Lake Elsinore and Canyon Lake Watersheds Nutrient TMDL Monitoring 2016-2017 Annual Report

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ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
µS/cm	microSiemens per centimeter
Basin Plan	Water Quality Control Plan for the Santa Ana River Basin
CCC	criterion continuous concentration
cf	cubic feet
cfs	cubic feet per second
CMC	criterion maximum concentration
DO	dissolved oxygen
EVMWD	Elsinore Valley Municipal Water District
EMC	event mean concentration
Forest Service	San Bernardino Nation Forest Service
FY	fiscal year
kg	kilogram
LESJWA	Lake Elsinore and San Jacinto Watersheds Authority
LA	load allocation
Mgal	million gallons of water
mg/L	milligrams per liter
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
ND	non-detect
QAPP	Quality Assurance Project Plan
RCFC&WCD	Riverside County Flood Control and Water Conservation District
RWQCB	Regional Water Quality Control Board, Santa Ana Region
SAWPA	Santa Ana Watershed Project Authority
TDS	Total Dissolved Solids
TMDL Task Force	Lake Elsinore and Canyon Lake TMDL Task Force
TMDL	Total Maximum Daily Load
US EPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
WLA	waste load allocation

1.0 Introduction

The following document summarizes results of compliance monitoring required in support of the Lake Elsinore and Canyon Lake Nutrient Total Maximum Daily Load (TMDL) for the 2016-2017 fiscal year (FY). The monitoring was performed according to the Lake Elsinore & Canyon Lake Nutrient TMDL Monitoring Quality Assurance Project Plan (QAPP) (Amec Foster Wheeler, September 2016), and the associated Compliance Monitoring Work Plan (Haley & Aldrich, Inc., July 2016).

1.1 Background

Lake Elsinore is a natural freshwater lake in southern California that provides a variety of natural habitats for terrestrial and aquatic species. The beneficial uses of the lake include water contact recreation (REC1), non-water contact recreation (REC2), commercial and sportfishing (COMM), warm freshwater habitat (WARM), wildlife habitat (WILD), and rare, threatened or endangered species (RARE)[1]. Canyon Lake was constructed in 1928 as the Railroad Canyon Reservoir. It is located approximately two miles upstream of Lake Elsinore and water spilled from Canyon Lake is a main source of water for Lake Elsinore during wet years. The beneficial uses of Canyon Lake include municipal and domestic water supply (MUN), agricultural supply (AGR), groundwater recharge (GWR), body contact recreation (REC1), non-body contact recreation (REC2), commercial and sportfishing (COMM), warm freshwater aquatic habitat (WARM), and wildlife habitat (WILD). The beneficial uses of COMM and RARE in Lake Elsinore and COMM in Canyon Lake were recently approved by the California Regional Water Quality Control Board, Santa Ana Region (RWQCB) as a Basin Plan Amendment under tentative resolution R8-2017-0019 on June 16, 2017.

In 1994, Lake Elsinore and Canyon Lake were first listed by the RWQCB on its Clean Water Act Section 303(d) list of impaired waterbodies. Both lakes remain on the latest approved 303(d) list finalized in 2010. Impairments identified for these waters included excessive levels of nutrients in both lakes, as well as organic enrichment/low dissolved oxygen (DO), sedimentation/siltation, unknown causes of toxicity in Lake Elsinore, and high bacterial indicators in Canyon Lake[2]. The Clean Water Act Section 303(d) requires the development and implementation of a TMDL for waters that do not or are not expected to meet water quality standards (beneficial uses, water quality objectives). In 2000, the RWQCB initiated the development of TMDLs for nutrients for Lake Elsinore and Canyon Lake.

In December 2004, the RWQCB adopted amendments to the Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) to incorporate TMDLs for nutrients in Canyon Lake and Lake Elsinore. The Regional Board adopted the Resolution, and it was subsequently approved by the U.S. Environmental Protection Agency (US EPA) on September 30, 2005. The Basin Plan Amendment specifies, among other things, monitoring recommendations to track compliance with the TMDL and associated waste load allocations (WLAs) and monitoring to measure compliance

[1] Based on federally listed Riverside fairy shrimp (*Streptocephalus woottoni*) in adjacent wetlands.
[2] The 303d listing for bacteria in Canyon Lake was addressed by the TMDL Task Force and Elsinore Valley Municipal Water District (EVMWD) through an enhanced special bacteria indicator monitoring study in 2009 by Montgomery Watson (EVMWD/ MWH, 2009). The results of this study found no exceedances relative to recreational contact water quality standards.

towards in-lake numeric water quality targets. Numeric targets have been established and incorporated in the TMDL for nutrients (total nitrogen, phosphorous, and ammonia), DO, and chlorophyll-a; however, the ultimate compliance goal for beneficial uses in both lakes is to reduce enhanced eutrophication, which can negatively affect biological communities, result in fish kills, and impact recreational use. The recommendations outlined in RWQCB Resolution No. R8-2004-0037 required stakeholders to develop management plans and conduct long-term monitoring and implementation programs aimed at reducing nutrient loads to Lake Elsinore and Canyon Lake. Task 4 of the adopted Lake Elsinore and Canyon Lake TMDL Amendment required stakeholders to prepare and implement a Nutrient Monitoring Program. The program was to include the following:

1. A watershed-wide monitoring program to determine compliance with interim and/or final nitrogen and phosphorus allocations; compliance with the nitrogen and phosphorus TMDL, and load allocations (LAs), including WLAs.

2. A Lake Elsinore in-lake nutrient monitoring program to determine compliance with interim and final nitrogen, phosphorus, chlorophyll-a, and DO numeric targets. This program will evaluate and determine the relationship between ammonia and total nitrogen allocation to ensure that the total nitrogen allocation will prevent ammonia toxicity in Lake Elsinore.

3. A Canyon Lake in-lake nutrient monitoring program to determine compliance with interim and final nitrogen, phosphorus, chlorophyll-a, and DO numeric targets. The monitoring program will evaluate and determine the relationship between ammonia and the total nitrogen allocation to ensure that the total nitrogen allocation will prevent ammonia toxicity in Canyon Lake.

4. An annual report summarizing the data collected for the year and evaluating compliance with the TMDL, due August 15 of each year.

Since August 2001, the Lake Elsinore and San Jacinto Waters Authority (LESJWA) has been working with Local stakeholders and the Santa Ana Regional Water Quality Control Board to identify the source of nutrients impairing each lake, and evaluate the impacts to water quality and beneficial uses incurred from nutrient sources.

At that time, LESJWA contracted with the State to serve as a neutral facilitator for the RWQCB to assist in formation of a TMDL workgroup and assisting the workgroup in participating with the RWQCB in the development and definition of the TMDLs.

With formal adoption of the Lake Elsinore and Canyon Lake nutrient TMDLs on December 20, 2004, stakeholders named in the TMDLs began the process to create a formal cost sharing body, or Task Force to implement a number of tasks defined within the TMDLs.

In November 2006, stakeholders finalized an agreement to form the Lake Elsinore and Canyon Lake TMDL Task Force. The TMDL Task Force consists of representatives from local cities, Riverside County, agriculture and dairy, and the regulatory community. At the request of the stakeholders and RWQCB, LESJWA staffed by the Santa Ana Watershed Project Authority (SAWPA) serves as administrator of the Task Force and overseesthe TMDL development process for Lake Elsinore and Canyon Lake.

LESJWA, in support of the TMDL Task Force, provided funding to meet the requirement of the TMDL by developing a single comprehensive watershed-wide nutrient Monitoring Plan. The Lake Elsinore and Canyon Lake Nutrient TMDL Monitoring Plan was approved by the RWQCB in March 2006 and subsequently implemented by the TMDL Task Force in April 2006 through October 2012. During this time frame, the in-lake monitoring for both lakes was conducted through the Elsinore Valley Municipal Water District (EVMWD) National Pollutant Discharge Elimination System (NPDES) compliance program (Order No. R8-2005-0003 for NPDES No. CA8000027 for the Regional Water Reclamation Plant, Lake Elsinore, Riverside County approved March 4, 2005). On October 26, 2012 the Regional Board issued a resolution (Resolution No. R8-2012-0052) granting the TMDL Task Force a temporary suspension of in-lake TMDL monitoring programs to achieve cost savings that were applied to implementing lake improvement projects aimed at reducing nutrient impacts in Canyon Lake and Lake Elsinore. Therefore, the in-lake Lake Elsinore and Canyon Lake TMDL compliance monitoring was not conducted for the 2013-2014 and 2014-2015 FY cycles.

The in-lake water quality monitoring for both lakes was resumed in July 2015 as Phase II of the Lake Elsinore and Canyon Lake Nutrient TMDL Monitoring Program moving forward. Under the Phase II Monitoring Program, concurrent efforts are underway to reevaluate the appropriateness and applicability of the TMDL criteria. The results of the 2016-2017 FY in-lake and watershed monitoring efforts are summarized herein.

2.0 San Jacinto River Watershed-Wide Monitoring

The study design for Phase II of the San Jacinto River Watershed Monitoring Program is to continue to determine nutrient loading into Canyon Lake and Lake Elsinore from upstream watershed sources to add to the historical monitoring data set to evaluate long-term trends. The primary objectives of the Phase II San Jacinto River Watershed Monitoring Program are as follows:

1. Determine the total nutrient loads into Lake Elsinore and Canyon Lake from their tributaries (i.e., the San Jacinto River, Salt Creek, and Cottonwood Creek).

2. Determine the total nutrient load from various sources categorized by land use types, namely, agricultural, urban runoff, and open space sources which drain into the above-mentioned tributaries.

3. Provide water quality data for watershed model updates.

4. Provide water quality data to evaluate TMDL compliance with WLAs and LAs.

Watershed monitoring and reporting was performed by Alta Environmental of San Diego, California.

2.1 Summary of 2016-2017 Watershed Monitoring and Nutrient Loads

A summary of the water quality monitoring data for each of the five monitoring locations for the period of July 1, 2016 through June 30, 2017, is presented in Table 2-1 below. A more detailed account, including storm hydrographs and event loads are presented in Section 2.7 for each

monitoring location. The complete set of water quality data, including water quality field measurements is included in Appendix A.

Table 2-1. Summary of 2016-2017 Monitoring

Number and Location Description	Total Annual Flow [a] (Mgal)	Annual Event Mean Storm Concentration (mg/L)		Estimated Annual Load (kg)	
		Total Nitrogen	Total Phosphorus	Total Nitrogen	Total Phosphorus
Site 3 - Salt Creek at Murrieta Road (USGS 11070465)	1,596	2.07	0.62	12,366	4,026
Site 4 - San Jacinto River at Goetz Road (USGS 11070365)	2,802	2.03	1.23	21,651	14,403
Site 6 - San Jacinto River at Ramona Expressway [b] (USGS 11070210)	0	-	-	-	-
Site 30 - Canyon Lake Spillway [c] (USGS 11070500)	4,850	1.85	0.36	33,759	6,637
Site 1 - San Jacinto River at Cranston Guard Station (USGS 11069500)	6,194	Not Measured [d]	Not Measured [d]	Not Measured [d]	Not Measured [d]

Notes:
a - Flow data after 11/02/2016 are provisional and may be subject to change.
b - No flows occurred at the TMDL monitoring location just downstream of Mystic Lake, which has been actively subsiding.
c - TMDL monitoring location just below the Canyon Lake spillway. The USGS stream gauge at Site 30 (USGS 11070500) is located downstream of Canyon Lake on the San Jacinto River close to the river entrance to Lake Elsinore. This downstream location is influenced by local urban runoff and groundwater seepage in addition to the flows from Canyon Lake.
d - This location was monitored by the U.S. Forest service from 2007-2011. Monitoring has since been discontinued.
Mgal = million gallons; 1 million gallons = 133,680 cubic feet; mg/L = milligrams per liter; kg = kilograms; USGS = United States Geological Survey.

2.2 Monitoring Strategy

Phase II of the San Jacinto River Watershed Monitoring Program follows the guidelines detailed in the Lake Elsinore and Canyon Lake Nutrient TMDL Compliance Monitoring Plan, which may be found at:

http://www.sawpa.org/wp-content/uploads/2012/05/2015_0423_HAI_LakeElsinorePhII-MonPln__F.pdf

The Phase II San Jacinto River Watershed Monitoring Program sampling activities during the 2016-2017 monitoring period included collection of samples during three storm events at the designated monitoring stations throughout the San Jacinto River Watershed.

2.3 Monitoring Stations and Stream Gauge Locations

To monitor TMDL compliance, five sampling stations were carefully selected to reflect various types of land uses within the San Jacinto River Watershed. These locations have been monitored since 2006. Sampling station locations were deliberately set up to be within the vicinity of United States Geological Survey (USGS) or the Riverside County Flood Control and Water Conservation District (RCFC&WCD) stream gauge stations. The sampling stations are listed in Table 2-2 below and shown on Figure 2-1.

Three of the five sites (Station IDs 745, 759, and 741) were selected because they are indicative of inputs to Canyon Lake originating from the main stem of the San Jacinto River, Salt Creek, and

the watershed above Mystic Lake. The sampling location along the San Jacinto River at Ramona Expressway (Station 741) is located downgradient of Mystic Lake, an area of land subsidence. Flow has not been observed at this location since a strong El Niño event in the mid-1990s. Because of the active subsidence, this monitoring station is not expected to flow except under extremely high rainfall conditions.

Table 2-2. San Jacinto River Watershed Monitoring Stations

Station ID	USGS Station ID	Agency	Site Number and Location Description
745	11070465	USGS	Site 3 - Salt Creek at Murrieta Road
759	11070365	USGS	Site 4 - San Jacinto River at Goetz Road
741	11070210	USGS	Site 6 - San Jacinto River at Ramona Expressway
841	11070500	USGS	Site 30 - Canyon Lake Spillway
792	11069500	RCFC&WCD or USGS	Site 1 - San Jacinto River at Cranston Guard Station

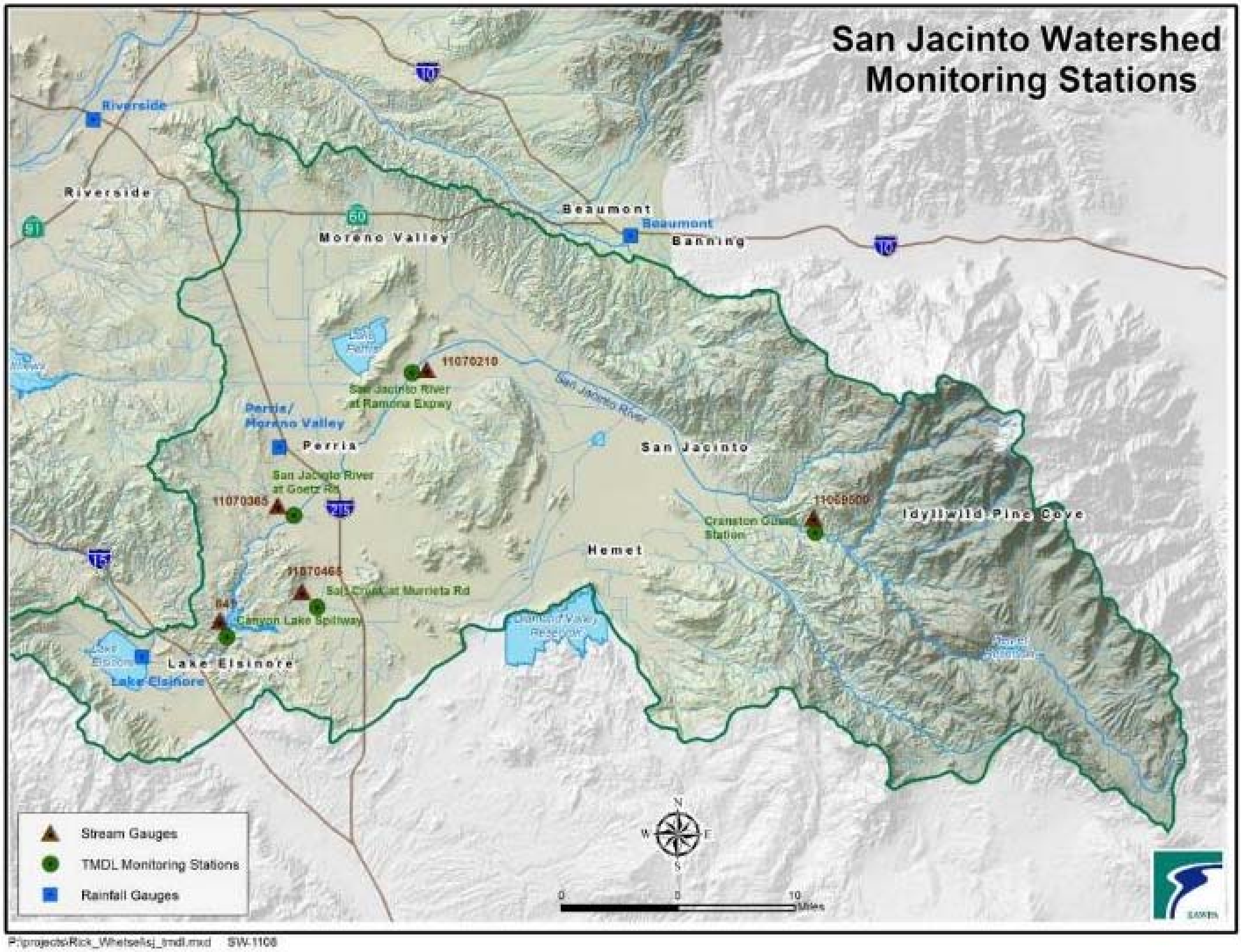


Figure 2-1. San Jacinto River Watershed Monitoring Stations

The fourth site, located below the Canyon Lake Dam (Station ID 841) is indicative of loads entering Lake Elsinore from Canyon Lake and the upstream watershed when the water level overtops the Railroad Canyon Dam Spillway. The Railroad Canyon Dam Spillway elevation at Canyon Lake is 1,381.76 feet. Samples are collected from this location during storm events that create lake levels that overtop the dam spillway elevation. The Canyon Lake level is publicly available at the following website:

http://www.evmwd.com/lakelevel/lakelevel.pdf

The fifth site at the Cranston Guard Station site on the San Jacinto River (Station 792) was only monitored between 2007 and 2011 by the San Bernardino National Forest Service (Forest Service), in accordance with their agreement for in-lieu obligations to the Task Force. This work, however, was dependent on sufficient funds being allocated by Congress to complete the work. In 2012, the Forest Service pulled out of the Task Force and no longer provides monitoring support.

2.4 Stream Gauge Records

The USGS and RCFC&WCD monitor stream flow from several gauging stations in the San Jacinto River Watershed. Stream gauging stations maintained and operated for Phase II of the San Jacinto Watershed Monitoring Program are shown in Figure 2-1 and identified in Table 2-2.

The data record captured per USGS stream gauge is publicly available at the following website:

http://waterdata.usgs.gov/ca/nwis/current/?type=flow

A summary of the stream gauge data recorded at each of the stations with measured flow for the monitoring period of July 1, 2016 through June 30, 2017 is presented in Table 2-3 and visually presented in Figure 2-2 through Figure 2-5. The mean monthly flows reported in Table 2-3 characterize the average instantaneous flow rate at the USGS station during both dry and wet weather conditions. The flow data are downloaded from the USGS website and are considered provisional for approximately six months; therefore, flow data presented after November 2, 2016, in this report are provisional. The provisional data provided by the USGS are subject to change and are not citable until reviewed and approved by the USGS. The complete set of stream gauge data is included as Appendix A.

Table 2-3. Summary of Stream Gauge Data (July 2016 through June 2017)

July 2016-June 2017 Mean Monthly Flow (cfs) [a]	Site 3 - Salt Creek at Murrieta Road (11070465)	Site 4 - San Jacinto River at Goetz Road (11070365)	Site 6 - San Jacinto River at Ramona Expressway [b] (11070210)	Site 30 - Canyon Lake Spillway (11070500)	Site 1 - San Jacinto River at Cranston Guard Station (11069500)
July	0.00	0.00	-	3.10	0.05
August	0.00	0.00	-	2.89	0.03
September	0.00	0.00	-	0.16	0.01
October	0.17	0.00	-	0.15	0.02
November	3.67	3.01	-	0.67	0.05
December	23.51	32.95	-	25.80	14.41
January	43.55	90.61	-	176.06	72.75
February	9.01	14.48	-	25.04	125.53
March	0.73	0.31	-	6.39	86.86
April	0.00	0.00	-	1.03	15.60
May	0.00	0.00	-	2.98	5.71
June	0.00	0.00	-	0.27	0.84
Mean Annual Flow (cfs)	**6.98**	**12.26**	**-**	**20.56**	**27.77**

Notes:
a - This value characterizes the average instantaneous flow rate at the USGS station during both dry and wet weather conditions in a given month. Flow data after 11/02/2016 are provisional and may be subject to change.
b - No flows were reported at Site 6 for the monitoring period.
cfs = cubic feet per second.

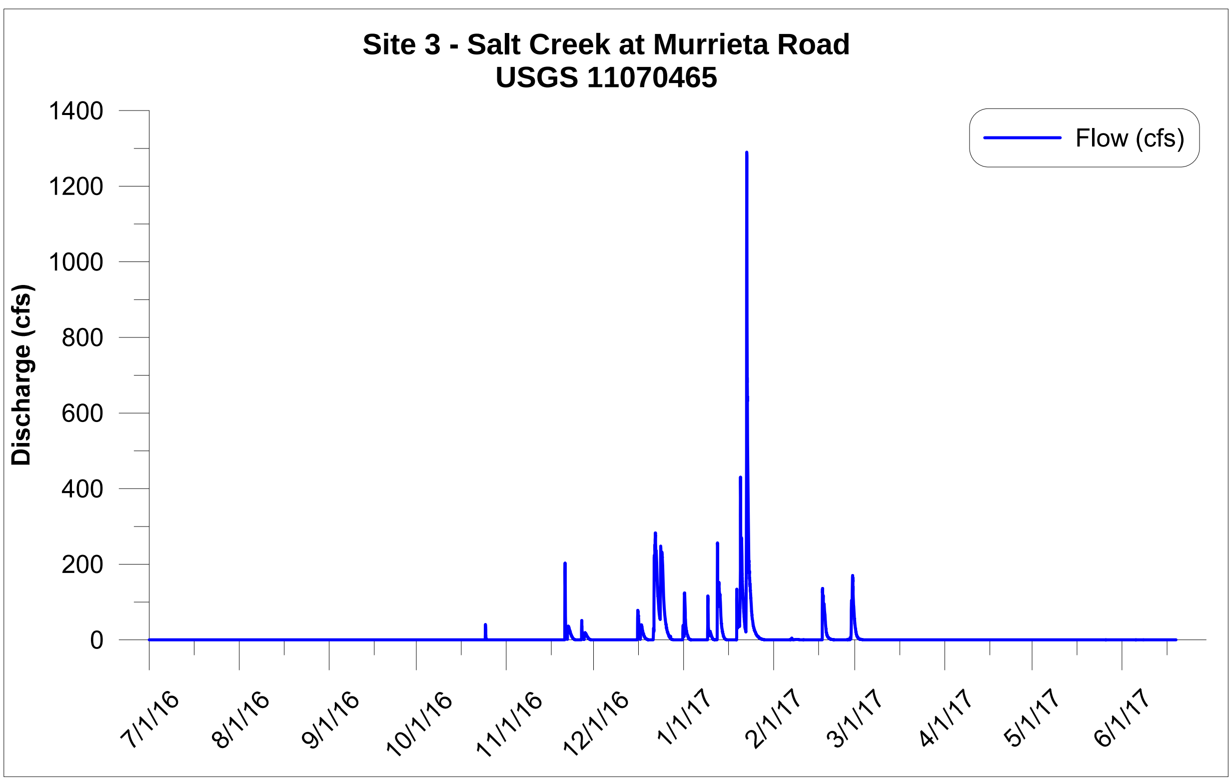


Figure 2-2. Site 3 – Salt Creek at Murrieta Road – Daily Stream Gauge Records

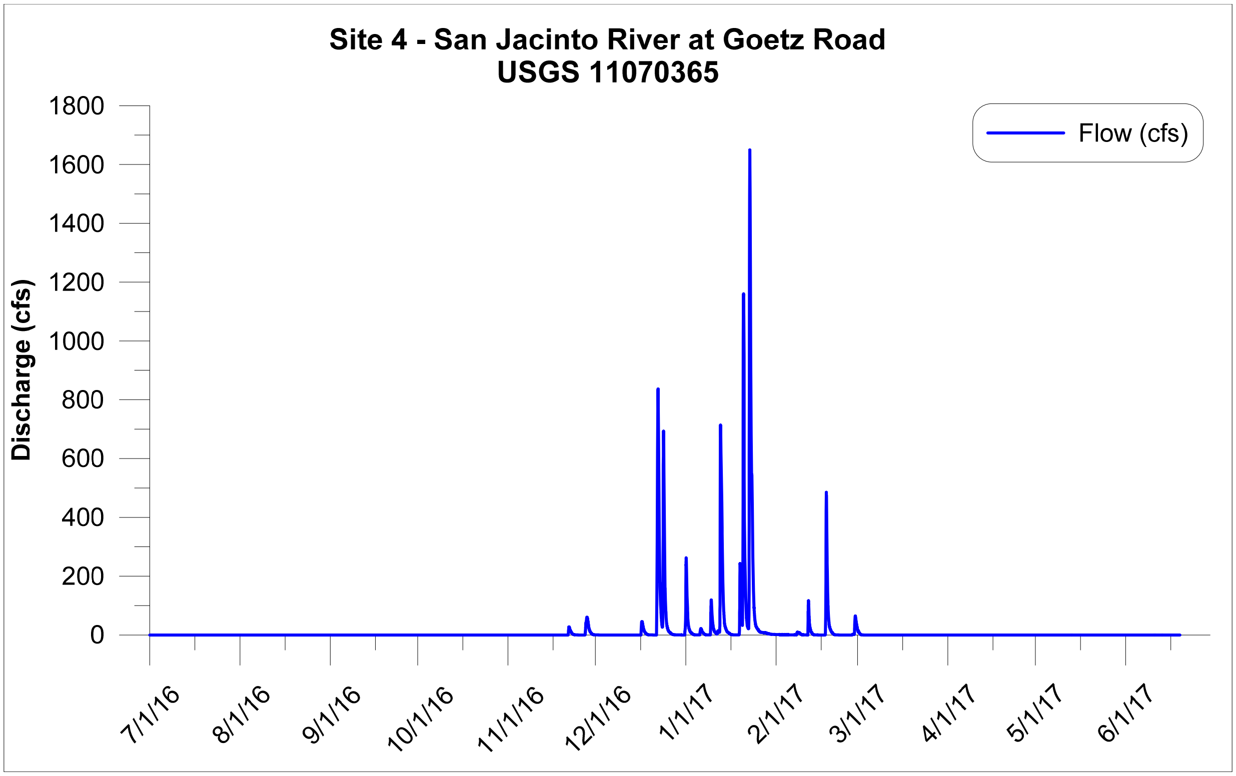


Figure 2-3. Site 4 – San Jacinto River at Goetz Road – Daily Stream Gauge Records

