clay, finely divided organic material, soluble organic compounds, and microorganisms (Michaud 1994, MELP 1998). Turbidity values are reported in NTUs. In general, turbidity values of 10 NTU or less represent very clear water; 50 NTU is cloudy; and 100 to 500 NTU is very cloudy or muddy. Rivers and streams in the Sierra Nevada are typically very clear, with turbidity measurements ranging between 1.65 and 5.73 NTU (EPA 2000).

High turbidity levels can have adverse effects in aquatic ecosystems. High turbidity reduces light penetration, which impairs photosynthesis of submerged vegetation and algae (MELP 1998, Michaud 1994). A reduction in plant growth will reduce the production of aquatic invertebrates and fish species. In addition, as particulates settle, they can adversely affect larvae by filling in the spaces between the rocks that may be used as habitat. High turbidity also affects the ability of fish to find and capture food and can impair gill function in some fish under chronically high levels (Michaud 1994). High turbidity also increases the total available surface area of suspended solids upon which metals and other pollutants can attach and bacteria can grow.

Turbidity values can be naturally variable. Waters are often more turbid following rain events, which may increase erosion and urban runoff. Turbidity increases can also be caused by effluents from wastewater and septic systems, decaying plants and animals, and bottom-feeding fish.

Total Organic Carbon

Total Organic Carbon (TOC) is a measure of the dissolved and particulate organic carbon in water, which is primarily composed of humic substances and decomposing plant and animal materials. Total organic carbon is reported as mg/L. Values in natural waters are usually between 1 and 30 mg/L (Hem 1989, MELP 1998). In small streams, the proportion of dissolved organic carbon relative to particulate organic carbon increases downstream as particles are broken down and decomposed. In slower moving larger rivers, TOC can also be derived from phytoplankton growth and rooted plants (Schlesinger 1997).

Carbon is required for biological processes. Dissolved oxygen concentrations are inversely related to organic carbon concentrations. The amount of TOC in the water varies with flow with generally higher concentrations at higher flows (Schlesinger 1997). Natural sources include decomposing leaves and

roots that may enter directly into a stream or waterbody, particularly from the adjacent riparian zone and floodplain. Dissolved sources include soluble carbohydrates and amino acids that are leached from decomposing leaves and roots and humic acids from soil organic matter (Schlesinger 1997). Sources of TOC include agriculture and municipal and industrial water discharges (MELP 1998).

Total Alkalinity (as CaCO₃)

Alkalinity is a measurement of the ability of water to neutralize acids (buffering capacity). Alkalinity is the concentration of bases in dissolved in water. These bases are usually carbonate and bicarbonate, but can also be hydroxides. These buffers are important because they slow the rate at which the pH changes. The pH can change naturally as a result of photosynthetic activity of the aquatic vegetation. When the pH is very high (greater than 9) hydroxide ions may also be present. In addition, carbonate and bicarbonate reduce the toxicity of some toxic heavy metals (EPA 1986, Hem 1989, Wetzel 2001). Alkalinity is typically expressed as an equivalent amount of calcium carbonate (CaCO₃) in mg/L and generally ranges from 0 to 500 mg/L in fresh waters (MELP 1998). Alkalinity levels up to 400 mg/L are not considered to be detrimental to human health (EPA 1986). Alkalinity values less than 10 mg/L are considered very low and the pH of these waters is very susceptible to acid inputs. Alkalinity values are often very low in granitic drainages (Wetzel 2001). Values between 10 and 20 mg/L are considered moderately susceptible to acid inputs.

In general, very low or high alkalinity itself does not cause detrimental effects to aquatic organisms. However, the concentration of the dissolved materials (alkalinity) and their ratio to one another determines the actual pH and buffering capacity in a given water system (EPA 1986, Wetzel 2001). Waters with very low alkalinity values have little capacity to buffer acid inputs and are thus susceptible to acidification (MELP 1998). As previously discussed, extreme pH values can adversely affect aquatic biota, particularly in low pH (acidic) waters. Acidified drainage basins are known to possess increased sulfate and dissolved aluminum concentrations, as well as significant changes in the ion species and ratios (Wetzel 2001). In some inland waters of extremely high salinity, hydroxide, borate, silicate, phosphate, and sulfide may be the major sources of alkalinity (Wetzel 2001). Relatively few aquatic organisms are adapted to these unusual conditions.

