

TMDL Progress Report:
**Evaluation of Compliance with the 2015 Interim Response Targets for
Dissolved Oxygen and Chlorophyll-a in Canyon Lake and Lake Elsinore**



Prepared for:

Lake Elsinore - Canyon Lake Nutrient TMDL Task Force

June 30, 2016

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1.0 Background

In 1994, Lake Elsinore was added to EPA's list of impaired waterbodies due to excessive algae levels and low dissolved oxygen (DO) concentrations. The poor water quality is principally the result of elevated nitrogen and phosphorus pollution in the lake. In 1998, Canyon Lake was deemed to be impaired for the same reasons and also added to EPA's 303(d) list.

In 2004, the Santa Ana Regional Water Quality Control Board ("Regional Board") adopted a Total Maximum Daily Load (TMDL) to reduce nutrient loads to both lakes.¹ The TMDL restricts the amount of nitrogen and phosphorus that can be discharged by wastewater treatment facilities, municipal stormwater systems and commercial agriculture operations.²

The TMDL specifies a number of targets that should be met by the end of 2015 in order to assure progress toward meeting the water quality standards presently at-risk in Canyon Lake and Lake Elsinore. The purpose of this Interim Compliance Report is to summarize the status for each of these milestones.

1.1 TMDL Water Quality Targets

Table 1 describes the interim numeric targets for Chlorophyll-a (algae) and Dissolved Oxygen that are "*to be attained no later than 2015*" in both lakes.³ The TMDL does not specify any interim targets for nitrogen or phosphorus.

Table 1: Interim Response Targets⁴

Water Quality Metric	Lake Elsinore	Canyon Lake
Chlorophyll-a	Summer average no greater than 40 ug/L	Annual average no greater than 40 ug/L
Dissolved Oxygen	Depth average no less than 5 mg/L	Minimum of 5 mg/L above the thermocline

¹ California Regional Water Quality Control Board - Santa Ana Region Res. No. R8-2004-0037 (Dec. 20, 2004); subsequently approved by the State Water Resources Control Board on May 19, 2005 and by the California Office of Administrative Law (OAL) on July 26, 2005. The TMDL became effective upon final approval by U.S. EPA on September 30, 2005.

² For Elsinore Valley MWD, compliance with the TMDL is required by NPDES Permit No. CA8000392). For the Riverside County Stormwater Program compliance with the TMDL is required by NPDES Permit No. CAS618033 and described in the Comprehensive Nutrient Reduction Program (CNRP) approved as Regional Board Res. No. R8-2013-0044 (July 19, 2013). For Commercial Agriculture Operations compliance with the TMDL is governed by a Conditional Waiver of Waste Discharge Requirements and an Ag Nutrient Management Plan (both are pending Regional Board approval).

³ The TMDL also specifies several additional FINAL targets, wasteload allocations and load allocations that must be met by 2020. These final threshold values are not addressed in this Interim Compliance Report.

⁴ Table 1 is derived from Table 5-9n in Res. No. R8-2004-0037 (Dec. 20, 2004).

1.2 TMDL Task Force

To assure rapid and cost-effective compliance with the numerous TMDL requirements, stakeholders throughout the San Jacinto River watershed formed a voluntary Task Force to coordinate implementation efforts. The Task Force is comprised of nearly all dischargers named in the TMDL and is managed by the Lake Elsinore & San Jacinto Watersheds Authority (LESJWA).⁵ The Task Force meets monthly and staff from the Regional Board regularly attend and participate in these meetings.

Collectively, the Task Force manages an annual budget of more than \$1 million and is responsible for:

- a) Implementing the watershed-wide water quality monitoring program.⁶
- b) Implementing the water quality monitoring program for both lakes.⁷
- c) Updating the watershed runoff model used to estimate nutrient loads.⁸
- d) Conducting special studies to aid in selection of mitigation projects.⁹
- e) Implementing the Lake Elsinore Sediment Nutrient Reduction plan.¹⁰
- f) Implementing the Canyon Lake Sediment Nutrient Reduction plan.¹¹
- g) Revising and updating the TMDL (incl. targets and allocations).¹²

In the 10 years since it commenced operation, the Task Force has implemented several large-scale water quality improvement projects to reduce nutrient loads released by lake bottom sediments. In addition, individual Task Force agencies have implemented a wide array of new Best Management Practices (BMPs) designed to reduce nitrogen and phosphorus pollution in the stormwater runoff that originates from urban and agricultural areas.

The remainder of this report will describe both the in-lake projects and watershed BMPs and summarize the effectiveness of these efforts at improving water quality. Special emphasis will be given to the question of whether the lakes are meeting the aforementioned Interim Response Targets. The status of each lake is addressed separately.

⁵ The U.S. Forest Service and the U.S. Fish and Wildlife Service are not active members of the Task Force.

⁶ Approved in Regional Board Res. No. R8-2006-0031 (March 3, 2006). Revised plan (2015) pending approval.

⁷ Modified by Regional Board Res. No. R8-2011-0023 (March 4, 2011). Revised plan (2015) pending approval.

⁸ TetraTech, Inc. San Jacinto Watershed Model Update - Final (2010). Completed Oct. 7, 2010

⁹ See: <http://www.sawpa.org/collaboration/projects/lake-elsinore-canyon-lake-tmdl-task-force/>

¹⁰ Approved in Regional Board Res. No. R8-2007-0083 (Nov. 30, 2007).

¹¹ See: <http://www.sawpa.org/task-10-cl-in-lake-sediment-reduction-plan/>

¹² The TMDL review and revision process was initiated in January of 2016. All proposed changes will be submitted to the Regional Board for formal consideration in the fall of 2018 and the regulatory approval process and is expected to be complete two years later.

2.0 Canyon Lake

2.1 Principal Water Quality Improvement Programs for Canyon Lake

2.1.1 Alum Application Pilot Demonstration Project

After reviewing a variety of potential water quality improvement projects, the TMDL Task Force determined that large-scale application of alum was likely to produce the best results in Canyon Lake.¹³ Alum (aluminum sulfate) binds with phosphorus to form a relatively insoluble and inert compound (aluminum phosphate) that settles to the lake bottom. Phosphorous that is bound by alum is no longer bioavailable and cannot support algae growth. A pilot project was developed to demonstrate the efficacy of alum addition as an algae control strategy.¹⁴

CEQA evaluation and review was completed in the summer of 2013 and the first of five alum applications commenced in September that same year. Alum was also applied in February and September of 2014 and 2015.¹⁵ Altogether, a total of 840 tons (763,035 kg) of alum was sprayed as a liquid slurry across the surface of Canyon Lake.¹⁶ Two-thirds of the alum was applied to the main body of the lake and the remaining third was applied to the East Bay. Although less alum was dispersed the effective dose was more than two times higher in the East Bay than in the main body of the lake. This is due to the fact that the main body holds 7 times more water than the East Bay.¹⁷

Routine water quality monitoring is performed at four lake stations before and after each alum application. Two of the sampling sites are located in the main body of Canyon Lake and two are located in the East Bay. Figure 1 shows how phosphorus concentrations declined at all stations immediately following each alum application. Figure 1 also shows how phosphorus levels rose in response to local storm events.

Since December of 2014, samples collected in the main body of Canyon Lake show that phosphorus concentrations are consistently at or below 0.1 mg/L - a final TMDL target the stakeholders were not required to meet until 2020. By June of 2015, phosphorus concentrations in the East Bay were also less than 0.1 mg/L and meeting the final TMDL target five years ahead of schedule.

¹³ Dr. Michael Anderson (U.C.-Riverside); Technical Memorandum - Task 6: Predicted Water Quality in Canyon Lake with In-Lake Alum Treatments and Watershed BMPs. Nov., 27, 2012. Also: Dr. Michael Anderson; Technical Memorandum - Task 3: Evaluation of Alum, Phoslock® and Modified Zeolite to Sequester Nutrients in Inflow and Improve Water Quality in Canyon Lake. May 17, 2012. Also: Dr. Michael Anderson; Technical Memorandum - Task 2: Evaluation of Long-Term Reduction of Phosphorus Loads from Internal Recycling as a Result of Hypolimnetic Oxygenation in Canyon Lake. April 22, 2012.

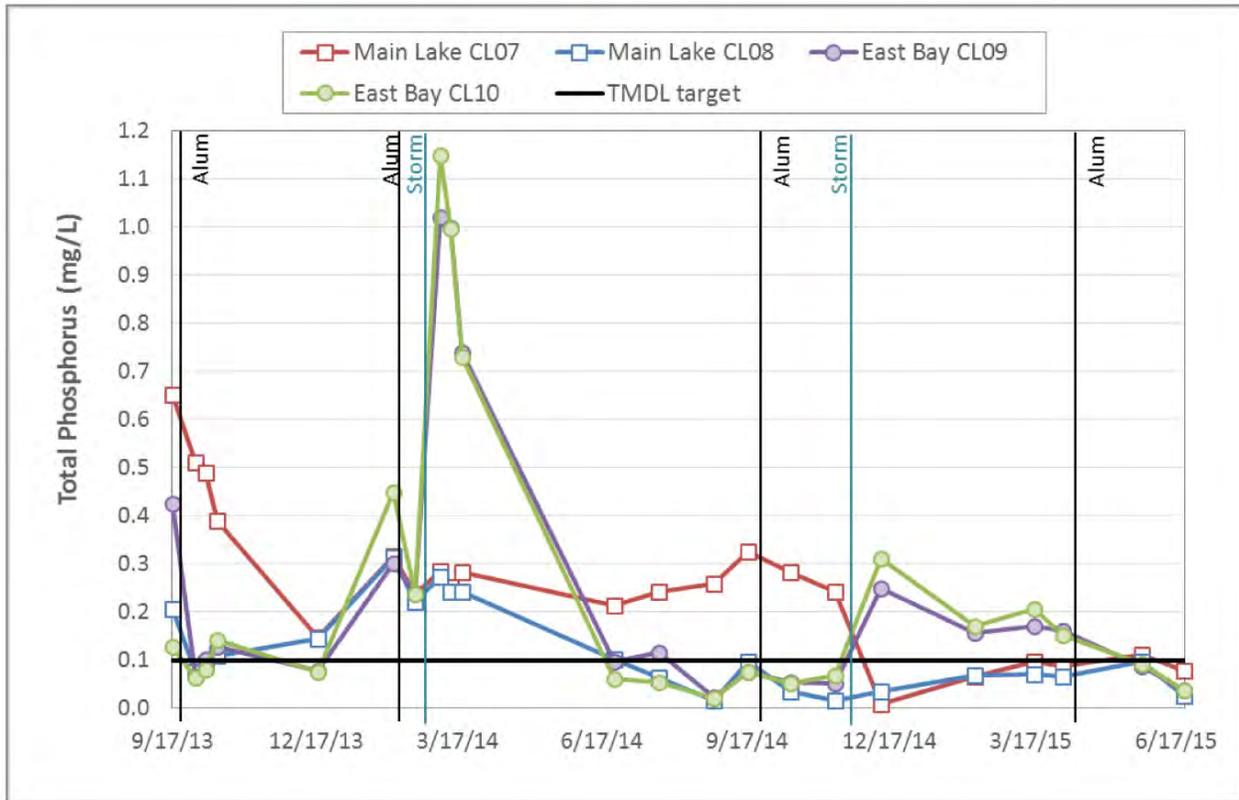
¹⁴ The alum demonstration project was partially funded by a state Prop-84 grant.

