In-Lake Sediment Nutrient Reduction Plan

for

Lake Elsinore

Submitted to:

California Regional Water Quality Control Board – Santa Ana Region

Submitted by:

Lake Elsinore/Canyon Lake TMDL Task Force

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Table of Contents

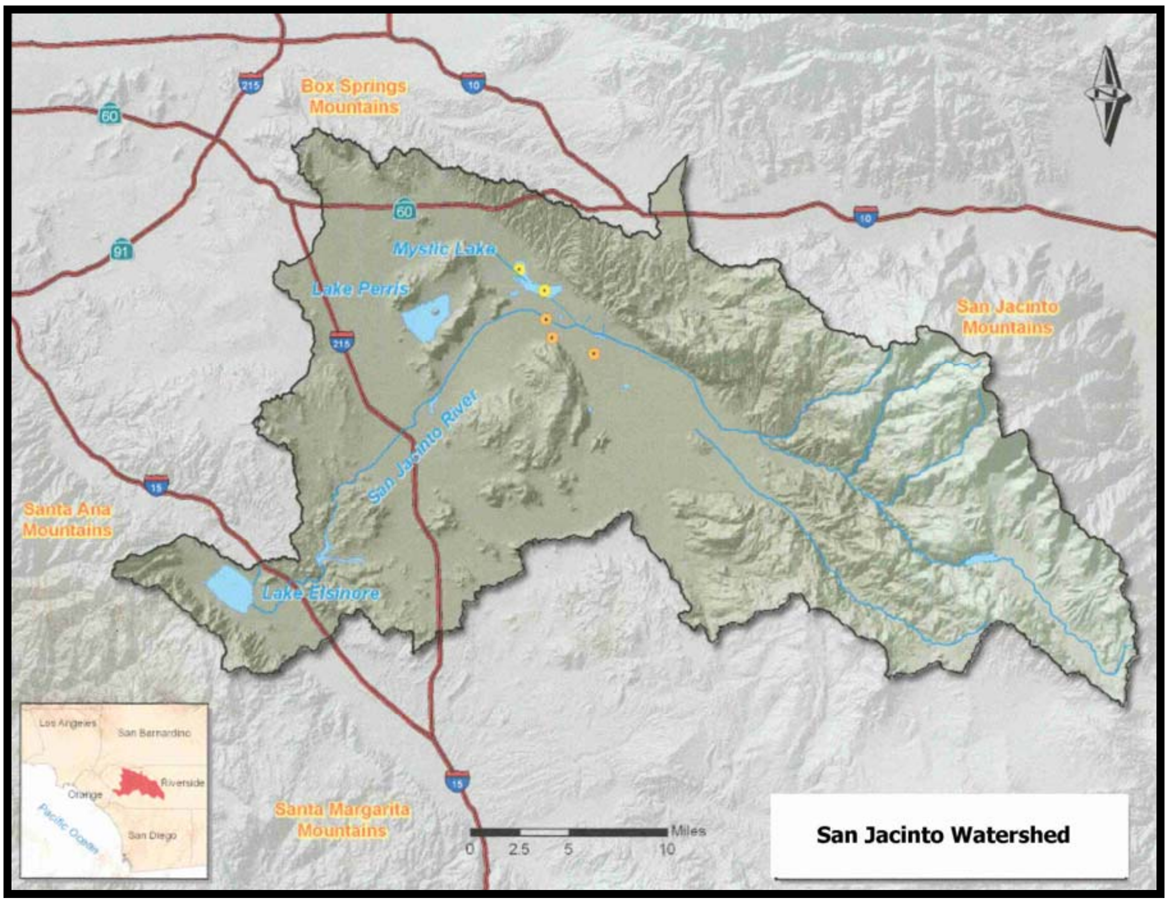
List of Figures

List of Tables

1.0 Background

Lake Elsinore is located approximately 60 miles southeast of downtown Los Angeles (see Fig. A). It has a surface area of approximately 3,000 acres and a mean depth of approximately 13 ft. The lake provides aquatic habitat for a variety of freshwater species and recreational opportunities for a large number of people living throughout southern California.

Figure A: Lake Elsinore in Riverside County, California



In 1998, the Santa Ana Regional Water Quality Control Board added Lake Elsinore to the 303(d) list of impaired water bodies because it is eutrophic. Excessive algal blooms and low dissolved oxygen levels are caused by elevated nutrient (e.g. nitrogen and phosphorus) concentrations in the water column. These conditions, in turn, cause recurring fish kills and other noxious conditions in the lake.

For several years, the Regional Board worked closely with stakeholders to identify and quantify all natural and anthropogenic sources of nutrients in the watershed. In 2004, the Regional Board relied on results from these on-going investigations to adopt a Total Maximum Daily Load (TMDL) to control nitrogen and phosphorus concentrations in Lake Elsinore.[1] The TMDL was subsequently approved by the State Water Resources Control Board[2] and by the U.S. Environmental Protection Agency.[3]

The TMDL Implementation Plan enacted by the state and federal regulatory authorities requires point and non-point dischargers in the watershed to develop and submit an "In-Lake Sediment Nutrient Reduction Plan" for Lake Elsinore.[4] The purpose of the plan is to describe a long-term strategy to control nutrients released from in-lake sediments.

2.0 Goals and Outcomes

The foremost goal of the TMDL process is to protect the designated beneficial uses of Lake Elsinore. Therefore, the intended outcome is to achieve the level of water quality needed to support warm water aquatic habitat and recreational activities; at a minimum, this includes preventing excessive algae growth, dissolved oxygen depletion and fish kills in the lake. The Regional Board set forth specific indicators by which to measure successful implementation of the TMDL (see Table 1).

Table 1: Biological and Physical Indicators for Lake Elsinore[5]

Indicator	Interim Target *(by 2015)*	Final Target *(by 2020)*
Chlorophyll-a (algae)	Summer average no greater than 40 ug/L	Summer average no greater than 25 mg/L
Dissolved Oxygen	Depth average no less than 5 mg/L across all depths	No less than 5 mg/L at one meter above the lake bottom

[1] California Regional Water Quality Control Board #8 - Santa Ana Region; Resolution No. R8-2004-0037 (Dec. 20, 2004).
[2] California State Water Resources Control Board; Resolution No. 2005-0038 (May 19, 2005).
[3] U.S. EPA Approval Letter dated September 30, 2005
[4] The Lake Elsinore In-Lake Nutrient Reduction Plan is identified as Task #9 in Table 5-9s on page 7 of 21 of the TMDL (Resolution No. R8-2004-0037).
[5] Source: Table 5-9n on page 2 of 21 of Resolution No. R8-2004-0037.

It is expected that if the targets for dissolved oxygen and Chlorophyll-a can be met, then the fish kills and other aesthetic impairments to recreational uses will be virtually eliminated. It is also assumed that nutrient concentrations in the water column must be significantly reduced in order to achieve the desired outcome. Therefore, the Regional Board also adopted numeric targets for certain chemical concentrations in Lake Elsinore (see Table 2). These chemical targets were intended to ensure compliance with the Basin Plan's narrative water quality objectives that prohibit the discharge of substances that cause excessive algae growth or other nuisance conditions.[6]

Table 2: Water Chemistry Indicators for Lake Elsinore[7]

Indicator	Final Target Concentration *(by 2020)*
Total Phosphorus	Annual average no greater than 0.10 mg/L
Total Nitrogen	Annual average no greater than 0.75 mg/L
Ammonia-Nitrogen	Equation-based on Temperature & pH

In order to meet the physical, chemical and biological target values established in the TMDL, the Regional Board supported development of water quality models to estimate the assimilative capacity for nitrogen and phosphorus in Lake Elsinore.[8] These models, developed by Tetra Tech, Inc. and Dr. Michael Anderson, were used to establish load allocations for non-point sources and wasteload allocations for point sources (see Table 3).

Table 3: TMDL Allocations for Lake Elsinore[9]

	Phosphorus	Nitrogen
Current Loading	64,923 kg/yr	345,689 kg/yr
Allowed Loading	28,584 kg/yr	239,025 kg/yr
Net Excess Load	36,339 kg/yr	106,664 kg/yr
Required Reduction	56%	31%

Note: all source allocations are expressed as 10-year running averages.