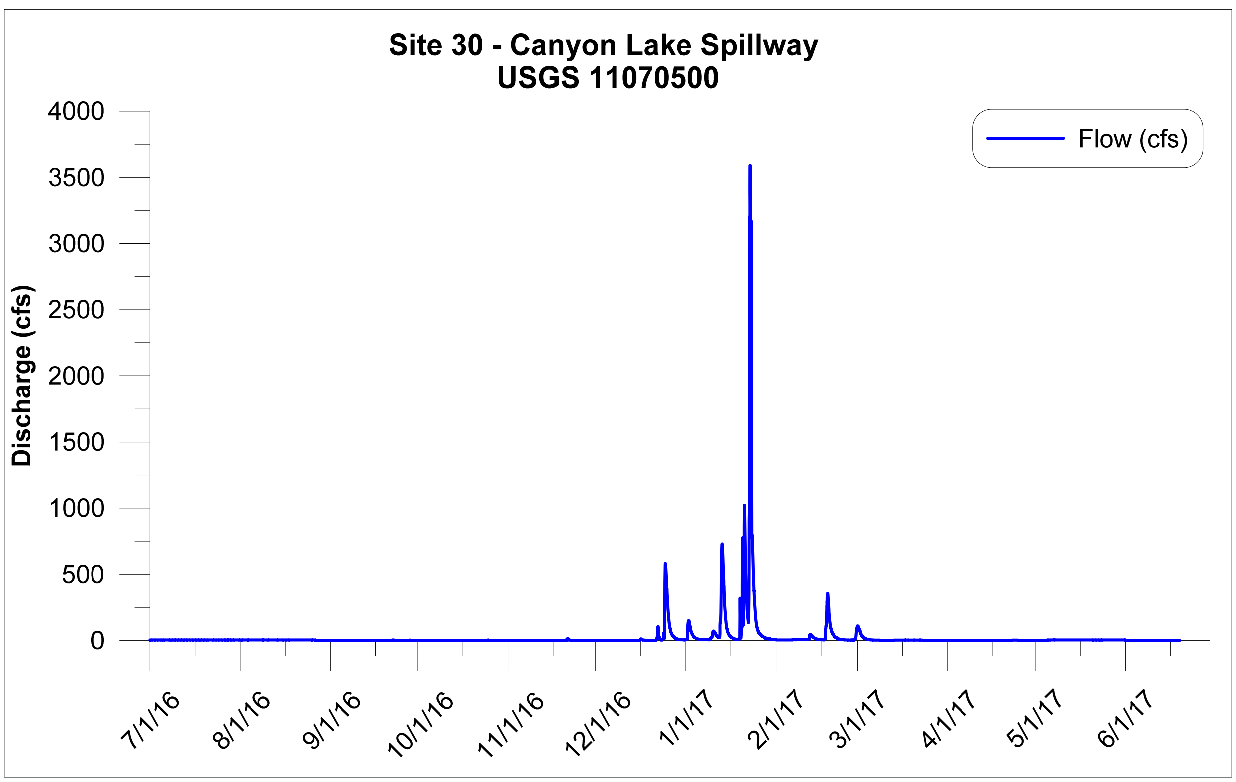


Figure 2-4. Site 30 – Canyon Lake Spillway – Daily Stream Gauge Records

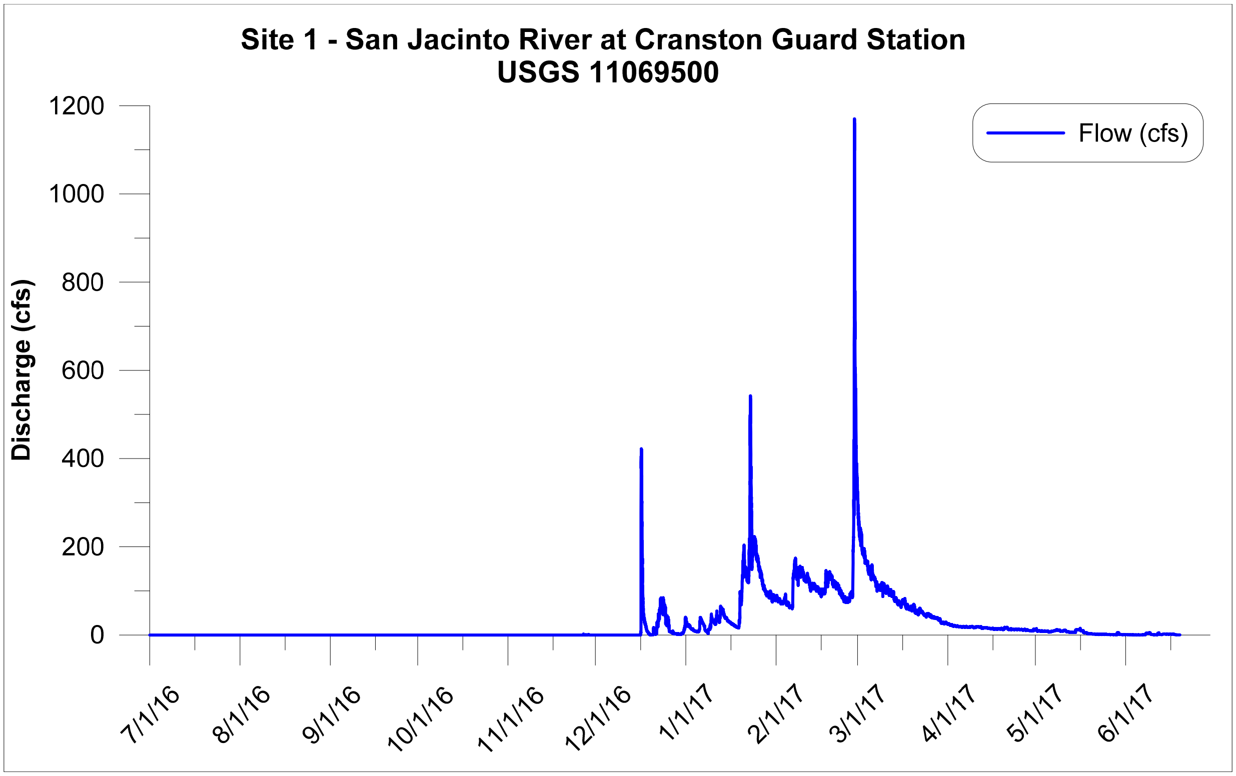


Figure 2-5. Site 1 – San Jacinto River at Cranston Guard Station – Daily Stream Gauge Records

2.5 Sampling Strategy

Phase II of the San Jacinto River Watershed Monitoring Program includes collecting water quality samples during three storm events at the designated monitoring stations throughout the San Jacinto River Watershed. Throughout the wet weather monitoring period from October 1, 2016 to April 30, 2017, the National Weather Service (NWS) forecasts were monitored to determine when storm events met the mobilization criteria. The mobilization criteria for sampling requires a NWS quantitative precipitation forecast greater than a 1.0-inch forecast within 24 hours from October 1 through December 31, and greater than an 0.5-inch forecast within 24 hours from January 1 through April 30.

Flow-weighted composite samples were collected during three storm events at the designated monitoring stations. Discrete sample aliquots were collected over the rising limb (increasing flow) and the falling limb (decreasing flow) of the hydrograph using automatic sampling equipment (e.g., ISCO autosamplers). The first sample aliquot was taken at or shortly after the time that storm water runoff began, and each subsequent aliquot of equal volume was collected at intervals of approximately 1/2 to 2 hours across the hydrograph, depending on the forecasted size of the storm event. Flow rates and volumes were based on data from USGS stream gauges located near the sampling stations. Upon completion of sampling, field teams downloaded the USGS flow data and subsampled each discrete sample to create a single flow-weighted composite sample for laboratory analysis.

The following protocols were applied:

- Sampling commenced once flow was established in the channel.
- Field measurements (temperature, pH, conductivity, dissolved oxygen, and turbidity) were recorded in the field using portable calibrated YSI multi-parameter meters, or equivalent.
- Biochemical Oxygen Demand and Chemical Oxygen Demand were analyzed for the first discrete grab sample only.

Sampling and analysis followed the guidelines detailed in the Lake Elsinore and Canyon Lake Nutrient TMDL Compliance Monitoring Plan. More detail regarding the sampling approach (e.g., compositing, sample naming conventions) are described in the Lake Elsinore and Canyon Lake Nutrient TMDL Compliance QAPP.

Samples for all analytical chemistry measurements were submitted to Babcock Laboratories Inc. located in Riverside, California.

2.6 San Jacinto Watershed Monitoring Events

Water quality samples were collected during three storm events that met the mobilization criteria during the wet weather monitoring period from October 1, 2016 to April 30, 2017.

The first monitoring event occurred on December 16, 2016 through December 18, 2016. Water quality samples were collected at Salt Creek at Murrieta Road (Station ID 745) and San Jacinto River at Goetz Road (Station ID 759). A peak flow of 78 cubic feet per second (cfs) was recorded at Salt Creek at Murrieta Road (Station ID 745) and a peak flow of 45 cfs was recorded at San Jacinto River at Goetz Road (Station ID 759). While localized flow was recorded at the USGS gauging station located downstream of the Canyon Lake Spillway (Station ID 841) site, no flows exited Canyon Lake during the monitoring event (i.e., the water level in Canyon Lake did not crest the spillway) (Appendix B). There were no flows recorded at the San Jacinto River at Ramona Expressway (Station ID 741). A total of 0.43 to 0.78 inches of rainfall was recorded in the region during this storm[3].

The second monitoring event occurred on January 19, 2017 through January 22, 2017. Water quality samples were collected at Salt Creek at Murrieta Road (Station ID 745), San Jacinto River at Goetz Road (Station ID 759), and Canyon Lake Spillway (Station ID 841). A peak flow of 430 cubic feet per second (cfs) was recorded at Salt Creek at Murrieta Road (Station ID 745) and a peak flow of 1,160 cfs was recorded at San Jacinto River at Goetz Road (Station ID 759). During the monitoring event, Canyon Lake level crested the spillway and flow discharged from Canyon Lake. A peak flow of 1,020 cubic feet per second (cfs) was recorded at the USGS gauging station located downstream of the Canyon Lake Spillway (Station ID 841) station. No flows were recorded at the San Jacinto River at Ramona Expressway (Station ID 741). A total of 1.32 to 2.08 inches of rainfall was recorded in the region during this storm[1].

The third monitoring event occurred on February 17, 2017 through February 20, 2017. Water quality samples were collected at Salt Creek at Murrieta Road (Station ID 745), San Jacinto River

[3] http://www.floodcontrol.co.riverside.ca.us/RainFallMap.aspx

at Goetz Road (Station ID 759), and Canyon Lake Spillway (Station ID 841). A peak flow of 136 cubic feet per second (cfs) was recorded at Salt Creek at Murrieta Road (Station ID 745) and a peak flow of 485 cfs was recorded at San Jacinto River at Goetz Road (Station ID 759). During the monitoring event, Canyon Lake level crested the spillway and flow discharged from Canyon Lake. A peak flow of 356 cubic feet per second (cfs) was recorded at the USGS gauging station located downstream of the Canyon Lake Spillway (Station ID 841) station. No flows were recorded at the San Jacinto River at Ramona Expressway (Station ID 741). A total of 0.97 to 1.66 inches of rainfall was recorded in the region during this storm[1].

No additional storm events met the mobilization criteria during the remainder of the wet weather monitoring period through April 30, 2016.

2.7 San Jacinto Watershed Annual Water Quality Summary

A summary of watershed water quality monitoring data for each of the five monitoring locations for the monitoring period of July 1, 2016 through June 30, 2017, is presented below. The complete set of water quality data for the monitoring period is included as Appendix A.

Included with each summary of the monitoring data are the event mean concentrations (EMC) for each analyte. Also included are the estimated storm event loads and annual loads for each analyte.

2.1.1 Summary of Monitoring Data – Salt Creek at Murrieta Road

Water quality samples were collected during three storm events at Salt Creek at Murrieta Road (Station ID 745) during the wet weather monitoring period from October 1, 2016 to April 30, 2017.

During the first storm event on December 16, 2016 through December 18, 2016, a total of 53 discrete samples were collected across the hydrograph at one-hour intervals and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070465), flow for the storm event was estimated at 6,057,414 cubic feet (cf) or 45 million gallons (Mgal).

During the second storm event on January 19, 2017 through January 22, 2017, a total of 52 discrete samples were collected across the hydrograph at one-hour intervals for the first 28 discrete samples and at two-hour intervals for the final 24 discrete samples and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070465), flow for the storm event was estimated at 29,740,797 cf or 223 Mgal.

During the third event on February 17, 2017 through February 20, 2017, a total of 41 discrete samples were collected across the hydrograph at one-hour intervals for the first 19 discrete samples and at two-hour intervals for the final 22 discrete samples and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070465), flow for the storm event was estimated at 10,485,387 cf or 78 Mgal.

Photos taken during the storm events are provided in Figure 2-6, Figure 2-7, and Figure 2-8.

Figure 2-6. Storm Event at Salt Creek at Murrieta Road (January 19-22, 2017)

Figure 2-7. Storm Event at Salt Creek at Murrieta Road (January 19-22, 2017)

Figure 2-8. Storm Event at Salt Creek at Murrieta Road (February 17-20, 2017)

Event and annual mean EMCs for each analyte are presented in Table 2-4. Event and annual loads for each analyte are presented in Table 2-5. EMCs for nutrients for the three storm events range from 1.9 to 2.3 milligrams per liter (mg/L) for total nitrogen, and 0.32 to 1.10 mg/L for total phosphorus (Table 2-4). Based on flow data provided by the nearby USGS stream gauge (Station ID 11070465), the total annual flow was estimated at 231,354,279 cf or 1,596 Mgal for the period of July 1, 2016 through June 30, 2017. No dry weather flows enter Canyon Lake from Salt Creek at Murrieta Road (Station ID 745) and the storm flows account for the estimated annual load of nutrients. The estimated annual nutrient load was calculated to be 12,366 kg for total nitrogen and 4,026 kg for total phosphorus (Table 2-5) for the period of July 1, 2016 through June 30, 2017.

Table 2-4. Water Quality EMCs at Salt Creek at Murrieta Road

Analyte	Units	EMC Event 1	EMC Event 2	EMC Event 3	Mean EMC	Geomean EMC
Ammonia-Nitrogen	mg/L	0.220	0.067	0.086	0.120	0.108
Chemical Oxygen Demand	mg/L	47	22	81	50	44
Kjeldahl Nitrogen	mg/L	1.8	1.4	1.6	1.6	1.6
Nitrate as N	mg/L	0.56	0.61	0.42	0.53	0.52
Nitrite as N	mg/L	0.021	0.021	0.021	0.021	0.021
Organic Nitrogen*	mg/L	1.6	1.2	1.5	1.4	1.4
Total Nitrogen	mg/L	2.3	1.9	2.0	2.1	2.1
Total Phosphorus	mg/L	0.32	1.10	0.43	0.62	0.53
Ortho Phosphate Phosphorus	mg/L	0.12	0.33	0.25	0.23	0.21
Total Dissolved Solids	mg/L	520	240	280	346	327
Total Hardness	mg/L	260	140	140	180	172
Total Suspended Solids	mg/L	24	120	53	66	53

Table 2-5. Water Quality Event and Annual Loads at Salt Creek at Murrieta Road

Analyte	Units	Load Event 1	Load Event 2	Load Event 3	Annual Load
Ammonia-Nitrogen	kg	38	56	26	708
Chemical Oxygen Demand	kg	8,062	18,528	24,050	287,185
Kjeldahl Nitrogen	kg	309	1,179	475	9,532
Nitrate as N	kg	96	514	125	3,242
Nitrite as N	kg	3.6	18	6	127
Organic Nitrogen	kg	274	1,011	445	8,511
Total Nitrogen	kg	395	1,600	594	12,366
Total Phosphorus	kg	55	926	128	4,026
Ortho Phosphate Phosphorus	kg	21	278	74	1,477
Total Dissolved Solids	kg	89,194	202,120	83,136	2,014,500
Total Hardness	kg	44,597	117,903	41,568	1,055,633
Total Suspended Solids	kg	4,117	101,060	15,736	431,576

Hydrographs with flow-weighted sample aliquot times are provided in Figure 2-9, Figure 2-10, and Figure 2-11. The figures were developed based on flow data provided by the nearby USGS stream gauge (Station ID 11070465).

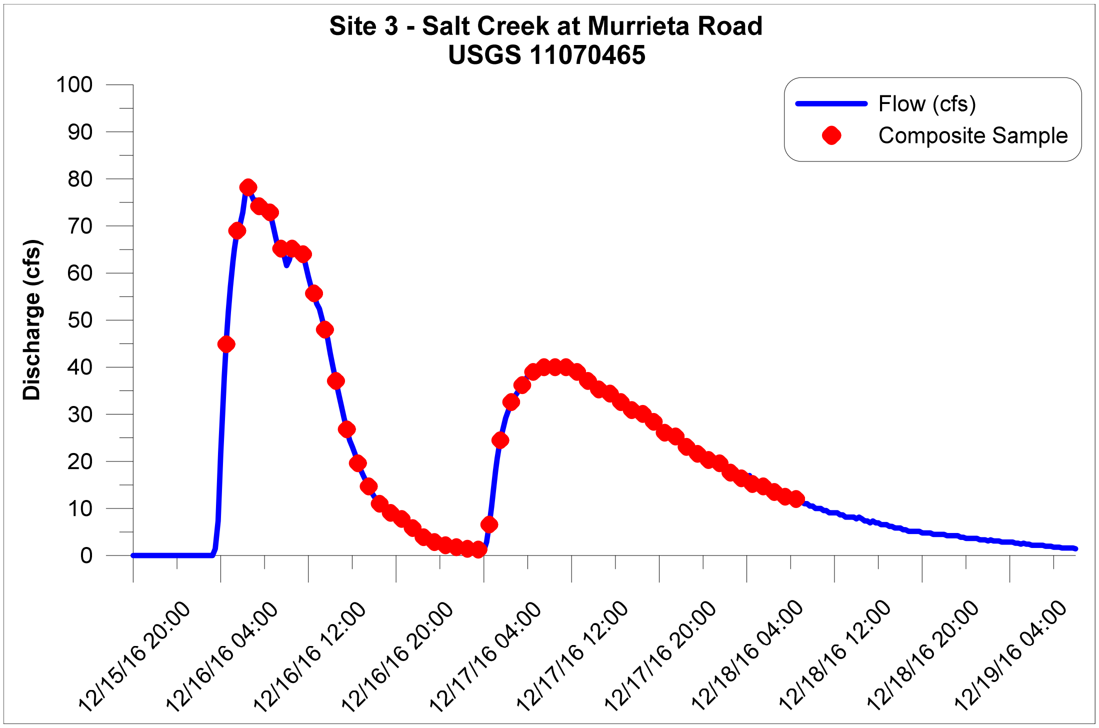


Figure 2-9. Hydrograph of First Storm Event at Salt Creek at Murrieta Road (December 16-18, 2016)

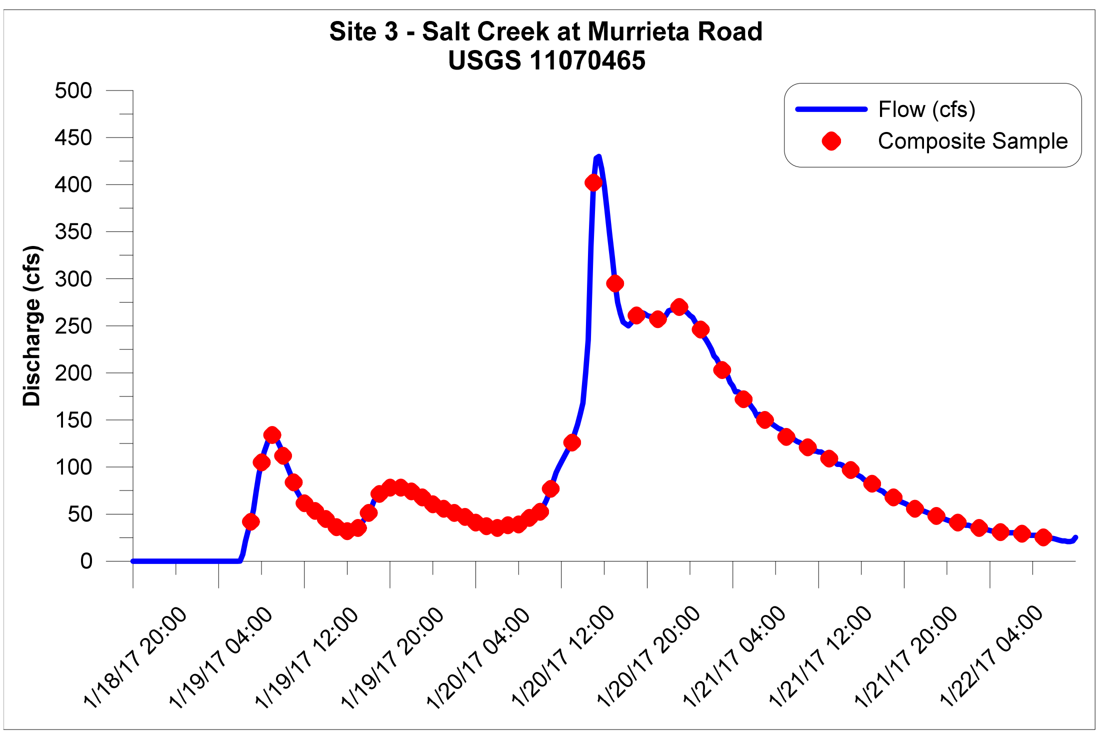


Figure 2-10. Hydrograph of Second Storm Event at Salt Creek at Murrieta Road (January 19-22, 2017)

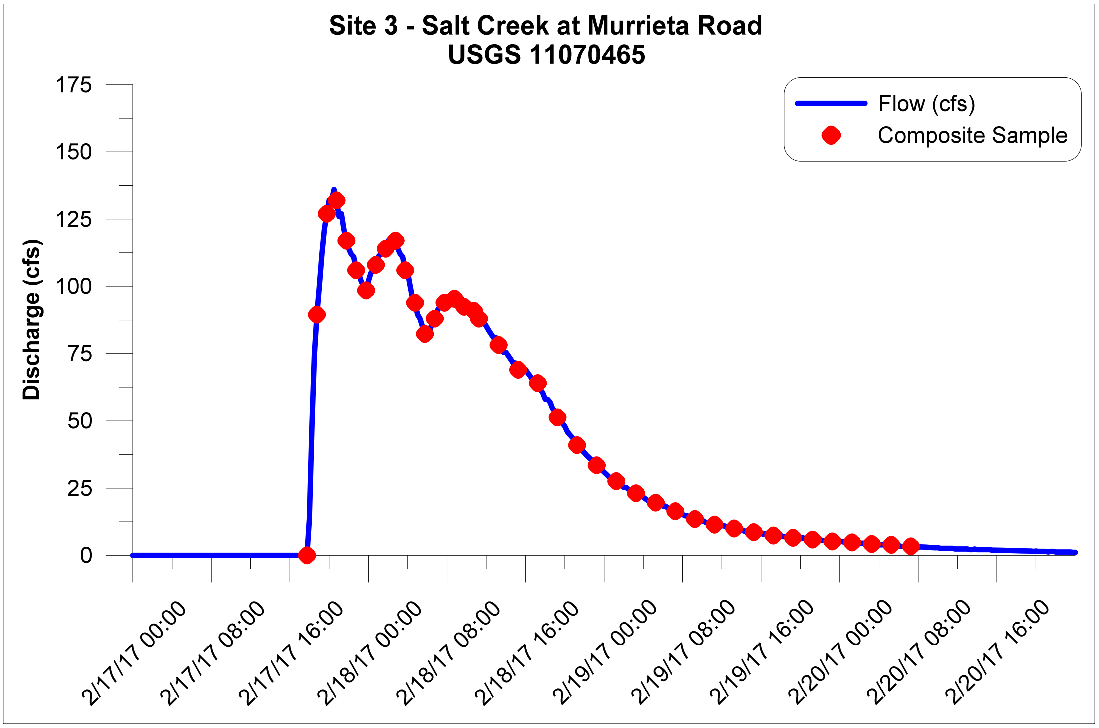


Figure 2-11. Hydrograph of Third Storm Event at Salt Creek at Murrieta Road (February 17-20, 2017)

2.1.2 Summary of Monitoring Data – San Jacinto River at Goetz Road

Water quality samples were collected during three storm events at San Jacinto River at Goetz Road (Station ID 759) during the wet weather monitoring period from October 1, 2016 to April 30, 2017.

During the first storm event on December 16, 2016 through December 18, 2016, a total of 44 discrete samples were collected across the hydrograph at one-hour intervals and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070365), flow for the storm event was estimated at 3,646,035 cf or 27 Mgal.

During the second storm event on January 19, 2017 through January 22, 2017, a total of 50 discrete samples were collected across the hydrograph at one-hour intervals for the first 25 discrete samples and at two-hour intervals for the final 25 discrete samples and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070365), flow for the storm event was estimated at 62,651,799 cf or 469 Mgal.

During the third event on February 17, 2017 through February 20, 2017, a total of 39 discrete samples were collected across the hydrograph at one-hour intervals for the first 17 discrete samples and at two-hour intervals for the final 22 discrete samples and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS

stream gauge (Station ID 11070365), flow for the storm event was estimated at 24,507,180 cf or 183 Mgal.

Photos taken during the storm events are provided in Figure 2-12, Figure 2-13 and Figure 2-14.

Figure 2-12. Storm Event at San Jacinto River at Goetz Road (December 16-18, 2016)

Figure 2-13. Storm Event at San Jacinto River at Goetz Road (January 19-22, 2017)

Figure 2-14. Storm Event at San Jacinto River at Goetz Road (February 17-20, 2017)

Data for the EMCs of each analyte are presented in Table 2-6. Event and annual loads for each analyte are presented in Table 2-7. The EMC for nutrients for the storm event was 2.0 mg/L for total nitrogen, and 1.23 mg/L for total phosphorus (Table 2-6). Based on flow data provided by the nearby USGS stream gauge (Station ID 11070365), the total annual flow was estimated at 374,618,682 cf or 2,802 Mgal for the period of July 1, 2016 through June 30, 2017. No dry weather flows enter Canyon Lake from San Jacinto River at Goetz Road (Station ID 759) and the storm flows account for the estimated annual load of nutrients. The estimated annual nutrient load was calculated to be 21,651 kg for total nitrogen and 14,403 kg for total phosphorus (Table 2-7) for the period of July 1, 2016 through June 30, 2017.

Table 2-6. Water Quality EMCs at San Jacinto River at Goetz Road

Analyte	Units	EMC Event 1	EMC Event 2	EMC Event 3	Mean EMC	Geomean EMC
Ammonia-Nitrogen	mg/L	0.084	0.085	0.078	0.080	0.082
Chemical Oxygen Demand	mg/L	70	88	140	99	95
Kjeldahl Nitrogen	mg/L	1.4	1.5	1.1	1.3	1.3
Nitrate as N	mg/L	0.76	0.65	0.57	0.66	0.66
Nitrite as N	mg/L	0.060	0.021	0.021	0.030	0.030
Organic Nitrogen*	mg/L	1.3	1.4	1.6	1.4	1.4
Total Nitrogen	mg/L	2.2	2.2	1.7	2.0	2.0
Total Phosphorus	mg/L	0.71	2.20	0.78	1.23	1.07
Ortho Phosphate Phosphorus	mg/L	0.19	0.36	0.22	0.26	0.25
Total Dissolved Solids	mg/L	200	190	120	170	166
Total Hardness	mg/L	92	110	72	91	90
Total Suspended Solids	mg/L	180	410	230	273	257

Table 2-7. Water Quality Event and Annual Loads at San Jacinto River at Goetz Road

Analyte	Units	Load Event 1	Load Event 2	Load Event 3	Annual Load
Ammonia-Nitrogen	kg	9	151	54	875
Chemical Oxygen Demand	kg	7,227	156,121	97,155	1,058,816
Kjeldahl Nitrogen	kg	145	2,661	763	14,285
Nitrate as N	kg	78	1,153	396	6,931
Nitrite as N	kg	6	37	15	331
Organic Nitrogen	kg	134	2,484	1,110	15,248
Total Nitrogen	kg	227	3,903	1,180	21,651
Total Phosphorus	kg	73	3,903	541	14,403
Ortho Phosphate Phosphorus	kg	20	639	153	2,874
Total Dissolved Solids	kg	20,649	337,079	83,276	1,807,244
Total Hardness	kg	9,498	195,151	49,966	988,635
Total Suspended Solids	kg	18,584	727,382	159,612	3,102,278

Hydrographs with flow-weighted sample aliquot times is provided in Figure 2-15, Figure 2-16, and Figure 2-17. The figure was developed based on flow data provided by the nearby USGS stream gauge (Station ID 11070365).