A.2.2 Metals Dissolved

Arsenic

Arsenic (As) is a widely distributed element in the Earth's crust (ATSDR 2007). It is highly volatile and is an important component in many biochemical processes (Hem 1989). In its elemental form, it appears as a metal-like substance but it is usually found in compounds with other elements and appears as white or colorless powder. Inorganic arsenic results from compounds with elements such as oxygen, chlorine, or sulfur. Organic arsenic results from compounds with hydrogen and carbon. Organic arsenic is generally less harmful than inorganic arsenic (ATSDR 2007). Arsenic is measured in µg/L or mg/L. Natural surface water normally contains an arsenic concentration of about 1 µg/L.

Arsenic can be highly toxic to most organisms in excess concentrations. Concentrations above 5 µg/L have been shown to reduce growth and reproduction in aquatic invertebrates and algae (MELP 1998). Concentrations of 550 µg/L have produced mortality in fish (MELP 1998). In addition, organic arsenic can bioaccumulate in fish and shellfish (ATSDR 2007). Concentrations above 25 µg/L can have negative effects on livestock and, therefore, are potentially toxic to wildlife (MELP 1998). Arsenic is used as a preservative for wood, and is used in pesticides, metal alloys (especially in automobile batteries), and semiconductors and light diodes. Anthropogenic sources of arsenic include coal-fired power plants, industrial water discharge, and agricultural runoff (Hem 1989). It occurs naturally in soil and can enter water from wind-blown dust, runoff, and leaching. Volcanoes are another natural source of arsenic (ATSDR 2007).

Cadmium

Cadmium (Cd) is an element that occurs naturally in the environment. It is usually found combined with other elements, such as zinc and lead, rather than occurring as a pure metal (MELP 1998, ATSDR 1999). It can be measured in either the dissolved (as in this study) or in the total state in water. It dissolves in water at varying degrees depending on which other elements it is combined. Cadmium most easily dissolves in water when it is in a compound with chlorides and sulfates. These compounds are usually present only in small amounts in the environment (ATSDR 1999). It is reported in mg/L or µg/L. It usually found in very small concentrations (less than 0.1 µg/L) (Wetzel 2001).

Cadmium has highly toxic effects on aquatic plants and animals in all chemical forms. It is extremely toxic to fish and zooplankton, and has been found to accumulate in plant cells and some aquatic organisms. It also diminishes plant growth. Its toxicity increases with the presence of other metals, including zinc and copper (MELP 1998, Oram 2007). The majority of cadmium is released into the environment from natural sources, primarily from the weather of rocks that naturally contain various amounts of cadmium. In addition, it can be released into the environment by forest fires and volcanoes. Anthropogenic sources of cadmium include industrial effluents, fossil fuels burning, and mining (ATSDR 1999).

Copper

Copper (Cu) is a metallic element, which can occur as a free native metal or combined with ionic metals (Hem 1989). It is measured in either the total or dissolved state in water samples, and reported in µg/L or mg/L. Copper is typically found in trace concentrations from 1 to 10 µg/L (MELP 1998) and levels near 10 µg/L are common in river water (Hem 1989). The fresh water aquatic life criterion for copper depends on the hardness of the water body being tested. Copper toxicity decreases with increasing hardness and increases with increasing pH (EPA 1986, Wetzel 2001).

Copper is an essential element in plant and animal metabolism, but quantities above normal trace concentrations are highly toxic to most aquatic life forms (MELP 1998). Many of the deleterious effects of copper, such as inhibition of phosphorus uptake in green algae, are highly variable depending on other environmental conditions such as pH, alkalinity, total organic carbon, and water hardness (EPA 1986, Wetzel 2001). Copper may be released during industrial, agricultural, and mining activities. Other common sources include copper plumbing and equipment (Hem 1989, MELP 1998).

Iron

Iron (Fe) is the second most abundant metallic element in the Earth's outer crust, but concentrations in water tend to be small (Hem 1989). Iron can be measured in either the total or dissolved state and reported as µg/L or mg/L. Average iron concentrations of 40 µg/L are found in the world's lake and rivers. The typical amount found in neutral and alkaline surface waters ranges from 0.05 to 0.20 mg/L (Wetzel 2001), with an average of 0.16 mg/L in surface waters in North America (Schlesinger 1997). High concentrations of iron are generally only found in acidic waters (pH less than 3 to 4), such as in runoff of streams from strip mines (Wetzel 2001). Concentrations of iron above 0.3 mg/L cause undesirable taste, and when precipitated out of solution due to oxidation, cause a reddish brown color to the water.

Iron is an essential element in plant and animal respiration and its availability in lakes and streams can limit photosynthetic productivity (Wetzel 2001). The chemical behavior of iron is highly dependent on oxidation intensity and is a function of pH and temperatures (Hem 1989, Wetzel 2001). Iron is released in sediment when igneous rock minerals are broken down by water. Iron is also present in organic matter in soils and can be processed into surface water through oxidation and reduction activities that often involve microorganism (Hem 1989). Industrial effluent, acid mine drainage, and smelters are also sources of iron (MELP 1998).