[6] Regional Water Quality Control Board - Santa Ana Region. Water Quality Control Plan - Santa Ana River Basin (8). Resolution No. R8-1994-0001 (March 11, 1994). See page 4-5.
[7] Source: Table 5-9n on page 2 of 21 of Resolution No. R8-2004-0037.
[8] TetraTech Inc. Lake Elsinore and Canyon Lake Nutrient Source Assessment. 2003.
[9] Source: Table 5-9n on page 2 of 21 of Resolution No. R8-2004-0037.

The Santa Ana Regional Water Quality Control Board recognized that many different sources were contributing nutrient loads to Lake Elsinore. Consequently, maximum average loads were specified, by source, within the TMDL for both nitrogen (see Table 4) and phosphorus (see Table 5).[10] However, the TMDL does not require reductions in nitrogen loads from in-lake sediments because the Regional Board staff lacked sufficient data to calculate appropriate load allocations and wasteload allocations for nitrogen.[11] Additional studies are underway because control of nitrogen releases from sediment is likely to be important in order to ensure un-ionized ammonia toxicity does not cause or contribute to fish kills in the future. These studies are discussed in Section 4.3 of this Plan.

Table 4: Source Allocations for Nitrogen in Lake Elsinore

Source	Current Load	Allowed Load	Net Difference	Pct. Reduction
Internal Sediment	197,370 kg/yr	197,370 kg/yr	0 kg/yr	0%
Atmospheric Deposition	11,702 kg/yr	11,702 kg/yr	0 kg/yr	0%
Supplemental Water	59,532 kg/yr	7,442 kg/yr	52,090 kg/yr	87%
Septic Systems	1,058 kg/yr	608 kg/yr	450 kg/yr	43%
Urban Runoff	606 kg/yr	349 kg/yr	257 kg/yr	42%
Open or Forest Land	567 kg/yr	567 kg/yr	0 kg/yr	0%
Agriculture	371 kg/yr	213 kg/yr	158 kg/yr	43%
Outflow from Canyon Lake	25,547 kg/yr	20,774 kg/yr	4,773 kg/yr	19%
Total	**296,753 kg/yr**	**239,025 kg/yr**	**57,528 kg/yr**	**19%**

Table 5: Source Allocations for Phosphorus in Lake Elsinore

Source	Current Load	Allowed Load	Net Difference	Pct. Reduction
Internal Sediment	33,160 kg/yr	21,554 kg/yr	11,606 kg/yr	35%
Supplemental Water	14,883 kg/yr	3,721 kg/yr	11,162 kg/yr	75%
Open or Forest Land	178 kg/yr	178 kg/yr	0 kg/yr	0%
Urban Runoff	124 kg/yr	124 kg/yr	0 kg/yr	0%
Atmospheric Deposition	108 kg/yr	108 kg/yr	0 kg/yr	0%
Septic Systems	69 kg/yr	69 kg/yr	0 kg/yr	0%
Agriculture	60 kg/yr	60 kg/yr	0 kg/yr	0%
Outflow from Canyon Lake	7,294 kg/yr	2,770 kg/yr	4,524 kg/yr	62%
Total	**55,876 kg/yr**	**28,584 kg/yr**	**27,292 kg/yr**	**49%**

[10] Source: Table 5-9r on page 5 of 21 in Resolution No. R8-2004-0037. Note: allocations for internal sediment, supplemental water, open/forest land, urban runoff, atmospheric deposition, septic systems and agriculture refer only to the watershed area that drains directly to Lake Elsinore. Separate source allocations exist for these land-use types where they flow to Lake Elsinore, indirectly, through Canyon Lake.

[11] California Regional Water Quality Control Board - Santa Ana Region. Lake Elsinore and Canyon Lake Nutrient TMDL Technical Report, 2004, pg. 74.

In order to restore the nutrient balance in Lake Elsinore, it will be necessary to reduce total phosphorus loads by nearly 23,000 kg/yr. Reductions of such magnitude can only be achieved by controlling contributions from the three largest sources of phosphorus: in-lake sediment releases, reclaimed water discharges and in-flows from Canyon Lake. Remediation strategies aimed at controlling the latter two sources are governed by Elsinore Valley MWD's NPDES permit and other nutrient management plans specified in the Implementation Section of the TMDL (see Table 6).

Table 6: Nutrient Management Plans for <u>External Sources</u> to Lake Elsinore

Source	TMDL	Description	Due Date	Status
Agriculture	Task #5	Agricultural Discharges - Nutrient Management Plan	Sept. 30, 2007	☐
Septic Systems	Task #6	On-site Disposal Systems - Management Plan	Dependent on St. Bd. approval of relevant regulations	☐
Urban Runoff	Task #7	Revision of Drainage Area Mngt. Plan (DAMP) and Water Quality Management Plan (WQMP)	Aug. 1, 2006	☑
Forest Lands	Task #8	Forest Area Review/Revision of Forest Service Management Plans	Sept. 30, 2007	☐
Canyon Lake Pass-Thru	Task #10	Canyon Lake In-Lake Sediment Treatment Evaluation	May 31, 2007	☑

Most external nutrient loads are transported to the lake in the very wettest (aka "El Niño") years (see Table 7). Sustained heavy rains, like as those that occurred in 1993 and 1995, occur less than 17% of the time but contribute nearly three-quarters of all <u>new</u> phosphorus loads to Lake Elsinore. During the dry and moderate weather conditions that normally predominate in the region, the vast majority of the San Jacinto watershed contributes virtually no flow or nutrient loads to Lake Elsinore.[12] Rather, during dry and moderate years, most stormwater runoff is retained in Mystic Lake and/or Canyon Lake before it reaches Lake Elsinore.

Given the immense flows that occur during El Niño, sometimes exceeding 500 cfs in the San Jacinto River channel, it is technically infeasible to divert the stormwater runoff.[13] In addition, even if all external nutrient loads were eliminated entirely, water quality conditions in Lake Elsinore would likely remain impaired for many decades, perhaps centuries.[14] Nevertheless, the TMDL requires external loads to be reduced or offset in order to comply with relevant nutrient targets and related water quality objectives.

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[12] Tetra Tech, Inc.; Lake Elsinore and Canyon Lake Nutrient Source Assessment Final Report. January, 2003; see Tables 5-5 thru 5-13 on pgs. 5-8 thru 5-12.

[13] Riverside County Flood Control and Water Conservation District. Canyon Lake, Lake Elsinore and San Jacinto River Watershed Tour. Handout Packet dated Nov. 30, 2004.

[14] MWH. Final Report: Engineering and Feasibility Study for NPDES Permit for Discharge to Lake Elsinore. Feb., 2002. See pg. 4-4.

Nutrient cycling from bottom sediments is now the dominant factor driving ambient water quality conditions in the lake.[15] Therefore, the most practical approach is to mitigate the adverse effects of phosphorus after it reaches the lake but before it can impair the beneficial uses. However, if this "offset approach" proves unsuccessful at meeting water quality objectives in Lake Elsinore, additional controls to reduce external loads more directly may become necessary to comply with the TMDL.

Table 7: Estimated External Phosphorus Loads to Lake Elsinore (1993 – 2004)[16]

Rank	Year	External Load	Percent of 12-yr. Load	Cumulative Percent	TMDL Category
1	1993	99,487 kg	59%	59%	Wet
2	1995	22,257 kg	13%	72%	Wet
3	2004	9,897 kg	6%	78%	Moderate
4	1998	9,107 kg	5%	83%	Moderate
5	2003	8,593 kg	5%	88%	Moderate
6	2002	4,339 kg	3%	91%	Moderate
7	1997	3,816 kg	2%	93%	Moderate
8	1994	2,948 kg	2%	95%	Dry
9	1996	2,455 kg	1%	96%	Dry
10	2001	2,330 kg	1%	97%	Dry
11	1999	1,207 kg	1%	98%	Dry
12	2000	1,191 kg	1%	99%	Dry

3.0 In-Lake Nutrient Control Strategies

Historical records and data from sediment core samples indicate that phosphorous levels in Lake Elsinore have been elevated for many centuries.[17] However, there is growing concern that agricultural activities and urban development may cause these natural water quality conditions to worsen.[18] As a result, many studies have been performed to evaluate various nutrient reduction strategies for the lake (see Table 8).

