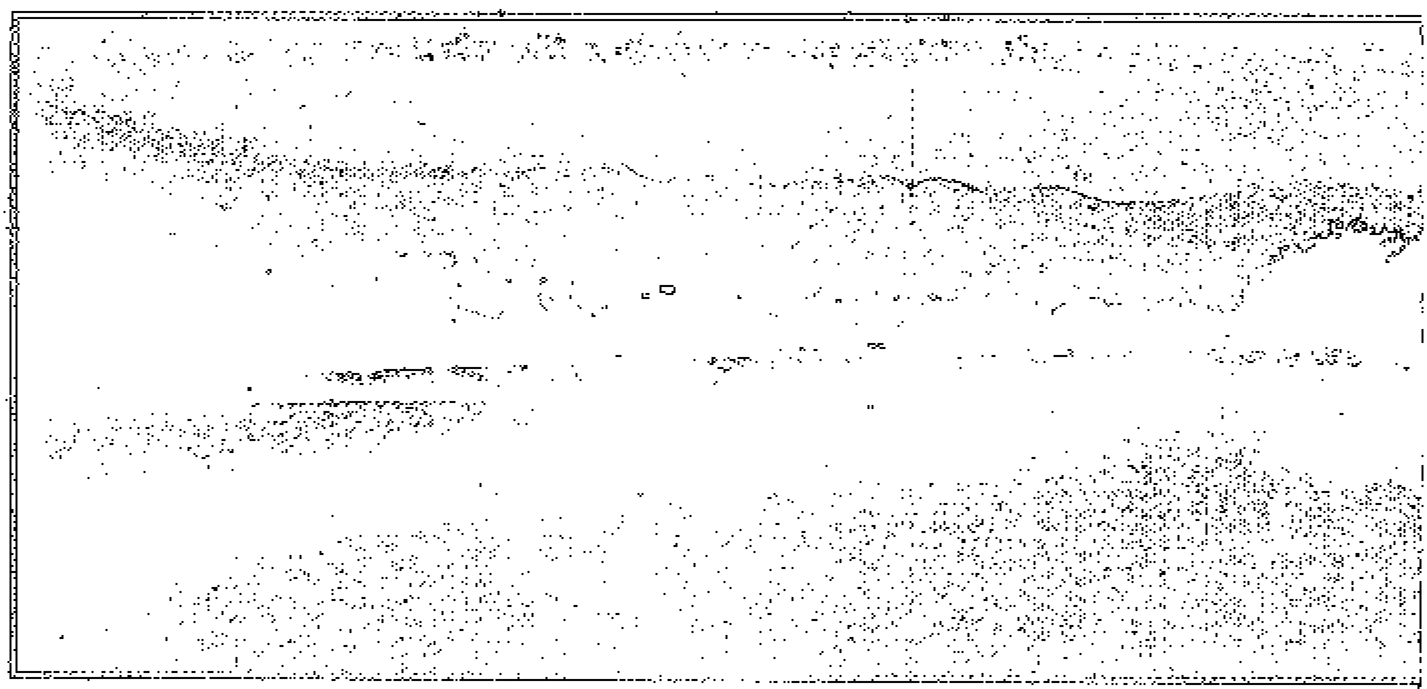
Elsinore Valley Municipal Water District

Final Report

Engineering Feasibility Study for NPDES Permit for Discharge to Lake Elsinore

February 2002



EVMWD
Elsinore Valley Municipal Water District

MWH
MONTGOMERY WATSON HARZA

MWH
MONTGOMERY WATSON HARZA

February 18, 2002

Mr. Phil Miller, PE
District Engineer
Elsinore Valley Municipal Water District
PO Box 3000
31315 Chaney Street
Lake Elsinore, CA 92531-3000

Subject: Engineering Feasibility Study for
NPDES Permit for Discharge to Lake Elsinore

Dear Mr. Miller:

MWH Americas, Inc. is pleased to submit the final report on Engineering Feasibility Study for NPDES Permit for Discharge to Lake Elsinore.