¹⁵ Alum was not applied to the main body of Canyon Lake in February of 2015 because water quality was already very good (e.g. low chlorophyll-a and low phosphorus concentrations).

¹⁶ A total of 311,000 gallons of liquefied alum was applied to Canyon Lake between Sept., 2013 and Sept., 2015.

¹⁷ Riverside County MS4 Permittees CNRP Implementation Summary FY 2014-15; see Table 2 on pg. 2.

Fig. 1: Total Phosphorus Concentrations in Canyon Lake¹⁸



To date, the alum application project has neutralized more than 7,600 pounds (3,447 kg) of phosphorus - an amount equal to the total average load contributed to Canyon Lake by 3 years of urban runoff. Dr. Michael Anderson (U.C. Riverside) estimates that, so far, alum addition has sequestered approximately 30% of the bioavailable phosphorus that was present in the lake when the demonstration project began.¹⁹

An odd problem was encountered the first time alum was applied during the winter season (February, 2014). Initially, the alum formed floc that floated on the surface for a few days. Eventually, the floc sank to the bottom of the lake as it is supposed to. Analysis of the data gathered during the event indicates that two factors led to this atypical result. First, the alum tended to form a floc with the large concentration of algae present in the lake. Second, the cold water was supersaturated with oxygen, which helps the algae-alum floc stay afloat. To avoid this problem in the future, subsequent alum applications were timed to occur before the algae bloom occurs in early spring or after that bloom has dissipated.

¹⁸ Riverside County MS4 Permittees CNRP Implementation Summary FY 2014-15. Fig. 1 on pg. 2.

¹⁹ Dr. Michael Anderson (U.C.-Riverside). Presentation to the residents of Canyon Lake. Sept. 9, 2015.

2.1.2 Sediment Dredging Pilot Demonstration Project

According to the TMDL adopted by the Regional Board 34% of the annual phosphorus load to Canyon Lake originates from the bottom sediments.²⁰ To address this problem the Canyon Lake Property Owners Association (CLPOA) began dredging nutrient-enriched sediments from the East Bay.²¹

In the 9 month period commencing in July of 2006 and ending in March of 2007, the dredging project removed nearly 15,000 cubic yards of sediment from the East Bay. Table 2 provides a more detailed summary by month.

Table 2: Sediment Dredged from the East Bay of Canyon Lake²²

Month	Volume	Mass
July, 2006	980 cu. yds.	1,323 tons
August, 2006	1,320 cu. yds.	1,782 tons
September, 2006	2,1170 cu. yds.	2,849 tons
October, 2006	1,740 cu. yds.	2,349 tons
November, 2006	1,070 cu. yds.	1,444 tons
December, 2006	1,865 cu. yds.	2,518 tons
January, 2007	2,160 cu. yds.	2,916 tons
February, 2007	1,465 cu. yds.	1,878 tons
March, 2007	2,225 cu. yds.	3,003 tons
Total	14,935 cu. yds.	20,162 tons

²⁰ California Regional Water Quality Control Board - Santa Ana Region. Supplemental Staff Report: Proposed Basin Plan Amendment - Incorporation of Total Maximum Daily Loads for Nutrients for Lake Elsinore and Canyon Lake. Dec. 20, 2004. See Attachment - Table 1: Revised TMDL Allocation for Lake Elsinore and Canyon Lake to meet the revised final TP and TN targets.

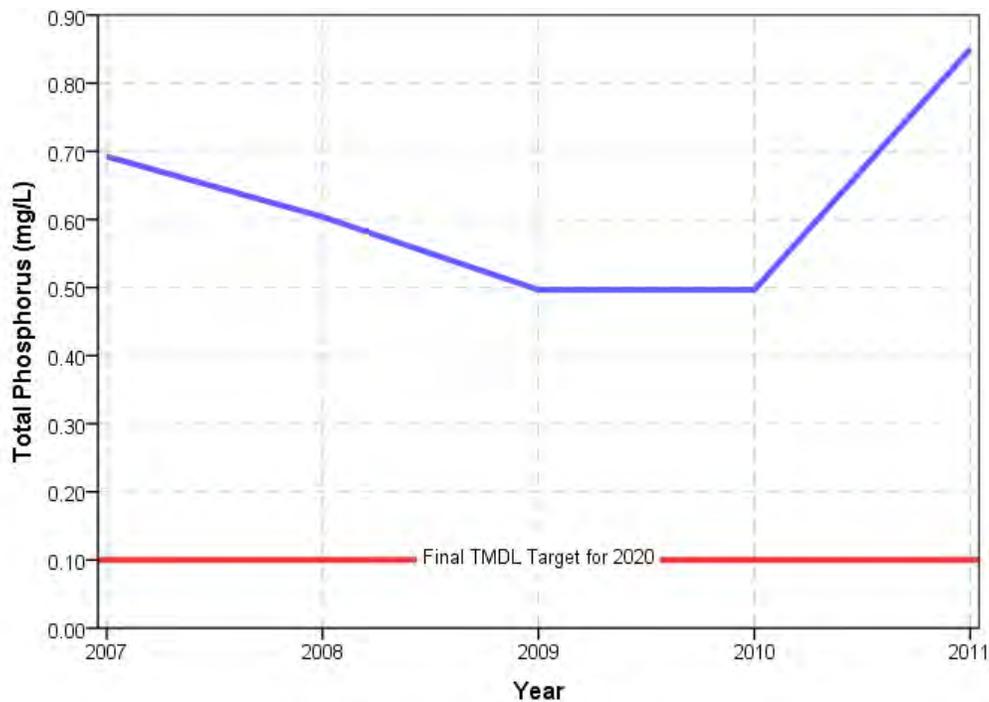
²¹ The dredging project was operated in accordance with NPDES Permit No. CA8000405 approved by the Regional Board as Order No. R8-2004-0046 on June 4, 2004 and was partially funded by a state Prop-13 grant.

²² Dredge volumes reported to the Regional Board as required by the Monitoring and Reporting Program for NPDES Permit No. CA8000405 (Res. No. R8-2004-0046). Copies of the monthly Discharge Monitoring Reports (DMR) are on-file and available for review at the Regional Board's main office in Riverside, CA.

Laboratory analysis of core samples showed that sediment from the East Bay contained an average phosphorus concentration of 519 mg/kg.²³ Thus, about 9,493 kilograms of phosphorus was removed from Canyon Lake during the pilot dredging project. This equates to approximately 1 pound of phosphorus for each ton of sediment extracted.

Routine water quality monitoring indicates that the average phosphorus concentration in the East Bay declined from 0.70 mg/L to 0.50 mg/L (a 40% improvement) in the two years following the conclusion of the dredging project (see Fig. 2). Phosphorus concentrations in the East Bay began to rise again as stormwater runoff transported new sediment loads to the lake during the relatively wet winters of 2010 and 2011).

Fig. 2: Average Annual Phosphorus Concentration in East Bay of Canyon Lake²⁴



The pilot dredging project was discontinued in the spring of 2007 when the CLPOA lost access to a nearby fill site for the de-watered sediment materials and legal complications arose regarding proper application of prevailing wage laws under the state grant program.

²³ HDR, Inc. Canyon Lake East Bay Sedimentation Characterization. Report to the Lake Elsinore & San Jacinto Watersheds Authority. August, 2002 (based on samples of East Bay sediments collected and analyzed by Dr. Michael Anderson of U.C. Riverside on May 29, 2002).

²⁴ Based on analysis of data collected as part of the routine water quality monitoring program sponsored and supervised by the TMDL Task Force. All of this data was previously submitted to the Regional Board as part of the Annual Report on Water Quality in Lake Elsinore and Canyon Lake.

2.1.3 Watershed Best Management Practices (BMPs) for MS4 Dischargers

The TMDL established a Waste Load Allocation (WLA) of only 306 kg/year total phosphorus for "Urban" stormwater discharges to Canyon Lake.²⁵ To demonstrate direct compliance with this WLA, the Regional Board estimated that MS4 permittees would need to reduce their existing phosphorus loads by approximately 73%.²⁶

In order to reduce nitrogen and phosphorus loads in urban stormwater to the Maximum Extent Practicable (MEP), the MS4 agencies developed a Comprehensive Nutrient Reduction Plan (CNRP).²⁷ The NPDES permit obligates these agencies to implement the pollution control strategies described in the CNRP.²⁸

The NPDES permit also requires the MS4 agencies to develop and implement a Water Quality Management Plan (WQMP) for Urban Runoff from areas undergoing new development or significant redevelopment.²⁹ The NPDES permit specifies the amount runoff that must be infiltrated, filtered or treated prior to discharge from these development areas.³⁰

In the several years since the NPDES permit was adopted and the related CNRP was approved, the MS4 agencies have implemented a wide range of Best Management Practices (BMPs) to reduce urban runoff in general and nutrient loads in particular. Each year the co-permittees summarize their implementation efforts in a report to the Regional Board (see Table 3). A similar report, summarizing the BMPs implemented by the commercial agriculture operators will likely be required if a Conditional Waiver of Agricultural Discharge (CWAD) Requirements is authorized by the Regional Board.³¹

²⁵ California Regional Water Quality Control Board - Santa Ana Region Res. No. R8-2004-0037 (Dec. 20, 2004); See Table 5-9q: Canyon Lake Nitrogen and Phosphorus Wasteload and Load Allocation. The WLA is expressed as a 10-year running (annualized) average. Compliance with the final WLA must be achieved no later than December 31, 2020.

²⁶ California Regional Water Quality Control Board - Santa Ana Region. Supplemental Staff Report: Proposed Basin Plan Amendment - Incorporation of Total Maximum Daily Loads for Nutrients for Lake Elsinore and Canyon Lake. Dec. 20, 2004. See Attachment - Table 1: Revised TMDL Allocation for Lake Elsinore and Canyon Lake to meet the revised final TP and TN targets.

²⁷ California Regional Water Quality Control Board - Santa Ana Region Res. No. R8-2013-0044 (July 19, 2013)

²⁸ NPDES Permit No. CAS618033; see §VI-D-2-f @ pg. 67 of 117 (Order No. R8-2010-0033; Jan. 29, 2010).

²⁹ NPDES Permit No. CAS618033; see §XII-D (Order No. R8-2010-0033; Jan. 29, 2010).

³⁰ NPDES Permit No. CAS618033; see §XII-D-4-a & §XII-D-4-b (Order No. R8-2010-0033; Jan. 29, 2010).

³¹ The Regional Board is scheduled to consider whether to approve a proposed on July 22, 2016.