[15] Michael A. Anderson; Internal Loading and Nutrient Cycling in Lake Elsinore. August 31, 2001. See, also, Anderson, Michael; Lake Elsinore Water Quality Model. 2003

[16] M.A. Anderson; Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. March 12, 2006. See Table 4 on pg. 17.

[17] Matthew E. Kirby, et al. Developing a Baseline of Natural Lake-Level/Hydrologic Variability and Understanding Past versus Present Lake Productivity Over the Late-Holocene: A Paleo-Perspective for Management of Modern Lake Elsinore. March, 2005.

[18] California Regional Water Quality Control Board -Santa Ana Region. Problem Statement for Total Maximum Daily Load for Nutrients in Lake Elsinore - Staff Report. 2001; See, also, U.S. Geological Survey. Effects of Increased Urbanization from 1970's to 1990's on Storm-Runoff Characteristics in Perris Valley, California. Water-Resources Investigations Report 95-4273. 1996.

Table 8: Key Studies Used to Evaluate and Select Nutrient Reduction Strategies

Date	Report	Author(s)
1994	Lake Elsinore Water Quality Management Plan	Black & Veatch, Inc.
1994	Lake Elsinore Master Plan / Economic Feasibility Study: 1995-2015	Noble Consultants, Inc.
1997	EVMWD: Lake Elsinore NPDES Permit Feasibility Study; Final Phase 1 Technical Report	Montgomery Watson Americas, Inc.
2000	Lake Elsinore Sediment-Water Interface Study Final Report	M. Beutel
2000	Laboratory and Limnocosm-Scale Evaluation of Restoration Alternatives for Lake Elsinore. Final Report.	Dr. Michael A. Anderson
2001	Alum Application to Lake Elsinore: Responses to Questionnaire	Dr. G. Dennis Cooke
2001	Internal Loading and Nutrient Cycling in Lake Elsinore	Dr. Michael A. Anderson
2002	Rainfall-Runoff Characteristics and Effects of Increased Urban Density on Streamflow and Infiltration in the Eastern Part of the San Jacinto River Basin	U.S. Geological Survey Water Resources Report 02-4090
2002	Proposed Lake Aeration and Biomanipulation for Lake Elsinore, CA	Arlo W. Fast
2002	Alum Application to Lake Elsinore: Questionnaire Update	Dr. G. Dennis Cooke
2002	Restoration of Canyon Lake and Benefits to Lake Elsinore Downstream	Dr. Alex J. Horne
2002	Impacts of Alum Addition on Water Quality in Lake Elsinore	Dr. Michael A. Anderson
2002	EVMWD: Engineering Feasibility Study for NPDES Permit for Discharge to Lake Elsinore Final Report	Montgomery Watson Harza, Inc.
2002	Lake Elsinore Replenishment Level Study Alternatives Analysis	Tetra Tech, Inc.
2002	Evaluation of Calcium Treatment for Control of Phosphorus in Lake Elsinore	Dr. Michael A. Anderson
2002	Report on Evaluation of Potential Calcium Treatment to Enhance Water Quality in Lake Elsinore	Dr. Ellie E. Prepas
2003	Lake Elsinore and Canyon Lake Nutrient Source Assessment	Tetra Tech, Inc.
2004	San Jacinto Nutrient Management Plan Final Report	Tetra Tech, Inc.
2004	Lake Elsinore Nutrient Removal Study	CH2M-Hill, Inc.
2004	Removal of Dissolved Phosphorus Using Calcium Amendment	Dr. Michael A. Anderson
2005	Developing a Baseline of Natural Lake-Level/Hydrologic Variability and Understanding Past Versus Present Lake Productivity Over the Late-Holocene: a Paleo-Perspective for Management of Modern Lake Elsinore	Dr. Matthew E. Kirby and Dr. Michael A. Anderson
2005	Lake Elsinore Stabilization and Enhancement Project: Draft PEIR	MWH
2005	Final Fisheries Management Plan for Lake Elsinore	EIP Associates
2006	Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results	Dr. Michael A. Anderson
2006	Feasibility Study Report: Nutrient Reduction Alternatives for Regional Water Reclamation Facility Effluent Discharge to Lake Elsinore	MWH Americas, Inc.
2006	White Paper: Reasons for the TMDL Nitrogen Additional Studies of Lake Elsinore in 2006-07	Dr. Alex J. Horne
2007	Sediment Nutrient Flux and Oxygen Demand Study for Canyon Lake with Assessment of In-Lake Alternatives	Dr. Michael A. Anderson

Some control strategies, such as large-scale dredging, were found to be impractical because it would be necessary to remove 20 feet of sediment to have a significant effect on phosphorus concentrations in the water column.[19] Other methods commonly used elsewhere to control algae, such as applying liquid alum to bind with phosphorus and render it inert, are relatively ineffective for Lake Elsinore due local water chemistry conditions (high pH) which are ill-suited to such treatments except, perhaps, during short periods of time immediately following a storm event.[20]

Relying on the large volume of technical reports prepared by interdisciplinary experts in lake management, local stakeholders developed an innovative new approach for improving water quality in Lake Elsinore. The approach, called "Biomanipulation," implements several coordinated projects designed to reduce phosphorus loads from in-lake sediments. The three primary mitigation strategies are: 1) a Lake Level Stabilization program, 2) an In-Lake Aeration System, and 3) a Targeted Fisheries Management effort.

3.1 Lake Level Stabilization

Water levels in Lake Elsinore vary over a wide range (±18 ft.) due to natural fluctuations in rainfall. During times of prolonged drought, such as occurred in the mid-50's and early 60's, the lake nearly dried up altogether. As evaporation diminishes the volume of lake water, conservative elements such as phosphorus become more concentrated. Elevated nutrient concentrations, in turn, increase the risk of beneficial use impairment. Large changes in lake elevation also make it very difficult to establish a stable riparian zone along the shoreline.

In 1995, a large levee was constructed to reduce the surface area of Lake Elsinore by nearly 50% thereby minimizing the adverse effects of evaporation. However, by itself, even this drastic reconfiguration is insufficient to provide the stable lake levels. Supplemental flow is provided by several island wells which pump 3,000 acre-feet of groundwater into the lake each year.

In June of 2007, Elsinore Valley Municipal Water District (EVMWD) agreed to augment lake levels by discharging high quality reclaimed water to Lake Elsinore. By stabilizing lake levels in a range between 1240-1248 feet above mean sea level, the supplemental water project will establish the conditions necessary to promote more productive shoreline vegetation. The direct and indirect environmental benefits of such bank habitat are numerous.