Lead

Lead (Pb) is a metallic element, which is widely dispersed in sedimentary rocks, but has low natural mobility due to low solubility (Hem 1989). The criterion for lead is expressed in terms of dissolved metal in the water column (MELP 1998). Lead concentration is reported in $\mu\text{g/L}$. The relative abundances of different species of lead are pH dependent and solubility increases with increasing alkalinity (EPA 1986). The freshwater aquatic life criterion for lead depends on the hardness of the water body being tested. The toxic effects of lead decreases as DO and hardness concentrations increase (MELP 1998).

Lead is toxic to all animals (MELP 1998) and is particularly toxic to aquatic organism at relatively low concentrations (Wetzel 2001). Fossil fuel combustion, especially of leaded gasoline, contributed greatly to the deposition of lead in waterways in the twentieth century. Other sources of lead include industrial effluent, smelting and refining, batteries, and lead pipe used to transport drinking water (Wetzel 2001).

Manganese

Manganese (Mn) is one of the more abundant metallic elements, although there is only one-fiftieth the amount of manganese in the Earth's crust as there is iron (Hem 1989). It does not naturally occur as a metal, but is found in association with various salts and minerals, often with iron compounds (EPA 1986). Its chemical reactivity is very similar to that of iron and they behave much the same way in freshwater systems (Wetzel 2001). It is a minor constituent of many igneous and metamorphic minerals (Hem 1989). It can substitute for iron, magnesium, or calcium in silicate structures, but it is not an essential element of silicate rock minerals (Hem 1989). Small amounts of manganese are often present in dolomite or limestone as a substitute for calcium. The average concentration of manganese in surface waters is about $35 \mu\text{g/L}$ (Wetzel 2001). It is rarely found in surface waters at concentrations greater than 1 mg/L (EPA 1986).

Manganese is an essential nutrient for microflora, plants, and animals as an enzyme catalyst and as an important component of photosynthesis and nitrogen fixation (EPA 1986, Hem 1989). High concentrations of manganese can have an inhibitory effect on cyanobacteria and green algae and tend to favor diatom growth (Wetzel 2001). Divalent manganese is released into aqueous solution during weathering of rock and through organic processes (Hem 1989).

Nickel

Nickel (Ni) is one of the five ferromagnetic elements. It only occurs as a very small fraction (0.018 percent) in the Earth's crust (HSDB 2007). It can be combined with various other metals, including iron, copper, chromium, and zinc, and may substitute for iron in igneous rocks. Nickel also may be precipitated with iron oxides and manganese oxides (Hem 1989, ATSDR 2005). In addition, nickel can also be combined with other elements, most commonly sulfur, and oxygen. Many of the compounds containing nickel easily dissolve in water (ATSDR 2005). Concentrations in natural surface waters are usually low ($10 \mu\text{g/L}$, Hem 1989).

Nickel is an essential element in some enzymes found in bacteria and plants. It is an important component in nitrogen fixation and some enzymes (Wetzel 2001). However, when it occurs in large quantities and is combined with some elements, for example nitrate, sulfur, and chloride, nickel can be very toxic to aquatic biota. It may accumulate in some plants (ATSDR 2005). The toxicity of nickel to aquatic biota is dependent on hardness. Toxicity is greater when the water is softer compared to harder water conditions. It can also be released from volcanoes. Nickel is naturally found in all soils, and strongly attaches to particles that contain iron or magnesium. When this occurs, it is not readily available for uptake by plants and animals. Nickel is found in surface waters as a result of weathering of rocks containing nickel. Anthropogenic sources of nickel include industrial effluent, oil-burning and coal-burning power plants, mining, and trash incinerators (ATSDR 2005).

Chromium

Chromium (Cr) is naturally present in the environment and has a number of oxidation states. The most common forms are chromium (0), trivalent (chromium (III)), and hexavalent (chromium (VI)). Hexavalent chromium (chromium VI) compounds are the most toxic state. It is usually measured as total chromium. Naturally, chromium concentrations in surface water are usually less than 10 µg/L (Hem 1989).

Chromium (VI) compounds adversely affect all aquatic biota, including algae. It does not appear to bioaccumulate in plants and animals. It is also a known human carcinogen (EPA 1986). The toxicity of chromium (VI) increases as hardness and pH increase. Chromium (III) is more toxic in soft waters. Chromium naturally occurs in rocks and soil, but in very small amounts. It is also released during volcanic eruptions. Anthropogenic sources of chromium (0), (III) and (VI) include emissions from coal and oil burning and industrial effluents (ATSDR 2000).