Table 3: Summary of MS4 Implementation Efforts (FY 2014-15)³²

Best Management Practice	Effectiveness
Septic Systems Managed ³³	2,140 systems
Stormwater Infiltration	949 acres treated
Extended Detention	4,163 acres treated
Hydrodynamic Separator	1,058 acres treated
Vegetated Swale	288 acres treated
Media Filters	458 acres treated
Street Sweeping	16,168 metric tons collected
Debris in MS4 Facilities	758 metric tons removed

Table 4 shows the nutrient load reductions estimated to result from all the BMPs implemented by the MS4 agencies by mid-2015.

Table 4: Load Reductions to Canyon Lake from Urban Stormwater & Septic Systems³⁴

Nutrient	Mass Reduction	% of Existing Load
Phosphorus	559 kg/yr	34%
Nitrogen	3,827 kg/yr	30%

³² Riverside County MS4 Permittees CNRP Implementation Summary FY 2014-15. Table 3 (above) is a meta-summary of the data shown in Table 3 (pg. 4) and Table 4 (pg. 5) of the original report. Table 3 includes BMPs in the local Lake Elsinore watershed that do not flow to or through Canyon Lake. Note: values shown are incomplete because some cities are just beginning to develop systems to track and quantify the effectiveness of their BMP efforts and other cities have not yet reported their results.

³³ 50 septic systems were removed in the City of Beaumont and 2,090 were in the City of Moreno Valley.

³⁴ Spreadsheet analysis of BMP effectiveness provided by Steve Wolosoff (CDM-Smith) on March 18, 2016. Existing load is based on the values reported by the Regional Board in the adopted TMDL (see footnote 26).

2.1.4 Watershed Best Management Practices (BMPs) for Agricultural and Dairy Operators

Dairy operators have a NPDES permit which requires strict adherence to manure management practices including: recordkeeping, annual reporting and compliance with the TMDL.³⁵

Nutrient Management Plans (NMPs) are also required for dairies growing forage crops for their farms. The Concentrated Animal Feeding Operation (CAFO) permit has provisions prohibiting discharge in all but the most extreme storm events (e.g. those only expected to no more than once every 25 years or so). Importation of manure into the watershed from Chino is now prohibited and that has also significantly reduced manure used in ag practices in the watershed. Compliance with the permit effectively makes dairies De minimus dischargers of nutrients. In addition, nearly all of the dairies are located in an area of the watershed that flows into Mystic Lake and these discharges rarely make it all the way down to Canyon Lake.

In 2007, the Western Riverside County Agricultural Coalition (WRCAC) completed a comprehensive review of dairy management practices, available technologies and BMPs in the San Jacinto watershed.³⁶ Many of the best practices identified during that review were subsequently implemented at a number of other dairies in the region. A good example of a cost-effective BMP is "backhauling" - a practice of trucking manure out of the watershed and bringing feed back to the farm(usually from the same source). In 2000, only two dairies hauled manure out of the watershed. Today, ten different operators remove nearly 50% of all manure generated by local dairies out of the San Jacinto watershed. This trend is expected to continue.

The Scott Brothers Dairy Farm has invested in a multi-million dollar gasification project which creates Biodiesel SynFuel and biochar. The project has been funded through various grants and the Scott Brothers. Recently the EPA recognized Scott Brothers Dairy Farm with the 2016 Nutrient Challenge Honoree Award. The treatment system is designed to remove 98% of Total Suspended Solids (TSS), 40% of Total Dissolved Solids (TDS), 90% of the Phosphorous, 67% of the Nitrogen, and 40% of the Potassium from on-site dairy wastes.

Dairy operators have achieved 100% compliance with the TMDL requirements in their NPDES permits implementing individual BMPs, sponsoring regional WRCAC projects and participating in the LECL Task Force.

WRCAC has completed more than \$6 million dollars in projects (in addition to the funding provided to support the TMDL Task Force). A few examples of WRCAC's work on behalf of the agricultural operators include:

³⁵ General Waste Discharge Requirements for Concentrated Animal Feeding Operations (Dairies and Related Facilities) Within the Santa Ana Region. NPDES No. CAG019001 (Res. No. R8-2013-0001; June 7, 2013)

³⁶ San Jacinto Integrated Regional Dairy Management Plan (IRDMP)

- Spearheading the use of aerial mapping to accurately characterize land uses throughout the San Jacinto watershed (2005, 2007, 2010, and 2014);
- Initially identifying (2005) and then performing special studies (2014-15) to confirm significant subsidence in the Mystic Lake area. This information was essential to calculate nutrient loading to Canyon Lake more accurately;
- Sponsoring a special study of nutrient loads to Salt Creek that were used to establish a new and entirely different baseline for natural background conditions in the watershed;
- Partnering with UCR, and surveying Ag operators in the San Jacinto watershed, to identify the most cost-effective Best Management Practices (BMPs) for nutrient control;
- Prepared a feasibility study of pollutant trading between non-point sources (supported through a 319 grant);
- Developing a water quality index (WQI) tool designed to evaluate surface water runoff and groundwater recharge from agricultural operators more holistically.

Managing agricultural runoff is challenging due to ever-changing crop patterns and frequent changes in land ownership and leases. Nevertheless, agricultural operators have demonstrated exceptional long-term commitment to environmental stewardship in the watershed. It should be noted that all of their efforts to improve water quality in Canyon Lake and Lake Elsinore has occurred in advance of any formal Waste Discharge Requirements (WDRs) to implement the nutrient TMDL. Specific compliance obligations will likely be established if the Regional Board approves the proposed Conditional Waiver of Agricultural Discharge (CWAD).

Like most of the rest of Southern California, the agricultural activities that once dominated the San Jacinto watershed are slowly being displaced by urban development. Thus, over time, new nutrient loads from agricultural operators are expected to decline significantly. The TMDL will be periodically revised and updated to reflect this dynamic condition.

2.2 Interim Response Targets for Canyon Lake

2.2.1 Chlorophyll-a (algae)

Data from the routine water quality monitoring program shows that the average annual Chlorophyll-a concentration is meeting the interim TMDL target of <40 ug/L (see Fig. 3). This is true for both the main body of Canyon Lake as well as the East Bay.³⁷

Fig. 3: Average Annual Concentrations of Chlorophyll-a in Canyon Lake³⁸



It should be noted that actual Chlorophyll-a concentrations measured at each of the four separate sampling stations varies greatly over the course of a year and sometimes exceeds 40 ug/L at some locations (see Fig. 4 and Fig. 5). Nevertheless, the interim response target for Chlorophyll-a is specified as an annual average and, at present, Canyon Lake is meeting that target. In fact, the average annual concentration of Chlorophyll-a in the main body of Canyon Lake is now meeting the final 2020 response target of 25 ug/L five years ahead of the TMDL deadline.

³⁷ The TMDL specifies a the response target for Chlorophyll-a as an annual average for "Canyon Lake." Although the TMDL does not distinguish between the Main Body and the East Bay, doing so provides a more meaningful representation of water quality throughout the lake.

³⁸ There was very little in-lake monitoring done in the first 8 months of 2013 prior to the first alum application. Therefore, no average value if computed for 2013.

Fig. 4: Chlorophyll-a and Phosphorus Concentrations in Main Body of Canyon Lake³⁹

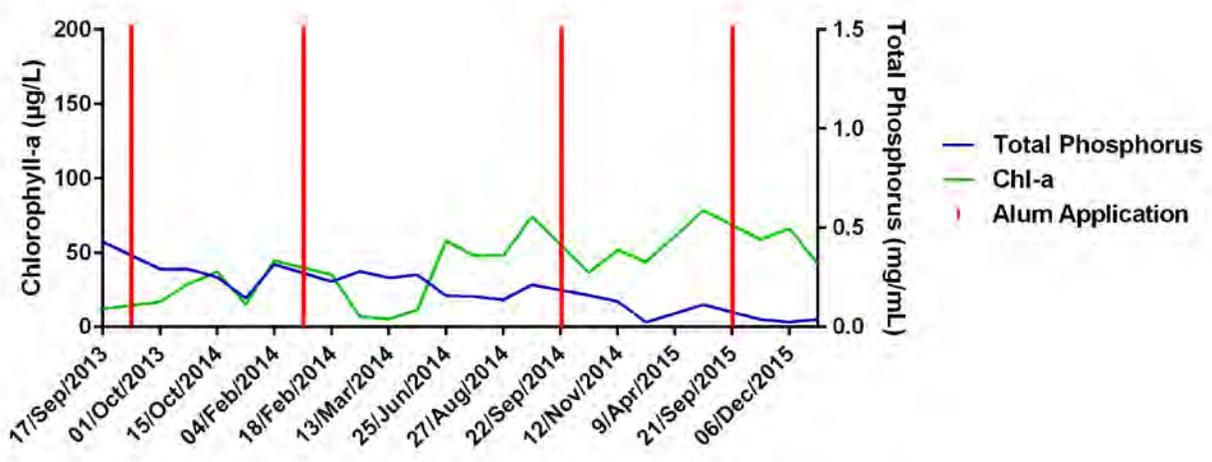
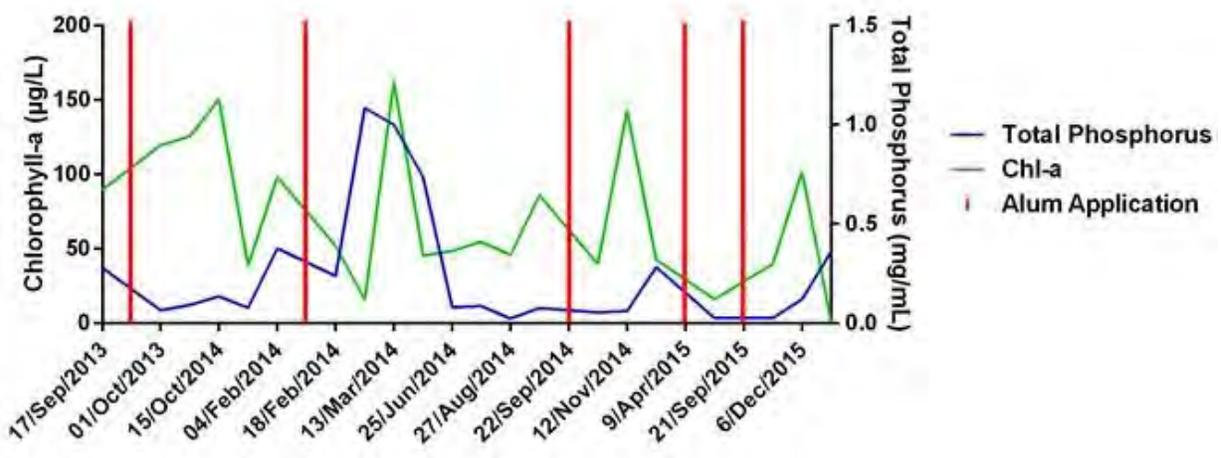