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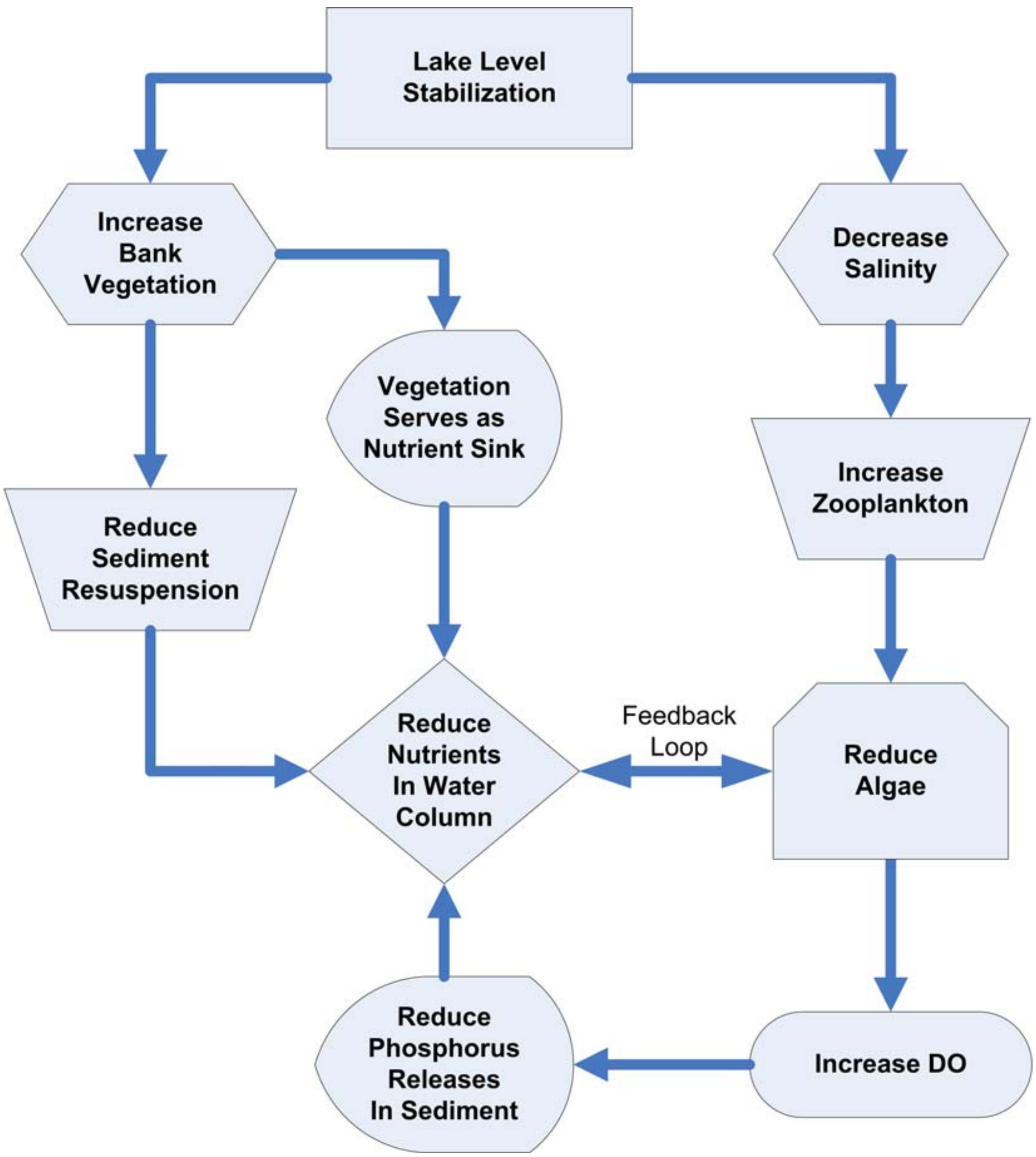
[19] See Table 5-2 on page 5-4 of Montgomery-Watson's Final Report entitled: "Engineering Feasibility Study for NPDES Permit for Discharge to Lake Elsinore." February, 2002.

[20] See, for example, G. Dennis Cooke. Alum Applications to Lake Elsinore. 2001 & 2002. See, also, CH2M-Hill. Lake Elsinore Nutrient Removal Study. April, 2004

First, aquatic plants shield the underlying sediments from wind-driven waves and, thereby, reduce the phosphorus releases that accompany resuspension. Second, the aquatic plants themselves take up and sequester nutrients that would otherwise contribute to excess algae growth. Third, the aquatic plants provide the type of habitat needed to support a stronger and more diverse community of aquatic species (see Fig. B).

Fig. B: Biological Benefits of Lake Level Stabilization



The last point is especially important. Some aquatic organisms, such as zooplankton, feed on algae thus helping to prevent beneficial use impairment. However, zooplankton reproduction is inhibited at the higher salinity levels likely to occur as water evaporates from Lake Elsinore. By providing supplemental flows of reclaimed water, Elsinore Valley MWD is stabilizing both the lake level and the salinity concentration in a range that promotes a healthy zooplankton population.

However, municipal effluent also contains elevated concentrations of nutrients such as nitrogen and phosphorus (see Tables 4 & 5, above). Consequently, the TMDL requires EVMWD to reduce nitrogen concentrations by 87% and phosphorus concentrations by 75% before the reclaimed water can be discharged to Lake Elsinore. These obligations are set forth and enforceable though a state and federal NPDES permit. In 2005, the Lake Elsinore and San Jacinto Watersheds Authority (LESJWA) provided funding from the State of California Prop-13 Water Bond to contract with EVMWD to construct advanced waste treatment facilities, using best available technology, to reduce nutrient concentrations in the effluent. Such treatment is essential to support a long-term strategy for providing reclaimed water to stabilize the level of Lake Elsinore.

Computer simulation studies, designed to model nutrient cycling processes in Lake Elsinore, indicate that adding 4000 af/yr of highly treated reclaimed water will reduce the algae concentrations by more than 50% and improve water clarity by nearly 100%.[21] These estimates are probably conservative because they are based solely on the expected benefit derived by reducing wind and wave-driven sediment resuspension. Increased zooplankton populations and enhanced shoreline vegetation are also expected to improve water clarity and reduce excessive algae. At present, there is insufficient data to calibrate the nutrient models to estimate all of the cause-effect relationships. However, on-going monitoring programs will be used to perform an empirical analysis of these biological factors over the long-term.

3.2 In-Lake Aeration and Destratification

Dissolved oxygen levels in Lake Elsinore vary greatly by depth; concentrations range from less than 1 mg/L near the bottom to over 11 mg/L near the surface. Low D.O. levels encourage greater phosphorus releases from the sediment. The higher phosphorus concentrations stimulate more algae growth which, in turn, consumes more oxygen especially during the nighttime hours. Nutrient cycling is now the principle cause of water quality impairment in Lake Elsinore.

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[21] M.A. Anderson. Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. March 12, 2006.

LESJWA undertook an evaluation of the necessary aeration and oxygenation system for Lake Elsinore and contracted with Dr. Arlo Fast to make appropriate recommendations. Dr. Fast's report indicated that sufficient oxygen already exists but was not well distributed in the water column.[22] He recommended a two phase mixing system to distribute and mix the oxygen throughout the water column.

The first phase of the system consisted of axial flow water pumps. The system was implemented in 2005 by the City of Lake Elsinore under contract with LESJWA with significant financial support provided by California's Prop-13 Water Bond.[23] The pumps are designed to reduce stratification by improving circulation in the lake. Forcing oxygen-saturated surface waters to the bottom of the lake inhibits the anoxic conditions that promote higher phosphorus release rates from the sediment.

The second phase consisted of a large-scale in-lake aeration system.[24] In June of 2007, LESJWA provided Prop-13 Water Bond funding to EVMWD to construct an in-lake aeration project is designed to pump air through a system of twelve perforated pipelines submerged along the bottom of Lake Elsinore (see Fig D). Like the axial pump, the aeration system improves circulation so that oxygen levels are better distributed throughout the water column. The bubble diffuser "lifts" oxygen-deficient bottom waters to the surface where it can be resaturated through direct contact with the atmosphere.

The aeration pumps are only scheduled to operate during the warm-weather months when oxygen levels are lowest, nutrient levels are highest, daylight hours are longest and algae growth is greatest. Additional water quality benefits may accrue if the system is run more frequently; however, it is considerably less efficient to operate outside the optimum range. Moreover, it may be unnecessary.

Laboratory testing indicates that the in-lake aeration system will reduce the sediment release rate for phosphorus by at least 35%.[25] However, computer simulation studies suggest that a 35% reduction in the sediment recycling rate may result in larger reductions for total phosphorus in the water column – perhaps as much as 70% lower.[26] Figure C illustrates how the benefits are expected to accrue.