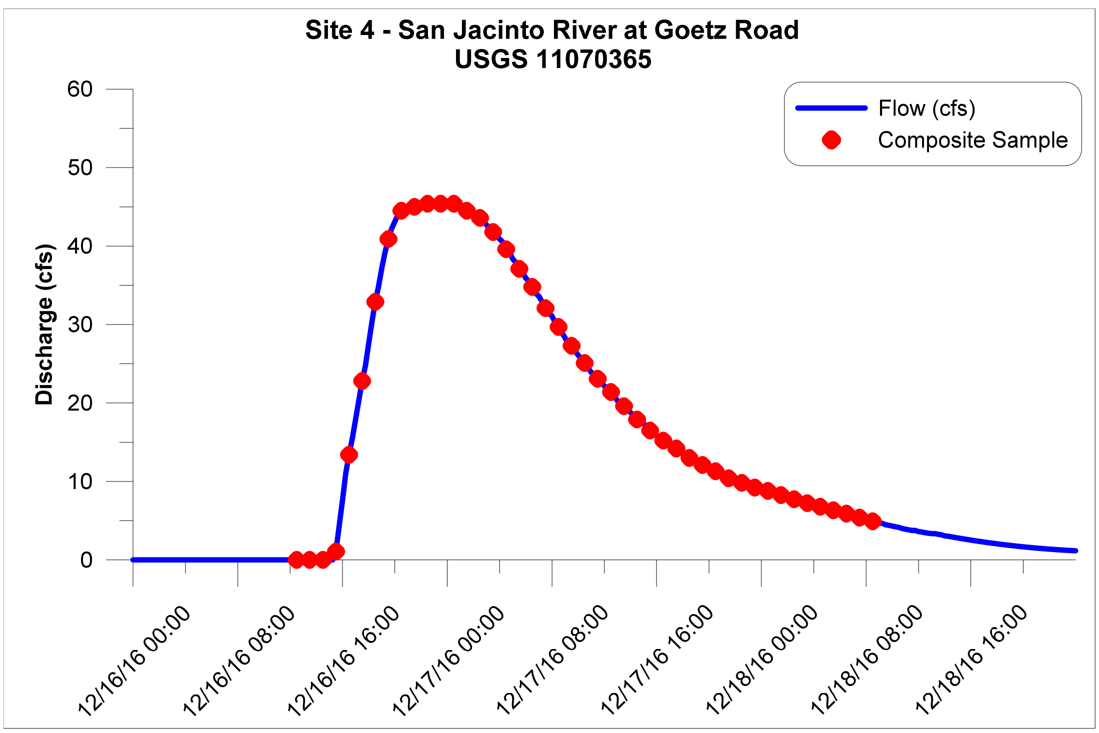


Figure 2-15. Hydrograph of First Storm Event at San Jacinto River at Goetz Road (December 16-18, 2016)

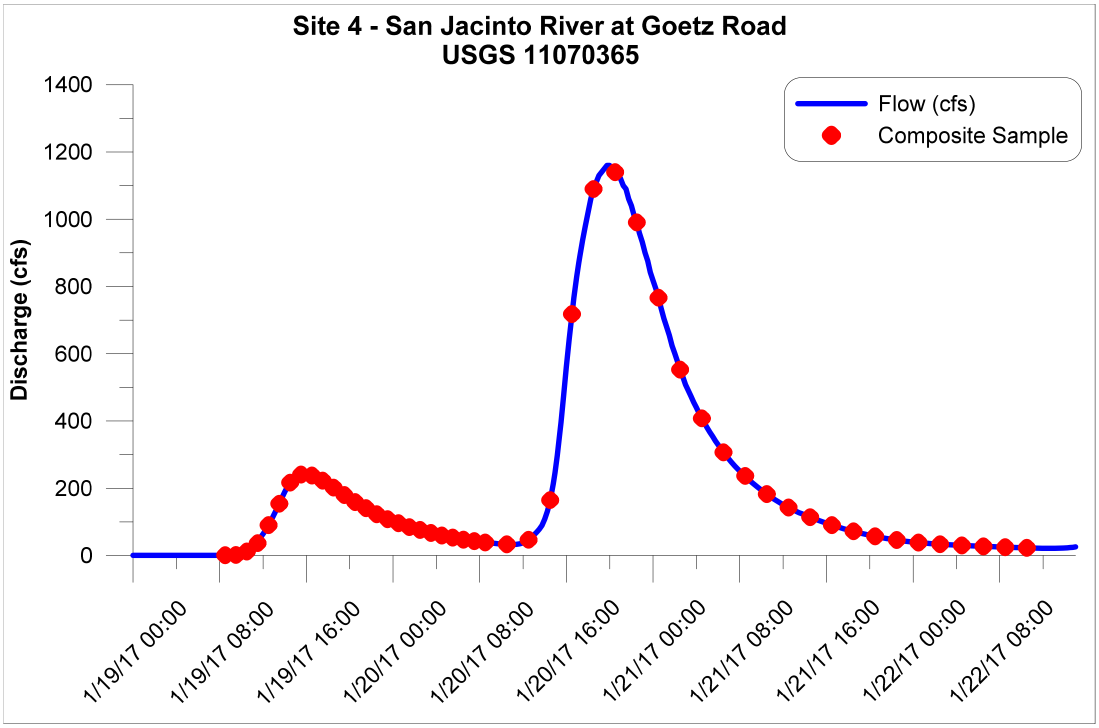


Figure 2-16. Hydrograph of Second Storm Event at San Jacinto River at Goetz Road (January 19-22, 2017)

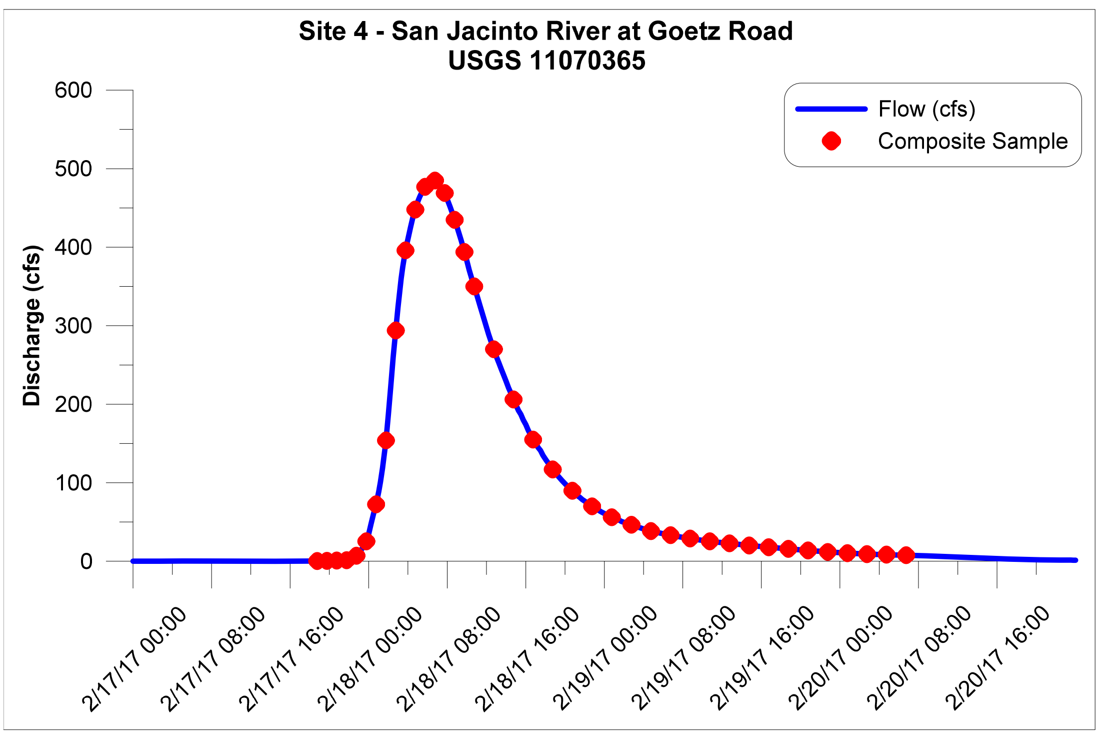


Figure 2-17. Hydrograph of Third Storm Event at San Jacinto River at Goetz Road (February 17-20, 2017)

2.1.3 Summary of Monitoring Data – San Jacinto River at Ramona Expressway

Mystic Lake did not overflow during the wet weather monitoring period from October 1, 2016 to April 30, 2017. Therefore, no samples were collected from the sampling station at San Jacinto River at Ramona Expressway (Station ID 741) during the 2016-2017 monitoring year.

2.1.4 Summary of Monitoring Data – Cranston Guard Station

The Cranston Guard Station site on the San Jacinto River was only monitored between 2007 and 2011 by the Forest Service. This work, however, was dependent on sufficient funds being allocated by Congress to complete the work. In 2012, the Forest Service pulled out of the Task Force and no longer provides monitoring. Thus, no samples were collected during the 2016-2017 monitoring year.

2.1.5 Summary of Monitoring Data – Canyon Lake Spillway

Water quality samples were collected during two storm events at Canyon Lake Spillway (Station ID 841) during the wet weather monitoring period from October 1, 2016 to April 30, 2017.

During the first storm event on December 16, 2016 through December 18, 2016 conducted at Salt Creek at Murrieta Road (Station ID 745) and San Jacinto River at Goetz Road (Station ID 759), Canyon Lake Dam did not overflow and no samples were collected at Canyon Lake Spillway (Station ID 841).

During the second storm event on January 19, 2017 through January 22, 2017, a total of 49 discrete samples were collected across the hydrograph at one-hour intervals for the first 25 discrete samples and at two-hour intervals for the final 24 discrete samples and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070500), flow for the storm event was estimated at 90,511,326 cf or 677 Mgal.

During the third event on February 17, 2017 through February 20, 2017, a total of 35 discrete samples were collected across the hydrograph at one-hour intervals for the first 11 discrete samples and at two-hour intervals for the final 24 discrete samples and a single flow-weighted composite sample was submitted for analysis. Based on data provided by the nearby USGS stream gauge (Station ID 11070500), flow for the storm event was estimated at 42,215,643 cf or 316 Mgal.

Photos taken during the storm events are provided in Figure 2-18 and Figure 2-19.

Figure 2-18. Storm Event at Canyon Lake Spillway (January 19-22, 2017)

Figure 2-19. Storm Event at Canyon Lake Spillway (February 17-20, 2017)

Data for the EMCs of each analyte are presented in Table 2-8. Event and annual loads for each analyte are presented in

Table 2-9. The EMC for nutrients for the storm event was 1.85 mg/L for total nitrogen, and 0.36 mg/L for total phosphorus (Table 2-8). Based on flow data provided by the nearby USGS stream gauge (Station ID 11070365), the total annual flow was estimated at 648,340,497 cf or 4,850 Mgal for the period of July 1, 2016 through June 30, 2017. The USGS stream gauge (Station ID 11070365) located downstream of the Canyon Lake Spillway (Station ID 841) sampling location

has minimal dry weather flow and storm flows account for the vast majority of the estimated annual load of nutrients exiting Canyon Lake.The estimated annual nutrient load was calculated to be 33,759 kg for total nitrogen and 6,637 kg for total phosphorus (

Table 2-9) for the period of July 1, 2016 through June 30, 2017.

Table 2-8. Water Quality EMCs at Canyon Lake Spillway

Analyte	Units	EMC Event 1	EMC Event 2	Mean EMC
Ammonia-Nitrogen	mg/L	0.060	0.053	0.057
Chemical Oxygen Demand	mg/L	17	24	21
Kjeldahl Nitrogen	mg/L	1.10	0.95	1.03
Nitrate as N	mg/L	0.66	1.00	0.83
Nitrite as N	mg/L	0.021	0.021	0.021
Organic Nitrogen*	mg/L	1.0	0.9	0.95
Total Nitrogen	mg/L	1.7	2.0	1.85
Total Phosphorus	mg/L	0.38	0.34	0.36
Ortho Phosphate Phosphorus	mg/L	0.13	0.23	0.18
Total Dissolved Solids	mg/L	510	320	415
Total Hardness	mg/L	260	150	205
Total Suspended Solids	mg/L	47	22	34

Table 2-9. Water Quality Event and Annual Loads at Canyon Lake Spillway

Analyte	Units	Load Event 1	Load Event 2	Annual Load
Ammonia-Nitrogen	kg	154	63.4	1,042
Chemical Oxygen Demand	kg	43,571	28,690	371,572
Kjeldahl Nitrogen	kg	2,819	1,136	18,921
Nitrate as N	kg	1,692	1,195	15,005
Nitrite as N	kg	54	25	386
Organic Nitrogen	kg	2,563	1,076	17,509
Total Nitrogen	kg	4,357	2,391	33,759
Total Phosphorus	kg	974	406	6,637
Ortho Phosphate Phosphorus	kg	333	2745	3,236
Total Dissolved Solids	kg	1,307,128	382,532	7,748,888
Total Hardness	kg	666,379	179,312	3,838,803
Total Suspended Solids	kg	120,461	26,299	650,479

Hydrographs with flow-weighted sample aliquot times is provided in Figure 2-20 and Figure 2-21. The figure was developed based on flow data provided by the nearby USGS stream gauge

(Station ID 11070365). A hydrograph of the Canyon Lake Level at Railroad Canyon Dam Spillway compared to the spillway elevation is provided in Figure 2-22.

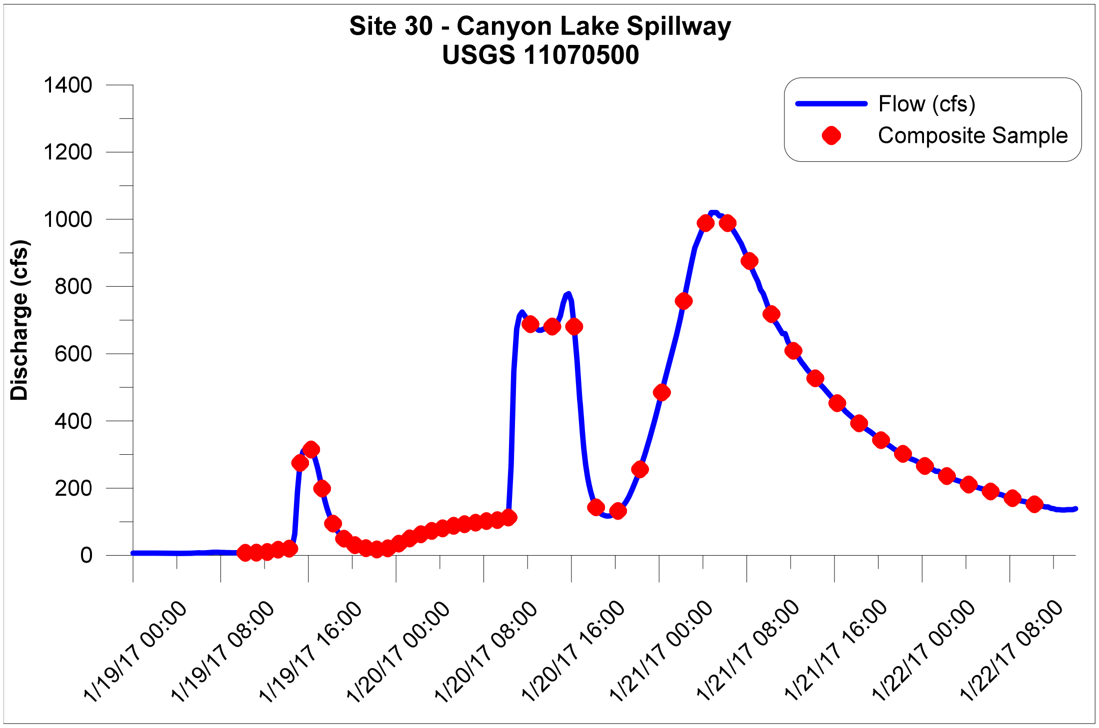


Figure 2-20. Hydrograph of First Storm Event at Canyon Lake Spillway (January 19-22, 2017)

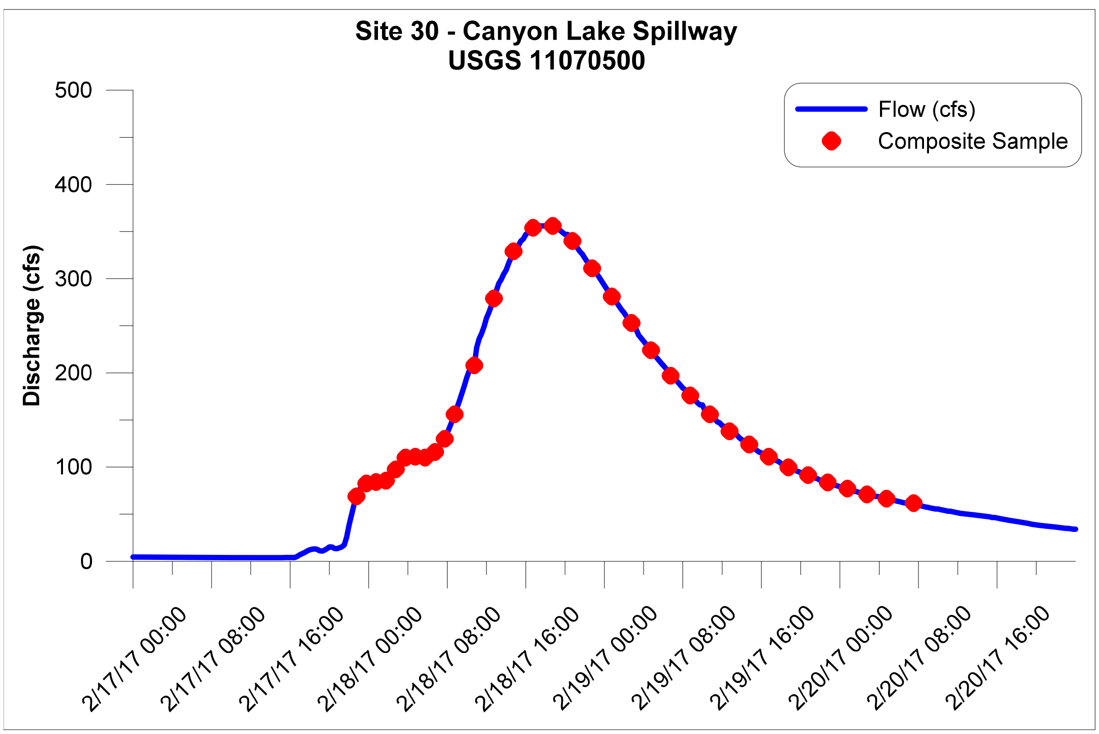


Figure 2-21. Hydrograph of Second Storm Event at Canyon Lake Spillway (February 17-20, 2017)

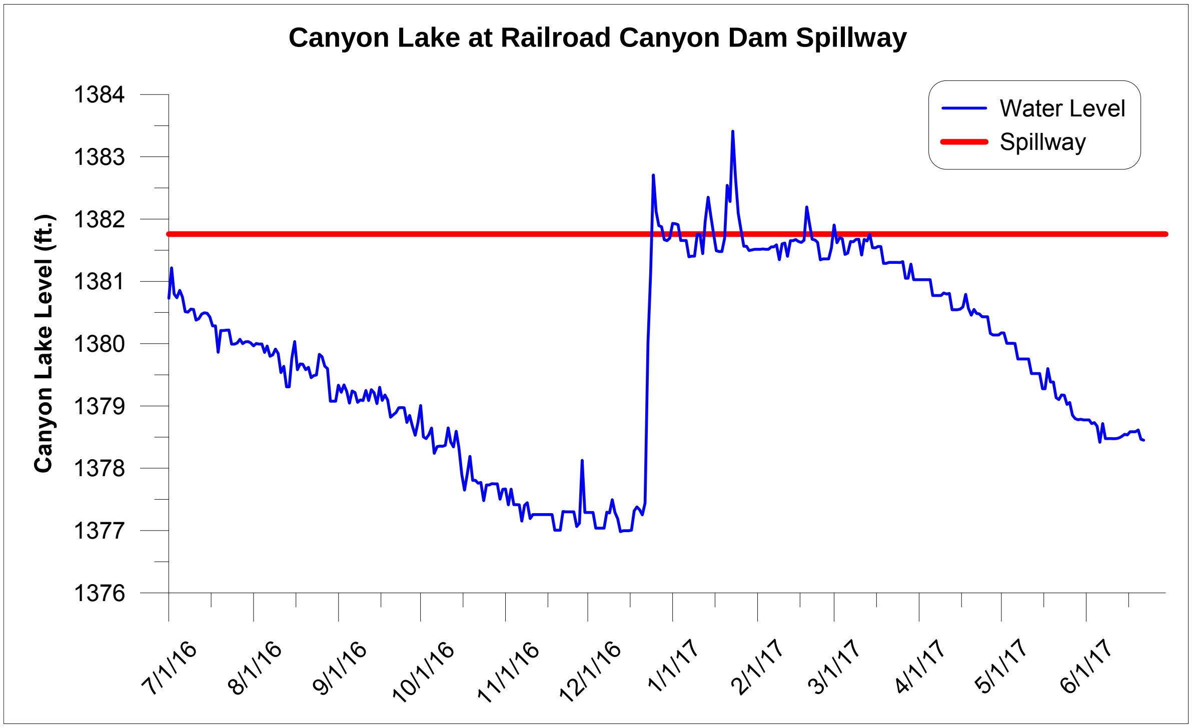


Figure 2-22. Canyon Lake Level at Railroad Canyon Dam Spillway

2.8 San Jacinto Watershed Rainfall Records

The RCFC&WCD maintains rainfall records for rain gauges located within or near the San Jacinto Watershed as shown in Table 2-10.

Table 2-10. San Jacinto River Watershed Rainfall Gauges

Station ID	Station Description	Latitude	Longitude	Elevation (ft.)
67	Lake Elsinore	33.668712	-117.332380	1281
152	Perris	33.786980	-117.231831	1494
155	Perris / Moreno Valley – Pigeon Pass	33.987703	-117.270221	1902
186	Hemet / San Jacinto	33.787067	-116.959024	1554
248	Winchester	33.702903	-117.090382	1466

Rainfall data recorded at these five stations for the period July 1, 2016, through June 30, 2017, are summarized in Table 2-11. The complete set of rainfall gauge data is included as Appendix A.

Table 2-11. Summary Rainfall Data (July 2016 to June 2017)

Monthly Rainfall (inches)	Lake Elsinore	Perris CDF	Pigeon Pass	Hemet / San Jacinto	Winchester
Jul	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00
Sep	0.08	0.08	0.00	0.16	0.12
Oct	0.24	0.35	0.78	0.34	0.28
Nov	0.98	0.90	1.35	1.09	1.03
Dec	3.60	3.21	3.94	3.20	3.17
Jan	6.68	6.04	6.78	6.23	4.86
Feb	3.02	2.06	2.61	2.86	2.31
Mar	0.03	0.02	0.16	0.21	0.06
Apr	0.02	0.00	0.02	0.00	0.00
May	0.27	0.06	0.26	0.25	0.08
Jun	0.00	0.00	0.00	0.00	0.02
Annual Rainfall (Inches)	**14.92**	**12.72**	**15.90**	**14.34**	**11.93**

3.0 In-Lake Monitoring

3.1 Background

Routine in-lake monitoring was initiated in 2006 by local stakeholders in cooperation with the RWQCB at three open water locations in Lake Elsinore and four locations in Canyon Lake. Monitoring consisted of monthly sampling October to May, and biweekly sampling June to September, with grab samples collected at the surface, within the water column, and/or as depth-integrated samples (depending on the lake and the analyte). Based on modifications adopted to the sampling program (Regional Board Resolution No. R8-2011-0023), in 2011-2012 sampling locations in Lake Elsinore and Canyon Lake were reduced to one and three stations, respectively for analytical chemistry. This decision was based ona review of available data that indicated consistent similar nutrient concentrations and physical water quality parameters among the three sampling sites in Lake Elsinore and two sites in the eastern arm of Canyon Lake. This saving also shifted resources toward a number of implementation strategies aimed at reducing nutrient impacts in both lakes as described in RWQCB Resolution No. R8-2011-0023. All in-lake monitoring was then suspended temporarily during the 2013-2014 and 2014-2015 FYs to further redirect additional resources toward implementing in-lake best management practices. However, ongoing in-lake sampling has resumed and is required to estimate progress toward attaining nutrient TMDL targets and calculating annual and 10-year running averages. The following sections describe monitoring methods and results in both lakes for the 2016-2017 FY.

3.2 Lake Elsinore Monitoring

3.2.1 Sampling Station Locations and Frequency

In order to maintain consistency and facilitate the assessment of trends toward meeting compliance goals, the in-lake monitoring design halted in 2012 (LESJWA, 2012) was resumed using the three former stations outlined in the approved Lake Elsinore and Canyon Lake Nutrient TMDL Monitoring Plan (LESJWA, 2006; Figure 3-1, Table 3-1). Analytical chemistry samples and in-situ water quality profile readings were collected at Site LE02 (Figure 3-1), while only in-situ water quality profile readings were performed at the remaining two stations (LE01 and LE03, Figure 3-1). Water chemistry samples collected at Site LE02 were analyzed for those constituents outlined in Table 3-2. Sampling in Lake Elsinore was conducted monthly during summer months (June-September) and bi-monthly (i.e. every other month) for the remainder of the year. In-lake sampling dates were coordinated to correspond with LandSat satellite overpass dates to facilitate the comparison of in-lake and satellite derived chlorophyll-a data (see Section 3.4).

In addition to the routine water chemistry samples, collection of samples for analysis of cyanobacteria toxins (cyanotoxin) was initiated in June 2017 at the request of the TMDL Task Force. The cyanotoxin analysis is not required by the current TMDL and there are currently no formally adopted thresholds for cyanotoxin concentrations, so concentrations were compared against proposed trigger levels. These samples were collected at the same central location (LE02) and in the same manner as analytical chemistry samples. Specific cyanotoxins analyzed are outlined in Table 3-2, and proposed trigger levels are shown in Table 3-8.