Fig. 5: Chlorophyll-a and Phosphorus Concentrations in East Bay of Canyon Lake⁴⁰



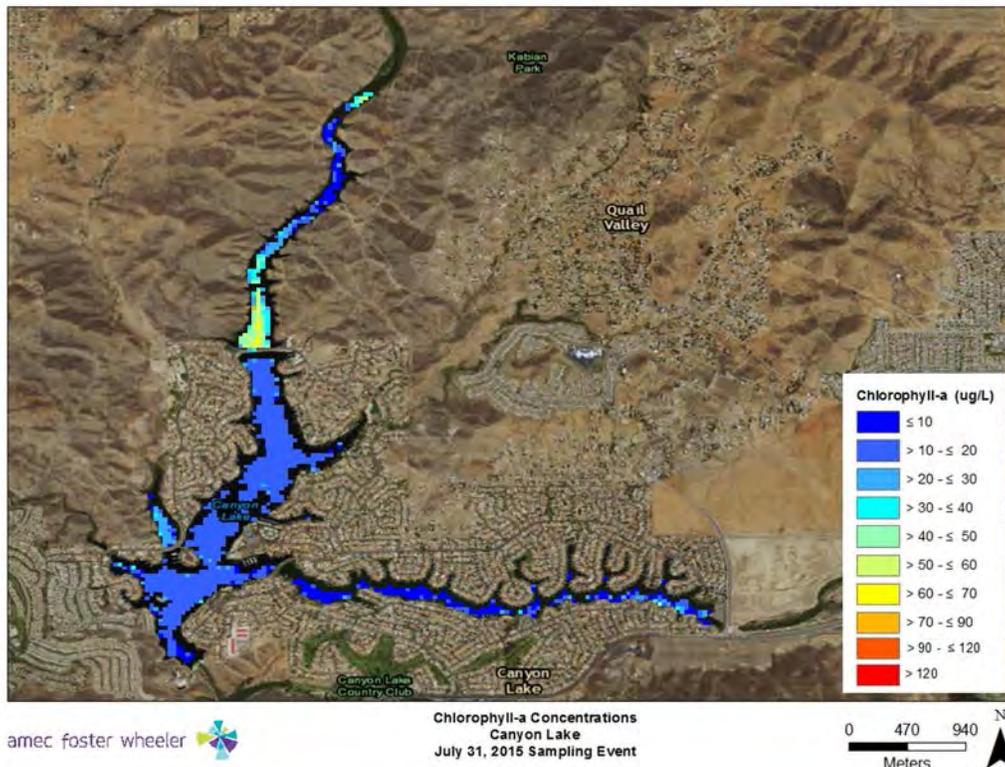
It is important to note that algae concentrations have been declining since 2012 despite a prolonged drought during which natural evaporation would tend to increase the average phosphorus concentration in Canyon Lake. The TMDL Task Force believes the alum application project, coupled with increased implementation of upstream BMPs throughout the watershed, have helped keep phosphorus levels in-check despite the drought conditions which have prevailed for the last 4 years.

³⁹ Graph for Main Body prepared by AMEC Foster Wheeler using Task Force monitoring data (Apr. 5, 2016)

⁴⁰ Graph for East Bay prepared by AMEC Foster Wheeler using Task Force monitoring data (Apr. 5, 2016)

A specialized analysis of images collected by NASA's Landsat satellite shows that Chlorophyll-a concentrations were generally low throughout Canyon Lake on July 31, 2015 (see Fig. 6). The sole exception was the area above the north causeway where the San Jacinto River merges with the lake. During summer months, the water level rarely rises high enough to flow through the culverts beneath the causeway and remains trapped in the shallow area north of the main body of Canyon Lake.

Fig. 6: Satellite Assessment of Chlorophyll-a Concentration on 7/31/2015

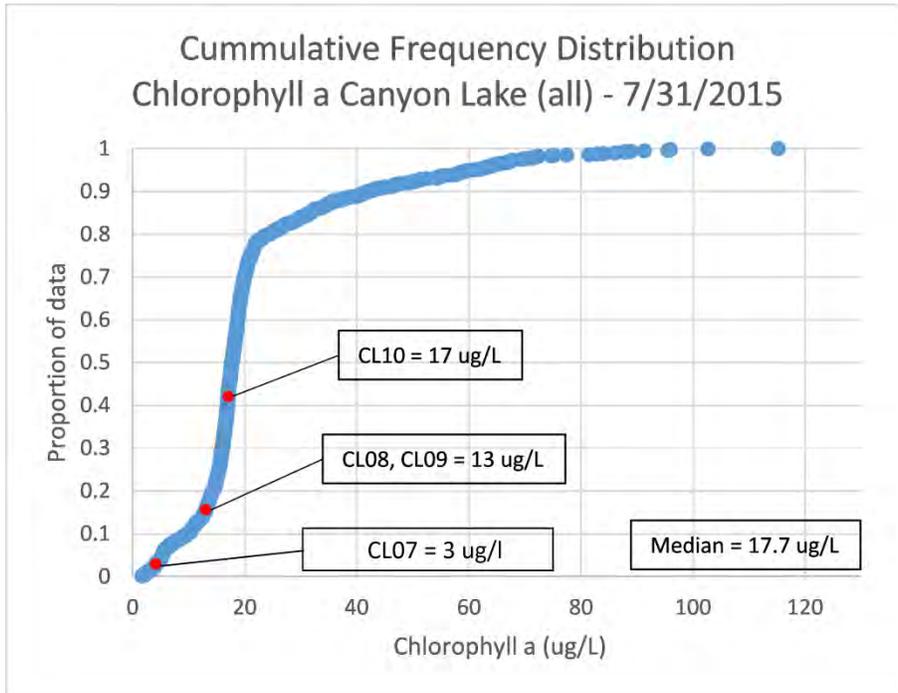


The satellite image provides five pixels for every surface acre of the lake. Each pixel represents an independent estimate of Chlorophyll-a concentrations at that specific point. Thus, the satellite image provides approximately 1,500 data points to supplement the laboratory analysis of samples collected at the 4 field locations.⁴¹

Figure 7 shows how the Chlorophyll-a concentration varied across these 1,500 pixel locations. On July 31, 2015 nearly 90% of the pixels registered a Chlorophyll-a concentration less than 40 ug/L. The median Chlorophyll-a concentration for all 1,500 pixels was 17.7 ug/L. The pixels located nearest to each of the four field sampling sites are highlighted as red dots in the CDF graph (Fig. 7). And, the satellite-based estimates of Chlorophyll-a concentrations for each of those four pixels are shown in the box legend linked to each dot.

⁴¹ Maps showing the location of in-lake sampling stations are provided in Appendix A to this report.

Fig. 7: Cumulative Distribution Function for Chlorophyll-a Concentrations on 7/31/2015



Satellite images have also been analyzed for December 18, 2015 and February 8, 2016. Table 5 provides a summary of the Cumulative Frequency Distribution Analyses for all three satellite images.⁴² These images illustrate the significant spatial and temporal variation of Chlorophyll-a concentrations in Canyon Lake.

Table 5: Summary of Satellite Imagery Analyses for Chlorophyll-a in Canyon Lake

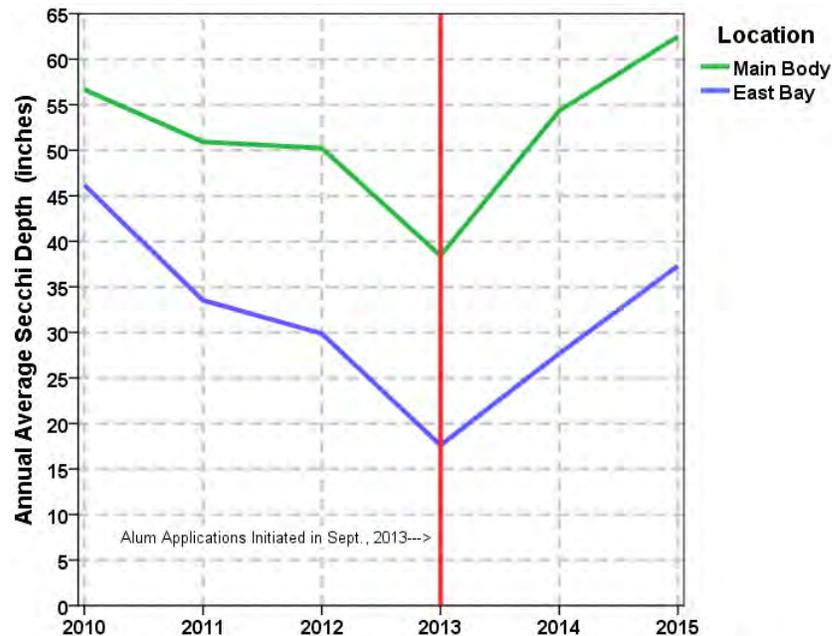
Chlorophyll-a	July 31, 2015	Dec. 18, 2015	Feb. 8, 2016
Median Value	17.7 ug/L	59 ug/L	18.9 ug/L
% <40 ug/L (compliance w/ 2015 target)	≈90%	≈30%	≈75%
% <25 ug/L (compliance w/ 2020 target)	≈80%	≈10%	≈70%

The Task Force is working on a method to provide a robust estimate of the annual average Chlorophyll-a concentration using data from multiple satellite images. Landsat takes approximately 20 pictures of the lake each year. Collectively, these satellite images could provide nearly 30,000 data points from which to calculate the annual average.

⁴² Figures illustrating the satellite-based assessment of Chlorophyll-a concentrations in December, 2015 and February, 2016 are provided as Appendix B to this report.

Back on Earth, long-term monitoring data shows that water clarity in Canyon Lake has also improved dramatically after the alum applications began in late 2013 (see Fig. 8). Water clarity is measured at each of the four sampling stations using the traditional Secchi disk method.

Fig. 8: Long-term Trend for Water Clarity in Canyon Lake



In 2015, average water clarity in the main body of Canyon Lake was more than 60% better than it was two years earlier. And, average water clarity in the East Bay improved by more than 100% during the same period. The Secchi disk data appears to corroborate the previous findings from the water quality monitoring samples and the satellite data: Chlorophyll-a concentrations in Canyon Lake have improved markedly in the last few years. This is most likely due to lower average phosphorus concentrations in the lake.

In late spring of 2015, a large bloom of brownish-colored algae occurred in the East Bay. Test samples showed that the algae, which appears brown to the naked eye, is actually a species called *Pseudoanabaena*, from the Blue-Green (cyanobacteria) classification.⁴³ According to Dr. Anderson, *Pseudoanabaena* does not produce dangerous cyanotoxins.

Some residents questioned whether the unusual bloom was caused by the prior alum applications. This is unlikely as a similar bloom of *Pseudoanabaena* also occurred at the same time in Lake Elsinore which receives no alum treatment. The Canyon Lake bloom dissipated in May and was followed by some of the lowest summer concentrations of Chlorophyll-a ever measured in the East Bay.