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[22] Arlo W. Fast. Proposed Lake Aeration and Biomanipulation for Lake Elsinore, CA. 2002

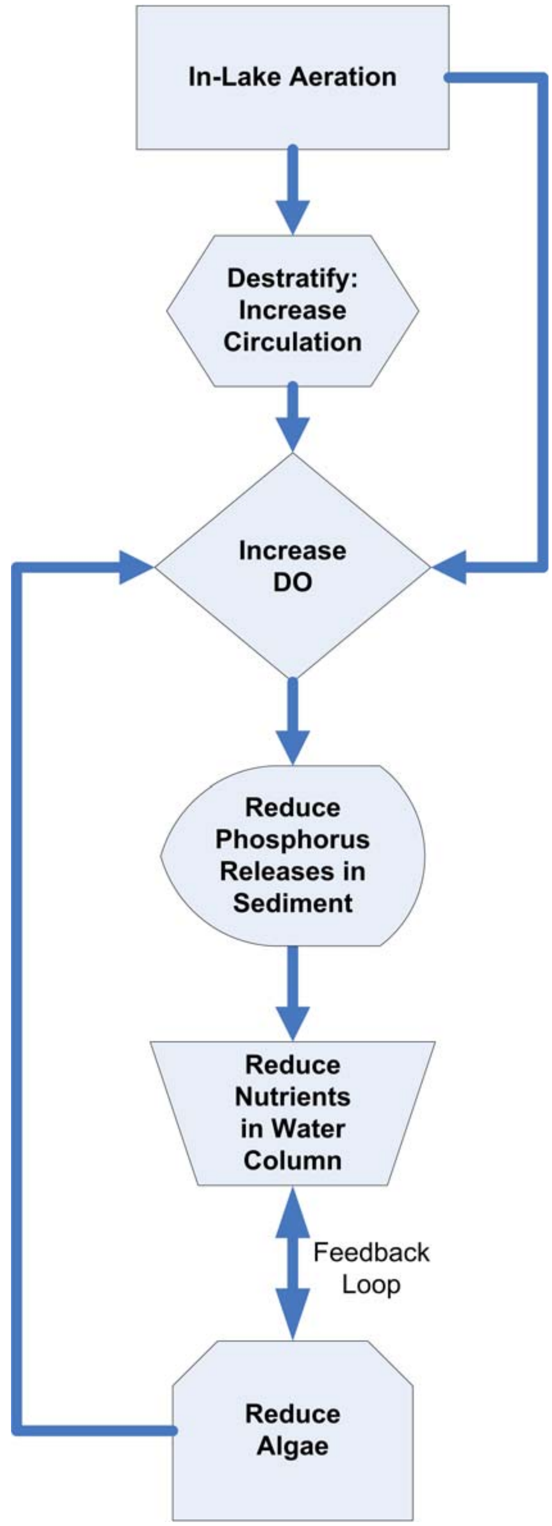
[23] Agreement for the Operations and Maintenance of the Axial Flow Water Pump Destratification System for Lake Elsinore. Feb. 11, 2003. Signatories: City of Lake Elsinore, Elsinore Valley Municipal Water District, & County of Riverside.

[24] Agreement for the Operation and Maintenance of the Lake Elsinore Phase II Aeration System. Aug. 1, 2006. Signatories: City of Lake Elsinore, Elsinore Valley Municipal Water District, & County of Riverside.

[25] Michael A. Anderson. Internal Loading and Nutrient Cycling in Lake Elsinore. Aug. 31, 2001.

[26] M.A. Anderson. Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. March 12, 2006. p. 25

Fig. C: Biological Benefits of In-Lake Aeration



The Santa Ana Regional Water Quality Control Board assumed the in-lake aeration and mixing systems would reduce phosphorus loads by 35% and included this assumption when formulating the TMDL for Lake Elsinore.[27] The County of Riverside, the City of Lake Elsinore and Elsinore Valley MWD have committed to continue operating the in-lake aeration and mixing systems until mid-2011. Data from the first four years of operation will be used to determine the overall effectiveness of the system. Based on this information, a new agreement will be negotiated among the responsible parties identified in the TMDL to govern future operations of the system. The new agreement will be submitted to the Santa Ana Regional Water Quality Control Board for approval in December, 2010.

3.3 Targeted Fisheries Management

Some fish species, notably Carp and Shad, are seriously aggravating the nutrient problem in Lake Elsinore. Carp forage for food in the sediment. This action, called "bioturbation," resuspends organic silt and thereby increases the amount of phosphorus released to the water column by as much as 5,000 kg/yr (≈ 5% of the total load). Shad consume the zooplankton species that would normally keep the algae population in check.

In order to improve water quality in Lake Elsinore, and provide better habitat or a wider range of fish species, it is necessary to reduce the number of Carp and Shad significantly. This will be accomplished by using direct and indirect methods (see Fig. D).

Direct methods are best exemplified by the City of Lake Elsinore's netting and stocking program. Each year, LESJWA provides Prop-13 Water Bond funding to support a large-scale netting effort designed to reduce the Carp population. The City also stocks the lake with sport fish (such as Stripers) that feed on Carp and Shad and out-compete the nuisance species for available habitat. Early indications are that these efforts have significantly reduced the number of both nuisance species and, in turn, helped improve water quality in the lake despite the influx of new sediment loads during the relatively wet winters of 2005 and 2006. Prop-13 funding will end in 2010; thereafter, local stakeholders must provide financial support for the program if it continues to prove effective. If so, the responsible parties identified in the TMDL will negotiate a long-term contract to extend the fishery management program (netting and stocking) and submit the agreement to the Santa Ana Regional Water Quality Control Board by December, 2010.

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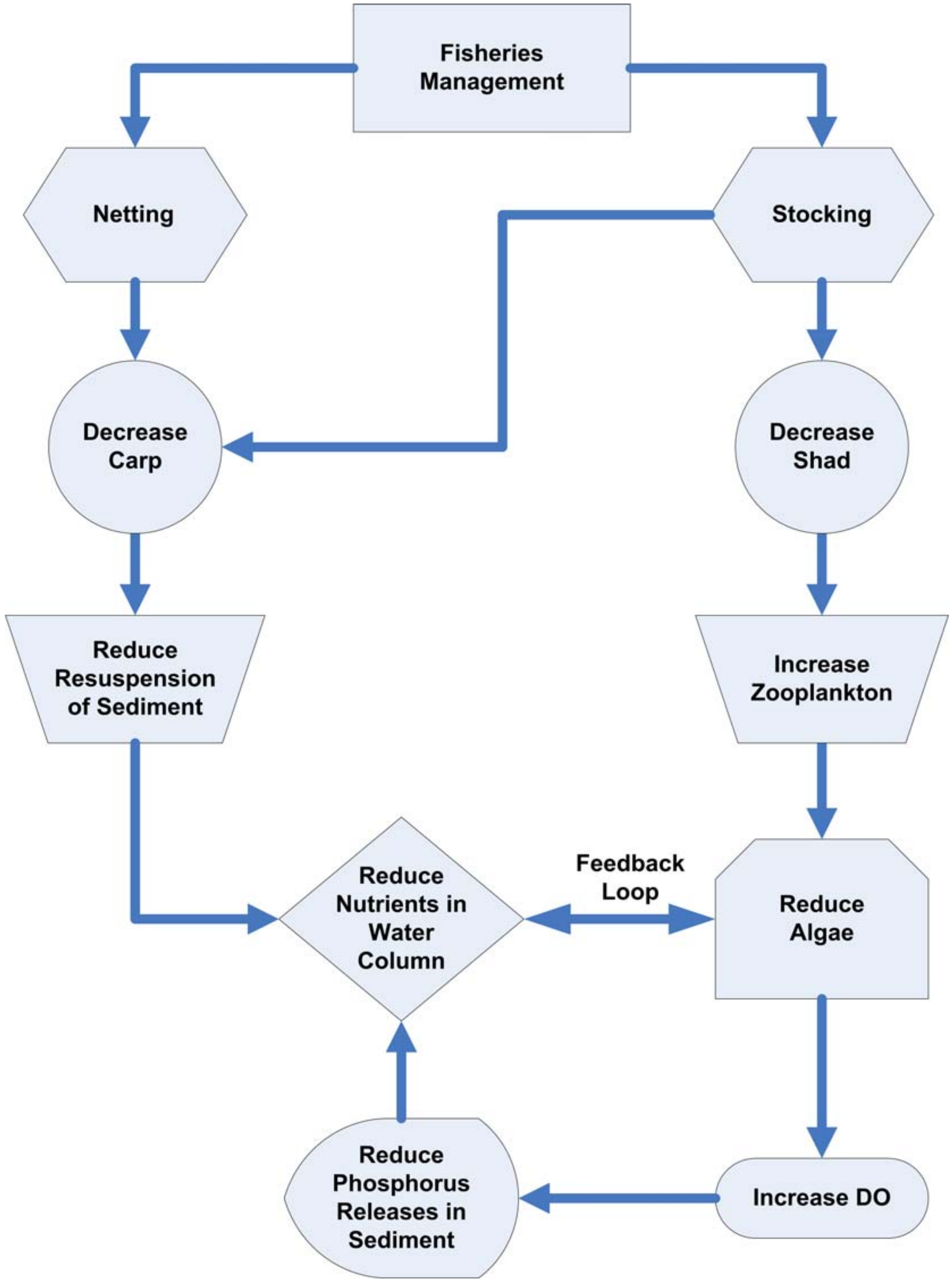
[27] California Regional Water Quality Control Board - Santa Ana Region. Lake Elsinore and Canyon Lake Nutrient TMDL Technical Report. 2004.