Figure 3-1. Lake Elsinore Sampling Locations

Table 3-1. Lake Elsinore Sampling Station Locations

Site	Latitude	Longitude
LE01	33.668978°	-117.364185°
LE02	33.663344°	-117.354213°
LE03	33.654939°	-117.341653°

Table 3-2. Lake Elsinore In-lake Analytical Constituents and Methods

Parameter	Analysis Method	Sampling Method
Analytical Chemistry		
Nitrite Nitrogen (NO_2-N)	SM4500-NO2 B	Depth Integrated
Nitrate Nitrogen (NO_3-N)	EPA 300.0	Depth Integrated
Total Kjeldahl Nitrogen (TKN)	EPA 351.3	Depth Integrated
Ammonia Nitrogen (NH4-N)	SM4500-NH_3 H	Depth Integrated
Sulfide	SM 4500S2 D	Depth Integrated
Total Phosphorus (TP)	SM4500-P E & EPA 365.1[1]	Depth Integrated
Soluble Reactive Phosphorus (SRP / Ortho-P)	SM4500-P E	Depth Integrated
Chlorophyll-a	SM 10200H	Surface & Depth Integrated
Total Dissolved Solids (TDS)	SM 2540 C	Depth Integrated
Cyanobacteria Toxins		
Microcystin	LC-MS/MS	Surface & Depth Integrated
Cylindrospermopsin	LC-MS/MS	Surface & Depth Integrated
Anatoxin-a	LC-MS/MS	Surface & Depth Integrated
Nodularin	LC-MS/MS	Surface & Depth Integrated

[1] The total phosphorus analysis method was switched to low level segmented flow analysis (EPA 365.1) during the final sampling event in June 2017. This method will be used for all future total phosphorus analyses.

3.2.2 Sampling Methods

Depth-integrated composite samples for analytical chemistry were collected at Site LE02 by utilizing a peristaltic pump and lowering/raising an inlet tube through the water column at a uniform speed, creating a composite sample of the entire water column at each station. Two discrete samples were collected for chlorophyll-a: 1) a full depth-integrated composite sample as described above; and 2) a 0-2-meter (m) depth-integrated composite surface sample. Cyanotoxin samples were collected as a full depth-integrated composite and a surface grab. All samples for chemical analysis were placed and held on wet ice immediately following collection, and

transferred to a local courier or shipping company on the same day of collection. Samples for analysis of nutrients, sulfide, TDS, and chlorophyll-a were submitted to Babcock Laboratories Inc. located in Riverside, California. For the June 2017 samples, low level total phosphorus samples were submitted to Babcock Laboratories Inc., and then subbed out to Eurofins CalScience, Inc. for analysis. Samples for analysis of cyanotoxins were shipped via overnight delivery to the Ocean Sciences Kudela Laboratory at the University of California, Santa Cruz.

In-situ water column profile data was recorded in the morning at all three Lake Elsinore stations using pre-calibrated hand-held YSI field meters or equivalent for pH, temperature, DO, and specific conductivity at 1-m intervals throughout the water column. These data were used to assess lateral and vertical spatial variability within the lake. End-of-the-day water column profiles (i.e. after ~2:30pm) were also recorded for the same suite of parameters at all three stations to assess any potential temporal variability in these parameters over the course of a day. Water clarity was also assessed with a Secchi disk at all three stations.

In addition to the water column data collected at each site, 1-m incremental water column measurements of pH, temperature, DO, and specific conductivity were recorded alongside each of the two currently installed automated data sondes near the center of the lake (Lakeshore and Grand Avenue Sondes). Surface and bottom readings were also performed along a transect at 500m, 1000m, and 1500m away from the data sondes, perpendicular to the nearest shoreline. These measurements were performed to assess comparability with the point in time sampling conducted for TMDL compliance.

LandSat satellite imagery was used as a tool to remotely measure chlorophyll-a and turbidity concentrations. These images provide a more complete picture of spatial variability that can exist for these two parameters at any given point in time. In-lake sampling dates were selected to correspond with satellite overpasses to enable direct comparison of analytical laboratory and satellite derived chlorophyll-a concentrations. Processed satellite imagery and associated reports were provided by EOMAP GmbH & co. KG (EOMAP) based in Germany (Castle Seefeld Schlosshof).

3.2.3 Water Quality Summary

A summary of the in-lake monitoring events for Lake Elsinore for the period of July 1, 2016 to June 30, 2017 is presented below. A total of eight Lake Elsinore events were sampled during this time period under the TMDL monitoring program, with five occurring in 2016 (July 25, August 18, September 19, October 5 and December 8) and three in 2017 (February 2, April 7 and June 2). Complete water quality profile measurements can be found in the quarterly reports contained in Appendix B. Detailed analytical chemistry lab reports for each event are contained in Appendix C. Satellite imagery reports for each event are provided in Appendix D.

<u>Water Column Profiles</u>

A summary of mean water column profile values for each site and monitoring event are presented in Tables 3-3 and 3-4. Water column profile statistics for each site across the entire monitoring period are presented in Table 3-5. Mean values for water column measurements are also visually summarized in Figures 3-2 through 3-4 for each site. In addition, in an effort to assess the

variability in water quality parameters over the course of a day, a comparison of morning and afternoon water column profile data collected over the current and prior year was performed. This data is presented in Appendix F. The measurements during the am and pm for any given day were averaged prior to summarizing in the tables and figures below. A comparison of water column data collected by the in-lake automated data sondes with concurrent data collected by Amec Foster Wheeler adjacent to the sondes can be found in Appendix G.

Table 3-3. In-Situ Water Quality Parameter Measurements in Lake Elsinore – 2016 Monthly Means for Each Site

Site	Measure	Jul-16		Aug-16		Sep-16		Oct-16		Dec-16	
		Water Column Mean	1m from Bottom	Water Column Mean	1m from Bottom	Water Column Mean	1m from Bottom	Water Column Mean	1m from Bottom	Water Column Mean	1m from Bottom
LE01	Temp (°C)	27.8	27.3	27.5	26.9	23.7	23.5	22.2	21.9	11.3	11.1
	Cond (µS/cm)	5814	5805	5861	5861	5975	5978	6155	6142	6123	6123
	pH	9.00	8.97	9.34	9.37	9.25	9.32	9.56	9.54	9.21	9.19
	DO (mg/L)	2.4	0.4	5.4	2.3	8.6	5.8	7.7	6.0	7.0	5.6
LE02	Temp (°C)	27.6	27.1	27.2	26.7	22.7	22.6	21.7	21.6	10.8	10.7
	Cond (µS/cm)	5809	5809	5848	5847	5974	5975	6144	6145	6124	6131
	pH	8.98	8.95	9.21	9.24	9.28	9.28	9.51	9.50	9.19	9.19
	DO (mg/L)	3.2	0.9	3.0	0.8	5.0	4.2	5.2	4.4	5.2	5.3
LE03	Temp (°C)	28.3	27.7	27.4	27.2	23.5	23.3	21.5	21.2	11.3	11.1
	Cond (µS/cm)	5803	5803	5863	5936	5955	5957	6095	6124	6162	6148
	pH	8.89	8.91	8.98	9.04	9.29	9.27	9.50	9.49	9.18	9.21
	DO (mg/L)	2.9	0.7	3.3	1.7	6.8	6.8	6.7	5.6	7.3	6.6
All Stations Combined	Temp (°C)	27.9	27.4	27.3	26.9	23.3	23.1	21.8	21.6	11.1	10.9
	Cond (µS/cm)	5809	5806	5857	5881	5968	5970	6131	6137	6137	6134
	pH	8.96	8.94	9.18	9.21	9.27	9.29	9.52	9.51	9.19	9.19
	DO (mg/L)	2.8	0.6	3.9	1.6	6.8	5.6	6.5	5.3	6.5	5.9

Notes:
°C = degrees Celsius; µS/cm = microsiemens per centimeter; mg/L = micrograms per liter.

Table 3-4. In-Situ Water Quality Parameter Measurements in Lake Elsinore – 2017 Monthly Means for Each Site

Site	Measure	Feb-17		Apr-17		Jun-17	
		Water Column Mean	1m from Bottom	Water Column Mean	1m from Bottom	Water Column Mean	1m from Bottom
LE01	Temp (°C)	11.6	10.9	19.4	18.3	23.3	22.6
	Cond (µS/cm)	3734	4035	3477	3474	3640	3633
	pH	9.17	9.02	9.27	9.17	9.28	9.21
	DO (mg/L)	11.5	5.6	7.9	3.7	6.5	3.5
LE02	Temp (°C)	11.1	10.8	18.9	18.1	22.9	22.4
	Cond (µS/cm)	3739	4020	3470	3474	3643	3630
	pH	9.13	9.04	9.27	9.21	9.27	9.19
	DO (mg/L)	11.0	6.2	8.2	5.6	6.8	2.8
LE03	Temp (°C)	11.1	10.9	19.2	18.6	23.3	22.5
	Cond (µS/cm)	3716	3960	3477	3470	3648	3643
	pH	9.09	9.00	9.25	9.22	9.33	9.24
	DO (mg/L)	9.7	5.4	7.9	6.5	8.4	4.1
All Stations Combined	Temp (°C)	11.2	10.8	19.1	18.3	23.1	22.5
	Cond (µS/cm)	3730	4005	3475	3473	3644	3635
	pH	9.13	9.02	9.26	9.20	9.29	9.21
	DO (mg/L)	10.8	5.7	8.0	5.2	7.2	3.5

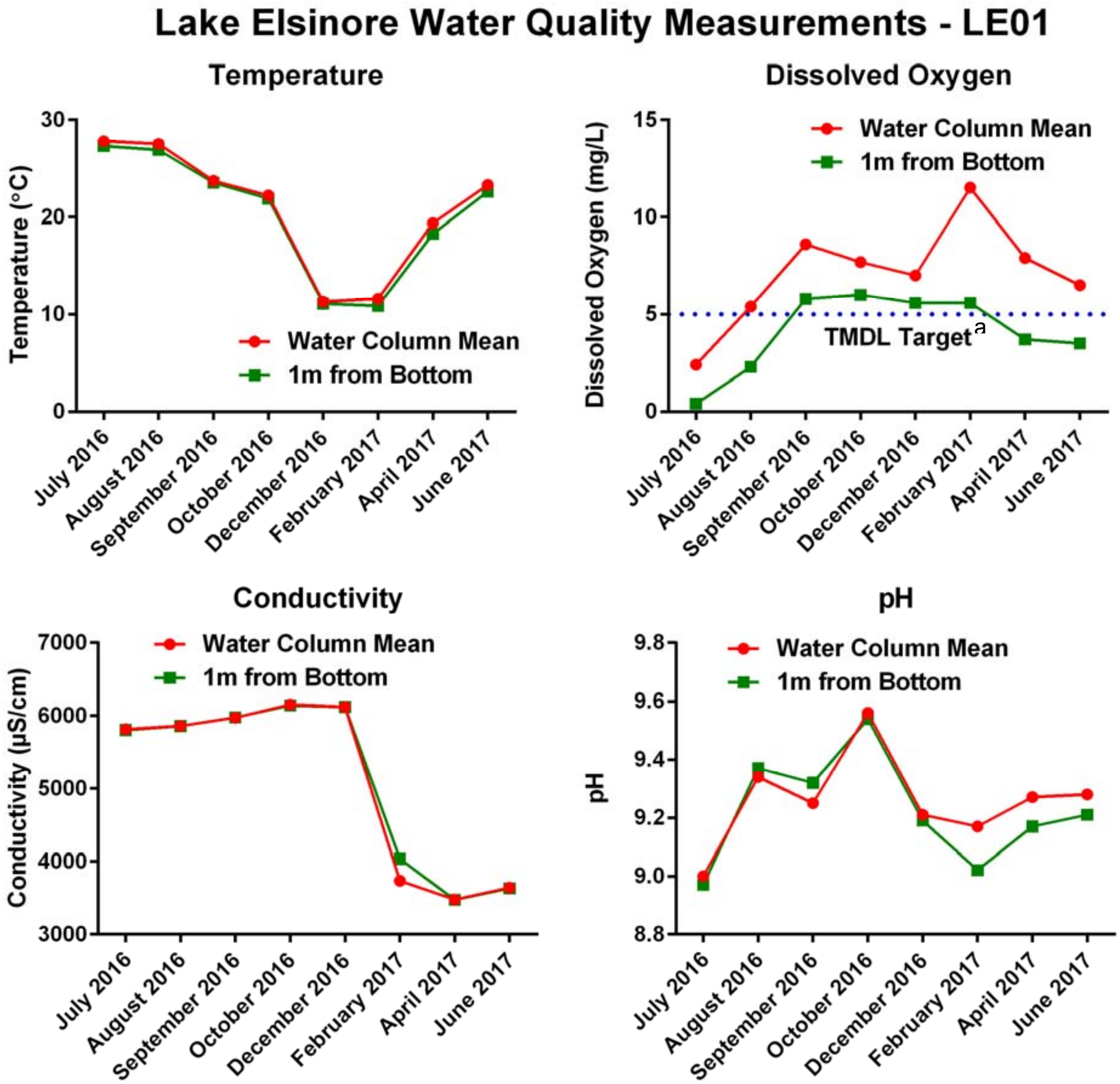
Notes:
°C = degrees Celsius; µS/cm = microsiemens per centimeter; mg/L = micrograms per liter.

Temperature exhibited a typical pattern with lowest values occurring during the winter events (December and February) and highest values in summer months (July and August). The greatest water column mean DO concentrations were observed in February at all three locations. Concentrations of DO near the bottom generally tracked with the overall water column mean, and remained relatively stable from September through April. Conductivity exhibited a gradual increase from July through December 2016, from approximately 5800 to 6100 microsiemens per centimeter (µS/cm). Following several large storm events on December 16th, January 12th, and January 22nd, lake-wide conductivity dropped to approximately 3700 µS/cm during the February monitoring event, and decreased again to approximately 3400 µS/cm following another series of storms. A substantial increase in pH values from July through October 2016 was observed, in which an approximate 0.7 unit increase was observed lake-wide. Following this, a sharp lake-wide decrease was exhibited between October and December 2016 that appears unrelated to any precipitation, as the first significant rain event of the wet season occurred eight days after the December monitoring event. The water column mean DO concentration was above the 2015 TMDL target of 5.0 mg/L as a depth average for six of the eight events among the three sites. The dissolved oxygen concentration was above the 2020 TMDL target of 5.0 mg/L 1-m above the lake bottom for three (LE02) to five (LE03) of the eight events.

Table 3-5. In-Situ Water Quality Parameter Measurements in Lake Elsinore - Annual Mean Statistics for Each Site

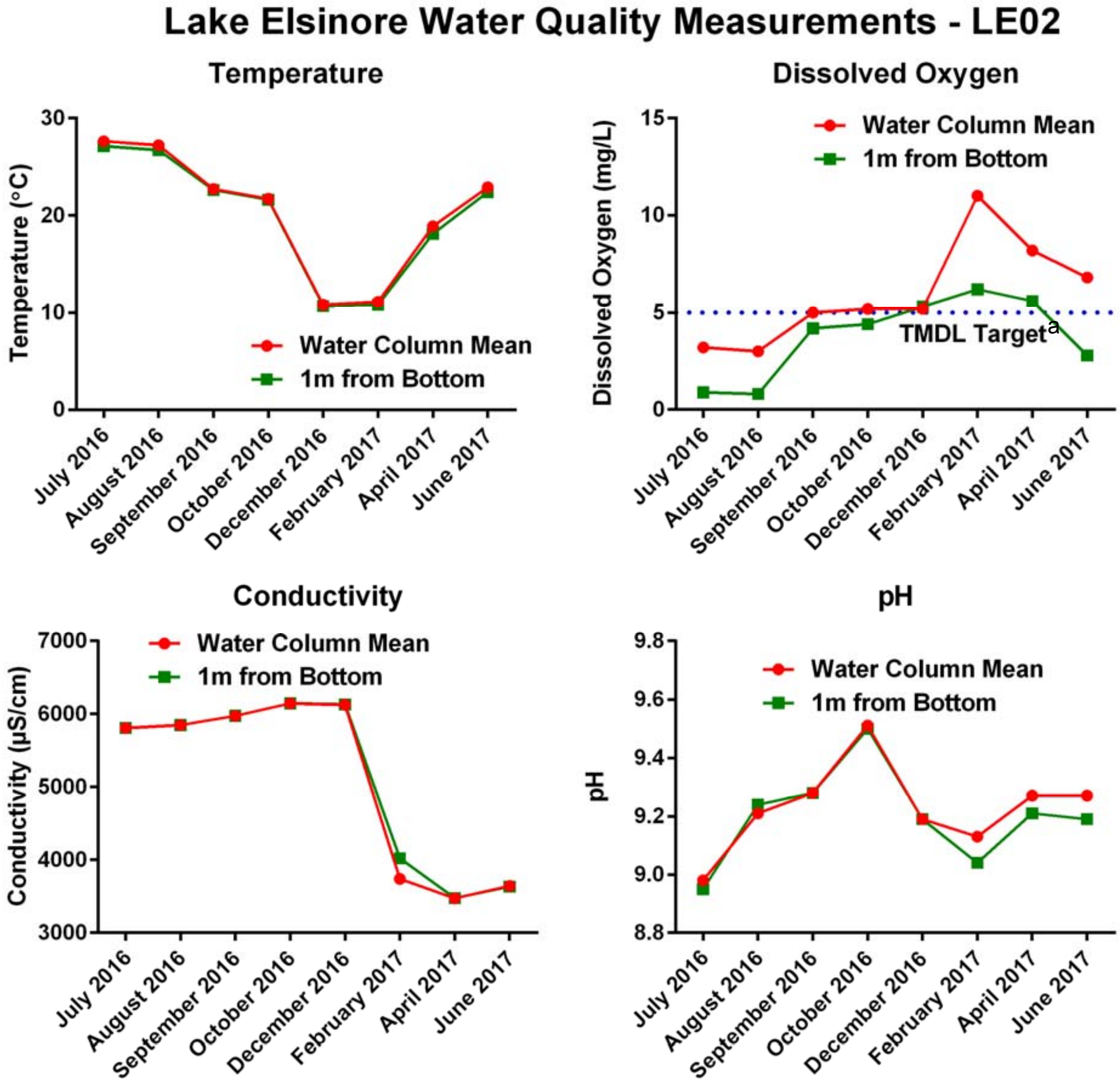
		Measure	LE01	LE02	LE03	Average
Water Column Mean	Min	Temp (°C)	11.3	10.8	11.1	11.0
		Cond (µS/cm)	3477	3470	3477	3475
		pH	9.00	8.98	8.89	8.96
		DO (mg/L)	2.4	3.0	2.9	2.8
	Max	Temp (°C)	27.8	27.6	28.3	27.9
		Cond (µS/cm)	6155	6144	6162	6154
		pH	9.56	9.51	9.50	9.52
		DO (mg/L)	11.5	11.0	9.7	10.8
	Average	Temp (°C)	20.8	20.3	20.7	20.6
		Cond (µS/cm)	5097	5094	5090	5094
		pH	9.26	9.23	9.19	9.23
		DO (mg/L)	7.1	6.0	6.6	6.6
1m from Bottom	Min	Temp (°C)	10.9	10.7	10.9	10.8
		Cond (µS/cm)	3474	3474	3470	3473
		pH	8.97	8.95	8.91	8.94
		DO (mg/L)	0.4	0.8	0.7	0.6
	Max	Temp (°C)	27.3	27.1	27.7	27.4
		Cond (µS/cm)	6142	6145	6148	6145
		pH	9.54	9.50	9.49	9.51
		DO (mg/L)	6.0	6.2	6.8	6.3
	Average	Temp (°C)	20.3	20.0	20.3	20.2
		Cond (µS/cm)	5131	5129	5130	5130
		pH	9.22	9.20	9.17	9.20
		DO (mg/L)	4.1	3.8	4.7	4.2

Notes:
°C = degrees Celsius; µS/cm = microsiemens per centimeter; mg/L = micrograms per liter.



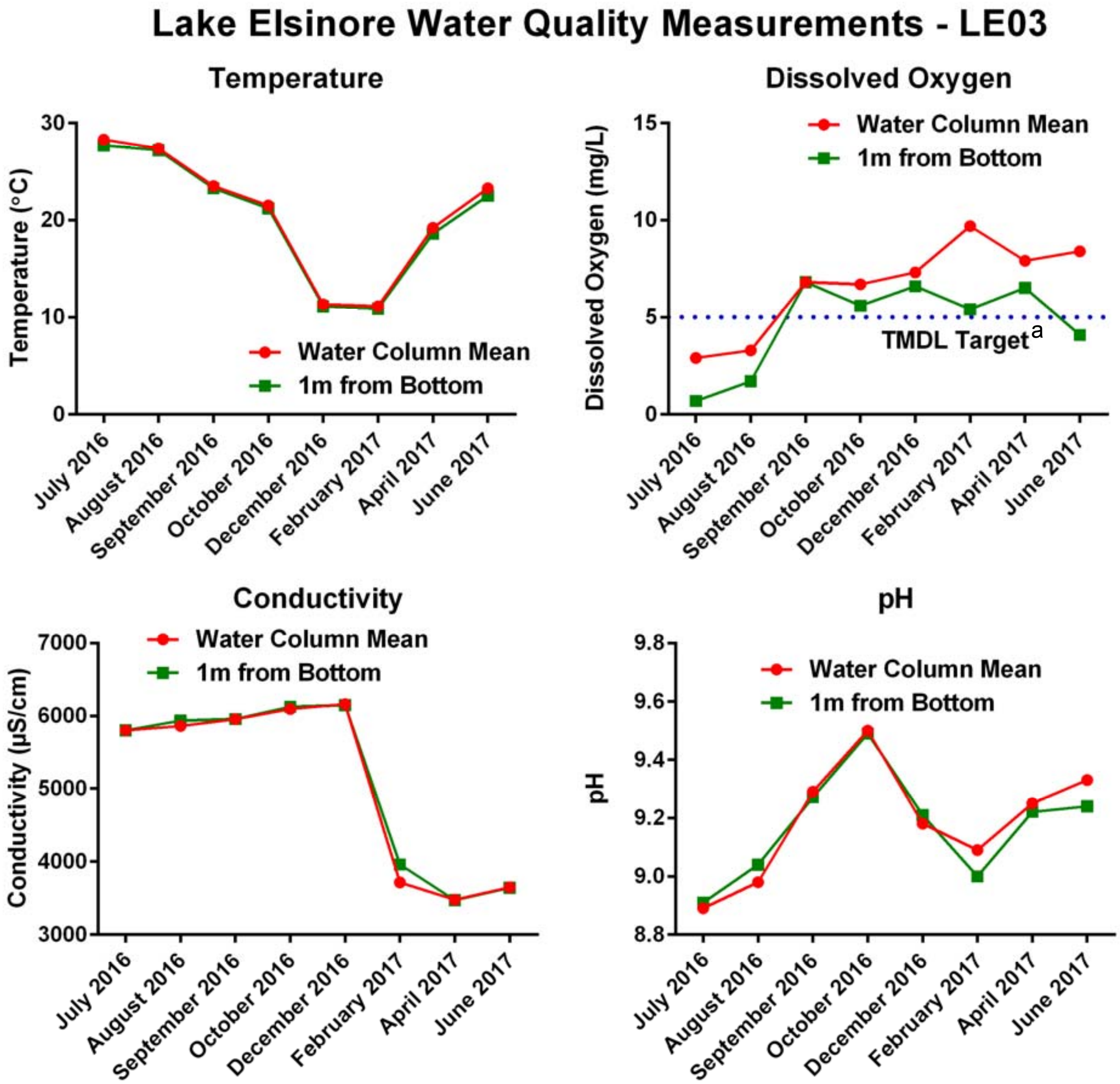
[a]TMDL Target for dissolved oxygen is depth average no less than 5 mg/L no later than 2015, no less than 5 mg/L 1 meter above lake bottom no later than 2020

Figure 3-2. In- Situ Physical Water Quality Parameters - Lake Elsinore - Site LE01



[a]TMDL Target for dissolved oxygen is depth average no less than 5 mg/L no later than 2015, no less than 5 mg/L 1 meter above lake bottom no later than 2020

Figure 3-3. In- Situ Physical Water Quality Parameters - Lake Elsinore Site LE02



[a]TMDL Target for dissolved oxygen is depth average no less than 5 mg/L no later than 2015, no less than 5 mg/L 1 meter above lake bottom no later than 2020

Figure 3-4. In- Situ Physical Water Quality Parameters - Lake Elsinore Site LE03

Analytical Chemistry

Summaries of analytical chemistry concentrations for each monitoring event at Site LE02 across the entire monitoring period are presented in Tables 3-6 and 3-7, respectively. Concentrations of analytes at Site LE02 are graphically presented in Figures 3-5 and 3-6.

Total nitrogen concentrations ranged from 3.7 to 9.3 mg/L across the eight sampling events with the annual mean of 6.3 mg/L, which exceeds the current 2020 TMDL target of 0.75 mg/L. Total

phosphorus concentrations ranged from 0.18 to 0.82 mg/L, with the annual mean of 0.39 mg/L exceeding the current 0.10 mg/L 2020 TMDL target. Chlorophyll-a depth-integrated concentrations across all eight sampling events ranged from 72 to 349 µg/L. Surface (0-2m) concentrations of chlorophyll-a were similar to depth-integrated values for the entire water column, ranging from 52 to 309 µg/L. The mean chlorophyll-a concentration observed in samples collected during the summer months (June 2016 through September 2016), corresponding to the TMDL chlorophyll summer compliance period was 249 µg/L. This summer chlorophyll-a concentration exceeds the current 2015 and 2020 TMDL targets of 40 and 25 µg/L, respectively. Un-ionized ammonia concentrations ranged from 0.01 to 0.06 mg/L, with no samples exceeding the US EPA acute water quality Criterion Maximum Concentration (CMC) or US EPA chronic water quality Criterion Continuous Concentration (CCC) values for the protection of aquatic life.

A spike in total phosphorus was observed in September 2016, expressed as an almost two-fold increase in total phosphorus concentration between August and September 2016 (0.47 to 0.82 mg/L). The concentration then decreased by over half during the next monitoring event in October. Total phosphorus concentrations during the remainder of monitoring events were relatively stable. While total phosphorus exhibited a slight increase following the large December 2016 and January 2017 storms, total nitrogen concentrations decreased by half (7.9 to 3.8 mg/L) and remained at this level for the balance of the reporting period. Total ammonia exhibited a four-fold spike following the large December 2016 and January 2017 storms, and subsequently returned back to values observed during the pre-storm period.

All chlorophyll-a values observed exceeded the 2015 TMDL target concentration of 40 µg/L. The highest depth-integrated chlorophyll-a concentration was observed in September 2016 at 349 µg/L, and subsequently exhibited a decrease with each monitoring event through April 2017 to 72 µg/L. The June 2017 monitoring event saw an increase back up to 145 µg/L.

Cyanobacterial toxin concentrations of total nodularin and cylindrospermopsin observed at LE02 were below detection limits (<0.001 µg/L). The total microcystin concentration observed in the depth-integrated and surface samples was 1.4 and 1.2 µg/L, respectively. This is just above the 0.8 µg/L State of California “Caution” trigger (see Table 3-8), the lowest of three tiers indicating elevated human health risk. Similarly, anatoxin-a was measured at 0.11 µg/L in the depth-integrated sample, just above the “Caution” trigger set as any detection of anatoxin-a

The current 2016-2017 FY Lake Elsinore data in the context of historical data can be found in Appendix H.