⁴³ SePRO Research and Technology Campus. SeSCRIPT Analysis Report. Prepared by AquaTechnex for a sample collected in June of 2015. *Pseudoanabaena* sp. density = 13,400 cells/mL.

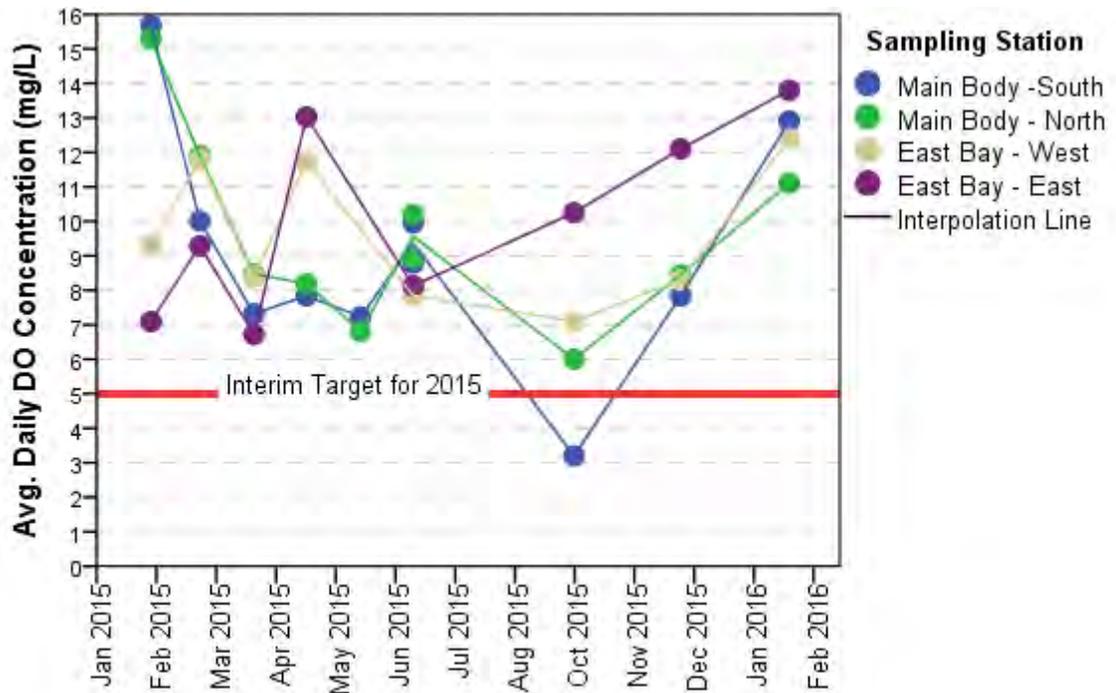
2.2.2 Dissolved Oxygen

Through the process of photosynthesis, algae produces oxygen during daylight hours. But, algae consume oxygen after the sun goes down. Even dead algae consume oxygen as it decomposes. Consequently, excessive algae concentrations can significantly depress dissolved oxygen (DO) levels in the water column. Extreme algae infestations can lead to major fish kills like the one that occurred in Canyon Lake in 2009.

Now that algae concentrations are declining, it is reasonable to expect that DO levels should also be improving. The best evidence to support this conclusion is the fact that there have been no significant fish kills in Canyon Lake in the last 6 years. This roughly corresponds with the period where stakeholders throughout the watershed have been aggressively implementing BMPs and supporting the alum application project to reduce phosphorus loads released from lake-bottom sediments.

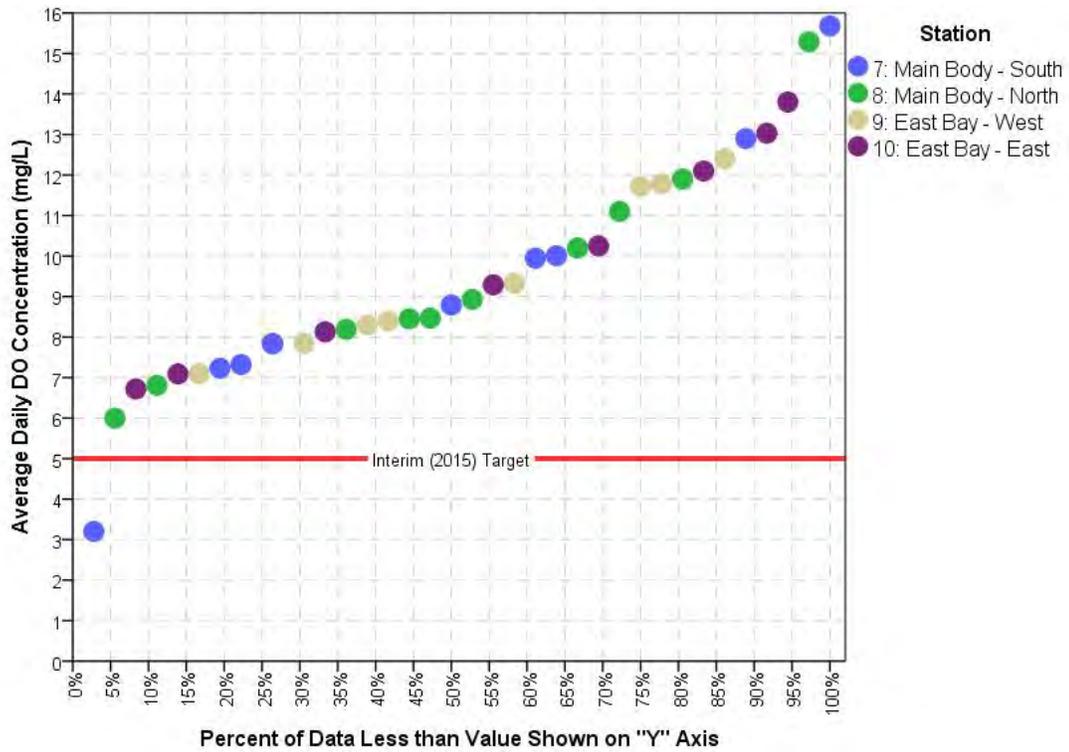
Water quality monitoring data indicates that DO concentrations in Canyon Lake are now consistently meeting the Interim (2015) Target specified in the TMDL (see Fig. 9). Only one of the 52 field measurements taken from February of 2015 through February of 2016 fell below the 5.0 mg/L target level for DO. This occurred at the Main Body sampling station (#7) in the fall of 2015, shortly after the lake underwent its annual turnover.

Fig. 9: Dissolved Oxygen in the Epilimnion of Canyon Lake (2015-16)



Overall, samples collected in 2015 and early 2016 indicate that Canyon Lake is meeting the interim DO target about 98% of the time (see Fig. 10)

Fig. 10: Compliance with Interim DO Target in Canyon Lake



3.1 Principal Water Quality Improvement Programs for Lake Elsinore

3.1.1 Lake Level Stabilization Project

Historically, the combination of natural evaporation and prolonged droughts caused Lake Elsinore to dry up completely from time to time (see Fig. 11 & Fig. 12). In 1996 a levee was constructed to reduce the surface area of Lake Elsinore by 50%. Nevertheless, even with the levee in place, annual water losses due to evaporation are greater than 12,000 acre-feet/year.

Fig. 11: Lake Elsinore, Riverside County, CA (circa 1965)



In 2002-3, a pilot project to stabilize the lake level using high quality recycled water was initiated.⁴⁴ The project proved successful and the Regional Board authorized Elsinore Valley Municipal Water District (EVMWD) to continue adding treated municipal effluent (aka "recycled water) to Lake Elsinore.⁴⁵ The NPDES discharge permit must be reviewed and reauthorized every 5 years.

⁴⁴ The pilot demonstration project included recycled water from both EVMWD and Eastern MWD. Today, only EVMWD has a valid NPDES permit to discharge recycled water to Lake Elsinore.

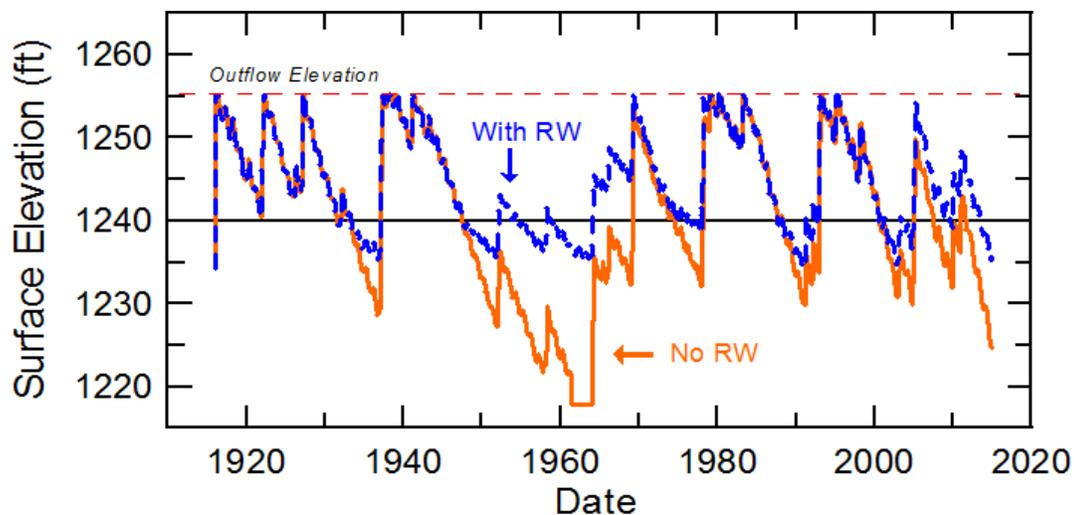
⁴⁵ EVMWD's current NPDES permit (CA8000392) was reauthorized by the Regional Board in 2013 (R8-2013-0017) and expires on Sept. 30, 2018.

The NPDES permit limits the average phosphorus and nitrogen concentrations of the effluent to no more than 0.5 mg/L and 1.0 mg/L, respectively. EVMWD installed advanced treatment technology to comply with these restrictions. EVMWD also joined with the City of Lake Elsinore and the County of Riverside to operate and maintain an in-lake aeration and mixing system to "offset" any excess nutrient loads resulting from the use of recycled water (see Section 3.1.2).

Using recycled water to stabilize the level of Lake Elsinore is a key part of the Sediment Nutrient Reduction Plan developed by the Task Force and approved by the Regional Board.⁴⁶ Since 2007, EVMWD had discharged more than 5 million gallons-per-day (>6,700 acre-feet/year) of high quality recycled water to Lake Elsinore.

Currently, recycled water replaces about 56% of lake volume that is lost to evaporation each year. Dr. Anderson was asked to simulate the net effect of this project on lake levels over a wide-variety of historical precipitation conditions. The results show that, without the recycled water that EVMWD has been discharging for the last 7 years, Lake Elsinore would be about 11 feet lower than it already was in 2015 (1224' vs. 1235'; see Fig. 12).