Fig. D: Biological Benefits of Targeted Fisheries Management



Indirect methods are best illustrated by EVMWD's flow augmentation program. Stabilizing the lake level with reclaimed water will improve shoreline vegetation that provides habitat for desirable zooplankton and fish species. In addition, the reclaimed water will help control salinity concentrations in a range more favorable to the zooplankton. A large population of zooplankton is essential to prevent excessive algae growth in Lake Elsinore.

Computer simulation studies indicate that reducing Carp populations by 50% will lower the phosphorus loading rate by 5 $mg/m^2/day$ (nearly 13%).[28] Reducing the Carp population by 75% will lower the phosphorus loading rate by 16 $mg/m^2/day$ (32%). At present, the simulation models cannot quantify the benefits of increasing the zooplankton population by decreasing water salinity and the number of Shad in Lake Elsinore. However, the long-term monitoring program is designed to track such phenomena and the computer programs can be updated when the data become available.

3.4 Compound Effects

The nutrient targets specified in the TMDL can be achieved by implementing several remediation measures simultaneously. For example, installing the aeration system and reducing the Carp population by 50% will decrease the phosphorus loading rate by 78%.[29] This estimate is conservative because it assumes the total phosphorus concentration in recycled water is 2 mg/L rather than the 0.5 mg/L allowed by permit. In addition, it does not include the expected benefits derived from higher lake levels or larger zooplankton populations.

Biomanipulation is a complex implementation strategy with many inter-related cause and effect relationships. The cumulative beneficial impact of this integrated remediation effort is actually greater than the sum of the individual interventions.

Ultimately, compliance must be assessed using actual water quality monitoring data not the results of sophisticated computer simulations. And, such a monitoring program is already underway. Nevertheless, analysis-to-date indicates that the on-going biomanipulation strategy will restore water quality in Lake Elsinore to better than natural background conditions.

[28] M.A. Anderson. Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. March 12, 2006. p. 25
[29] M.A. Anderson. Predicted Effects of Restoration Efforts on Water Quality in Lake Elsinore: Model Development and Results. March 12, 2006. p. 25

4.0 Compliance Monitoring

The monitoring program proposed for Lake Elsinore is not merely designed to demonstrate compliance with the numeric nutrient targets identified in the TMDL but, also, to show that the beneficial uses themselves are being attained. To that end, many different parameters are evaluated simultaneously to better assess the health of Lake Elsinore's aquatic ecosystem.

4.1 Water Quality Monitoring

The most direct method of establishing compliance with water quality objectives in the Basin Plan is to collect and analyze water samples on a regular basis. The TMDL requires samples to be collected from at least three stations in Lake Elsinore. The samples are to be collected monthly between October and May and biweekly in the months of June through September.[30] In addition to other parameters, samples are analyzed for all of constituents listed in Table 9.

Table 9: In-Lake Water Quality Monitoring Program for Lake Elsinore

Category	Parameter
Oxygen	Dissolved Oxygen*
	Chemical Oxygen Demand (COD)
	Biological Oxygen Demand (BOD)
Water Clarity	Secchi Depth
	Turbidity
	Total Suspended Solids (TSS)
	Chlorophyll *a**
Nutrients	Ortho-phosphate (SRP)*
	Organic Phosphorus*
	Organic Nitrogen*
	Nitrite Nitrogen*
	Nitrate Nitrogen*
	Ammonia Nitrogen*
Salinity	Total Dissolved Solids (TDS)
	Specific Conductance
	Total Hardness
Physical	pH
	Water Temperature

**Indicates a parameter that must meet specific numeric targets identified in the TMDL. Nutrient parameters are summed into Total Phosphorus and Total Nitrogen.*

[30] A more detailed description is provided in the Proposed Lake Elsinore and Canyon Lake Nutrient TMDL Monitoring Plan (Feb. 15, 2006) approved by the Regional Board on March 3, 2006 as Resolution No. R8-2006-0031.

Results from the water quality monitoring program will be compared to the numeric targets identified in the TMDL, using the methods and procedures specified in the State Water Resources Control Board's 303(d) listing policy.[31] In addition, the data may be used to update and revise the various computer simulation models used to predict changes in water quality in Lake Elsinore.

4.2 Biological Monitoring

The primary purpose of improving water quality in Lake Elsinore is to protect aquatic organisms. Although one may infer that lower nutrient concentrations and high DO levels are beneficial to fish and other species living in the lake, it is desirable to demonstrate such improvements more directly. This is especially important when implementing strategies designed to mitigate the adverse effects of pollution rather than relying, exclusively, on pollution reduction programs. For example, it may be more efficient and effective to control algae by stimulating the zooplankton population than it is to reduce phosphorus concentrations. The In-Lake Nutrient Reduction Plan for Lake Elsinore intends to pursue both of these strategies in addition to several other compliance initiatives. And, as a result, it is likely that beneficial uses will be protected (e.g. response targets will be attained) even if nutrient targets are not always met.

Some response variables, such as D.O. and Chlorophyll-a, are already included among the parameters that must be evaluated as part of the regular water quality monitoring program. Compliance with these TMDL targets would form the primary basis for assessing beneficial use protection . However, there are other indicators of biological integrity which should also be considered (see Table 10). A plan to expand the current monitoring program to include additional biological monitoring will be submitted to the Regional Board by June of 2008.

Table 10: Recommended Biological Monitoring Program for Lake Elsinore

Parameter	Frequency
Fish Richness and Abundance	Annually
Zooplankton Abundance	Annually
Algae Richness and Abundance	Annually
Shoreline Vegetation Survey	Bi-annually
Aquatic Plant Survey	Bi-annually

[31] California State Water Resources Control Board. Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List. September 30, 2004.

Results from the biological monitoring program will be used to recalibrate the computer simulation models used to predict changes in DO or algae concentrations based on changes in nutrient levels while controlling for other important variables such as the size of various fish and plant populations. Ultimately, as water quality improves, biological monitoring data may be used to demonstrate that DO and algae levels are better than would occur under natural conditions and that beneficial uses in Lake Elsinore are no longer impaired. In addition, results from the biological monitoring program will be invaluable for developing "biocriteria," an essential element of TMDL Task #13 (Reviewing and Revising Nutrient Water Quality Objectives."

4.3 Special Studies

Although the TMDL does not require the In-Lake Sediment Nutrient Reduction Plan to meet specific load allocations for total nitrogen, the Regional Board staff has indicated that some nitrogen-reduction benefits were expected to occur when the aeration system is installed. Therefore, some special studies have been initiated to provide additional scientific confirmation.[32] These include:

1) In-lake measurements of the sediment organisms as a living sink for Nitrogen.

2) Estimation of sediment denitrification as an atmospheric sink for Nitrogen.

3) In-lake samples of the nitrogen fixing potential of the lake as a source for Nitrogen.

EVMWD contracted with Dr. Alex Horne to perform the studies and initial samples were collected in September, 2006. Additional sampling is expected to be conducted in the Fall of 2007. Results will be reported to the Regional Board.