A.2.3 Metals - Total

Mercury

Mercury (Hg) is a trace element in the Earth's crust that normally occurs in quantities of only 1 to 2 ng/L in natural waters (MELP 1998). It may be present in the environment as elemental mercury (Hg⁰), inorganic mercury (Hg²⁺), or organic mercury (primarily methyl mercury, MeHg). Elemental mercury was commonly used in thermometers. Methyl mercury is the most toxic of these mercury compounds (EPA 1986). It is a serious neuron-toxin and has been found in high concentrations in lakes far removed from sources of mercury (EPA 1986). Methyl mercury bioaccumulates, which is the process by which organisms that are exposed to chemicals either from their diet, water, or other sources accumulate and retain the chemicals. Inorganic mercury does not accumulate in aquatic organisms. Various chemical and biological processes can readily convert the various forms of mercury. Anaerobic bacteria in sediments readily convert inorganic mercury into methyl mercury. With the exception of gold mining areas where elemental mercury is used, mercury is typically present in surface waters, sediment, or soils as inorganic mercury.

Mercury is highly toxic and has a long retention time in animal cells. Rates of methyl mercury production and bioaccumulation depend not only on the abundance of inorganic mercury but also on a complex assortment of environmental variables which affect the activities and species composition of the bacteria and the availability of the inorganic mercury for methylation (USGS 2003, HSDB 2007). These variables include, but are not limited to, pH of the water, the length of the food chain, dissolved organic matter, soil type, and the proportion of wetlands in the watershed. Once converted to methyl mercury by bacteria, it can bioaccumulate in aquatic organisms and be passed up the food chain (Hem 1989). Temperature, pH, alkalinity, suspended sediment load, and the geomorphology of the watershed are known to affect the accumulation of mercury in fish (Klasing et al. 2006). In addition to bioaccumulating, methyl mercury also biomagnifies (higher concentrations at higher levels in the food chain) (USGS 2003). Because bacteria mediate the rate of methyl mercury formation, fish living in even mildly contaminated waters are not safe to eat.

Detectable levels of mercury are found in almost all fish, with more than 95 percent of it occurring as methyl mercury (Klasing et al. 2006). People primarily become exposed to methyl mercury by consuming fish (Klasing et al. 2006). Fish at the highest trophic levels (higher up the food chain) tend to have higher levels of methyl mercury than those lower in the food chain. Larger and older fish of a given species also tend to have higher methyl mercury levels than smaller and younger fish of the same species. It is particularly toxic to the fetus and young children and can cause serious neurological abnormalities to a fetus even without symptoms in the mother. Recent studies indicate that the fetus is more sensitive to methyl mercury than adults. As a result, the Office of Environmental Health Hazard Assessment has established separate 'reference doses', which is "the daily exposure likely to be without significant risk of deleterious health effects during a lifetime". The reference dose for women of childbearing age and

children aged 17 and younger is 1×10^{-4} mg/kg-day. For men and women beyond childbearing age, the reference dose is 3×10^{-4} mg/kg-day (Klasing et al. 2006).

Mercury contamination can occur from both natural processes and human activities. Mercury is highly volatile and thus, atmospheric deposition is a major pathway into aquatic systems (Hem 1989, MELP 1998). Impounded water and flooding also cause the release of sedimentary mercury (MELP 1998). Sources of mercury contamination include coal combustion, waste incineration, mining and smelting, and production of fertilizers (MELP 1998, USGS 2003). Mercury is typically measured as the total mercury in water, soil, or tissue samples. Water samples containing just 5 to 10 ng/L are considered polluted (MELP 1998).

A.2.4 Bacteria

Total Coliform

Coliform bacteria are a group of several genera of relatively harmless microorganisms that live in soil, water, and the intestines of cold- and warm-blooded animals including humans (Murphy 2007). Total coliform concentrations are reported as the most probable number of bacteria colonies present per 100 milliliter (mL) of sample water (Michaud 1994).

Total coliform bacteria occur naturally in surface and shallow ground waters and are essential in the breakdown of organic matter in water. Oxygen is not a requirement for these bacteria, but they can use it. They produce acid and gas from the fermentation of lactose. Coliform bacteria are not pathogenic and are only mildly infectious. The total coliform group is relatively easy to culture in the lab, and therefore, has been selected as the primary indicatory bacteria for the presence of disease-causing organisms. If large numbers of coliform bacteria are found in water, there is a high probability that pathogenic bacteria or organisms, such as *Giardia* may be present. Coliform bacteria, rather than actual pathogens, are used to assess water quality because they are easier to isolate and identify (Murphy 2007).