Fig. 12: Elevation of Lake Elsinore With and Without Recycled Water (model estimates)⁴⁷

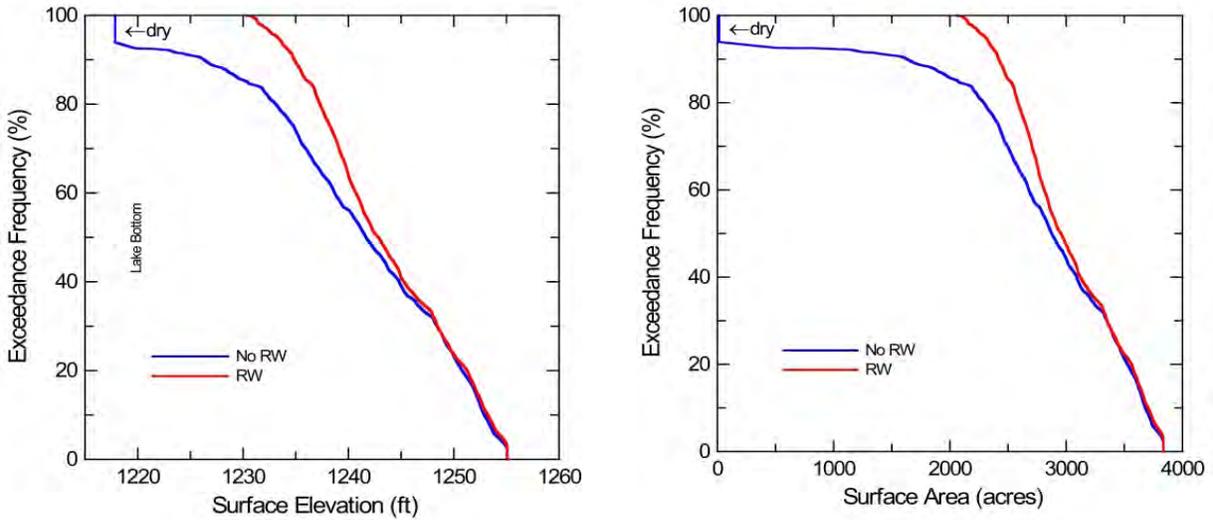


As the area continues to develop, EVMWD will eventually generate approximately 9 million gallons-per-day (\approx 12,000 acre-feet/year). If the additional volume of recycled water is also discharged, the level of Lake Elsinore will be very close to achieving long-term balance. If this lake stabilization strategy had been in place 50 years ago, the Lake Elsinore would not have gone dry as it did in the early 1960's. In fact, with recycled water, the lake elevation is not expected to fall below 1,230' and the lake area is not expected to be less than 2,000 acres (see Fig. 13).

⁴⁶ Regional Board Res. No. R8-2007-0083 (November 30, 2007).

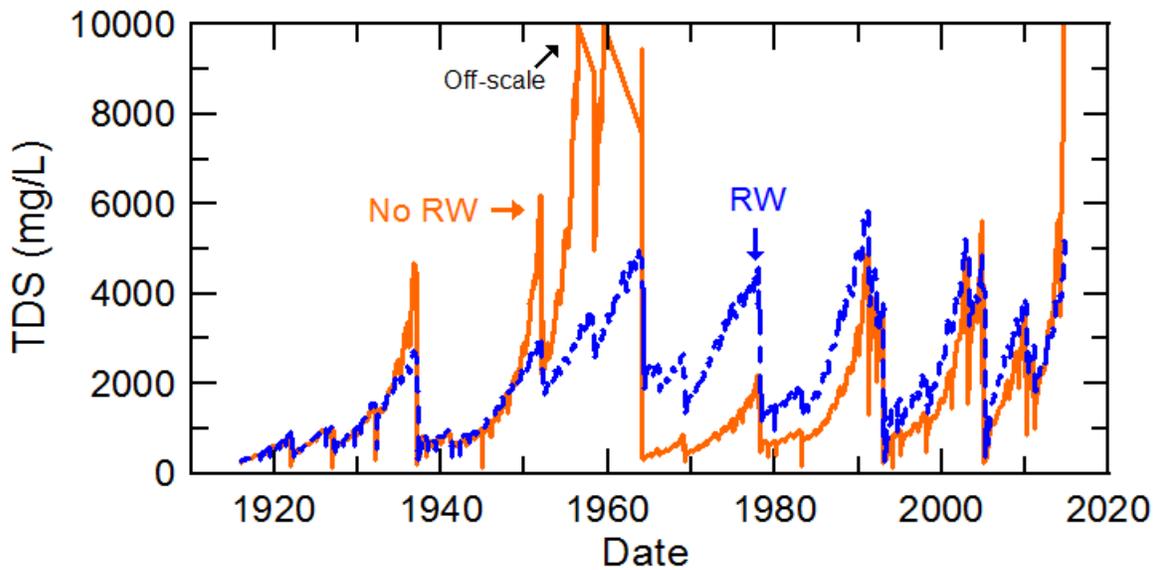
⁴⁷ Dr. Michael Anderson (U.C.-Riverside). Technical Memorandum for Task 1.2: Water Quality in Lake Elsinore Under Selected Scenarios - Model Predictions for 1916-2014 with Current (post-LEMP) Basin. Feb. 21, 2016.

Fig. 13: Elevation and Surface Area of Lake Elsinore With & Without Recycled Water⁴⁸



Discharging recycled water to Lake Elsinore also provides significant water quality benefits. Under natural conditions, as evaporation slowly dries-up the lake, salt concentrations would gradually rise to levels that eventually exceeded 10,000 ppm (see Fig. 14).

Fig. 14: Comparative Salinity Concentrations in Lake Elsinore⁴⁹



⁴⁸ Dr. Michael Anderson (U.C.-Riverside). Technical Memorandum for Task 1.2: Water Quality in Lake Elsinore Under Selected Scenarios - Model Predictions for 1916-2014 with Current (post-LEMP) Basin. Feb. 21, 2016.

⁴⁹ Dr. Michael Anderson (U.C.-Riverside). Technical Memorandum for Task 1.2: Water Quality in Lake Elsinore Under Selected Scenarios - Model Predictions for 1916-2014 with Current (post-LEMP) Basin. Feb. 21, 2016.

With the addition of recycled water, the total dissolved solids (TDS) concentrations in Lake Elsinore are not expected to exceed 6,000 mg/L even during severe droughts. That is 90% lower than the maximum salt concentration expected to occur under natural conditions in Lake Elsinore. Keeping salinity concentrations in-check is important because the existing water quality objective for Lake Elsinore is 2,000 mg/L. TDS concentrations greater than 2,000 mg/L are too high to support most lake species - including several species of *Daphnia* zooplankton that help improve water quality by grazing on algae. By offsetting some of the adverse effects of natural evaporation, recycled water helps preserve the freshwater conditions that are essential to provide aquatic habitat in Lake Elsinore even during prolonged drought conditions.

3.1.2 Lake Elsinore Aeration and Mixing System Project

The Lake Elsinore Aeration and Mixing System (LEAMS) was constructed in 2006-7 as a joint project developed by LESJWA and co-sponsored by EVMWD, the City of Lake Elsinore and the County of Riverside, CA.⁵⁰ LEAMS relies on a combination of slow-turning propellers submerged in the lake, and shoreline compressors that disperse air from pipelines anchored to the bottom of the lake, to circulate water in Lake Elsinore (see Fig. 15).

Fig. 15: Aeration Distribution Pipelines Submerged in Lake Elsinore



⁵⁰ LEAMS was originally designed and constructed by LESJWA and subsequently turned over to EVMWD, the City of Lake Elsinore and Riverside County to operate and maintain. Support from a large state grant, awarded under Prop-13, paid for most of the capital cost of this project. Historically, all O&M expenses (~\$450k/year) have been shared equally among the three cost-sharing partners.

Water near the bottom of the lake is low in dissolved oxygen. LEAMS is designed to push this bottom water toward the surface where it will be re-aerated, naturally. Higher DO levels are essential to support fish and other aquatic organisms living in the lake. However, stirring the lake to increase DO concentrations also helps improve water quality.

Higher DO concentrations help convert ammonia and nitrate to nitrogen gas. Higher DO concentrations also helps sequester nutrients by aiding the chemical process whereby phosphorus bonds with iron to form inert mineral compounds.

A comprehensive analysis of water quality data collected since the aeration system began full-time operations in 2008 shows that each hour of LEAMS operation converts more than 22 kg of total nitrogen into nitrogen gas.⁵¹ Consequently, the system removes approximately 44,000 kg of nitrogen from the water column every year. This is more than the total annual average nitrogen load contributed by all anthropogenic sources, including recycled water and stormwater runoff from urban and agricultural areas.

Before LEAMS was built, laboratory tests indicated that aeration would reduce phosphorus released from lake bottom sediments by at least 35%. This conservative estimate was accepted by the Regional Board and used when the Load Allocation was calculated in the TMDL.⁵² LEAMS is expected to reduce the existing phosphorus load from sediment by 11,600 kg/year. That, too, is enough to offset 100% of the incremental increase in phosphorus loads contributed by runoff from all anthropogenic sources in the watershed above Lake Elsinore.

The estimated effect of LEAMS on other water quality indicators (e.g. Chlorophyll-a and DO concentrations) are discussed in Section 3.2, below.

3.1.3 Fishery Management Project

Common carp are bottom-feeding fish that forage for food by wagging their tail fins in the sediment to stir up macroinvertebrates. This tail-wagging behavior also re-suspends nutrients from the sediment back to the water column. As a result, large carp populations can have a significant adverse effect on water quality. Experts estimate that reducing the total number of carp in Lake Elsinore by 75% would lower the average phosphorus concentration from 0.38 mg/L to 0.26 mg/L (a 31% improvement). Even reducing the total number of carp by only 50% is expected to provide a 12% improvement in average phosphorus concentrations.⁵³

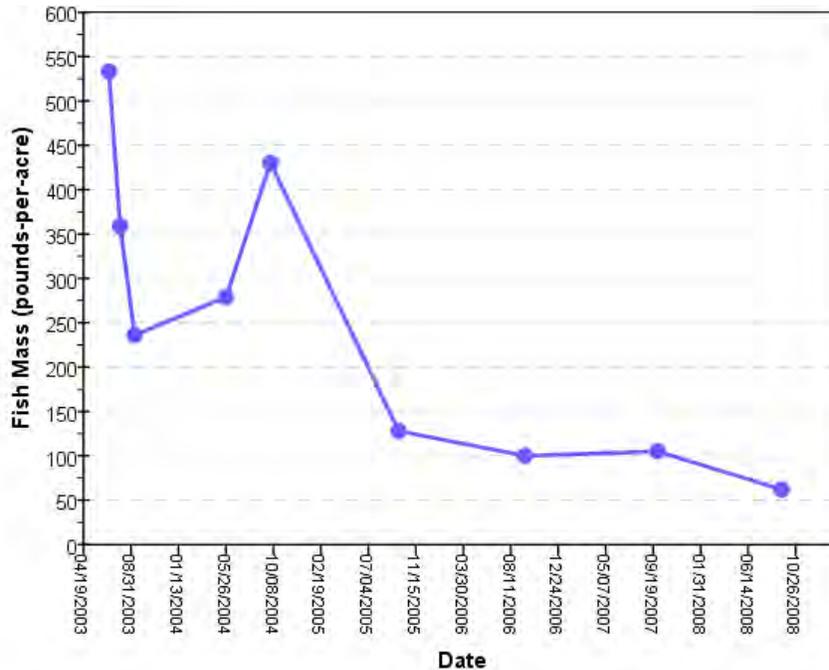
⁵¹ Dr. Alex Horne (U.C. - Berkeley). Nitrogen Offsets Produced by Artificial Water Column Mixing by Aeration Bubble Plumes in Lake Elsinore, CA. Dec. 3, 2012. Note: estimated nitrogen conversion/removal efficiency assumes that LEAMS operates a minimum of 2,000 hours/year. This is now a requirement in EVMWD's NPDES discharge permit.