[32] Alex J. Horne. White Paper: Reasons for the TMDL Nitrogen Additional Studies of Lake Elsinore in 2006-07. August 14, 2006.

4.4 Water Quality Modeling

All of the additional monitoring data described above is a necessary prerequisite to completing TMDL Task #11: Updating the Lake Elsinore In-Lake Water Quality Model.[33] Until the aeration system comes on-line, and new data are collected, there is little value in running the current water quality models for Lake Elsinore. Therefore, the Regional Board has extended the deadline to March of 2009 in order to collect additional chemical and biological data.[34]

5.0 Supplemental Control Strategies

The biomanipulation program described in Section 3 is expected to achieve compliance with the chemical and biological targets specified in the TMDL. However, in the event the proposed program proves inadequate, there may be additional options to further reduce nutrient loads released from in-lake sediments. These include:

5.1) An Enhanced Aeration System

The software code used to control the existing aeration system can be revised to operate the aerators more frequently (more months of the year, more days of the month, or more hours in a day). In addition, additional pipelines and/or aerators may be installed to provide better coverage. The utility of this option depends on the demonstrated effectiveness of the current aeration system and the related oxygenation efficiency curve of additional aeration.

5.2) Enhanced Treatment of Reclaimed Water

EVMWD's NPDES permit limits phosphorus concentrations in reclaimed water discharged to Lake Elsinore to less than 0.5 mg/L. Additional alum application at the wastewater treatment plant may reduce nutrient concentrations even further. This may provide any opportunity to offset non-point source loads by engaging in pollutant trading with point sources.

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[33] Source: Table 5-9s on pg. 7 of 21 in R8-2004-0037.

[34] California Regional Water Quality Control Board - Santa Ana Region. Letter to Mr. Mark Norton, Lake Elsinore & San Jacinto Watersheds Authority dated April 30, 2007.

5.3) Direct Application of Metal Salts

Alum and other metal salts are frequently used to reduce phosphorus concentrations in small lakes. In general, Lake Elsinore is poorly suited for the use of alum because the relatively high pH levels inhibit the intended formation of aluminum phosphate.[35] However, under certain conditions, pH levels may be low enough to support the application of metal salts, such as alum, to Lake Elsinore.

In very wet years, when the inflows to Lake Elsinore are greatest, pH levels tend to decrease. This is not surprising because the pH of rain water is naturally low. If large scale alum applications were timed to coincide with wet winters, much of the new dissolved phosphorus flowing into the lake might be neutralized. Another option may be to apply alum to Canyon Lake and reduce the phosphorus concentrations before the water overflows into Lake Elsinore.[36]

5.4 Targeted Suction Dredging

Previous studies indicate a disproportionate amount of phosphorus released from in-lake sediments is coming from the organic silt layer in the middle of the lake.[37] And, preliminary reports suggest that most of the phosphorus is coming from the top 15 cm of sediment. Therefore, limited suction dredging, targeting the top 6 inches of sediment in the middle of the lake may prove to be an effective mitigation strategy.

5.5 Constructed Wetlands

LESJWA is currently developing a pilot project to demonstrate the effectiveness of constructed wetlands for reducing nutrient concentrations in Lake Elsinore. Theoretically, stormwater runoff could be diverted through such wetlands for treatment prior to entering the lake. Alternatively, lake water could be pumped up and flow through the wetlands during drier years. When the levee was constructed, and the surface area of Lake Elsinore was cut in half, a large back-basin area was created that may serve as an ideal location to build treatment wetlands. Data from the pilot project will help determine whether such an approach would be practical on a larger scale.

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[35] Michael A. Anderson. Impacts of Alum Addition on Water Quality in Lake Elsinore. Feb. 1, 2002.

[36] These and other alternatives are described in CH2M-Hill's report entitled: Lake Elsinore Nutrient Removal Study. April, 2004.

[37] California Regional Water Quality Control Board - Santa Ana Region. Lake Elsinore and Canyon Lake Nutrient TMDL Technical Report; 2004 @ pgs. 29-31.

5.6 Active Aquatic Plant Management

Over time, stabilizing the lake level and reducing the algae infestation will provide an opportunity for native aquatic plants to recolonize the lake. It may also be possible to accelerate the process by initiating a program to actively revegetate the shoreline and the lake bottom. Aquatic plants will serve as a natural sink for nutrients, will provide better habitat for beneficial freshwater species, and reduce the level of sediment resuspension caused by wind and wave action.

5.7 Enhanced Fishery Management Program

The City of Lake Elsinore has demonstrated the general effectiveness of actively managing the fish populations through netting and stocking programs. Such programs, particularly stocking efforts, could be significantly expanded if there were a way to calculate and credit the nutrient-removal credit associated with such an effort. Data collected from the water quality monitoring program may provide the information needed to validate the beneficial use protection value and, thereby, create an incentive to augment the City's fishery management program.

5.8 Enhanced Lake Stabilization

Previous studies revealed that 13-15,000 acre-feet of water evaporates each year from Lake Elsinore.[38] On average, only about 1,400 acre-feet flows into Lake Elsinore annually. The island wells provide an additional 3,000 acre-feet of groundwater and reclaimed water adds 5,000 acre-feet of supplemental flow each year. Therefore, more water (up to 5,000 acre-feet/year) may be needed to fully offset evaporative losses and stabilize the lake level in the ideal range. The most cost-effective and reliable source is high quality reclaimed water from local wastewater plants. However, additional treatment would be necessary to reduce nutrient concentrations to acceptable levels before more reclaimed water could be added to Lake Elsinore. And, the cost of such treatment would have to be heavily subsidized by the responsible parties named in the TMDL.

[38] See Section 3 in CH2MHill's "Lake Elsinore Nutrient Removal Study;" April, 2004.

5.9 **Pollutant Trading**

Many of the supplemental control strategies seek to restore and protect beneficial uses through indirect means. Consequently, it is necessary to develop a system which can accurately assess the benefits and correctly credit those responsible for implementing these strategies. In fact, Task 12 of the TMDL envisions creating just such a system.[39]

The TMDL requires stormwater management agencies to employ Best Management Practices to minimize pollutants in urban runoff. However, as a practical matter, it may be infeasible to divert or treat the immense volume of urban runoff flowing to Lake Elsinore during wet years. Therefore, another way to comply with external load reductions mandated in the TMDL is to mitigate the negative effects after the nutrients enter Lake Elsinore but before the pollutants begin to impair beneficial uses.

This condition creates a strong economic incentive for the parties responsible for achieving external load reductions to fund offset programs designed to reduce internal nutrient loads. For example, if an appropriate credit can be affirmed by the Regional Board, it may be more cost-effective for stakeholders to operate the aerators more frequently, or apply alum intermittently, or dredge selectively then to build the infrastructure necessary to intercept urban or agricultural runoff to Lake Elsinore. Other nutrient offset programs may be available if a stakeholder were willing to fund additional efforts to reduce phosphorus concentrations in EVMWD's reclaimed water before it is discharged to Lake Elsinore.

The utility of a pollutant trading program depends on three things: 1) the need to further reduce nutrient concentrations in order to comply with the TMDL; 2) the availability of a cost-effective offset opportunity; and 3) regulatory acceptance of the offset trade as an alternative means of demonstrating legal compliance. Data from the on-going monitoring program will be needed to support all three. Therefore, the Regional Board has extended the deadline for submitting a Pollutant Trading Plan until Spring of 2009 so that the necessary information may be collected.

5.10 **Other Alternatives**

Previous reports have suggested other alternatives that may also be reevaluated in the future. These include: dredging, algae harvesting, sediment sealing, dye shading, dilution/flushing, selective withdrawal of low DO waters from lake bottom, etc.[40]

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[39] Source: Table 5-9s on pg. 7 of 21 in R8-2004-0037.

[40] See, for example, Table 5-2 on page 5-4 of report prepared by Montgomery-Watson entitled "Engineering Feasibility Study for NPDES Permit for Discharge to Lake Elsinore." February, 2002.