This report recommends using reclaimed water to make up for evaporative losses in Lake Elsinore and to stabilize the lake level. A phased approach for in-lake treatment is presented. Specifically, the recommendations include, in sequence:

- Oxygenation to increase dissolved oxygen in bottom waters and to substantially reduce the release of nitrogen and phosphorus from the nutrient rich bottom sediments.
- Biomanipulation through fish harvesting and macrophyte growth to favor increased population growth of *Daphnia*, which feed on algae.
- Wetlands treatment to filter out algae during the summer and lower the nutrient level of reclaimed water during the winter.
- Metal salt addition, such as sodium carbonate, may be considered as a last resort if the above three methods show limited success.

We are pleased for this opportunity to be of service and be part of this challenging project.

Sincerely,

MWH AMERICAS, INC.

Ajit S. Bhamrah, PE
Principal-in-Charge

ASB:bh

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EXECUTIVE SUMMARY

Need for recycled water in Lake Elsinore

Lake Elsinore is a natural lake near Riverside California that currently has a surface area of about 3,000 acres. Due to the semi-arid climate, rainfall and runoff are low and the water level varies dramatically from dry to wet years. Outflow occurs only during extremely wet years, and because the lake is shallow it can dry up completely during severe droughts, as happened during the 1950s. Even in normal water years, a five-foot elevation drop occurs in summer due to evaporation. Major construction in the 1990s halved the lake's area to reduce evaporation and moderate the lake's water level fluctuations, but even so the lake level has varied by as much as 18 feet in the last decade. The lake edges slope gently, so dry years result in extensive zones of unsightly exposed lake-bottom sediment and dead vegetation. The fluctuating lake level prevents development of the shoreline, hinders visitor access and excludes natural methods of lake cleanup involving the growth of rooted vegetation in shallow water. Lake Elsinore is a eutrophic lake with regular episodes of low dissolved oxygen in summer, nuisance blooms of blue-green algae, and occasional fish kills. Agricultural and residential development in the drainage basin provides an ample external supply of nutrients for algae growth in the lake. The warm, shallow water provides ideal conditions to recycle existing nutrients from the sediments each summer independently of winter inflows and their nutrient and sediment inputs. The purpose of this study is to examine options for lake level stabilization through the addition of recycled water, and recommend alternatives for water quality enhancement.

Stabilization of lake water level using recycled water would remove a major impairment to beneficial uses such as boating, fishing and aesthetic enjoyment. The present desirable lake level is 1240 feet above mean sea level. A more constant lake level would also assist other lake management methods employed to enhance water quality. Water level stabilization can only be achieved by the addition of new sources of water. In dry southern California, use of potable quality water from wells or imported from the Colorado or Sacramento Rivers is not allowed for recreational lakes under most circumstances. Use of modest additions of recycled water that contain 1-2 mg/L of total inorganic nitrogen (TIN) or total phosphorous (TP) have recently been shown to result in only limited increases in algae. Larger additions, as might occur during droughts, could result in significant increases in algae. With the volumes of water that would be added to Lake Elsinore in a normal year, any small decrease in beneficial uses resulting from the nutrients can be more than balanced by the substantial increases in beneficial uses due to a more stable water level. The increase in nutrient loading from the larger volumes of makeup water in dry years can also be offset by suppressing internal loading through such means as oxygenation, bio-manipulation, and filtration of summer algae using lakeside wetlands. These three lake management methods would require large capital investment and moderate operating costs. However, these costs are predicted to be small in comparison with the financial benefits resulting from lake level stabilization and a better fishery and recreational lake environment.