Table 3-6. Monthly Analytical Chemistry Results for Lake Elsinore

Method	Compound	Units	RL	Depth Integrated or Surface Sample	July 2016	August 2016	September 2016	October 2016	December 2016	February 2017	April 2017	June 2017
General Chemistry												
SM 2540C	Total Dissolved Solids	mg/L	10-40	DI	3400	3500	3800	3700	3900	2200	2100	2100
SM 4500S2 D	Sulfide	mg/L	0.1	DI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	DI	0.44	<0.2	<0.2	<0.2	<0.2	0.09	0.21	<0.2
SM 4500NO2 B	Nitrite as N	mg/L	0.1	DI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	DI	6.80	7.00	9.30	7.80	7.90	3.70	3.70	3.70
Calculated	Total Nitrogen[a]	mg/L	--	DI	7.24	7.00	9.30	7.80	7.90	3.79	3.91	3.70
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	DI	<0.1	<0.1	<0.1	0.10	<0.1	0.21	0.10	0.06
Calculated	Unionized Ammonia[b,c]	mg/L	--	DI	0.020	0.028	0.0241	0.061	0.011	0.047	0.037	0.032
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	DI	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SM 4500P B E	Total Phosphorus	mg/L	0.05	DI	0.34	0.47	0.82	0.36	0.30	0.43	0.21	0.18
Chlorophyll-a												
EPA 10200 H	Chlorophyll-a	µg/L	1.0	Surf	212	249	309	240	172	97	52	75
EPA 10200 H	Chlorophyll-a	µg/L	1.0	DI	265	235	349	302	235	75	72	145
Algae Toxins												
LC-MS/MS	Total Microcystin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	1.386
				SG	NS	NS	NS	NS	NS	NS	NS	1.221
LC-MS/MS	Total Nodularin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	<0.001
				SG	NS	NS	NS	NS	NS	NS	NS	<0.001
LC-MS/MS	Total Anatoxin-a	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	0.107
				SG	NS	NS	NS	NS	NS	NS	NS	<0.001
LC-MS/MS	Total Cylindospermopsin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	<0.001
				SG	NS	NS	NS	NS	NS	NS	NS	<0.001

Notes:
a - Total Nitrogen = $TKN+NO_2+NO_3$
b - Values are site specific dependent upon pH and temperature recorded at each location. Calculated using equation by Thursby (1986).
c – Un-ionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
NS – Not sampled; ND – Not detected
DI = Depth integrated; SG = Surface grab; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit.

Table 3-7. Analytical Chemistry Summary for Lake Elsinore– Annual Mean Statistics

Method	Compound	Units	RL	Basin Plan or TMDL Target	Depth Integrated or Surface Sample	Min	Max	Average	Summer Average[e]
General Chemistry									
SM 2540C	Total Dissolved Solids	mg/L	10-40	2000[3]	DI	2100	3900	**3088**	3200
SM 4500S2 D	Sulfide	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	NA	DI	<0.2	0.44	0.16	0.44
SM 4500NO2 B	Nitrite as N	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	NA	DI	3.7	9.3	6.2	6.7
Calculated	Total Nitrogen[a]	mg/L	--	0.75[b1]	DI	3.7	9.3	**6.3**	6.8
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	NA	DI	<0.1	0.21	0.08	0.06
Calculated	Unionized Ammonia[d,f]	mg/L	--	CMC: 0.67-1.3[1] CCC: 0.15-0.39[1]	DI	0.01	0.06	0.03	0.03
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	NA	DI	<0.05	<0.05	<0.05	<0.05
SM 4500P B E	Total Phosphorus	mg/L	0.05	0.1[b1]	DI	0.18	0.82	**0.39**	0.47
Chlorophyll-a									
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1c], 40[2c]	Surf	52	309	**190**	**211**
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1c], 40[2c]	DI	72	349	**219**	**249**

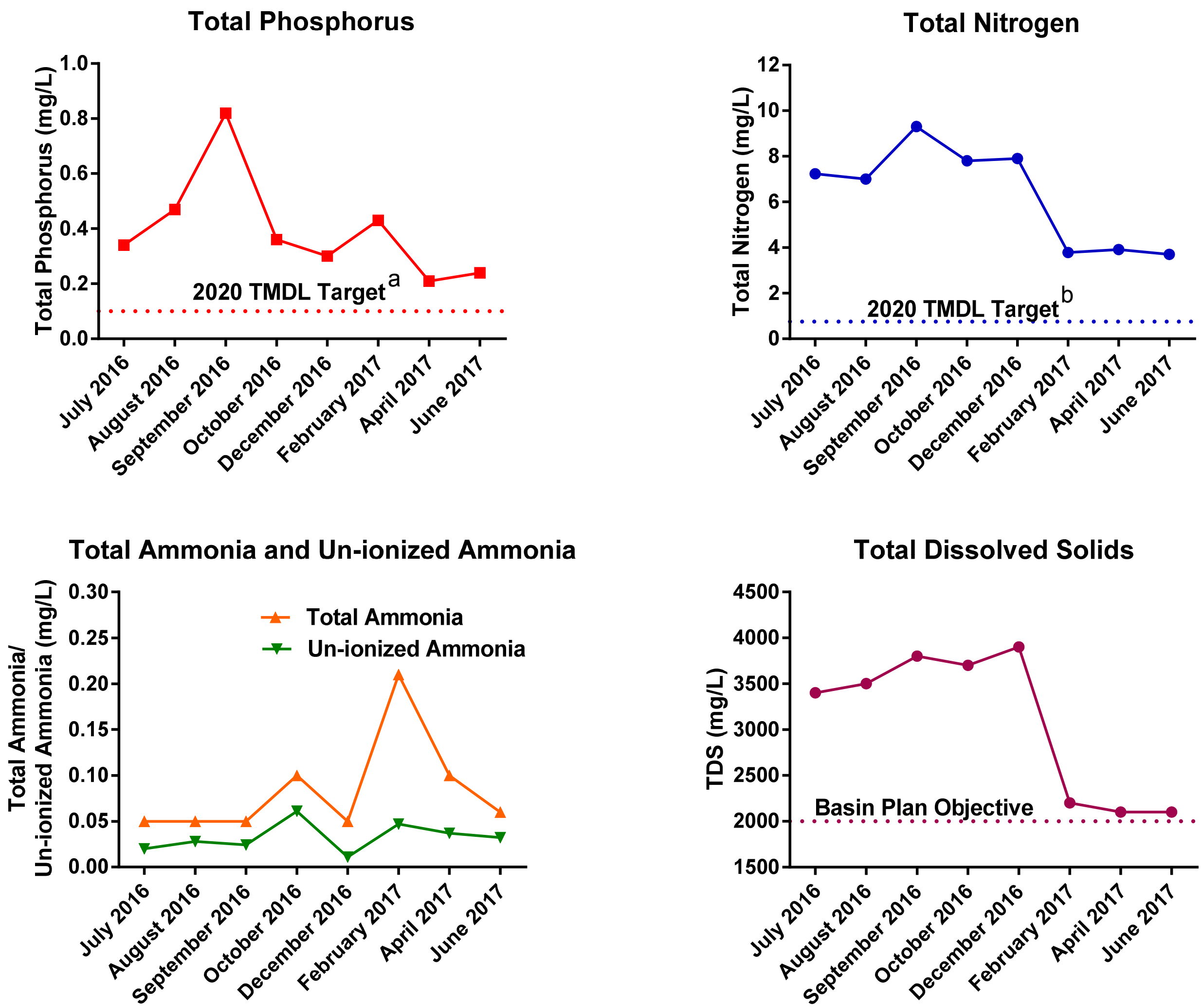
Notes:
a - Total Nitrogen = TKN+NO_2+NO_3
b - Annual average
c - Summer average
d - Values calculated using water column mean ammonia, temperature, salinity and pH. Calculated using equation by Thursby (1986).
e - Values are the mean of June through September 2016 results
f – Un-ionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
1 – 2020 TMDL Target, based on Table 5-9n of 2004 TMDL
2 – 2015 TMDL Target, based on Table 5-9n of 2004 TMDL
3 – Santa Ana Region Basin Plan Objective
NA – Not applicable/ available
DI = Depth integrated; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit
Bold Underline - Indicates exceedance of Basin Plan/TMDL target

.

Table 3-8. State of California Proposed[d] Cyanobacteria Harmful Algal Bloom Trigger Levels for Human Health

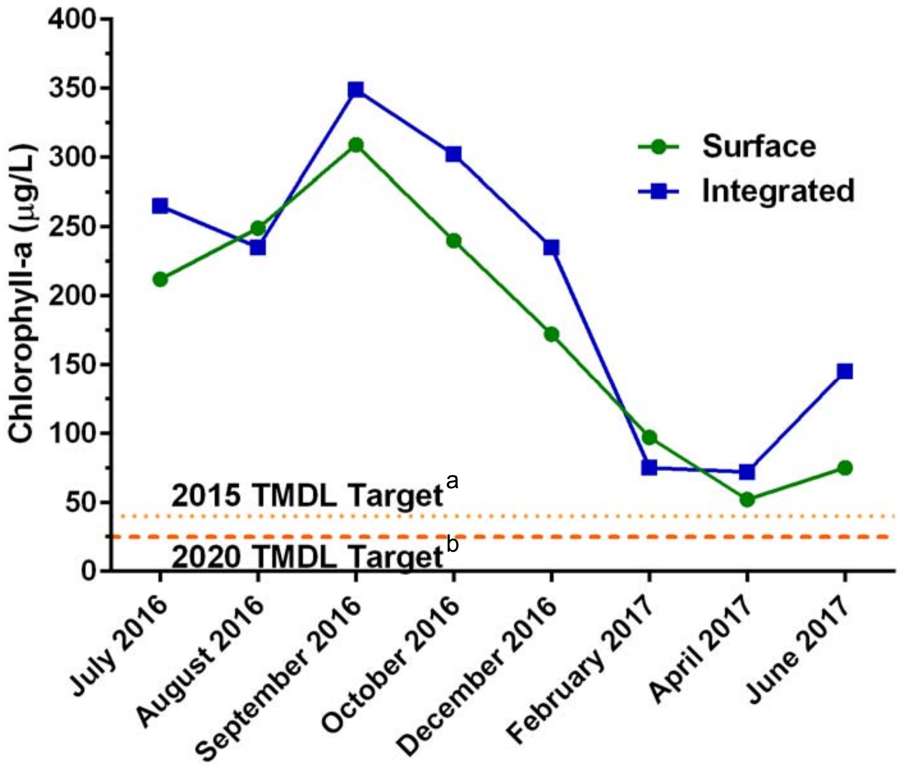
	Caution Action Trigger	Warning TIER I	Danger TIER II
Primary Triggers [a]			
Total Microcystins [b]	0.8 µg/L	6 µg/L	20 µg/L
Anatoxin-a	Detection [c]	20 µg/L	90 µg/L
Cylindrospermopsin	1 µg/L	4 µg/L	17 µg/L
Secondary Triggers			
Cell Density *(Toxin Producers)*	4,000 cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats, ect.	--	--

[a]The primary triggers are met when ANY toxin exceeds criteria
[b]Microcystins refers to the sum of all measured microcystin variants (see box 3)
[c]Must use an analytical method that detects ≤1 µg/L Anatoxin-a
[d]These trigger levels have not been formally adopted or approved by the EPA, Regional Water Board or State Water Board



[a]Annual average no greater than 0.1 mg/L no later than 2020
[b]Annual average no greater than 0.75 mg/L no later than 2020

Figure 3-5. Lake Elsinore Analytical Chemistry – Depth-Integrated Means



[a]Summer average no greater than 40 µg/L no later than 2015
[b]Summer average no greater than 25 µg/L no later than 2020

Figure 3-6. Lake Elsinore Analytical Chemistry – Depth-Integrated and Surface Chlorophyll-a

3.3 Canyon Lake Monitoring

3.3.1 Sampling Station Locations and Frequency

Similar to Lake Elsinore, sampling parameters and locations in Canyon Lake were based on the TMDL monitoring conducted between 2006 and 2012 to provide consistency in assessing trends toward meeting compliance goals. The in-lake monitoring design halted in 2012 was therefore resumed using the four stations outlined in the approved Lake Elsinore and Canyon Lake Nutrient TMDL Monitoring Plan (LESJWA, 2006; Figure 3-7, Table 3-9). These include two in the main body of the lake (CL07 near the dam and CL08 in the northern arm), and two in the East Bay (CL09 and CL10). Samples for analytical chemistry and in-situ water quality profile readings were collected at Sites CL07, CL08, and CL10, while only a surface (0-2-m) chlorophyll-a sample and in-situ water quality profile readings were performed at Site CL09. Site CL10 was selected as the primary monitoring location in the eastern arm of Canyon Lake for TMDL compliance monitoring in 2011-2012 FY following the approved reduction from four to three locations. This site is more centrally located within the eastern arm and past results indicated similar water quality between the two east bay sites overall. However, the width of the lake at Site CL10 is narrower than that at Site CL09, potentially resulting in confounding satellite imagery results due to edge interference at this location. Therefore, Site CL09 was sampled for surface chlorophyll-a to enable a more valid comparison to satellite imagery in the eastern arm.

Sampling in Canyon Lake was conducted bi-monthly (i.e., every other month) concurrent to the TMDL sampling in Lake Elsinore, and also coordinated with LandSat satellite overpass dates (see Section 3.4).

Table 3-9. Canyon Lake Sampling Station Locations

Site	Latitude	Longitude
CL07	33.678027°	-117.275135°
CL08	33.688211°	-117.268944°
CL09	33.681100°	-117.258892°
CL10	33.679495°	-117.250669°

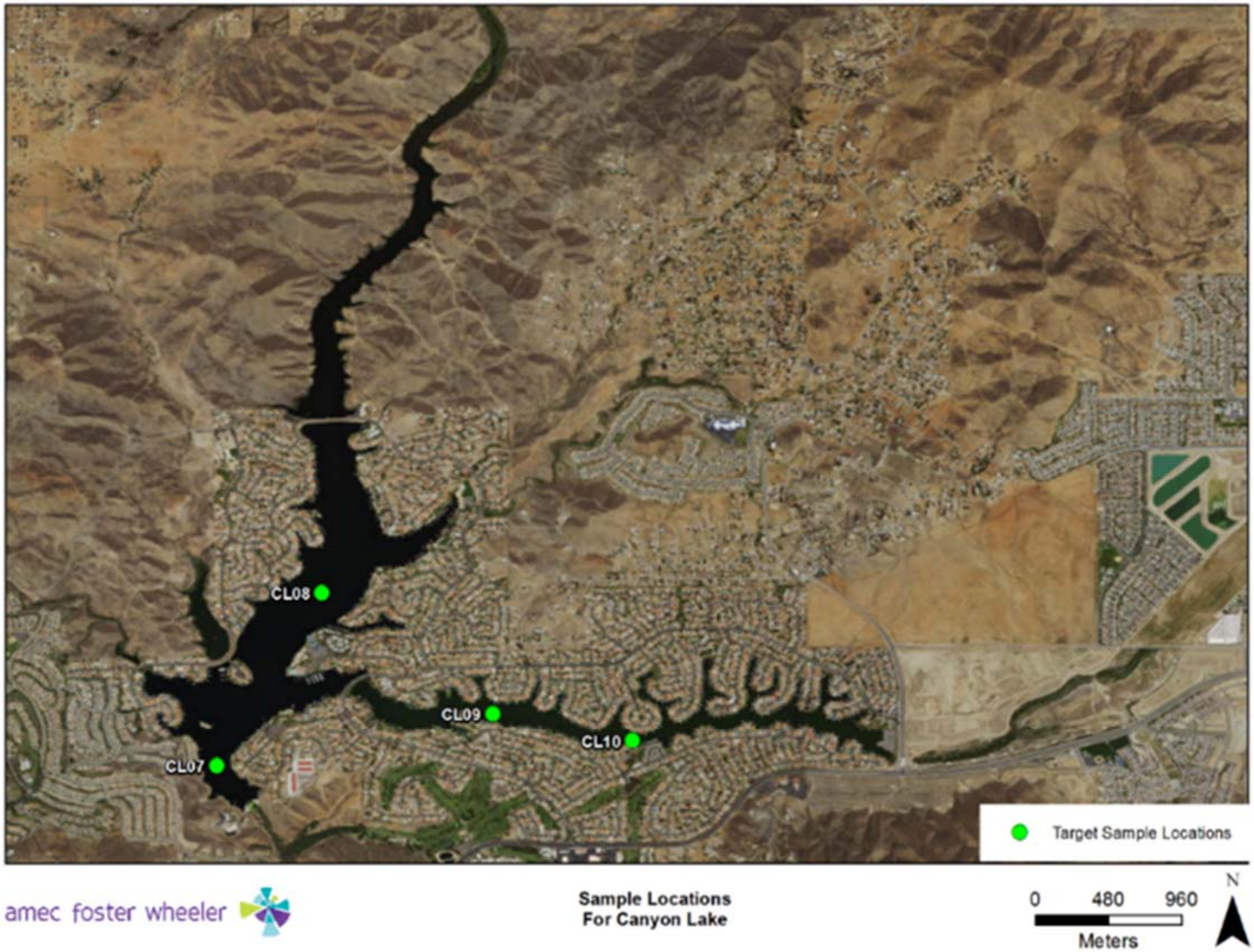


Figure 3-7. Canyon Lake Sampling Locations

3.3.2 Sampling Methods

Samples for analytical chemistry were collected in the same manner as in Lake Elsinore using a peristaltic pump. Two discrete samples were collected for chlorophyll-a: 1) a full depth-integrated composite sample; and 2) a 0-2-meter (m) depth-integrated composite surface sample. Cyanotoxin samples were collected as a full depth-integrated composite and a surface grab. All analytical samples for chemical analysis were collected by Amec Foster Wheeler staff, placed and held on wet ice immediately following collection, and transferred to a local courier or shipping company on the same day of collection. for Samples for analysis of nutrients, sulfide, TDS, and chlorophyll-a were, submitted to Babcock Laboratories Inc. located in Riverside, California. For the June 2017 samples, low level total phosphorus samples were submitted to Babcock Laboratories Inc., and then subbed out to Eurofins CalScience, Inc. for analysis. Samples for analysis of cyanotoxins were shipped via overnight delivery to the University of California, Santa Cruz.

Canyon Lake alum applications were performed by Aquatechnex on September 26-30, 2016 and February 8-13, 2017. As part of the alum application monitoring program, Amec Foster Wheeler performed pre- and post-alum application sampling on September 19, 2016 (pre) and October 5, 2016 (post), and again on February 2, 2017 (pre) and April 7, 2017 (post). During the September and October 2016 sampling events, distinct epilimnion and hypolimnion, as well as full depth-integrated samples were collected, with each being analyzed for the full suite of constituents outlined in Table 3-10. Beginning with the February 2017 sampling event, the TMDL Task Force directed that the pre- and post-alum application monitoring be integrated into the routine TMDL monitoring, given that the monitored analytes were largely identical to the TMDL monitoring, with the exception of aluminum and total suspended solids. Given this directive, distinct epilimnion and hypolimnion sampling was discontinued, along with total/dissolved aluminum and total suspended solids being added to the nutrient TMDL monitoring analyte list for all subsequent routine TMDL monitoring events. Additionally, Site CL09 which was previously only sampled for surface chlorophyll-a, would now have the full suite of analytes sampled during each monitoring event.

In-situ water column profile data was recorded in the morning at all four Canyon Lake stations using pre-calibrated hand-held YSI field meters or equivalent for pH, temperature, DO, and specific conductivity at 1-m intervals throughout the water column. End-of-the-day water column profiles (i.e. after ~2:30pm) were also recorded for the same suite of parameters at all stations to assess any potential temporal variability in these parameters over the course of a day. Water clarity was also assessed with a Secchi disk at all three stations.

LandSat satellite imagery was used to remotely measure chlorophyll-a and turbidity concentrations in Canyon Lake. In-lake sampling dates were selected to correspond with satellite overpasses.

Similar to Lake Elsinore, two types of cyanobacterial toxin samples were collected: 1) a subsample of the depth-integrated composite sample at all four sites, and 2) a surface grab at Site CL07, due to the known diurnal vertical migration of some cyanobacteria. Samples were

held on wet ice and shipped the following day to the University of California, Santa Cruz for analysis of cyanotoxins.

Table 3-10. Canyon Lake In-lake Analytical Constituents and Methods

Parameter	Analysis SOP #	Sampling Method
Analytical Chemistry		
Nitrite Nitrogen (NO_2-N)	SM4500-NO2 B	Depth Integrated
Nitrate Nitrogen (NO_3-N)	EPA 300.0	Depth Integrated
Total Kjeldahl Nitrogen (TKN)	EPA 351.3	Depth Integrated
Ammonia Nitrogen (NH4-N)	SM4500-NH_3 H	Depth Integrated
Sulfide	SM 4500S2 D	Depth Integrated
Total Phosphorus (TP)	SM4500-P E	Depth Integrated
Soluble Reactive Phosphorus (SRP / Ortho-P)	SM4500-P E	Depth Integrated
Chlorophyll-a	SM 10200H	Surface & Depth Integrated
Total Dissolved Solids (TDS)	SM 2540 C	Depth Integrated
Total Suspended Solids (TSS)[a]	SM 2540D	Depth Integrated
Total Aluminuma	EPA 200.7	Depth Integrated
Dissolved Aluminum[a]	EPA 200.7	Depth Integrated
Cyanobacteria Toxins		
Microcystin	LC-MS/MS	Surface & Depth Integrated
Cylindrospermopsin	LC-MS/MS	Surface & Depth Integrated
Anatoxin-a	LC-MS/MS	Surface & Depth Integrated
Nodularin	LC-MS/MS	Surface & Depth Integrated

Note:
[a] measured as part of the pre- and post-alum application monitoring program only

3.3.3 Water Quality Summary

A summary of the in-lake monitoring events for Canyon Lake for the period of July 1, 2016 to June 30, 2017 is presented below. A total of six events were sampled under the TMDL monitoring program, with three occurring in 2016 (August 18, October 5, December 8) and three in 2017 (February 2, April 7, and June 2). Complete water quality profile measurements can be found in the quarterly reports contained in Appendix B. Detailed analytical chemistry lab reports for each event are contained in Appendix C. Satellite imagery reports for each event are provided in Appendix D. A summary of Canyon Lake water levels is provided in Appendix E.

Water Column Profiles

A summary of water column profile mean values for each site and monitoring event are presented in Tables 3-11 and 3-12. A summary of water column profile mean values for each basin (i.e. Main Lake and Eastern Arm) are presented in Tables 3-13 and 3-14. Water column profile mean statistics for each site across the entire monitoring period are presented in Table 3-15. Water column profiles of the epilimnion, hypolimnion, and full water column are also visually summarized in Figures 3-8 and 3-9.

For the purposes of this report, the epilimnion is defined as the region of the water column above the thermocline, while the hypolimnion is the region of the water column below the thermocline, with both of these regions exhibiting relatively stable temperatures. The thermocline portion of the water column was defined as the region between the epilimnion and hypolimnion where a marked drop in temperature per unit of depth was evident. Measurements within the thermocline were excluded from epilimnion and hypolimnion averaging. Full water column means included data recorded from all three zones, if present.

For both the Main Basin and East Basin, temperature exhibited a typical pattern with lowest values occurring during the winter events (December and February) and highest values in summer months (August). Dissolved oxygen concentrations for both basins exhibited a similar pattern, in that during the winter months when the thermocline was weak or absent, DO concentrations were relatively stable throughout the water column (see Q2 and Q3 quarterly reports). When the thermocline developed, DO concentrations within the epilimnion and hypolimnion diverged, with hypolimnion concentrations falling substantially during that timeframe. Dissolved oxygen concentrations were greater than the current 2015 TMDL target of 5.0 mg/L within the epilimnion for all five events in the Main and East Basins when stratification was present. However, DO concentrations were never above the current 2020 TMDL target of 5.0 mg/L in the hypolimnion for either basin when stratification was present. During the winter months (December 2016 and February 2017) when no stratification was observed, one of the two events was above 5.0 mg/L DO in the Main Basin, while both were above 5.0 mg/L DO in the Eastern Basin.

Conductivity within the epilimnion and hypolimnion (when present) were similar throughout the monitoring period. Conductivity in both basins remained stable around 1200-1300 µS/cm until the December monitoring event, in which the water column mean decreased to approximately 1000 µS/cm, followed by a larger decrease in February down to approximately 400 µS/cm. In both basins, values for pH exhibited a pattern similar to that of dissolved oxygen, in that during months when the thermocline was weak or absent, pH values were comparable throughout the water column (see Q2 and Q3 quarterly reports). Values for pH within the epilimnion and hypolimnion tended to diverge as the thermocline developed, with pH generally greater in the epilimnion relative to that in the hypolimnion.