6.0 Implementation Schedule

The In-Lake Sediment Nutrient Reduction Plan for Lake Elsinore is divided into two phases. Phase 1, to stabilize lake levels, install aerators and initiate a fishery management strategy, is well underway. If, as expected, Phase 1 is successful, then there is no need to develop Phase 2 implementation strategies. There will, however, be a need to ensure that the previous projects continue to operate effectively.

If the monitoring program demonstrates that Phase 1 efforts fail to meet the targets identified in the TMDL, then a Phase 2 implementation strategy will be required. Phase 2 will likely focus on one or more of the Supplemental Control Strategies described in Section 5. However, it is not possible to predict, with any certainty, the order in which these strategies might be implemented. Too much depends on the monitoring results from Phase 1 and the related modeling predictions.

The load allocations and wasteload allocations specified in the TMDL are expressed and 10-year rolling averages and compliance with final targets is required by the year 2020. Compliance with the 10-year rolling average will be determined beginning with water quality data collected in 2011. In addition, responsible parties must demonstrate compliance with the interim targets for some of the response variables (e.g. DO & Chlorophyll-A) by 2015. Therefore, stakeholders must make a decision by 2010 as to whether additional efforts will be needed to meet the TMDL targets on schedule. Table 12 provides a more detailed schedule to guide both Phase 1 and 2.

7.0 Summary

Lake Elsinore is a dynamic and complex ecosystem. Manipulating several chemical and biological variables simultaneously to improve water quality and restore beneficial uses is an ambitious and somewhat daunting task.

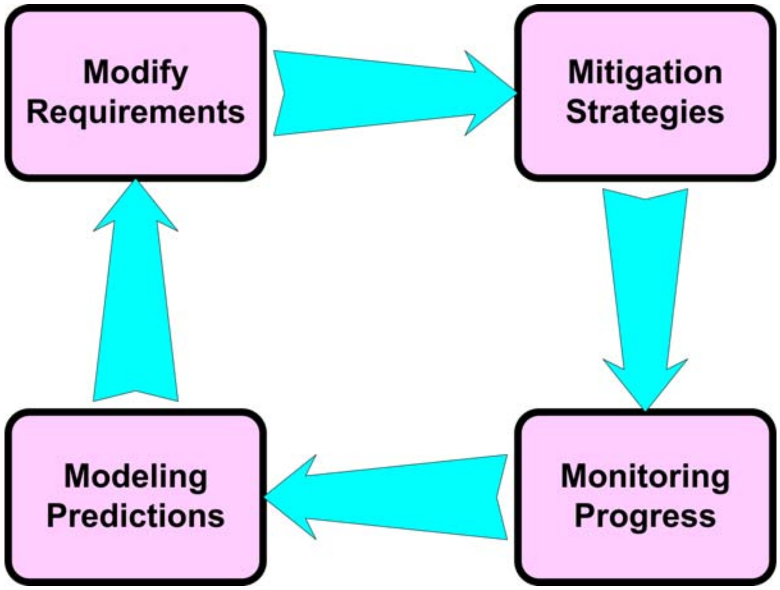
It is unlikely that the stakeholders will implement the perfect solution on the first try. Rather, success will depend on an iterative process of developing mitigation projects, measuring results, updating the predictive models and refine the follow-on strategy. This process of "adaptive implementation" makes best use of scarce public resources and reduces the risk of unforeseen consequences by emphasizing incremental changes.

Table 11: Schedule for Lake Elsinore In-Lake Sediment Nutrient Reduction Plan

Phase	Task Description	Deadline
1	Install Aeration & Axial Flow Pump Mixing Systems	Complete
1	Supplemental Reclaimed Water Flows	Complete
1	Submit Preliminary Plan to Update Water Quality Models*	Complete
1	Submit Preliminary Pollutant Trading Plan*	Complete
1	Revise and Update WDRs and MS4 Permits	Mar., 2008
1	Revise Monitoring Plan to include Biological Sampling Program	June, 2008
1	Summarize Results of Monitoring Program	Aug., 2008
1	Summarize Results of Monitoring Program	Aug., 2009
1	First TMDL Review	Nov., 2009
1	Review Nutrient Water Quality Objectives	Mar., 2010
1	Summarize Results of Monitoring Program	Aug., 2010
1	Update Water Quality Models	Nov., 2010
1	Submit O & M Agreement for Fishery Management Program	Dec., 2010
1	Submit O & M Agreement for Aeration & Mixing Systems	Dec., 2010
1	Submit Phase 2 Implementation Alternatives	Dec., 2010
2	Begin data collection to calculate 10-year rolling average	Jan., 2011
2	Submit Phase 2 Projects Plan	June, 2011
2	Summarize Results of Monitoring Program	Aug., 2011
2	Second TMDL Review	Nov., 2012
2	Revise & Update WDRs and MS4 Permits	Mar., 2013
2	Summarize Results of Monitoring Program	Aug., 2013
2	Summarize Results of Monitoring Program	Aug., 2014
2	Complete Phase 2 Project Implementation	Dec., 2014
2	Summarize Results of Monitoring Program	Aug., 2015
2	Third TMDL Review	Nov., 2015
2	Compliance Deadline for Interim Targets (DO & Chlorophyll-a)	Dec., 2015
2	Summarize Results of Monitoring Program	Aug., 2016
2	Summarize Results of Monitoring Program	Aug., 2017
2	Revise and Update WDRs & MS4 Permits	Mar., 2018
2	Summarize Results of Monitoring Program	Aug., 2018
2	Fourth TMDL Review	Nov., 2018
2	Summarize Results of Monitoring Program	Aug., 2019
2	Summarize Results of Monitoring Program	Aug., 2020
2	Compliance Deadline for 10-year Rolling Averages (N, P, NO3)	Dec., 2020
2	Final TMDL Review (De-Listing Petition)	Dec., 2021

* More detailed schedules to complete Updates to the Watershed and In-Lake Nutrient Models (TMDL Task #11) and the Pollutant Trading Program (TMDL Task #12) were submitted to the Regional Board in separate plans as required by Resolution No. R8-2004-0037.

Fig. E: Adaptive Management to Protect Lake Elsinore



Using the lake as a laboratory, successful projects can be repeated or expanded. Unsuccessful projects can be terminated and resources shifted to alternative approaches. Moreover, as additional data becomes available, the ability to accurately assess the lake's true potential, and the steps necessary to achieve that potential, will also improve.

By adopting the TMDL, and the related load allocations and wasteload allocations, the Santa Ana Regional Water Quality Control Board established a baseline set of expectations about the actions needed to meet the water quality objectives for Lake Elsinore. It will be necessary to reduce nutrient loads from both internal and external sources in order to comply with the TMDL.

The multi-pronged approach initiated in Phase 1 (e.g. lake stabilization, aeration/mixing, and fishery management) is expected to achieve the necessary internal load reductions. Implementing Best Management Practices (BMPs) as the watershed is developed is expected to reduce external loads sufficiently. However, some nutrient loading to Lake Elsinore comes from natural sources that cannot be easily controlled and responsibility cannot be easily assigned.

Therefore, it is useful to maintain a high level of flexibility to reallocate loads between point and non-point sources, to raise or lower water quality objectives, and to modify TMDL targets as necessary to ensure that beneficial uses are protected. The true end-goal is to prevent fish kills and excessive algae growth that interferes with recreational opportunities (see Table 13).

Table 12: Hierarchy of Use Impairment Indicators

Use Impairment	Aquatic Organisms	Human Recreation
Level 1 Indicator	Significant Fish Kills	Significant Illness
Level 2 Indicator	Species Richness & Abundance	User Acceptance
Level 3 Indicator	Un-ionized Ammonia & DO	Aesthetic Conditions
Level 4 Indicator	Algae Concentrations	Algae Concentrations
Level 5 Indicator	Nutrient Concentrations	Nutrient Concentrations

Achieving specific nutrient concentrations is a means to an end, not an end in itself. Success will be measured as much by increased public enjoyment of the lake and by greater richness and abundance of aquatic organisms as by chemical analyses. Adaptive management is designed to achieve those goals. Biological and chemical monitoring results will be reviewed annually and the TMDL targets and allocations will be reviewed every three years to maintain that "real-world" focus (see Fig. F).

Fig. F: TMDL Review Process