Previous lake studies suggested that supplemental water at an annual average volume of between 7,500 and 15,000 acre-feet/yr (depending on rainfall) would stabilize the lake to a desirable elevation level above 1240 feet. Elsinore Valley Municipal Water District (EVMWD) investigated the feasibility of further stabilizing the level of Lake Elsinore using recycled water from Eastern Municipal Water District (EMWD). A National Pollutant Discharge Elimination

System (NPDES) permit issued by the Regional Water Quality Control Board (RWQCB) will be required for the proposed recycled water discharge into the lake. Because of the nutrients present in the recycled water, engineering alternatives must be identified to mitigate the impact of recycled water discharge. The selected alternatives cannot exacerbate the existing eutrophic condition of the lake and should also take positive steps to improve the lake condition for recreational purposes. This project report is intended to serve as the engineering document required for the application of an NPDES permit that would allow the discharge of recycled water to Lake Elsinore.

Recycled Water Sources and Delivery

The two potential recycled water sources are the EVMWD Regional Plant and the Eastern Municipal Water District (EMWD), which could supply water via the Temescal Pipeline. The two agencies are negotiating the amount of tertiary treated recycled water that could be used to stabilize Lake Elsinore. As much as 15,000 acre-feet (af) of water would be needed. Other commitments limit the supply to Lake Elsinore to four winter months when irrigation demands are minimal. Thus the full amount of 15,000 af may not be immediately available. As the population increases, however, the supply of recycled water also increases so a complete supply to Lake Elsinore can be considered as a possible future option.

Recycled Water Quality

The desired acceptable nutrient levels in recycled water vary with intended use. For irrigation, the most common use of recycled water, higher nutrient concentrations are not an issue since most irrigated systems are also fertilized. For Lake Elsinore, higher nutrients are undesirable if they will impair beneficial uses of the lake. The nutrient concentrations present in the makeup water proposed for Lake Elsinore vary with the individual treatment plant, its operation, and current permit limits. For example, EMWD has a NPDES discharge permit with a total inorganic nitrogen (TIN) limit of 8 mg/L for Temescal Creek. For Lake Elsinore, 1-2 mg/L TIN is more appropriate. Currently the plants that could supply makeup water do not optimize treatment to meet low phosphorous or nitrogen limits, since their permits allow higher levels. Current TP effluent levels at EMWD plants range from 2-8 mg/L, but the design capability for some systems ranges down to 0.5 to 2.0 mg/L. Recent average effluent values for the EVMWD are 5.4 mg/L for TIN and 2.3 mg/L for TP. For both systems, lower effluent concentrations are achievable but at considerable cost.

Management Options

In addition to lake level stabilization, the project is also intended to enhance water quality by reducing the effects of eutrophication in a sustainable fashion. Seventeen in-lake treatment methods and five watershed management methods were considered. Five alternatives were chosen for further analysis: oxygenation, bio-manipulation, lake surface water filtration by wetlands, inflow treatment by wetlands, and nuisance flow treatment by dischargers. The proposed alternatives will create large areas of emergent riparian vegetation around the lake, improving fish and bird habitat and the aesthetic appearance of the lakeshore. Finally, this project will create approximately 350 acres of true wetland marsh and 60 acres of stream riparian area that will provide habitat for wildlife and increase the beauty of Lake Elsinore and its surroundings.