E. coli

Escherichia coli (*E. coli*) is the most common organism in the fecal coliform group, a subgroup of coliform bacteria that live in the intestinal tract and feces of warm-blooded animals (Murphy 2007). *E. coli* concentrations are reported as the most probable number of bacteria colonies present per 100 mL of sample water. The EPA conducted studies in the 1970s and 1980s evaluating fecal coliform, *E. coli*, and enterococci as indicators of fecal contamination and found that *E. coli* is a good predictor of gastrointestinal illness in fresh waters (EPA 2012).

Fecal coliform species by themselves are not usually harmful, although some strains of *E. coli*, such as *E. coli* O157:H7, which is found in the digestive tract of cattle, can cause intestinal illness. The presence of *E. coli* indicates contamination from the feces of humans or other animals, which can contain pathogenic organisms such as bacteria, viruses, and parasites that cause gastrointestinal illness (Windell 1992, Murphy 2007). The major sources of *E. coli* entering freshwater are wastewater treatment plant effluent, failing septic systems, storm water runoff, animal carcasses, and animal and human wastes, including runoff from animal manure and manure storage areas. Human and animal wastes can be washed into storm drains, streams, and lakes during storms (Michaud 1994, Murphy 2007; EPA 2015).

A.3 References

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Appendix B

Glossary of Analytical Laboratory Terminology, Units of Measurements, and Calculations

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B.1 Glossary

Method Detection Limit (MDL)

A measure of the method sensitivity. The MDL is the lowest concentration that can be detected by an instrument with correction for the effects of sample matrix and method-specified parameters such as sample preparation. It is defined as, “the minimum measured concentration of a substance that can be reported with 99 percent confidence that the measured concentration is distinguishable from method blank results” (EPA 2016).

Method Reporting Limit (MRL) or Reporting Limit (RL)

The lowest concentration of a substance that can be reliably reported under current laboratory operating conditions. Sometimes referred to as the reporting limit (RL). The MRL is based on the level of the low standard used in the instrument calibration and the volumes/weights used in the analysis of samples (BAL 2016). The MRL cannot be less than the MDL and is typically 3 to 10 times the MDL (BAL 2016). Different labs and agencies may use the terms MRL and Practical Quantitation Limit (PQL) slightly differently, and MRL and/or PQL values are calculated by each lab based on their unique set of instruments and experience. APPL Labs uses PQL and RL interchangeably, BSK Associates Labs uses RL, and Brooks Applied Labs uses MRL.

Practical Quantitation Limit (PQL)

The concentration that can be reliably measured within specified limits and accuracy during routine laboratory operating conditions. It is typically determined by a combination of the instrument detection limit (IDL, the lowest the instrument is capable of seeing with specified confidence limits) and the lowest calibration standard used. The calibration level is selected (usually greater than the IDL) based upon the needs of the specified batch of samples being run. Different labs and agencies may use the terms MRL and PQL slightly differently, and MRL and/or PQL values are calculated by each lab based on their unique set of instruments and experience. APPL Labs uses PQL and RL interchangeably, BSK Associates Labs uses RL, and Brooks Applied Labs uses MRL.

B.2 Units of Measure

The following table summarizes the units used by the laboratories, the Basin Plan (CVRWQCB 2015), and the EPA (65 FR 31682, EPA 2019). The laboratory/field units were used throughout the report, and the table below summarizes the conversions from the Basin Plan and EPA units to the units used in the report.