Table 3-11. In-Situ Water Quality Parameter Measurements for Canyon Lake- 2016 Monthly Means for Each Site

Basin	Site	Measure	Aug-16			Sep-16			Oct-16			Dec-16		
			Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo
Main Basin	CL07	Temp (°C)	21.4	28.4	13.6	20.6	25.3	13.9	20.0	23.3	14.2	14.2	NA	NA
		Cond (µS/cm)	1216	1240	1200	1240	1271	1212	1256	1284	1217	982	NA	NA
		pH	7.60	8.41	6.88	7.56	8.17	6.83	7.27	7.52	6.89	7.81	NA	NA
		DO (mg/L)	3.6	7.8	0.1	3.4	7.0	0.2	4.4	6.8	0.8	3.1	NA	NA
	CL08	Temp (°C)	26.6	28.7	17.8	24.6	25.3	20.7	23.2	23.5	21.3	14.2	NA	NA
		Cond (µS/cm)	1225	1235	1186	1260	1267	1207	1275	1279	1245	981	NA	NA
		pH	8.04	8.44	6.84	7.82	8.03	6.91	7.68	7.74	7.21	7.96	NA	NA
		DO (mg/L)	5.3	7.8	0.2	5.2	6.6	0.3	6.2	6.9	0.3	4.8	NA	NA
East Basin	CL09	Temp (°C)	25.90625	28.6	18.1	23.7	24.9	19.1	22.4	22.9	19.6	13.1	NA	NA
		Cond (µS/cm)	1314	1302	1348	1354	1347	1382	1375	1374	1383	1048	NA	NA
		pH	7.79	8.33	6.73	7.90	8.30	6.70	7.63	7.78	6.91	7.98	NA	NA
		DO (mg/L)	5.1	8.1	0.2	5.4	7.1	0.3	5.5	6.7	0.2	5.8	NA	NA
	CL10	Temp (°C)	28.5	30.6	28.2	25.4	NA	NA	23.0	25.0	22.5	13.1	NA	NA
		Cond (µS/cm)	1323	1319	1318	1367	NA	NA	1394	1372	1398	1055	NA	NA
		pH	8.30	8.12	8.20	8.26	NA	NA	7.69	7.86	7.71	7.96	NA	NA
		DO (mg/L)	8.8	9.5	8.7	8.7	NA	NA	7.1	7.9	6.6	7.8	NA	NA

NA – not applicable due to lack of thermocline

Table 3-12. In-Situ Water Quality Parameter Measurements for Canyon Lake- 2017 Monthly Means for Each Site

Basin	Site	Measure	Feb-17			Apr-17			Jun-17		
			Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo
Main Basin	CL07	Temp (°C)	10.6	NA	NA	15.0	19.9	12.2	18.2	24.8	12.9
		Cond (µS/cm)	377	NA	NA	589	586	590	621	657	586
		pH	7.97	NA	NA	7.82	8.50	7.43	7.82	8.75	7.28
		DO (mg/L)	5.9	NA	NA	3.4	10.8	0.1	2.6	7.3	0.2
	CL08	Temp (°C)	10.8	NA	NA	16.9	20.6	12.7	21.6	24.6	15.6
		Cond (µS/cm)	372	NA	NA	585	579	586	636	648	607
		pH	8.03	NA	NA	8.01	8.49	7.56	8.19	8.78	7.36
		DO (mg/L)	6.2	NA	NA	4.9	11.1	0.2	4.2	7.1	0.2
East Basin	CL09	Temp (°C)	10.5	NA	NA	17.9	20.5	12.5	21.3	24.7	15.2
		Cond (µS/cm)	424	NA	NA	814	802	844	854	831	882
		pH	8.01	NA	NA	7.72	7.97	7.21	8.15	8.97	7.19
		DO (mg/L)	5.9	NA	NA	4.1	7.7	0.2	5.8	11.3	0.2
	CL10	Temp (°C)	10.7	NA	NA	20.5	23.0	19.0	25.1	NA	NA
		Cond (µS/cm)	412	NA	NA	843	858	827	887	NA	NA
		pH	8.12	NA	NA	7.67	7.66	7.50	8.77	NA	NA
		DO (mg/L)	6.9	NA	NA	5.5	8.0	1.9	11.3	NA	NA

Table 3-13. In-Situ Water Quality Parameter Measurements for Canyon Lake - 2016 Monthly Means for Each Basin

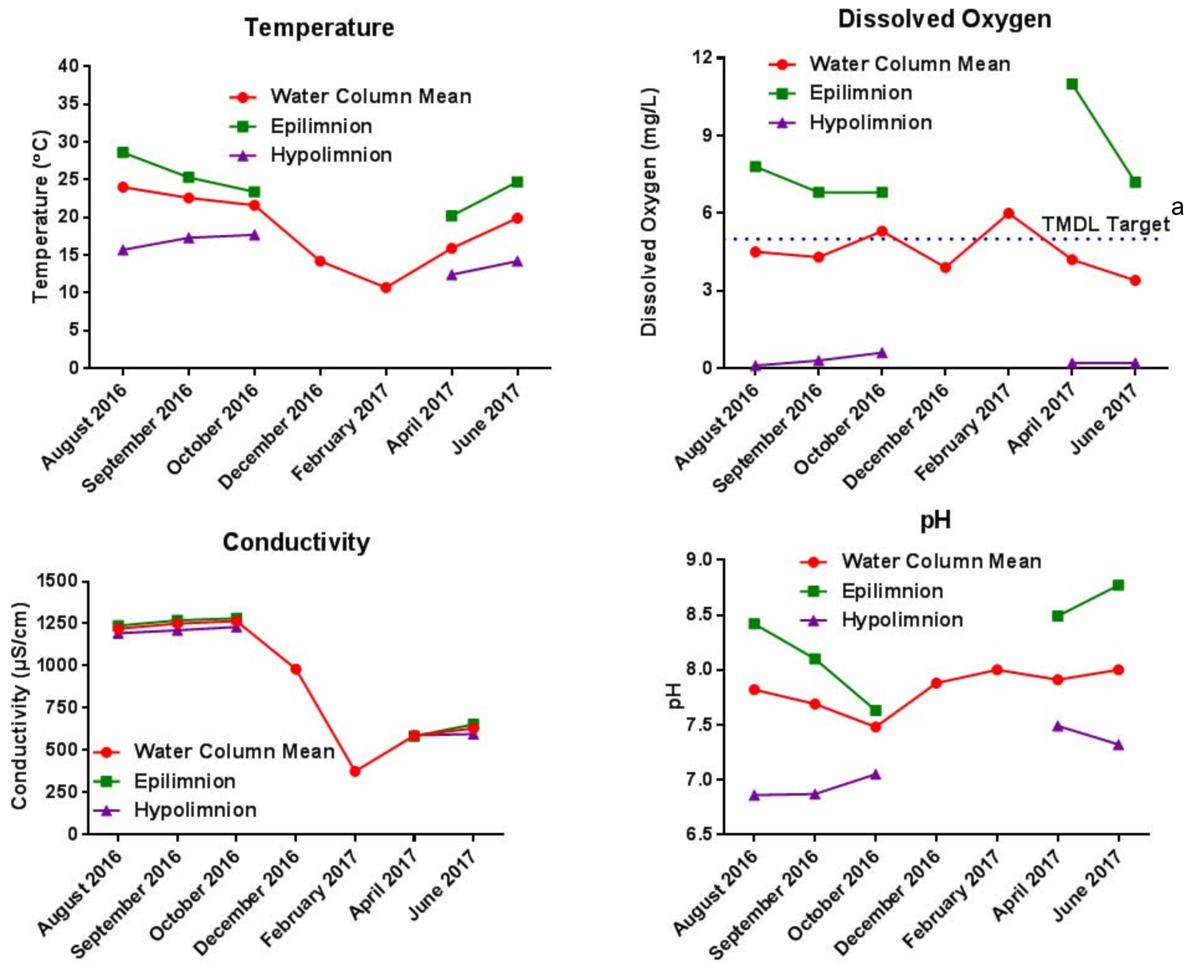
Basin	Measure	Aug-16			Sep-16			Oct-16			Dec-16		
		Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo
Main	Temp (°C)	24.0	28.6	15.7	22.6	25.3	17.3	21.6	23.4	17.7	14.2	NA	NA
	Cond (µS/cm)	1220	1238	1193	1250	1269	1210	1265	1282	1231	981	NA	NA
	pH	7.82	8.42	6.86	7.69	8.10	6.87	7.48	7.63	7.05	7.88	NA	NA
	DO (mg/L)	4.5	7.8	0.1	4.3	6.8	0.3	5.3	6.8	0.6	3.9	NA	NA
East	Temp (°C)	27.2	29.6	23.1	24.5	24.9	19.1	22.7	24.0	21.0	13.1	NA	NA
	Cond (µS/cm)	1319	1311	1333	1361	1347	1382	1385	1373	1391	1051	NA	NA
	pH	8.04	8.23	7.47	8.08	8.30	6.70	7.66	7.82	7.31	7.97	NA	NA
	DO (mg/L)	7.0	8.8	4.4	7.0	7.1	0.3	6.3	7.3	3.4	6.8	NA	NA

Table 3-14. In-Situ Water Quality Parameter Measurements for Canyon Lake – 2017 Monthly Means for Each Basin

Basin	Measure	Feb-17			Apr-17			Jun-17		
		Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo	Water Column Mean - All	Water Column Mean - Epi	Water Column Mean - Hypo
Main	Temp (°C)	10.7	NA	NA	15.9	20.2	12.4	19.9	24.7	14.2
	Cond (µS/cm)	374	NA	NA	587	583	588	629	653	596
	pH	8.00	NA	NA	7.91	8.49	7.49	8.00	8.77	7.32
	DO (mg/L)	6.0	NA	NA	4.2	11.0	0.2	3.4	7.2	0.2
East	Temp (°C)	10.6	NA	NA	19.2	21.7	15.7	23.2	24.7	15.2
	Cond (µS/cm)	418	NA	NA	828	830	835	870	831	882
	pH	8.07	NA	NA	7.69	7.81	7.35	8.46	8.97	7.19
	DO (mg/L)	6.4	NA	NA	4.8	7.9	1.0	8.5	11.3	0.2

Table 3-15. In-Situ Water Quality Parameter Measurements for Canyon Lake - Annual Mean Statistics for Each Site

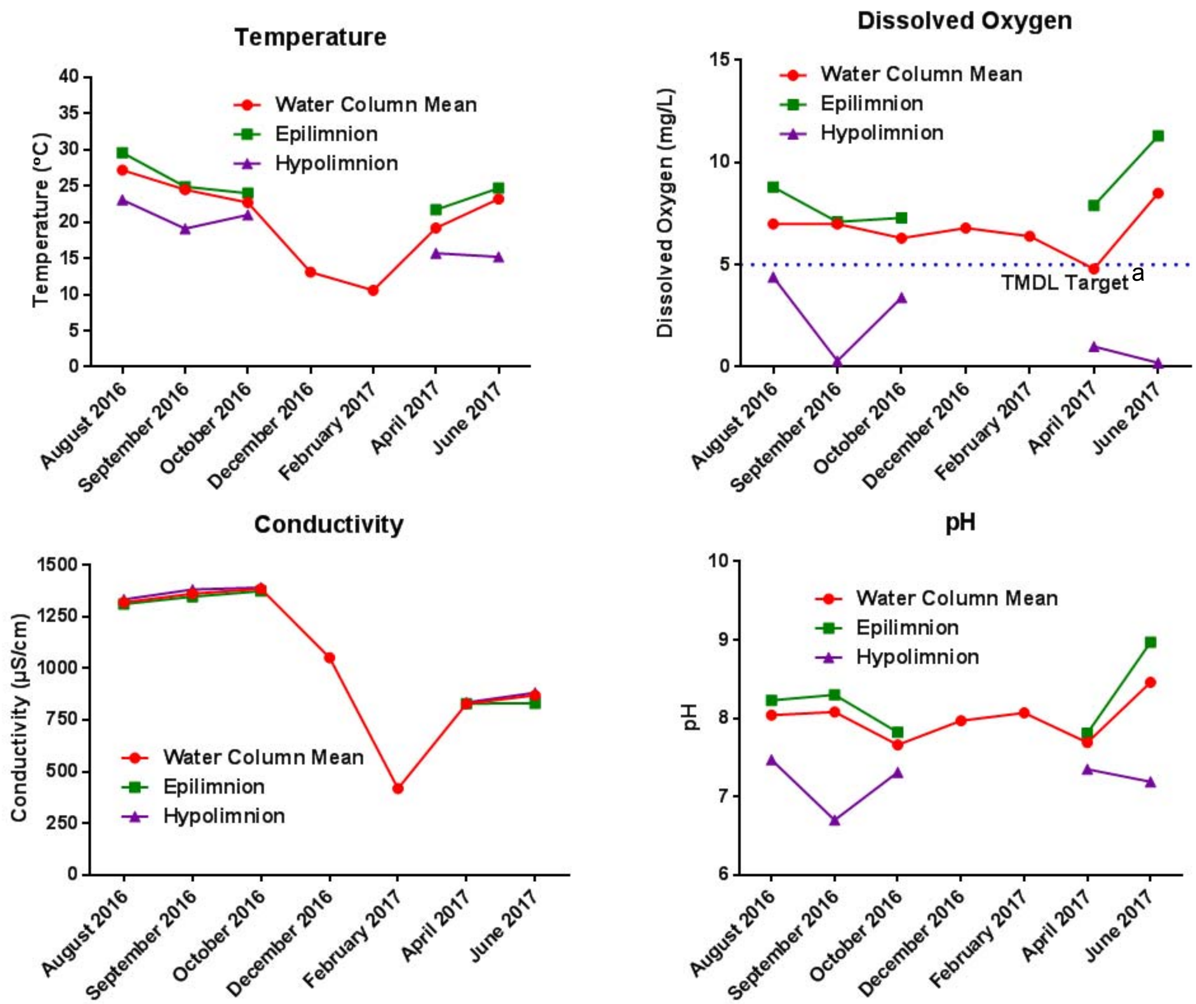
		Measure	CL07	CL08	Main Basin	CL09	CL10	East Basin
Water Column Mean	Min	Temp (°C)	10.6	10.8	10.5	10.7	10.7	10.6
		Cond (µS/cm)	377	372	424	412	374	418
		pH	7.27	7.68	7.63	7.67	7.48	7.65
		DO (mg/L)	2.6	4.2	4.1	5.5	3.4	4.8
	Max	Temp (°C)	21.4	26.6	25.9	28.5	24.0	27.2
		Cond (µS/cm)	1256	1275	1375	1394	1265	1385
		pH	7.97	8.19	8.15	8.77	8.08	8.46
		DO (mg/L)	5.9	6.2	5.9	11.3	6.0	8.6
	Average	Temp (°C)	17.1	19.7	19.3	20.9	18.4	20.1
		Cond (µS/cm)	897	905	1026	1040	901	1033
		pH	7.69	7.96	7.88	8.11	7.83	8.00
		DO (mg/L)	3.8	5.2	5.4	8.0	4.5	6.7
Epilimnion	Min	Temp (°C)	19.9	20.6	20.5	23.0	20.2	21.7
		Cond (µS/cm)	586	579	802	858	583	830
		pH	7.52	7.74	7.78	7.66	7.63	7.72
		DO (mg/L)	6.8	6.6	6.7	7.9	6.7	7.3
	Max	Temp (°C)	28.4	28.7	28.6	30.6	28.6	29.6
		Cond (µS/cm)	1284	1279	1374	1372	1282	1373
		pH	8.75	8.78	8.97	8.12	8.77	8.55
		DO (mg/L)	10.8	11.1	11.3	9.5	11.0	10.4
	Average	Temp (°C)	24.3	24.5	24.3	26.2	24.4	25.3
		Cond (µS/cm)	1008	1002	1131	1183	1005	1157
		pH	8.27	8.29	8.27	7.88	8.28	8.07
		DO (mg/L)	7.9	7.9	8.2	8.5	7.9	8.3
Hypolimnion	Min	Temp (°C)	12.2	12.7	12.5	19.0	12.4	15.7
		Cond (µS/cm)	586	586	844	827	586	835
		pH	6.83	6.84	6.70	7.50	6.83	7.10
		DO (mg/L)	0.1	0.2	0.2	1.9	0.1	1.0
	Max	Temp (°C)	14.2	21.3	19.6	28.2	17.7	23.9
		Cond (µS/cm)	1217	1245	1383	1398	1231	1391
		pH	7.43	7.56	7.21	8.20	7.49	7.70
		DO (mg/L)	0.8	0.3	0.3	8.7	0.6	4.5
	Average	Temp (°C)	13.3	17.6	16.9	23.2	15.5	20.0
		Cond (µS/cm)	961	966	1168	1181	963	1174
		pH	7.06	7.17	6.95	7.80	7.12	7.37
		DO (mg/L)	0.3	0.2	0.2	5.7	0.3	3.0



aTMDL Target for dissolved oxygen is no less than 5 mg/L above thermocline no later than 2015, no less than 5 mg/L in hypolimnion no later than 2020

Figure 3-8. Mean In-Situ Physical Water Quality Parameters – Canyon Lake Main Basin

(Values represent the mean of Sites CL07 & CL08. Missing values represent time periods when no stratification was present)



[a]TMDL Target for dissolved oxygen is no less than 5 mg/L above thermocline no later than 2015, no less than 5 mg/L in hypolimnion no later than 2020

Figure 3-9. Mean In- Situ Physical Water Quality Parameters - Canyon Lake East Basin

(Values represent the mean of Sites CL09 & CL10. Missing values represent time periods when no stratification was present.)

Analytical Chemistry

Summaries of analytical chemistry concentrations for each monitoring event in Canyon Lake across the entire monitoring period are presented in Tables 3-16 through 3-18. A summary of analytical chemistry mean statistics for each site across the entire monitoring period are presented in Tables 3-19 through 3-21. Concentrations of analytes are graphically presented in Figures 3-10 and 3-11.

Total nitrogen concentrations in the Main Basin (average of monthly values from CL07 and CL08) ranged from 0.61 to 2.28 mg/L across the six sampling events with the annual mean of 1.44 mg/L, exceeding the current 2020 TMDL target of 0.75 mg/L. Total nitrogen concentrations in the East Basin ranged from 1.15 to 1.86 mg/L across the six sampling events with the annual mean of 1.46 mg/L, also exceeding the current 2020 TMDL target.

Total phosphorus concentrations in the Main Basin ranged from non-detect (ND = 0.05 mg/L) to 0.77 mg/L, with an annual mean of 0.21 mg/L, exceeding the current 2020 TMDL target of 0.1 mg/L. Total phosphorus concentrations in the East Basin ranged from ND to 0.83 mg/L, with an annual mean of 0.19 mg/L, also exceeding the current 2020 TMDL target of 0.10 mg/L.

Depth-integrated samples in the Main Basin exhibited a steady decline in chlorophyll-a concentrations across the monitoring period. The East Basin exhibited more of a seasonal pattern with lower concentrations of chlorophyll-a in the winter and early spring months, and greater concentrations during the summer and fall months. Depth-integrated concentrations in the Main Basin (mean of Sites CL07 and CL08) across all six sampling events ranged from 2 to 42 µg/L, with a mean of 17 µg/L. Depth-integrated concentrations of chlorophyll-a in the East Basin (Site CL10) across all six sampling events ranged from 3 to 57 µg/L, with a mean of 22 µg/L. Both basins had mean annual concentrations below the current 2015 and 2020 TMDL targets annual mean of 40 and 25 µg/L, respectively.

Total ammonia concentrations observed in the Main and Eastern Basins showed somewhat contrasting patterns. While the Main Basin exhibited an increase in late summer and fall, then declined across the winter season, concentrations in the East Basin were relatively low across the summer and fall seasons and then increased in winter and spring 2017. No individual samples exceeded the US EPA CMC or CCC values for the protection of aquatic life.

Total dissolved solids concentration was relatively stable until the February 2017 sampling event, where following several large storms the TDS concentration decreased by approximately 500 mg/L. Prior to storms TDS concentrations were above the Basin Plan target of 700 mg/L, but fell below the target following storms.

All cyanobacterial toxins measured were below detection limits at sites CL07 and CL10 during the June 2017 monitoring event (<0.001 µg/L). Low concentrations of microcystin were observed in samples from Sites CL08 and CL09, at 0.003 and 0.009 µg/L respectively. This is well below the State of California’s lowest tier for human health risk at 0.8 µg/L. No anatoxin-a, cylindrospermopsin, or nodularin were detected at sites CL08 and CL09.

The current 2016-2017 FY Canyon Lake data in the context of historical data can be found in Appendix H.

Table 3-16. Analytical Chemistry Results for Canyon Lake - 2016 Monthly Depth-Integrated Results

Method	Compound	Units	RL	Depth Integrated or Surface	August 2016				September 2016				October 2016				December 2016			
					Main Basin		East Basin		Main Basin		East Basin		Main Basin		East Basin		Main Basin		East Basin	
					CL07	CL08	CL09	CL10	CL07	CL08	CL09	CL10	CL07	CL08	CL09	CL10	CL07	CL08	CL09	CL10
General Chemistry																				
SM 2540C	Total Dissolved Solids	mg/L	10-40	DI	790	770	NS	870	780	840	870	860	880	800	880	900	800	850	NS	900
SM 2540D	Total Suspended Solids	mg/L	2	DI	NS	NS	NS	NS	3	3	7	12	4	2	6	8	NS	NS	NS	NS
SM 4500S2 D	Sulfide	mg/L	0.1	DI	<0.1	<0.1	NS	<0.1	NS	NS	NS	NS	NS	NS	NS	NS	<0.1	<0.1	NS	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	DI	<0.2	<0.2	NS	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	NS	<0.2
SM 4500NO2 B	Nitrite as N	mg/L	0.1	DI	<0.1	<0.1	NS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	NS	<0.1
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	DI	1.6	1.1	NS	1.2	1.4	0.9	1.3	1.7	2.1	0.73	1.1	2.3	1.6	1.5	NS	1.7
Calculated	Total Nitrogen[a]	mg/L	--	DI	1.6	1.1	NS	1.2	1.4	0.9	1.3	1.7	2.1	0.73	1.1	2.3	1.6	1.5	NS	1.7
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	DI	0.67	<0.1	NS	<0.1	1.5	<0.1	<0.1	<0.1	1.4	<0.1	<0.1	<0.1	0.55	0.44	NS	0.4
Calculated	Unionized Ammonia[b,c]	mg/L	--	DI	0.001	0.003	NS	0.007	0.023	0.002	0.002	0.005	0.014	0.001	0.001	0.001	0.009	0.009	NS	0.007
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	DI	<0.05	<0.05	NS	<0.05	0.2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	NS	<0.05
SM 4500P B E	Total Phosphorus	mg/L	0.05	DI	0.21	<0.05	NS	0.18	0.1	<0.05	0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	NS	<0.05
EPA 200.7	Total Aluminum	µg/L	100	DI	NS	NS	NS	NS	<100	<100	<100	120	130	180	200	240	NS	NS	NS	NS
EPA 200.7	Dissolved Aluminum	µg/L	100	DI	NS	NS	NS	NS	<100	<100	<100	<100	<100	110	110	110	NS	NS	NS	NS
Chlorophyll-a																				
EPA 10200 H	Chlorophyll-a	µg/L	1.0	Surf	16	7	14	15	NS	NS	NS	NS	NS	NS	NS	NS	11	54	14	18
EPA 10200 H	Chlorophyll-a	µg/L	1.0	DI	54	29	NS	14	31	14	31	14	24	12	36	38	14	26	NS	16
Algae Toxins																				
LC-MS/MS	Total Microcystin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				SG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LC-MS/MS	Total Nodularin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				SG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LC-MS/MS	Total Anatoxin-a	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				SG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
LC-MS/MS	Total Cylindospermopsin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
				SG	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Notes:
a - Total Nitrogen = TKN+NO_2+NO_3
b - Values are site specific dependent upon pH and temperature recorded at each location. Calculated using equation by Thursby (1986).
c - Unionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
NS - Not sampled
DI = Depth integrated; SG = Surface grab; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit

Table 3-17. Analytical Chemistry Results for Canyon Lake- 2017 Monthly Depth-Integrated Results

Method	Compound	Units	RL	Depth Integrated or Surface	February 2017				April 2017				June 2017			
					Main Basin		East Basin		Main Basin		East Basin		Main Basin		East Basin	
					CL07	CL08	CL09	CL10	CL07	CL08	CL09	CL10	CL07	CL08	CL09	CL10
General Chemistry																
SM 2540C	Total Dissolved Solids	mg/L	10-40	DI	320	340	370	340	340	340	480	520	370	400	520	550
SM 2540D	Total Suspended Solids	mg/L	2	DI	NS	NS	NS	NS	3	3	2	2	<2	<2	8	12
SM 4500S2 D	Sulfide	mg/L	0.1	DI	NS	NS	NS	NS	<0.1	<0.1	NS	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	DI	1.10	1.10	0.83	0.88	0.71	0.56	0.11	0.06	<0.2	<0.2	<0.2	<0.2
SM 4500NO2 B	Nitrite as N	mg/L	0.1	DI	<0.1	0.05	<0.1	<0.1	<0.1	<0.1	NS	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	DI	1.00	1.30	1.00	1.00	1.10	1.10	1.30	0.83	0.85	0.37	1.20	1.10
Calculated	Total Nitrogen[a]	mg/L	--	DI	2.10	2.45	1.83	1.88	1.81	1.66	1.41	0.89	0.85	0.37	1.20	1.10
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	DI	0.3	0.28	0.43	0.21	0.33	0.22	0.69	0.24	0.6	0.091	<0.1	<0.1
Calculated	Unionized Ammonia[b,c]	mg/L	--	DI	0.006	0.006	0.007	0.003	0.005	0.005	0.008	0.002	0.014	0.006	0.003	0.012
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	DI	0.34	0.34	0.45	0.45	0.23	0.20	0.18	0.05	0.33	0.10	0.04	<0.05
SM 4500P B E	Total Phosphorus	mg/L	0.05	DI	0.76	0.78	0.83	0.83	0.26	0.21	0.20	0.07	0.30	0.13	0.09	0.04
EPA 200.7	Total Aluminum	µg/L	100	DI	4100	4100	2200	1800	160	100	60	70	68	76	71	94
EPA 200.7	Dissolved Aluminum	µg/L	100	DI	<100	<100	<100	<100	<100	<100	<100	44	<100	<100	44	66
Chlorophyll-a																
EPA 10200 H	Chlorophyll-a	µg/L	1.0	Surf	6	4	9	26	27	50	1	1	5	<1	17	46
EPA 10200 H	Chlorophyll-a	µg/L	1.0	DI	4	<1	4	10	7	12	4	2	2	2	63	50
Algae Toxins																
LC-MS/MS	Total Microcystin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	0.003	0.009	<0.001
				SG	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	NS	NS	NS
LC-MS/MS	Total Nodularin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	<0.001	<0.001	<0.001
				SG	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	NS	NS	NS
LC-MS/MS	Total Anatoxin-a	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	<0.001	<0.001	<0.001
				SG	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	NS	NS	NS
LC-MS/MS	Total Cylindospermopsin	µg/L	0.001	DI	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	<0.001	<0.001	<0.001
				SG	NS	NS	NS	NS	NS	NS	NS	NS	<0.001	NS	NS	NS

Notes:
a - Total Nitrogen = TKN+NO_2+NO_3
b - Values are site specific dependent upon pH and temperature recorded at each location. Calculated using equation by Thursby (1986).
c - Unionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
NS - Not sampled
DI = Depth integrated; SG = Surface grab; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit

Table 3-18. Analytical Chemistry Results for Canyon Lake- Monthly Epilimnion/Hypolimnion Results for Each Site

Method	Compound	Units	RL	September 2016								October 2016							
				Main Basin				East Basin				Main Basin				East Basin			
				CL07		CL08		CL09		CL10		CL07		CL08		CL09		CL10	
				Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo	Epi	Hypo
General Chemistry																			
SM 2540C	Total Dissolved Solids	mg/L	10-40	760	760	820	840	880	860	NS	NS	800	810	800	820	900	850	NS	NS
SM 2540D	Total Suspended Solids	mg/L	2	3	2	4	6	8	16	NS	NS	2	5	2	3	4	6	NS	NS
SM 4500S2 D	Sulfide	mg/L	0.1	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
EPA 300.0	Nitrate as N	mg/L	0.2	0.35	<0.2	<0.2	<0.2	<0.2	<0.2	NS	NS	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	NS	NS
SM 4500NO2 B	Nitrite as N	mg/L	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	NS	NS	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	NS	NS
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	0.6	4.3	2.7	2.4	1.4	6.5	NS	NS	1	5.5	0.81	1	1.7	1.4	NS	NS
Calculated	Total Nitrogen[a]	mg/L	--	0.95	4.3	2.7	2.4	1.4	6.5	NS	NS	1	5.5	0.81	1	1.7	1.4	NS	NS
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	<0.1	3.1	<0.1	<0.1	<0.1	4.9	NS	NS	<0.1	4.9	<0.1	0.14	<0.1	<0.1	NS	NS
Calculated	Unionized Ammonia[b,c]	mg/L	--	0.004	0.005	0.003	0.000	0.005	0.009	NS	NS	0.001	0.009	0.001	0.001	0.002	0.000	NS	NS
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	<0.05	0.23	<0.05	<0.05	<0.05	<0.05	NS	NS	<0.05	0.22	<0.05	<0.05	<0.05	<0.05	NS	NS
SM 4500P B E	Total Phosphorus	mg/L	0.05	<0.05	0.28	<0.05	<0.05	<0.05	0.08	NS	NS	<0.05	0.24	<0.05	<0.05	<0.05	<0.05	NS	NS
EPA 200.7	Total Aluminum	µg/L	100	<100	<100	<100	<100	<100	<100	NS	NS	190	<100	290	130	200	270	NS	NS
EPA 200.7	Dissolved Aluminum	µg/L	100	<100	<100	<100	<100	<100	<100	NS	NS	100	<100	120	<100	120	120	NS	NS
Chlorophyll-a																			
EPA 10200 H	Chlorophyll-a	µg/L	1.0	10	24	12	11	31	147	NS	NS	12	57	10	14	33	55	NS	NS

Notes:
a - Total Nitrogen = $TKN+NO_2+NO_3$
b - Values are site specific dependent upon pH and temperature recorded at each location. Calculated using equation by Thursby (1986).
c - Unionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
Epi = Epilimnion; Hypo = Hypolimnion
NM – Not measured
NS - Not sampled, due to lack of stratification
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit

Table 3-19. Analytical Chemistry Results for Canyon Lake- Annual Mean Statistics for Each Site in the Main Basin