Lake oxygenation is proposed as the primary alternative to prevent future fish kills and malodors. This method will also reduce internal ammonia, sulfide and phosphate loadings and reduce algae blooms. Studies in the lake and in laboratory experiments show that oxygen demand in Lake Elsinore is very high, but not uniquely so. An average daily delivery of 20 tons and a maximum daily delivery of 46 tons of oxygen to the lake bottom will be needed for the first few years. Oxygen demand should fall by up to two-thirds thereafter. A submerged Downflow Bubble Contact Oxygenation (DBCO) system located in a lakebed well would provide a sure method of delivering oxygen directly to the lake sediment, which is the site of nutrient and toxicant releases. Depending upon well-depth, the DBCO uses either a 200-hp or 100-hp submersible pump moving 150 cfs (or 75 cfs) of water down a 35-foot (or 70-foot) deep well below the lakebed, where oxygen is added under the natural pressure of depth. The deeper the well, the lower the subsequent operating costs. Alternatively, a pressurized DBCO could be installed on the lakeshore or lakebed. Water supersaturated with oxygen would be forced horizontally over the lakebed and diluted by entrained low-oxygen water, as it is forced out of jets in a small semi-circular manifold. Oxygenation is expected to provide an offset for nutrients of 12.5 tons/yr for phosphorus and 37 tons/yr for nitrogen. Once reversal of eutrophication has occurred with the initial oxygenation period, the amount of oxygen needed will decline substantially. Oxygenation will also provide a reduction in nutrients needed to increase water clarity and enhance submerged plant growth in the biomanipulation plan discussed below. For the purposes of estimating costs, a 200-hp submersible pump is assumed, moving 150 cfs of oxygenated water down a 35 foot well below the lakebed.

Bio-manipulation is an inexpensive and sustainable technique that modifies the aquatic food chain to favor clear algae-free water over muddy algae-rich conditions. It is achieved by increasing submerged aquatic vegetation and by the natural algae-filtration capacity of large zooplankton such as *Daphnia*. For Lake Elsinore, necessary bio-manipulation actions are: (1) removal of large bottom-grubbing fish such as carp, (2) selective harvesting of fish stocks to favor large predatory fish over small zooplankton-feeding fish, and (3) increasing submerged and emergent vegetation. Mechanical harvesting and/or herbicides can be used to manage excess submerged vegetation. Submerged vegetation stabilizes the sediments and prevents re-suspension, removes nitrogen and phosphorus that would otherwise be used by nuisance floating algae, traps planktonic algae, provides a daytime refuge for *Daphnia* from fish predation, and increases denitrification. Bio-manipulation requires a more stable water level than is present now in Lake Elsinore, and is thus an excellent match for the proposed lake level stabilization plan.

Lakeside wetlands will directly filter lake surface water to remove nuisance algae in the summer. About 800 acre-ft per day of lake surface water will be diverted from the lake to the wetlands located at the southeast end of the lake. Removal of up to 95% total nitrogen (TN) and total phosphorus (TP) can be expected during the summer period of nuisance algae blooms. The current 350-acre wetland must be redesigned to improve wildlife habitat, as it presently contains minimal aquatic plants and the water is too deep for emergent wetland vegetation. Pumping large volumes of water is expensive, but will be needed initially to reduce nutrients in the lake to appropriate levels. Once bio-manipulation and oxygenation are in place, wetland filtration may become unnecessary for much of the time.

Water treatment includes treatment of the makeup water and watershed dry weather "nuisance" flows. Removal of TN and TP contained in the recycled water and surface runoff in the tributary watershed can be achieved by the redesigned 350-acre wetland to incorporate a 60-acre treatment cell. Expected pollutant offsets are 6.5 to 27.5 tons/y for TP and 263 to 291 tons TN per year, depending on the volume of make-up water added and the concentrations of nutrients present. These positive offsets indicate that the lake will have a net reduction in that nutrient, except during severe droughts. Nuisance flow removal will consist of collection and treatment of various high nitrogen and phosphorus small discharges, and will utilize EVMWD facilities. Local nuisance flows usually contain high levels of total dissolved solids (TDS), which present problems for its future reuse, therefore diversion of local surface water into sanitary sewers has limited applicability in the Lake Elsinore Basin.

Project Costs

Makeup water costs for stabilizing the water level of Lake Elsinore depend on the source of water and its availability, as well as regulatory restrictions on the use of potable water for non-potable use. Costs of imported water from potable sources ranges from \$0.66 to \$1.2 million per year for normal water years and \$4 to \$7.1 million per year for dry years. These high costs, together with a State of California decree that essentially prohibits use of potable water to supplement non-potable supplies, eliminates use of potable water to stabilize Lake Elsinore. The use of local recycled water reduces the cost of makeup water to a range of from \$0.26 million/year to \$1.6 million/year, excluding any treatment needed to reduced nitrogen and phosphorus in the recycled water down to 1-2 mg/L.