Water Quality Analyte	Laboratory/ Field Unit	Basin Plan Unit	EPA Unit	Conversion to Standard Unit for Report
In-Situ Measurements				
Water Temperature	Celsius (°C)	Fahrenheit (°F)	--	$T(^{\circ}\text{C}) = (T(^{\circ}\text{F}) - 32) / 1.8$
Dissolved Oxygen (DO)	mg/L	mg/L	mg/L	No conversion
Turbidity	NTU	NTU	--	No conversion
Conductivity	µS/cm at 25°C	αmhos/cm	--	1 αmhos/cm = 1 µS/cm at 25°C
pH	unitless	unitless	unitless	No conversion
General Parameters				
Calcium	µg/L	--	--	No conversion
Chloride	mg/L	mg/L	µg/L	Divide µg/L by 1,000
Hardness (as CaCO ₃)	mg/L	--	--	No conversion
Magnesium	µg/L	--	--	No conversion
Nitrate	mg/L	mg/L	--	No conversion
Nitrite	mg/L	mg/L	--	No conversion
Nitrate/Nitrite (NO ₃)	mg/L	mg/L	--	No conversion
Ammonia as N	mg/L	mg/L	mg/L	No conversion
Total Kjeldahl Nitrogen (TKN)	mg/L	--	--	No conversion
Total Phosphorus	µg/L	--	--	No conversion
Ortho-phosphate	mg/L	--	--	No conversion
Potassium	µg/L	--	--	No conversion
Sodium	µg/L	--	--	No conversion
Sulfate (SO ₄)	mg/L	mg/L	--	No conversion
Total Dissolved Solids	mg/L	mg/L	--	No conversion
Total Suspended Solids	mg/L	--	--	No conversion
Turbidity	NTU	NTU	--	No conversion
Organic Carbon, Total (TOC)	mg/L	--	--	No conversion
Total Alkalinity (as CaCO ₃)	mg/L	--	mg/L	No conversion
Metals-Dissolved				
Arsenic	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Cadmium	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Copper	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Iron	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Lead	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Manganese	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Nickel	µg/L	mg/L	µg/L	Multiply mg/L by 1,000
Chromium-Total	µg/L	mg/L	--	Multiply mg/L by 1,000

Water Quality Analyte	Laboratory/ Field Unit	Basin Plan Unit	EPA Unit	Conversion to Standard Unit for Report
Metals-Total				
Mercury	ng/L	mg/L	µg/L	Multiply mg/L by 1,000,000 Multiply µg/L by 1,000
Bacteria				
Total Coliform	MPN/100 mL	--	--	No conversion
<i>E. coli</i>	MPN/100 mL	--	MPN/100 mL	No conversion

B.3 Calculations

Several criteria must be calculated on a site-by-site basis. The following equations apply to those analytes.

Ammonia

Criteria are temperature and pH dependent. Equations are from the EPA's Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater (EPA 2013). The Criteria Continuous Concentration (CCC) is a 30-day rolling average concentration of total ammonia nitrogen (milligrams per liter [mg/L]) that cannot be exceeded more than once every three years on average. The Criteria Maximum Concentration (CMC) is the one-hour average concentration of total ammonia nitrogen (mg/L) that cannot be exceeded more than once every three years on average where *Oncorhynchus* species are present. In these equations, temperature should be in degrees Celsius (°C).

$$CCC = 0.8876 \times \left(\frac{0.0278}{1 + 10^{7.688 - pH}} + \frac{1.1994}{1 + 10^{pH - 7.688}} \right) \times (2.126 \times 10^{0.028 \times (20 - \text{MAX}(T, 7))})$$

$$CMC = \text{MIN} \left(\left(\frac{0.275}{1 + 10^{7.204 - pH}} + \frac{39.0}{1 + 10^{pH - 7.204}} \right), \left(0.7249 \times \left(\frac{0.0114}{1 + 10^{7.204 - pH}} + \frac{1.6181}{1 + 10^{pH - 7.204}} \right) \times (23.12 \times 10^{0.036 \times (20 - T)}) \right) \right)$$

Cadmium (Cd)

Criteria are hardness dependent. The EPA's national water quality criteria equations for cadmium are more stringent than the California Toxics Rule (CTR) criteria equations (65 FR 31682), so the national water quality criteria equations are used (EPA 2019). These equations calculate the freshwater CCC and CMC for cadmium. Hardness should be in mg/L.

$$CCC \text{ (in } \mu\text{g/L)} = (1.101672 - [\ln(\text{hardness}) * 0.041838]) * e^{0.7977 * \ln(\text{hardness}) - 3.909}$$

$$CMC \text{ (in } \mu\text{g/L)} = (1.136672 - [\ln(\text{hardness}) * 0.041838]) * e^{0.9789 * \ln(\text{hardness}) - 3.866}$$

Copper (Cu):

Criteria are hardness dependent. The EPA's national water quality criteria equations for copper are the same as the equations in the CTR (65 FR 31682, EPA 2019). These equations calculate the freshwater CCC and CMC for copper. Hardness should be in mg/L.

$$CCC \text{ (in } \mu\text{g/L)} = 0.96 * e^{0.8545 * \ln(\text{hardness}) - 1.702}$$

$$CMC \text{ (in } \mu\text{g/L)} = 0.96 * e^{0.9422 * \ln(\text{hardness}) - 1.7}$$

Lead (Pb)

Criteria are hardness dependent. The EPA's national water quality criteria equations for lead are the same as the equations in the CTR (65 FR 31682, EPA 2019). These equations calculate the freshwater CCC and CMC for lead. Hardness should be in mg/L.