⁵² California Regional Water Quality Control Board - Santa Ana Region Res. No. R8-2004-0037 (Dec. 20, 2004).

⁵³ Dr. Michael Anderson (U.C. - Riverside). Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. March 12, 2006; see pg. 26.

In 2002, LESJWA and the City of Lake Elsinore initiated a multi-year demonstration project to reduce the carp population in Lake Elsinore.⁵⁴ From 2002 to 2008, a total of 1,316,650 pounds of carp was removed from the lake (see Fig. 16). By the end of 2008, the estimated carp population was only 138 fish per acre.⁵⁵

Fig. 16: Estimated Carp Mass in Lake Elsinore



The carp removal program was so successful that it was suspended in 2008 because the few remaining carp could not be captured efficiently. It was a problem of diminishing returns. In the early years, the cost of removing carp was only about 20 cents-per-pound. Near the end, the program cost over a dollar per pound of carp removed.

Since 2008, the Task Force has conducted periodic fish surveys to determine whether the carp population has, once again, expanded to the point where it makes sense to re-start the removal program. The 2015 lake assessment shows that the number of fish >20 cm in length, a surrogate indicator for carp, is less than 6 per acre.⁵⁶ There are now 90% fewer carp than there were when the carp removal program was suspended 7 years earlier. Thus, it appears that the original program continues to produce effective long-term results; although, rising salinity may also be inhibiting carp reproduction by reducing the available food supply.

⁵⁴ A total of \$600,000 was spent on the demonstration project. State grant funding (under Prop-13) reimbursed approximately 20% of the project cost.

⁵⁵ City of Lake Elsinore. Lake Elsinore Fishery Assessment and Carp Removal Program. Report to the LESJWA Board. Nov. 20, 2008.

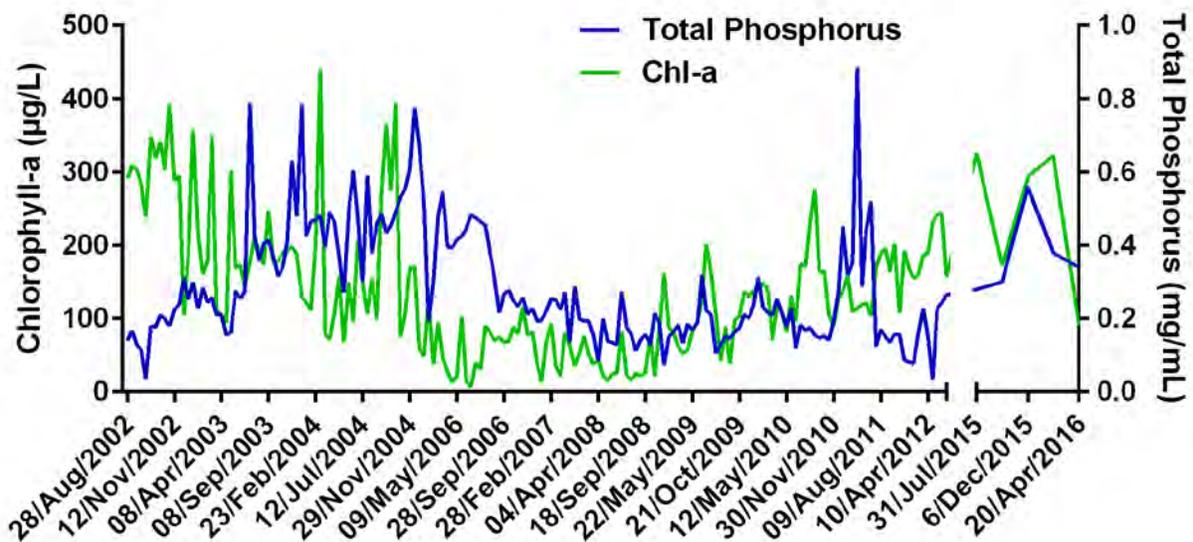
⁵⁶ Dr. Michael Anderson (U.C.-Riverside). Technical Memorandum for Task 2.2: Fishery Hydroacoustic Survey and Ecology of Lake Elsinore in the Spring of 2015. Draft Report dated Feb. 21, 2016.

3.2 Interim Response Targets for Lake Elsinore

3.2.1 Chlorophyll-a (algae)

Long-term water quality monitoring data indicates that the concentrations of total phosphorus and Chlorophyll-a in Lake Elsinore have been rising slowly since the last major El Niño event in the winter of 2004-5 (see Fig. 17).

Fig. 17: Long-term Trends for Phosphorus and Chlorophyll-a Concentration in Lake Elsinore

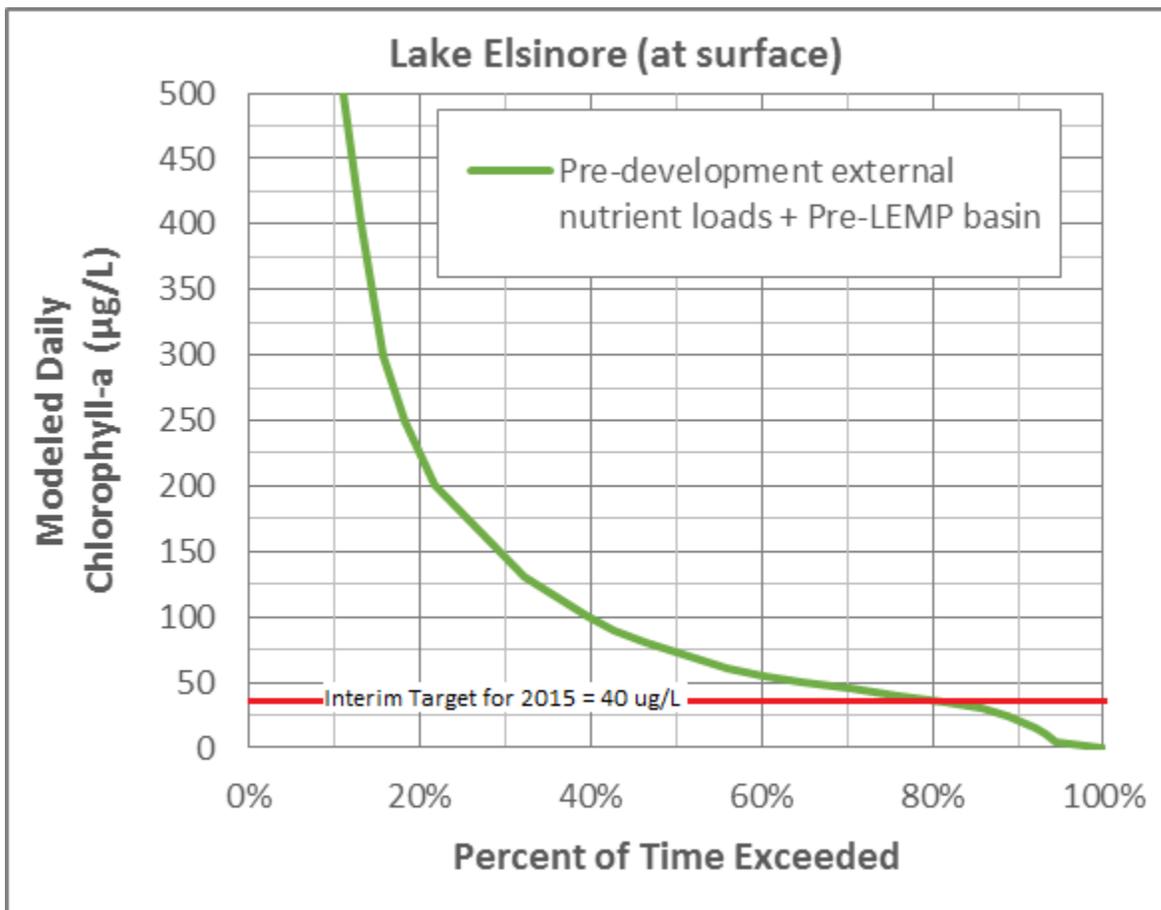


Analysis of satellite images collected in July and December of 2015 and February of 2016 also confirm that Lake Elsinore is not meeting the Interim Response Target for Chlorophyll-a that is specified in the TMDL. These results are discouraging in light of the considerable investment the stakeholders have made in water quality improvement projects over the last 10 years. However, this data does not mean prior efforts are totally ineffective.

Since 2006, the entire San Jacinto watershed has been in a protracted and extreme drought. The lake continues to evaporate at an alarming rate and Lake Elsinore is starting to approach historic low levels. Were it not for the addition of enormous quantities of recycled water over the last decade, Lake Elsinore would now be less than 5 feet deep ($\approx 1224'$ msl) and would probably dry up completely in the next 12-18 months unless the area experiences a huge *El Niño* winter like those which occurred in 1993 or 2005. With recycled water, the lake will remain wet for another 4-5 years while we wait for rain.

Cumulative evaporation is concentrating both salts and nutrients to levels that cannot be fully offset by the various BMP projects previously implemented by the stakeholders. But, the situation would be much worse if these mitigation efforts have never been undertaken. Results from the calibrated simulation model developed by Dr. Anderson indicate that Lake Elsinore would have exceeded the interim target for Chlorophyll-a (40 ug/L) more than 75% of the time even under natural pre-development conditions (see Fig. 18).