Method	Compound	Units	RL	Basin Plan or TMDL Target	Depth Integrated or Surface Sample	CL07			CL08			Main Basin[e]		
						Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
General Chemistry														
SM 2540C	Total Dissolved Solids	mg/L	10-40	700 [3]	DI	320	880	611	340	850	620	330	840	616
SM 2540D	Total Suspended Solids	mg/L	2	NA	DI	3	4	3	2	3	2	<2	3	2
SM 4500S2 D	Sulfide	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	NA	DI	0.71	1.10	0.40	<0.2	1.10	0.31	<0.2	1.10	0.32
SM 4500NO2 B	Nitrite as N	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1	0.05	0.05	<0.1	0.04	0.05
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	NA	DI	0.85	2.1	1.4	0.37	1.50	1.00	0.61	1.55	1.19
Calculated	Total Nitrogen[a]	mg/L	--	0.75[b1]	DI	0.85	2.1	**1.6**	0.37	2.45	**1.24**	0.61	2.28	**1.44**
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	NA	DI	0.30	1.50	0.76	<0.1	0.44	0.17	0.28	0.78	0.47
Calculated	Unionized Ammonia[c,d]	mg/L	--	CMC: 1.91-28.9[1] CCC: 0.36-3.72[1]	DI	0.001	0.023	0.010	0.001	0.009	0.005	0.002	0.012	0.007
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	NA	DI	<0.05	0.34	0.17	<0.05	0.34	0.11	<0.05	0.34	0.14
SM 4500P B E	Total Phosphorus	mg/L	0.05	0.1[b1]	DI	<0.05	0.76	**0.25**	<0.05	0.78	**0.17**	<0.05	0.77	**0.21**
EPA 200.7	Total Aluminum	µg/L	100	NA	DI	<100	4100	902	<100	4100	901	<100	4100	901
EPA 200.7	Dissolved Aluminum	µg/L	100	NA	DI	<100	<100	<100	<100	110	62	<100	80	56
Chlorophyll-a														
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1], 40[2]	Surf	5	27	13	<1	54	23	3	39	18
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1], 40[2]	DI	2	54	19	2	29	16	2	42	17

Notes:
a - Total Nitrogen = TKN+NO_2+NO_3
b - Annual average
c - Values calculated using water column mean ammonia, temperature, salinity and pH. Calculated using equation by Thursby (1986).
d - Unionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
e - Main Basin values are an average of minimum and maximum values for CL07 and CL08 and an overall mean of all values from both sites.
1 – 2020 TMDL Target, based on Table 5-9n of 2004 TMDL
2 – 2015 TMDL Target, based on Table 5-9n of 2004 TMDL
3 – Santa Ana Region Basin Plan Objective
NA – Not applicable/ available
NS - Not sampled
DI = Depth integrated; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit
Bold Underline - Indicates exceedance of Basin Plan/TMDL target

Table 3-20. Analytical Chemistry Results for Canyon Lake- Annual Mean Statistics for Each Site in the East Basin

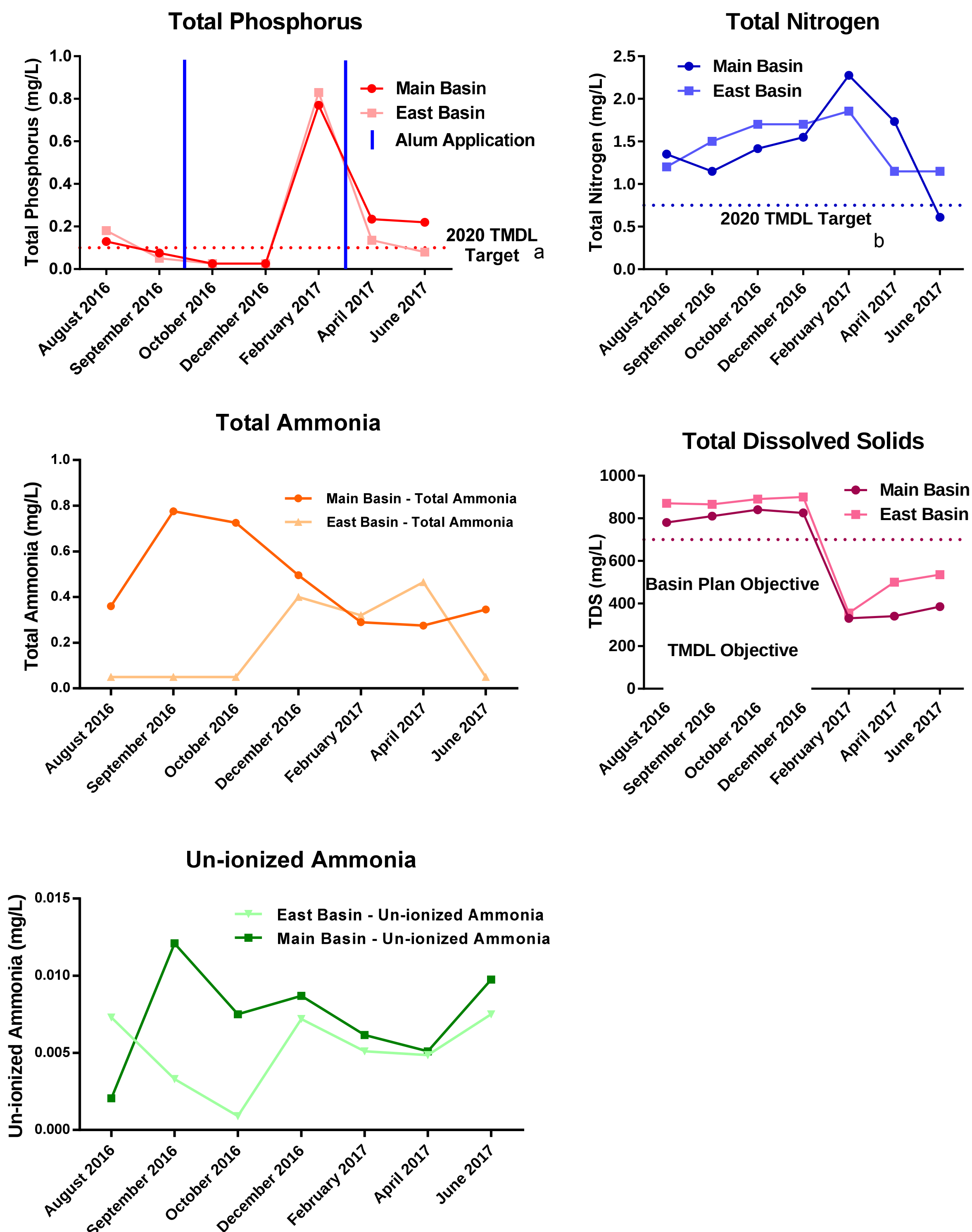
Method	Compound	Units	RL	Basin Plan or TMDL Target	Depth Integrated or Surface Sample	CL09			CL10			East Basin[e]		
						Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
General Chemistry														
SM 2540C	Total Dissolved Solids	mg/L	10-40	700 [3]	DI	370	880	624	340	900	**<u>706</u>**	355	900	**<u>702</u>**
SM 2540D	Total Suspended Solids	mg/L	2	NA	DI	6	8	7	8	12	11	7	10	9
SM 4500S2 D	Sulfide	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	NA	DI	<0.2	0.83	0.25	<0.2	0.88	0.21	<0.2	0.86	0.21
SM 4500NO2 B	Nitrite as N	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	NA	DI	1.00	1.30	1.18	0.83	2.30	1.40	1.00	1.70	1.33
Calculated	Total Nitrogen[a]	mg/L	--	0.75[b1]	DI	1.10	1.83	**<u>1.37</u>**	0.89	2.30	**<u>1.54</u>**	1.15	1.86	**<u>1.46</u>**
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	NA	DI	<0.1	0.69	0.25	<0.1	0.40	0.15	<0.1	0.47	0.20
Calculated	Unionized Ammonia[c,d]	mg/L	--	CMC: 1.91-28.9[1] CCC: 0.36-3.72[1]	DI	0.001	0.008	0.004	0.001	0.012	0.005	0.001	0.008	0.005
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	NA	DI	<0.05	0.45	0.14	<0.05	0.45	0.09	<0.05	0.45	0.10
SM 4500P B E	Total Phosphorus	mg/L	0.05	0.1[b1]	DI	<0.05	0.83	**<u>0.25</u>**	<0.05	0.83	**<u>0.17</u>**	<0.05	0.83	**<u>0.19</u>**
EPA 200.7	Total Aluminum	µg/L	100	NA	DI	<100	2200	516	70	1800	465	65	2000	491
EPA 200.7	Dissolved Aluminum	µg/L	100	NA	DI	<100	110	61	<100	110	73	<100	110	62
Chlorophyll-a														
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1], 40[2]	Surf	1	17	11	1	46	21	1	32	16
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1], 40[2]	DI	4	63	**<u>28</u>**	2	50	21	3	57	22

Notes:
a - Total Nitrogen = TKN+NO_2+NO_3
b - Annual average
c - Values calculated using water column mean ammonia, temperature, salinity and pH. Calculated using equation by Thursby (1986).
d - Unionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
e - East Basin values are an average of minimum and maximum values for CL09 and CL10 and an overall mean of all values from both sites.
1 – 2020 TMDL Target, based on Table 5-9n of 2004 TMDL
2 – 2015 TMDL Target, based on Table 5-9n of 2004 TMDL
3 – Santa Ana Region Basin Plan Objective
NA – Not applicable/ available
NS - Not sampled
DI = Depth integrated; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit
<u>Bold Underline</u> - Indicates exceedance of Basin Plan/TMDL target

Table 3-21. Analytical Chemistry Results for Canyon Lake- Annual Mean Statistics for Both Main and East Basins

Method	Compound	Units	RL	Basin Plan or TMDL Target	Depth Integrated or Surface Sample	Main Basin[e]			East Basin[e]		
						Min	Max	Avg	Min	Max	Avg
General Chemistry											
SM 2540C	Total Dissolved Solids	mg/L	10-40	700 [3]	DI	330	840	616	355	900	**<u>702</u>**
SM 2540D	Total Suspended Solids	mg/L	2	NA	DI	<2	3	2	7	10	9
SM 4500S2 D	Sulfide	mg/L	0.1	NA	DI	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
EPA 300.0	Nitrate as N	mg/L	0.2	NA	DI	<0.2	1.10	0.32	<0.2	0.86	0.21
SM 4500NO2 B	Nitrite as N	mg/L	0.1	NA	DI	<0.1	0.04	0.05	<0.1	<0.1	<0.1
EPA 351.2	Kjeldahl Nitrogen	mg/L	0.1-0.2	NA	DI	0.61	1.55	1.19	1.00	1.70	1.33
Calculated	Total Nitrogen[a]	mg/L	--	0.75[b1]	DI	0.61	2.28	**<u>1.44</u>**	1.15	1.86	**<u>1.46</u>**
SM4500NH3H	Ammonia-Nitrogen	mg/L	0.1	NA	DI	0.28	0.78	0.47	<0.1	0.47	0.20
Calculated	Unionized Ammonia[c,d]	mg/L	--	CMC: 1.91-28.9[1] CCC: 0.36-3.72[1]	DI	0.002	0.012	0.007	0.001	0.008	0.005
SM 4500P E	Ortho Phosphate Phosphorus	mg/L	0.05	NA	DI	<0.05	0.34	0.14	<0.05	0.45	0.10
SM 4500P B E	Total Phosphorus	mg/L	0.05	0.1[b1]	DI	<0.05	0.77	**<u>0.21</u>**	<0.05	0.83	**<u>0.19</u>**
EPA 200.7	Total Aluminum	µg/L	100	NA	DI	<100	4100	901	65	2000	491
EPA 200.7	Dissolved Aluminum	µg/L	100	NA	DI	<100	80	56	<100	110	62
Chlorophyll-a											
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1], 40[2]	Surf	3	39	18	1	32	16
EPA 10200 H	Chlorophyll-a	µg/L	1.0	25[1], 40[2]	DI	2	42	17	3	57	22

Notes:
a - Total Nitrogen = TKN+NO_2+NO_3
b - Annual average
c - Values calculated using water column mean ammonia, temperature, salinity and pH. Calculated using equation by Thursby (1986).
d - Unionized ammonia concentrations calculated based on ½ detection limit when ammonia nitrogen was ND
e - Main Basin values are an average of CL07 and CL08, East Basin is represented by CL09 and CL10
1 – 2020 TMDL Target, based on Table 5-9n of 2004 TMDL
2 – 2015 TMDL Target, based on Table 5-9n of 2004 TMDL
3 – Santa Ana Region Basin Plan Objective
NA – Not applicable/ available
DI = Depth integrated; Surf = Surface 0-2m
mg/L – micrograms per liter; ug/L – milligrams per liter; m – meters; RL – reporting limit
<u>Bold Underline</u> - Indicates exceedance of Basin Plan/TMDL target



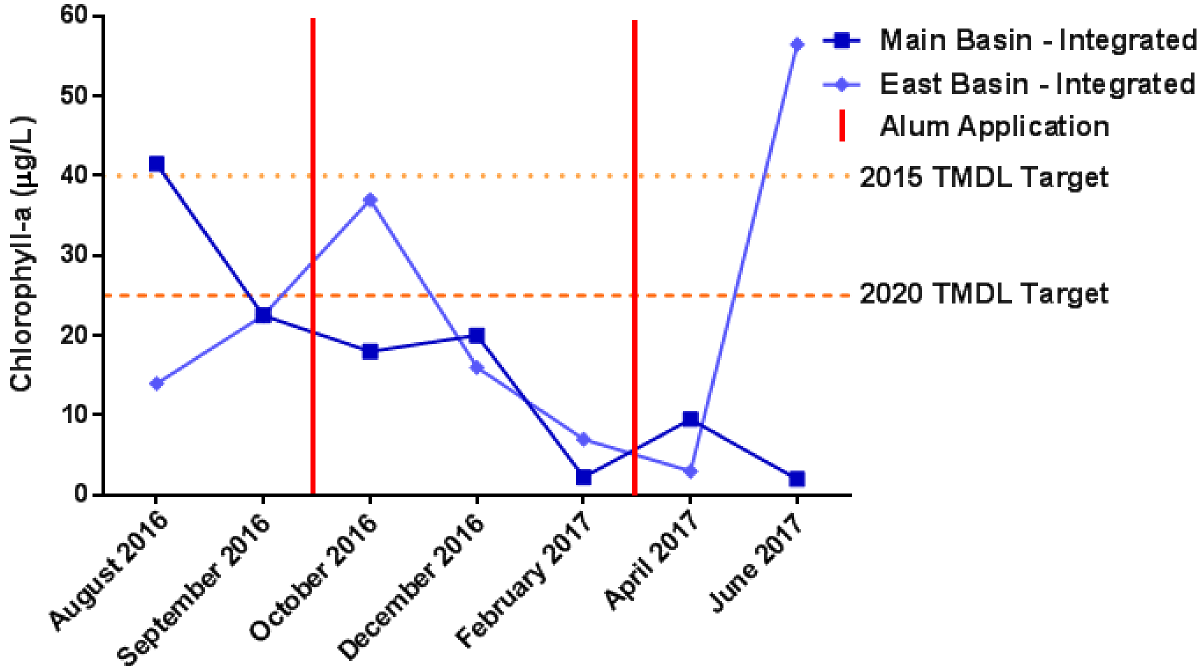
[a]Annual average no greater than 0.1 mg/L no later than 2020

[b]Annual average no greater than 0.75 mg/L no later than 2020

Figure 3-10. Canyon Lake Analytical Chemistry – Depth-Integrated Means

(Main Basin values represent Sites CL07 & CL08 mean, East Basin values represent Sites CL09 & CL10 mean)

a



[a]Annual average no greater than 40 µg/L no later than 2015
[b]Annual average no greater than 25 µg/L no later than 2020

Figure 3-11. Canyon Lake Analytical Chemistry – Depth-Integrated Chlorophyll-a

(Main Basin values represent mean of Sites CL07 & CL08, East Basin values represent mean of Sites CL09 & CL10 samples)

3.4 Satellite Imagery

Beginning with the 2015-2016 FY, the TMDL Task Force contracted with satellite vendor EOMAP to conduct remote sensing using LandSat satellite imagery to estimate chlorophyll-a and turbidity concentrations in Lake Elsinore and Canyon Lake. Using 30-m pixel resolution, this effort produced maps of the lake showing graphical, color-coded images of chlorophyll-a and turbidity concentrations at up to approximately 1,000 unique data points across Canyon Lake and approximately 11,000 unique data points across Lake Elsinore. This tool provides a snapshot of conditions throughout the entire lake at a given point in time, as opposed to the single data points provided at water quality collection locations and dates; however, the satellite imagery only represents approximately the upper 4 feet of the water column depending on water clarity, and therefore cannot completely replace manual sampling where depth-integrated values are required. It should also be noted that satellite data is overlayed on a fixed stock image of both lakes, so water level and lateral extent depicted in the stock image (particularly in Lake Elsinore) is not necessarily representative of the water extent at the time of the image capture. The true extent of water during each sampling event is represented by the satellite chlorophyll and turbidity data.

As part of the TMDL compliance monitoring, satellite imagery depicting lake-wide chlorophyll-a and turbidity concentrations in Lake Elsinore and Canyon Lake were generated for each in-lake monitoring event. Satellite images for each lake during the eight monitoring events evaluated in

the report are presented in Figures 3-12 through 3-15. Significant spatial variability in chlorophyll-a is evident across each lake providing a more complete assessment of algal density conditions across each lake.

The progression of the large cyanobacteria bloom in Lake Elsinore over the summer and fall of 2016 is apparent from the satellite imagery. The bloom began in early July 2016, and images show increasing chlorophyll-a concentrations across the summer, with large, thick floating mats of algae being responsible for the imagery data gaps in August, September, and December 2016. During massive cyanobacteria algal blooms with floating algal slicks such as the one on Lake Elsinore, the satellite data processors cannot detect water, and interpret the floating algal slicks as terrestrial vegetation, which are therefore flagged and removed from the data set. Lake-wide chlorophyll-a concentrations exhibit a decreasing trend January through June 2017 following the significant precipitation received December through February.

Satellite imagery in Canyon Lake experienced two months (October 2016 and February 2017) in which quality control issues impacted the data. In October 2016, high cirrus clouds above Canyon Lake partially obscured portions of the lake causing data gaps, while data derived from visible portions of the lake were flagged as unreliable and very likely biased high. Canyon Lake chlorophyll-a analytical concentrations from October 2016 ranged from 12 to 38 µg/L. Satellite chlorophyll-a values from the February 2017 sampling event (actual image taken January 25, 2017 due to dense cloud cover the day of in-lake sampling) are an overestimation of actual in-lake chlorophyll-a concentrations due to the high levels of inorganic/mineral turbidity in Canyon Lake (see Figure 3-15) as a result of recent large storms. Actual in-lake chlorophyll-a concentrations from February 2017 ranged from <1 to 10 µg/L. With the exception of those two months, chlorophyll-a concentrations in Canyon Lake derived from satellite imagery remained relatively consistent in the main body of the lake. The eastern arm of the lake did experience some months of elevated chlorophyll-a values, generally in the far eastern end, some of which may be due to edge interference, in which data pixels around the edges of the lake mix both water and land data to create a "composite" value. LandSat 7/8 imagery uses 30-m pixel resolution and requires a minimum mapping size of three pixels (90-m) to generate a valid concentration. The far eastern arm of Canyon Lake is generally below this minimum width in most places. Sentinel 2-A satellite data being implemented in the next fiscal year (FY 2017-2018) utilizes 10-m resolution and records 3 times as many pixels which should rectify most of the edge interference issue.

Cumulative frequency distribution plots showing lake-wide chlorophyll-a concentrations based on individual satellite data pixels is provided in Figures 3-16 and 3-17. Median values along with measured chlorophyll-a concentrations collected in-lake are provided for each date showing these single data points relative to concentrations throughout the entire lake. Median values were derived from satellite imagery data treating each pixel as a unique individual data point.

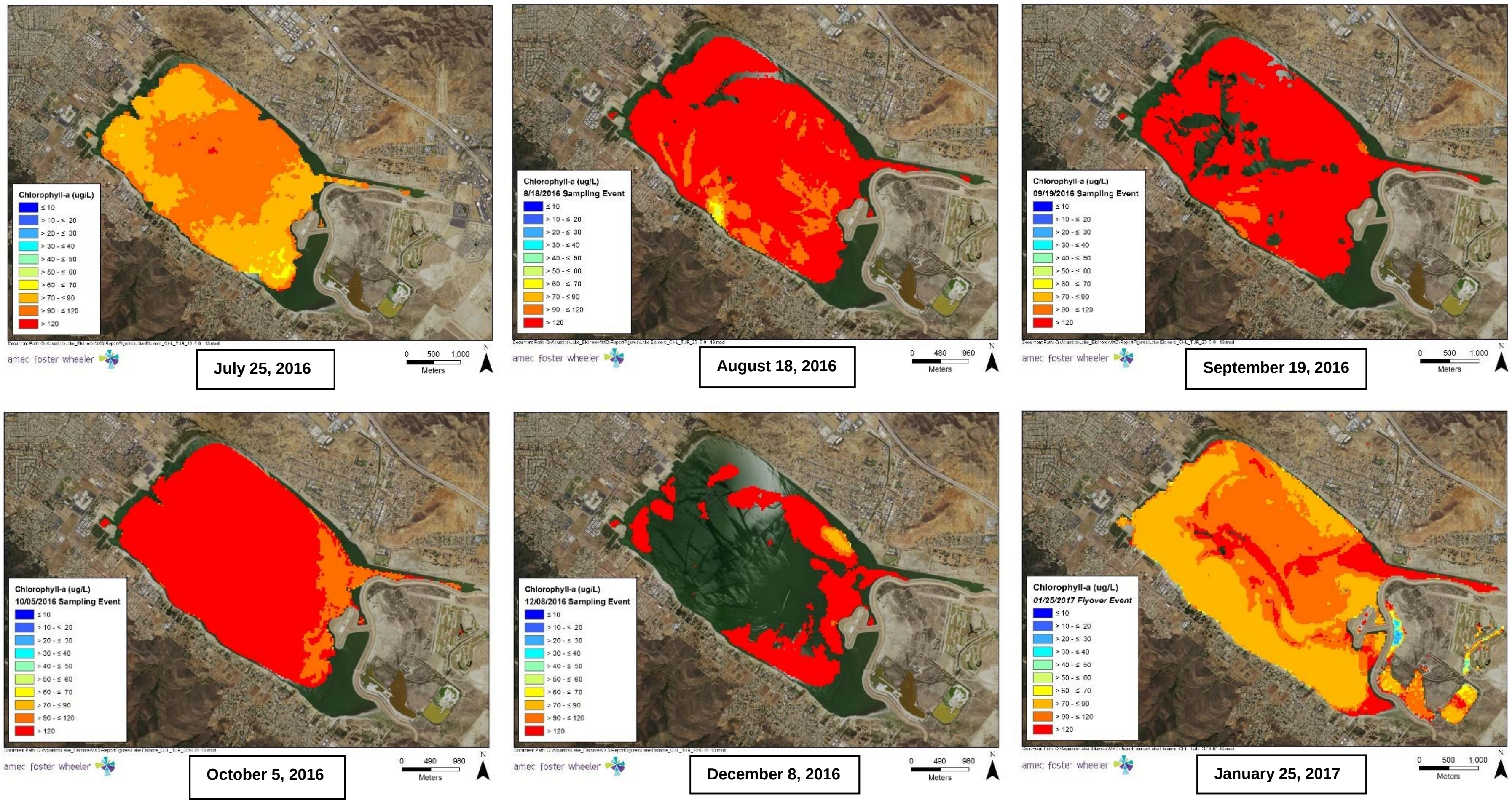


Figure 3-12. Satellite Imagery of Chlorophyll-a Concentrations in Lake Elsinore

(data gaps in August, September, and December are due to large surface cyanobacterial slicks)

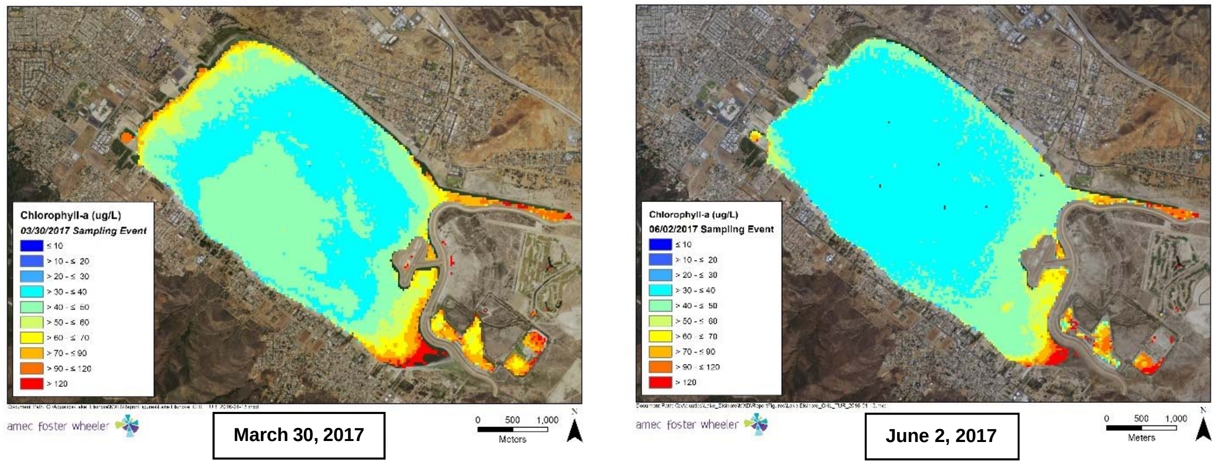


Figure 3-12 (cont). Satellite Imagery of Chlorophyll-a Concentrations in Lake Elsinore

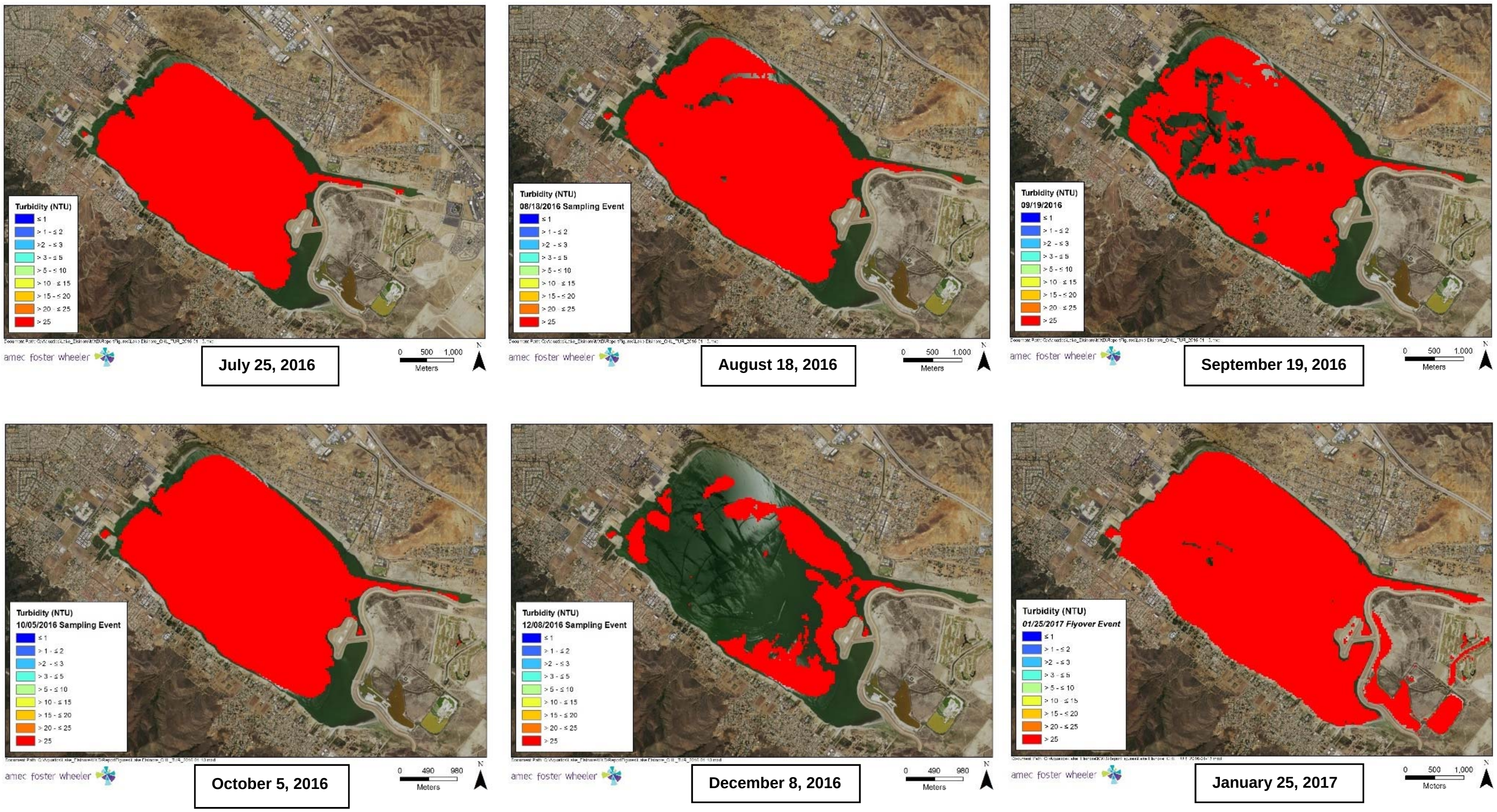


Figure 3-13. Satellite Imagery of Turbidity Concentrations in Lake Elsinore

(data gaps in August, September, and December are due to large surface cyanobacterial slicks)