$$CCC \text{ (in } \mu\text{g/L)} = (1.46203 - [\ln(\text{hardness}) * 0.145712]) * e^{1.273 * \ln(\text{hardness}) - 4.705}$$

$$CMC \text{ (in } \mu\text{g/L)} = (1.46203 - [\ln(\text{hardness}) * 0.145712]) * e^{1.273 * \ln(\text{hardness}) - 1.46}$$

Nickel (Ni)

Criteria are hardness dependent. The EPA's national water quality criteria equations for nickel are the same as the equations in the CTR (65 FR 31682, EPA 2019). These equations calculate the freshwater CCC and CMC for nickel. Hardness should be in mg/L.

$$CCC \text{ (in } \mu\text{g/L)} = 0.997 * e^{0.846 * \ln(\text{hardness}) + 0.0584}$$

$$CMC \text{ (in } \mu\text{g/L)} = 0.998 * e^{0.846 * \ln(\text{hardness}) + 2.255}$$

B.4 Sources Cited in this Appendix

65 FR 31682. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California. Federal Register. Vol. 65, No. 97. Thursday, May 18, 2000. Rules and Regulations.

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Appendix C

Quality Assurance / Quality Control Laboratory Review

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A quality assurance/quality control (QA/QC) review was performed on the laboratory reports received from APPL Labs, BSK Associates Labs, and Brooks Applied Labs. The review consisted of (1) checking that the sample identification numbers, sample dates and times, and analytes requested on the chain of custody forms matched the sample identification numbers, sample dates and times, and analytes measured in the laboratory reports; (2) checking that the sample identification numbers were consistent throughout the laboratory reports; (3) identifying any samples that did not meet the required holding times; and (4) noting which samples were flagged with quality control data issues by the laboratories. The results of this QA/QC review are summarized for the spring 2018 sampling period in Table C-1 and for the summer 2018 sampling period in Table C-2.

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Table C-1. Quality Assurance/Quality Control Review of Spring 2018 Sample Laboratory Analyses.

Report ID	APPL: 85715	BSK: A8E1235	APPL: 85726	BSK: A8E1690	APPL: 85743	BSK: A8E1691	BAL: 1819010	APPL: 85929	BSK: A8E3998	BSK: A8F0101	BAL: 1822029
Sample Locations	K1 Flowline Below K1 Div. EF Upstream of K1 Div. EF Downstream of K1 Div. KR Upstream of PH2 K2 Flowline Above PH2	K1 Flowline Below K1 Div. EF Upstream of K1 Div. EF Downstream of K1 Div. KR Upstream of PH2 K2 Flowline Above PH2	K3 Flowline Above PH3 KR Downstream of PH3 KR Upstream of PH3 K2 Flowline Below PH3 KR Upstream of the Conf. with EF KR Downstream of the Conf. with EF	K3 Flowline Above PH3 KR Downstream of PH3 KR Upstream of PH3 K2 Flowline Below PH3 KR Upstream of the Conf. with EF KR Downstream of the Conf. with EF	K1 Flowline Above PH1 KR Downstream of PH1 KR Upstream of PH1 KR Downstream of PH2	K1 Flowline Above PH1 KR Downstream of PH1 KR Upstream of PH1 KR Downstream of PH2	K1 Flowline Below K1 Div. EF Upstream of K1 Div. EF Downstream of K1 Div. KR Upstream of PH2 K2 Flowline Above PH2 K3 Flowline Above PH3 KR Downstream of PH3 KR Upstream of PH3 K2 Flowline Below PH3 KR Upstream of the Conf. with EF KR Downstream of the Conf. with EF K1 Flowline Above PH1 KR Downstream of PH1 KR Upstream of PH1 KR Downstream of PH2	EF Upstream of the Conf. with KR	EF Upstream of the Conf. with KR	EF Upstream of the Conf. with KR	K1 Flowline Above PH1 KR Upstream of PH2 K2 Flowline Above PH2 K3 Flowline Above PH3 EF Downstream of K1 Div. EF Upstream of the Conf. with KR KR Downstream of PH1 KR Upstream of PH1 KR Downstream of PH2
Sample ID Numbers	1 2 3 4 5	1 2 3 4 5	6 7 8 9 10 11	6 7 8 9 10 11	12 13 14 15	12 13 14 15	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	21	21	21	16 17 18 19 20 21 22 23 24
Date Sampled	5/7/2018	5/7/2018	5/8/2018	5/8/2018	5/9/2018	5/9/2018	5/7/2018 - 5/9/2018	5/30/2018	5/30/2018	5/30/2018	5/30/2018 - 5/31/2018
Analysis	General Parameters	General Parameters (TOC)	General Parameters	General Parameters (TOC)	General Parameters	General Parameters (TOC)	Metals (Dissolved and Total)	General Parameters	General Parameters (TOC)	General Parameters (Turbidity)	Metals (Dissolved and Total)
Do all samples match COC?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is sample ID consistent throughout report?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were all sample holding times met?	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes
Were there any quality control data issues?	No	Yes B2.0: TOC for all samples	No	No	Yes B: Total Alkalinity for Sample 12	No	Yes H: As Cd Cr Cu Fe Mn Ni and Pb for Samples 12 13 14 and 15. These samples were excluded from the report.	Yes B: Total Kjeldahl Nitrogen for Sample 21	No	Yes HT1.0: Turbidity for Sample 21 SC1.1: Turbidity for Sample 21	No