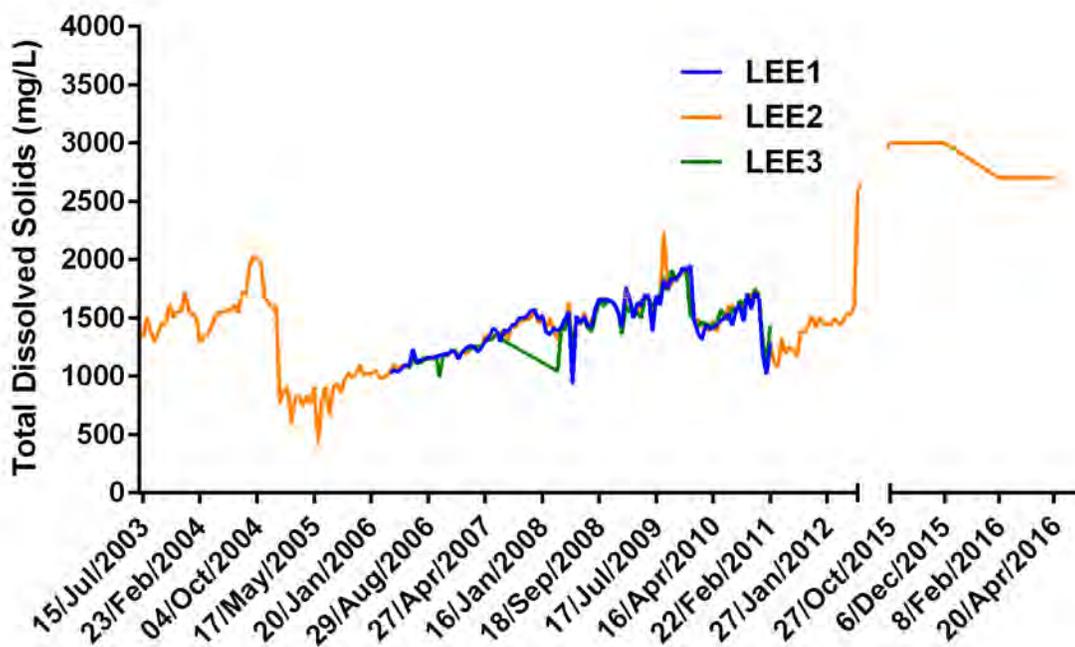
Fig. 18: Natural Exceedance Frequency for Chlorophyll-a in Lake Elsinore⁵⁷
 (Original Natural Lake Configuration Under Pre-Development Land Use Conditions)



⁵⁷ Graph produced by CDM-Smith from data generated using Dr. Anderson's 3D simulation model.

Average TDS concentrations are presently over 3,000 mg/L (see Fig. 19). However, using results from Dr. Anderson's calibrated model, TDS concentrations would be more than 3x higher (over 10,000 mg/L) if recycled water was not currently helping to offset some of the natural evaporation in Lake Elsinore. Such high salinities, which occurred under natural pre-development conditions, are lethal to all freshwater species normally found in Lake Elsinore. Improving water quality, by reducing the amount of natural evaporation, was one of the principal reasons that the levee was constructed in 1996.⁵⁸

Fig. 19: Long-Term Trend for Measured TDS Concentrations in Lake Elsinore⁵⁹



Note: from 2006 to 2011, TDS concentrations were measured at three in-lake sampling stations. Prior to 2006 and after 2011, TDS is measured at only one in-lake sampling station.

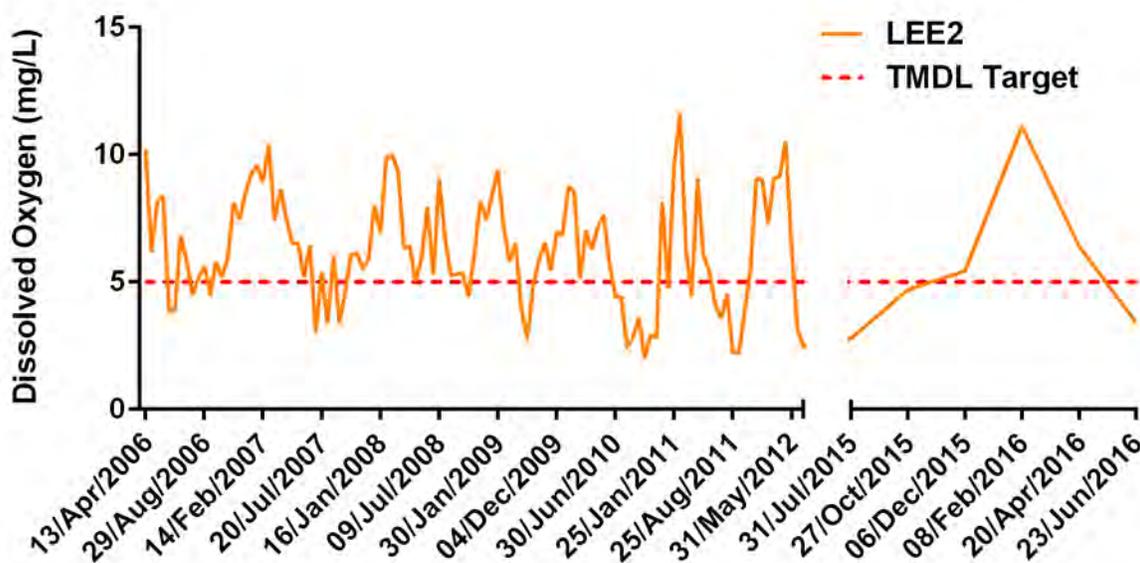
⁵⁸ Engineering Science. Final Environmental Assessment for Proposed Lake Elsinore Management Project. Report prepared for Elsinore Valley Municipal Water District. November, 1984. (see Chapter 3)

⁵⁹ AMEC Foster Wheeler. Lake Elsinore Canyon Lake Historic Data Figures. Draft dated April 5, 2016.

3.2.2 Dissolved Oxygen

Long-term monitoring data shows that the interim target for dissolved oxygen is being met much (but not all) of the time in Lake Elsinore (see Fig. 20). While there was a modest fish kill in the summer of 2015, it fell far short of those observed during previous prolonged droughts.⁶⁰ City officials estimate that 10-15 million fish perished during the 2009 event.⁶¹ This suggests that LEAMS may be mitigating some of the problems associated with extremely low DO concentrations that occurred under similar lake-level conditions in the past.

Fig. 20: Depth-Integrated Daily Average for Dissolved Oxygen in Lake Elsinore⁶²



The TMDL Task Force has asked Dr. Michael Anderson (U.C.-Riverside) to prepare a new analysis, using the validated water quality model for Lake Elsinore, to determine whether current DO conditions are better or worse than what would likely occur under natural pre-development conditions. The results of that analysis will be used to inform the TMDL update process currently underway.

⁶⁰ City officials reported removing 10-15,000 pounds of dead fish in August of 2015.

⁶¹ San Diego Tribune; August 9, 2009.

⁶² AMEC Foster Wheeler. Lake Elsinore Canyon Lake Historic Data Figures. Draft dated April 5, 2016.

4.0 Conclusions

In the ten years since the nutrient TMDL was first enacted, considerable progress has been made improving water quality in Lake Elsinore and Canyon Lake. There is no doubt that the TMDL provided much of the initial impetus; however, the collaborative stakeholder process can be credited for most of the recent success. By pooling and focusing resources, by coordinating complex implementation efforts, and by meeting regularly to assess progress, the stakeholder process is accomplishing all that was intended when the TMDL was adopted.

The extreme asymmetric hydrology of the San Jacinto watershed makes it virtually impossible to rely on traditional source reduction strategies to achieve compliance with the TMDL. Therefore, the Regional Board elected to implement and enforce the TMDL through a Comprehensive Nutrient Reduction Plan (CNRP) in the MS4 permit and an analogous plan for agricultural sources in the proposed CWAD. This performance-based, outcome-oriented approach provides the regulatory flexibility needed to develop and implement innovative solutions that are more likely to achieve eventual attainment of water quality standards.

Canyon Lake is meeting the interim response targets which are the primary indicators of whether water quality is protecting the designated beneficial uses. Regular alum applications, and installation of additional BMPs when and where needed, are expected to result in water quality that is better than what would have occurred under natural pre-development conditions by the TMDL deadline for meeting the final response targets (December, 2020).⁶³

Prolonged drought conditions are making it more difficult to meet the interim response targets in Lake Elsinore. Nevertheless, current water quality is significantly better than that observed in prior long-term droughts. There is no question that the addition of recycled water, operation of the aeration and mixing system, and the fishery management program are making a real difference. In fact, these projects are keeping the lake alive when, under natural conditions, it has previously evaporated entirely.

Eventually, there may be sufficient recycled water available to fully offset the evaporative losses in Lake Elsinore. But, it will be at least another ten years before population growth will supply enough wastewater to make this possible. Until then, stakeholders are reviewing other near-term alternatives to hold the line while waiting for rain to refill Lake Elsinore. Any new initiatives will be integrated into the implementation requirements of the updated TMDL that is presently under development. The revised TMDL, and related Implementation Plan, are scheduled to be submitted to the Regional Board for review and approval in 2017.

⁶³ The MS4 permittees are required to periodically review and revise the CNRP. The next such update is due in late 2016. Any additional BMPs that the dischargers are planning to implement will be identified and described in that document.

Appendix A: Locations of In-Lake Water Quality Sampling Stations

Fig. A-1: TMDL Field Sampling Stations for Canyon Lake



Fig. A-2: TMDL Field Sampling Stations for Lake Elsinore



Appendix B: Satellite Assessment of Chlorophyll-a Concentration in Canyon Lake

Fig. B-1: Landsat Image for December 14, 2015

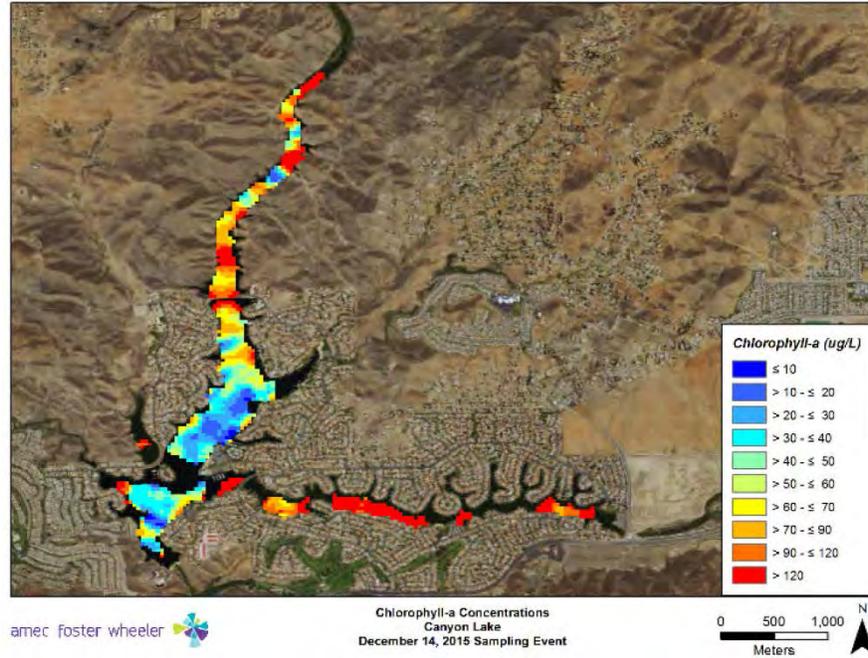


Fig. B-1: Landsat Image for February 8, 2016