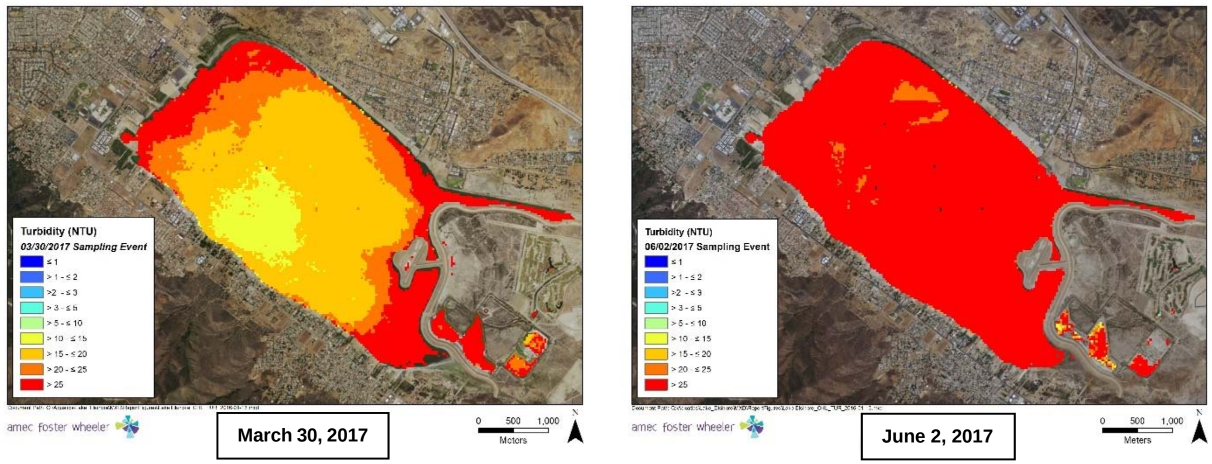


Figure 3-13 (cont). Satellite Imagery of Turbidity Concentrations in Lake Elsinore

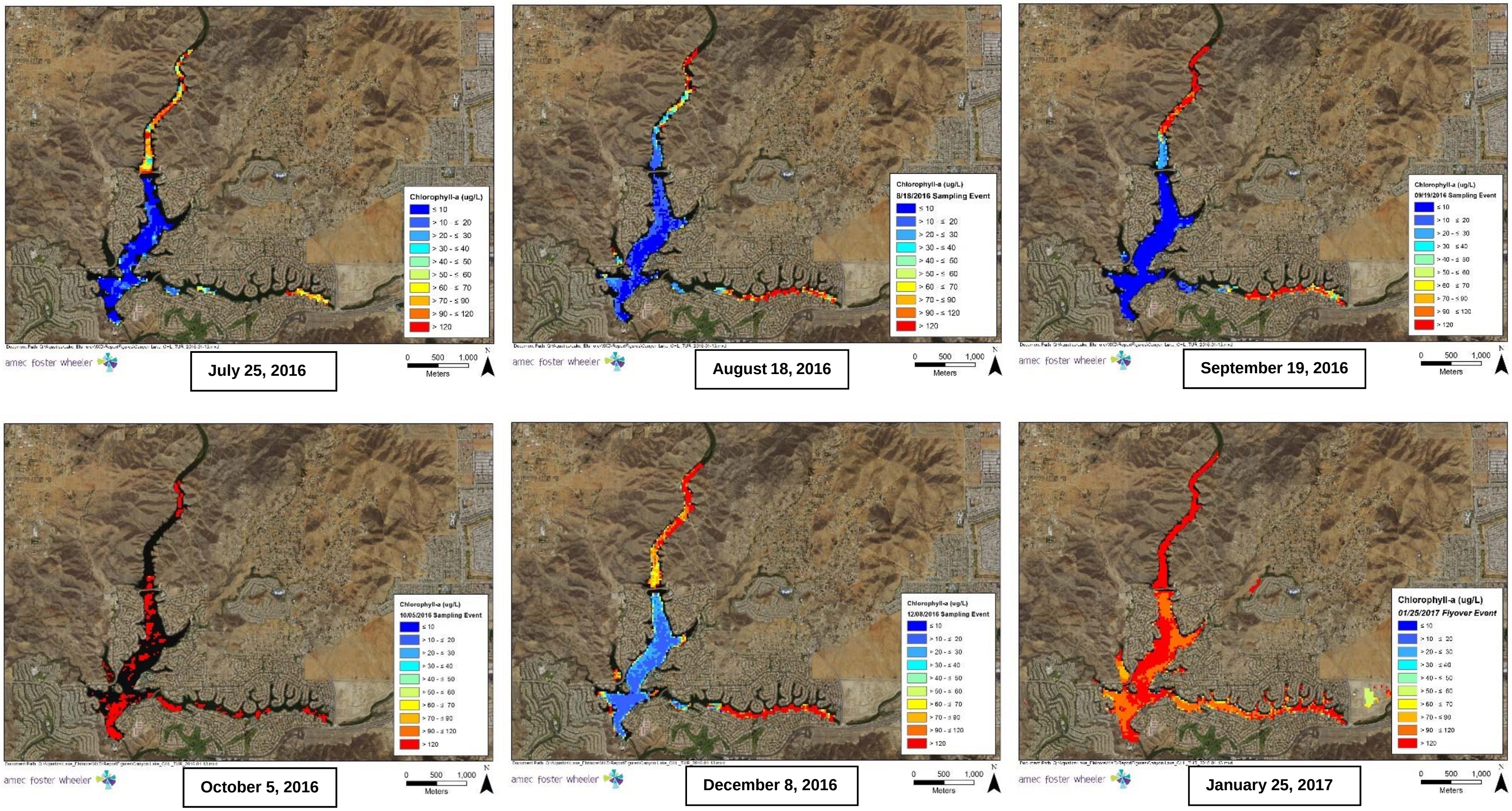


Figure 3-14. Satellite Imagery of Chlorophyll-a Concentrations in Canyon Lake

(high cirrus cloud interference caused data gaps and overestimates of chlorophyll-a in October; substantial overestimate of lake-wide chlorophyll-a concentrations in January due to high turbidity levels)

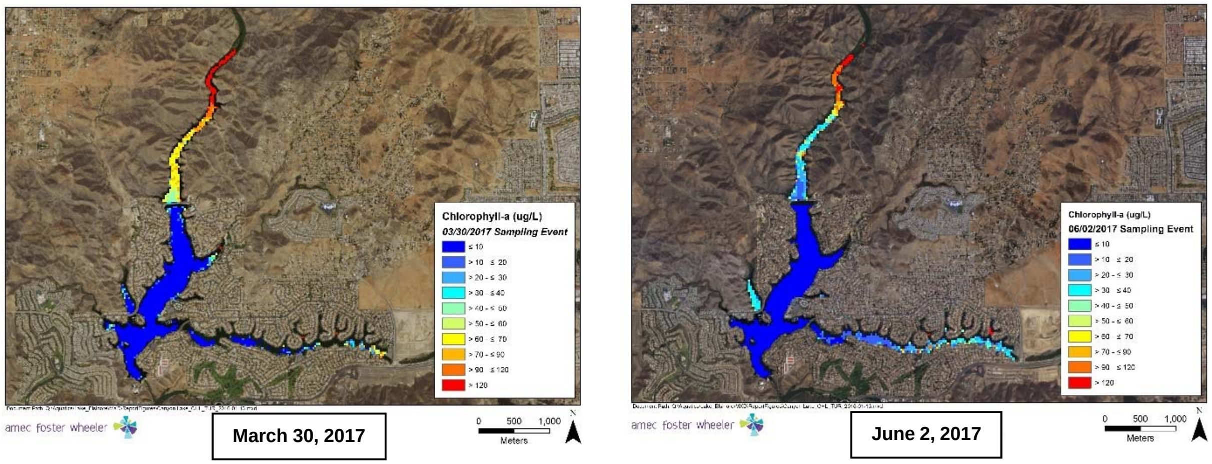


Figure 3-14 (cont). Satellite Imagery of Chlorophyll-a Concentrations in Canyon Lake

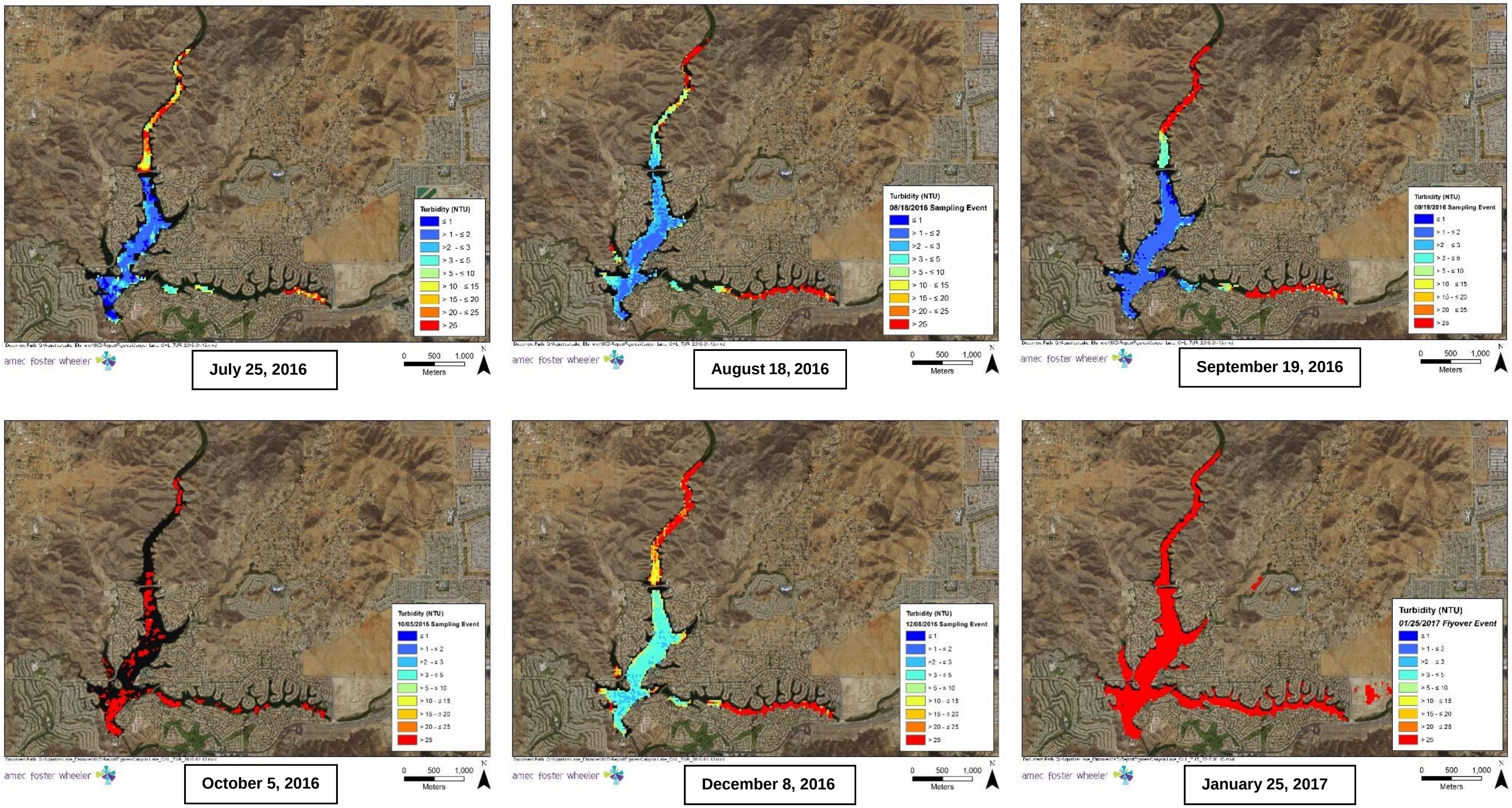


Figure 3-15. Satellite Imagery of Turbidity Measurements Canyon Lake

(high cirrus cloud interference caused data gaps and overestimates of turbidity in October)

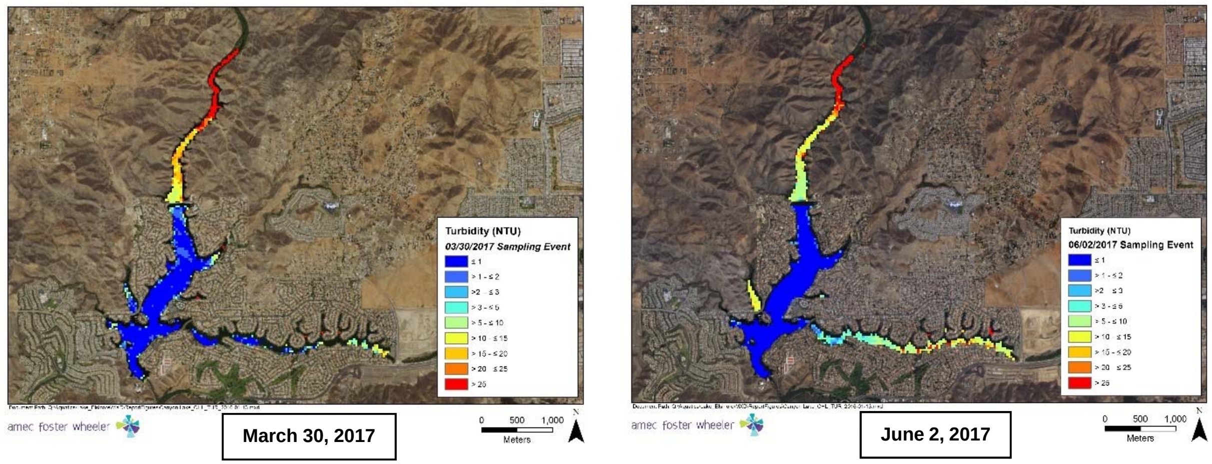


Figure 3-15 (cont). Satellite Imagery of Turbidity Measurements Canyon Lake

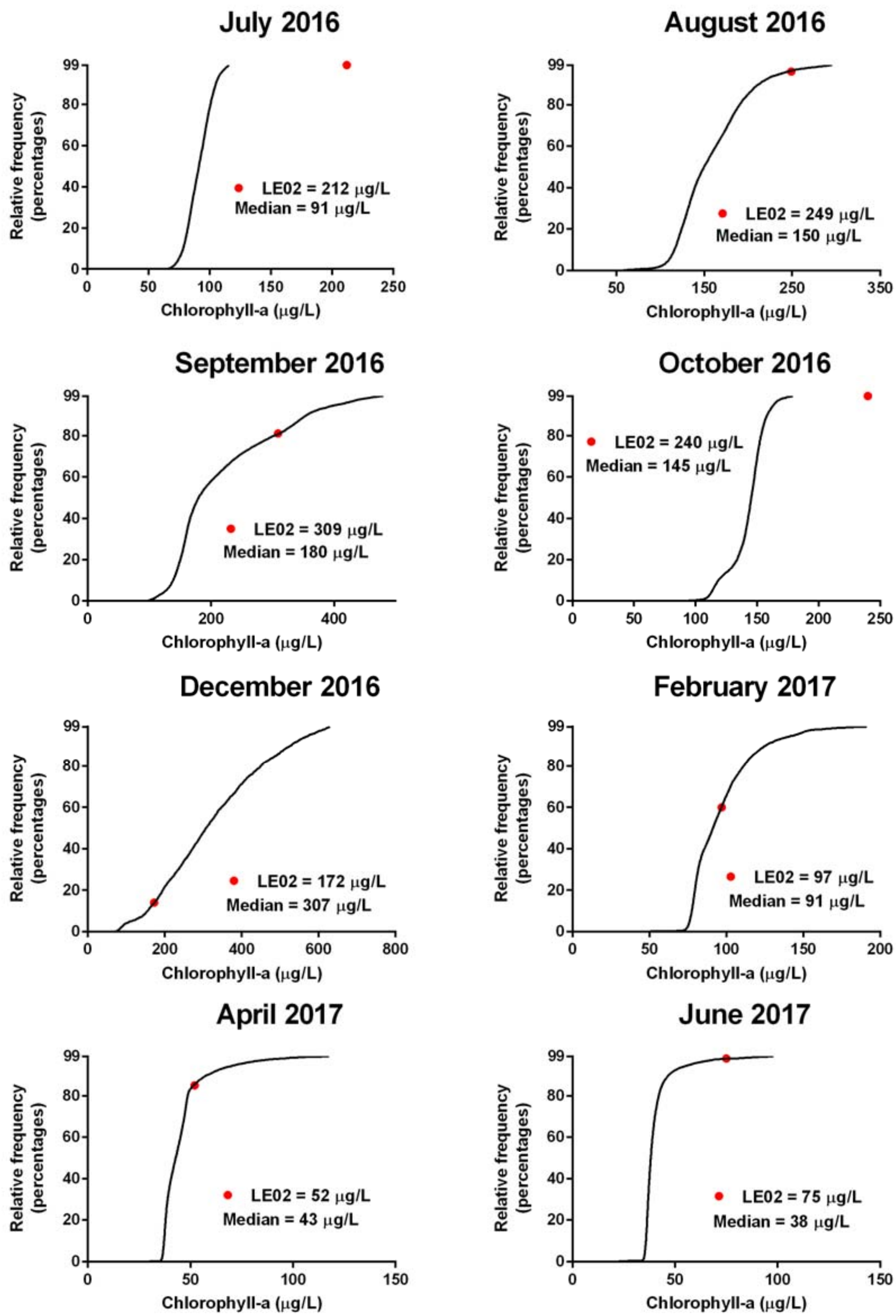


Figure 3-16. Cumulative Distribution of Satellite Derived Chlorophyll-a Concentrations in Lake Elsinore Relative to Field Collected Samples

(Note: 99^{th} percentile shown to better show field collected values on curve)

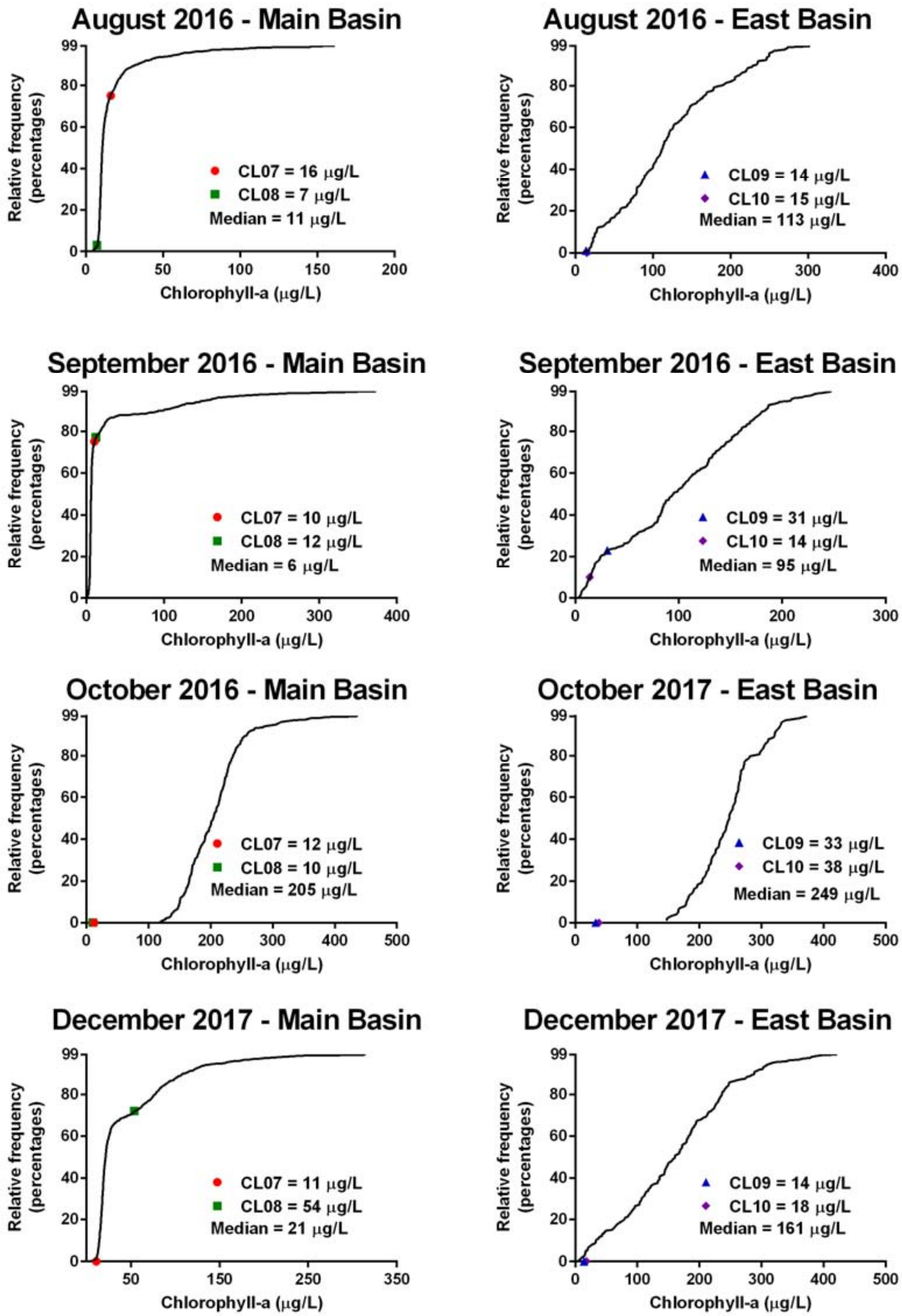


Figure 3-17. Cumulative Distribution of Satellite Derived Chlorophyll-a Concentrations in Canyon Lake Relative to Field Collected Samples

(Note: 99th percentile shown to better show field collected values on curve. Satellite data may over-represent actual chlorophyll-a values in East Basin due to edge effects. See discussion in section 3.4)

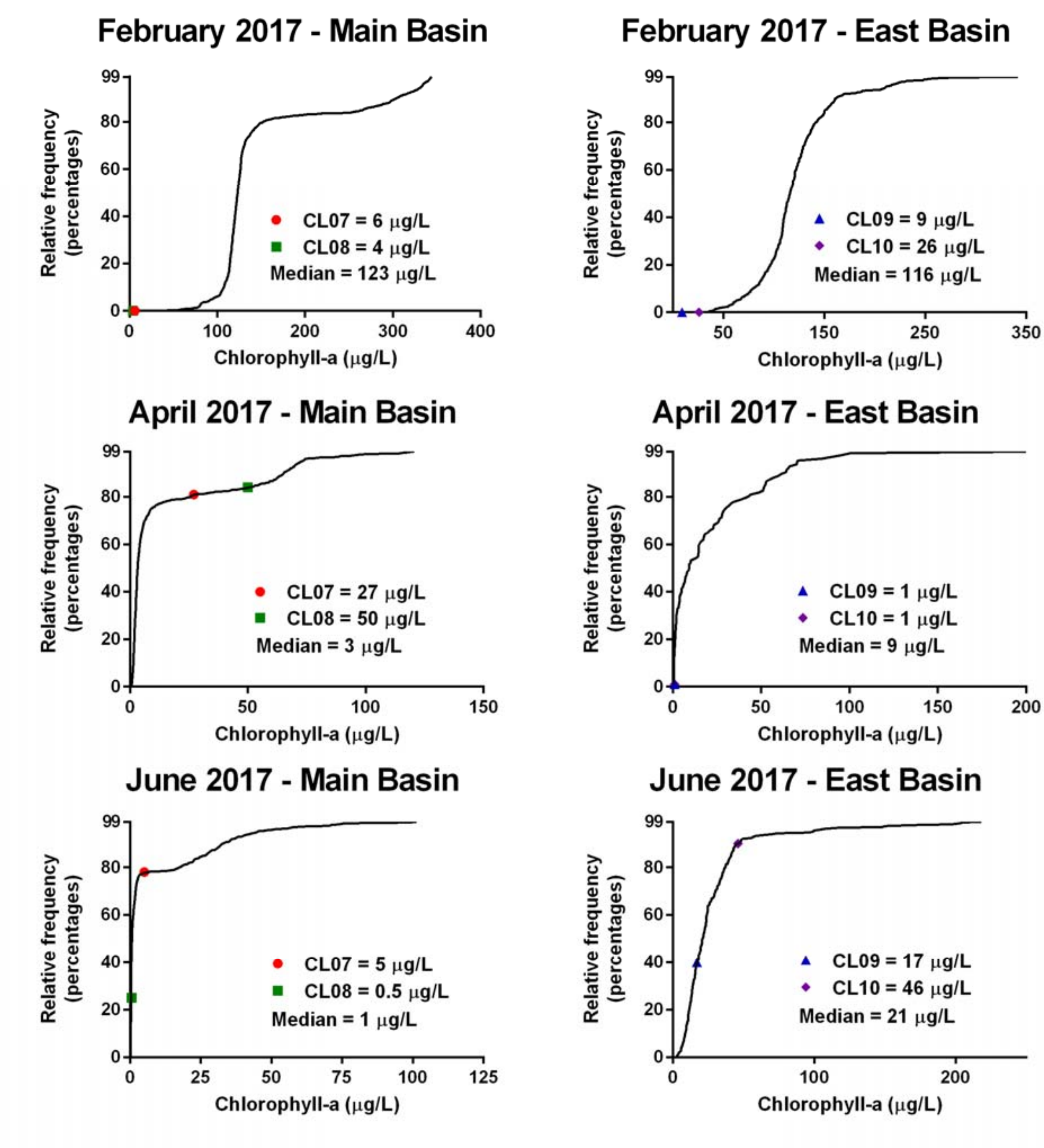


Figure 3-17 (cont). Cumulative Distribution of Satellite Derived Chlorophyll-a Concentrations in Canyon Lake Relative to Field Collected Sample

(Note: 99th percentile shown to better show field collected values on curve. Satellite data may over-represent actual chlorophyll-a values in East Basin due to edge effects or high turbidity interferences. See discussion in section 3.4)

4.0 References

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