Notes:
 APPL = APPL Labs
 BAL = Brooks Applied Labs
 BSK = BSK Associates Laboratory
 TOC = Total Organic Carbon

APPL Labs QC Code:

B: The analyte was found in a method blank, as well as in the sample.

Brooks Applied Labs (BAL) QC Code:

H: Holding time and/or preservation requirements not met.

BSK Associates Laboratory QC Code:

B2.0: Analyte present in the method blank above the method detection limit (MDL). Laboratory does not determine batch acceptance on detections below the reporting limit (RL).

HT1.0: Holding time exceeded. Sample was received at the lab past holding time.

SC1.1: Sample was received above the mandated temperature.

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Table C-2. Quality Assurance/Quality Control Review of Summer 2018 Sample Laboratory Analyses.

Report ID	APPL: 86644	BSK: A8H2862	BSK: A8H3259	APPL: 86653	BSK: A8H3117	APPL: 86677	BSK: A8H3462	BAL: 1834011
Sample Locations	KR Upstream of PH3, KR Downstream of PH3, KR Upstream of the Conf. with EF	KR Upstream of PH3, KR Downstream of PH3, KR Upstream of the Conf. with EF	KR Upstream of PH3, KR Downstream of PH3, KR Upstream of the Conf. with EF	EF Upstream of K1 Div., EF Downstream of K1 Div., K2 Flowline Below K1 Div.	EF Upstream of K1 Div., EF Downstream of K1 Div., K2 Flowline Below K1 Div.	KR Upstream of the Conf. with EF, EF Upstream of the Conf. with KR, KR Downstream of the Conf. with EF, KR Downstream of PH1, KR Upstream of PH1, KR Upstream of PH2, K2 Flowline Above PH2, KR Downstream of PH2	EF Upstream of the Conf. with KR, KR Downstream of the Conf. with EF, KR Downstream of PH1, KR Upstream of PH1, KR Upstream of PH2, K2 Flowline Above PH2, KR Downstream of PH2	KR Upstream of PH3, KR Downstream of PH3, KR Upstream of the Conf. with EF, EF Upstream of K1 Div., EF Downstream of K1 Div., K2 Flowline Below K1 Div., EF Upstream of the Conf. with KR, KR Downstream of the Conf. with EF, KR Downstream of PH1, KR Upstream of PH1, KR Upstream of PH2, K2 Flowline Above PH2, KR Downstream of PH2
Sample ID Numbers	25, 26, 27	25, 26, 27	25, 26, 27	28, 29, 30	28, 29, 30	27, 31, 32, 33, 34, 35, 36, 37	31, 32, 33, 34, 35, 36, 37	25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37
Date Sampled	8/20/2018	8/20/2018	8/20/2018	8/21/2018	8/21/2018	8/23/2018	8/23/2018	8/20/2018 - 8/23/2018
Analysis	General Parameters	General Parameters (Turbidity)	General Parameters (TOC)	General Parameters	General Parameters (TOC, Turbidity)	General Parameters	General Parameters (TOC, Turbidity)	Metals (Dissolved and Total)
Do all samples match COC?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Is sample ID consistent throughout report?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were all sample holding times met?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were there any quality control data issues?	No	No	No	No	Yes SC1.4: TOC for Samples 28 and 29	Yes B: Total Alkalinity for Sample 36 (Sample was rerun by lab. Rerun sample was 1 day outside of holding time limit.)	No	No

Notes:

APPL = APPL Labs

BAL = Brooks Applied Labs

BSK = BSK Associates Laboratory

TOC = Total Organic Carbon

APPL Labs QC Code:

B: The analyte was found in a method blank, as well as in the sample.

BSK Associates Laboratory QC Code:

SC1.4: Sample was received without chemical preservation.

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