Economic benefits of lake stabilization are many, especially in an area with considerable tourist potential that is close to several large metropolitan areas (Riverside, San Diego and Los Angeles). Because the lake dries up completely every decade or so, makeup water is essential to maintain the lake level for recreation. The economic benefit of stabilizing the lake with recycled water at an elevation above 1240 feet was estimated at \$2.4 million per year or about \$24 million per decade (or between total desiccations). This cost can be compared with the costs for restoration below.

Cost of the proposed project considers capital costs and operation and maintenance (O & M) costs of both in-lake and watershed restoration projects. The total cost for the new recycled water pipeline modification, redesigned wetlands, bio-manipulation, and lake oxygenation systems was estimated at \$21.1 million (capital cost) with annual O & M costs of approximately \$1 million. This cost can be compared with the annual benefit of a stabilized lake of \$2.4 million per year. The cost benefit ratio for O & M and direct recreational benefits of lake stabilization is thus well on the positive side.

SECTION 1
INTRODUCTION

1.1 PURPOSE

Lake Elsinore experiences substantial water level variation that inhibits shoreline development and the growth of riparian vegetation. Low water levels also can impact recreational activity and exacerbate conditions causing fish kills in the Lake. The purpose of this study is to examine options for lake level stabilization through the addition of recycled water, and recommend alternatives for water quality enhancement.

Elsinore Valley Municipal Water District (EVMWD) initiated this study to investigate the feasibility of discharging excess recycled water from Eastern Municipal Water District (EMWD) to Lake Elsinore as makeup water to maintain desirable lake levels. Per agreement with the City of Lake Elsinore, the lake is to be maintained at a water surface elevation of 1240 feet above sea level when supplemental water is available. A National Pollutant Discharge Elimination System (NPDES) permit issued by the California Regional Water Quality Control Board, Santa Ana Region (RWQCB) would be required for the proposed recycled water discharge. Because of the nutrients in the recycled water, engineering alternatives must be identified to mitigate the impact of recycled water discharge. The selected alternatives must not exacerbate the existing eutrophic condition of the lake and should also take positive steps to improve the lake condition for recreational purposes. This document evaluates the alternatives available to mitigate the impact of recycled water and serves as the "engineering document" required for the application of an NPDES permit that would allow the discharge of recycled water to Lake Elsinore.

1.2 PROJECT BACKGROUND

Lake Elsinore is a natural lake that, under historical conditions, varied in size from over 6,000 acres in very wet years to a dry playa in drought years. To moderate these extreme swings in the lake's area, a levee was constructed across the lake to limit its surface area to about 3,000 acres. An improved outlet system was built at the same time to prevent flooding, since the lake's ability to store floods was also decreased. Lake Elsinore is a terminal lake, a natural sink with no outflow except during extremely wet years, when it drains to Temescal Wash. At an elevation of approximately 1240 feet, the lake now encompasses 3,000 surface acres and 14 miles of shoreline. Lake levels and water quality vary widely with precipitation in the tributary watershed. Given good water quality conditions, Lake Elsinore provides an array of water recreation opportunities. Previous lake studies suggested that supplemental water of up to 15,000 acre-feet per year (AFY) would be needed for lake stabilization in order to maintain the lake within a desirable elevation range.

Naturally Eutrophic Lake. Lake Elsinore is a moderately large lake located in a very large drainage basin in semi-arid conditions between Riverside and San Diego. The lake is technically eutrophic in that it exhibits the following characteristics:

- Large algae blooms (chlorophyll-*a* > 50 µg/L) and common presence of blue-green algae (cyanobacteria), in this case especially *Microcystis*.

- Large seasonal and daily swings in concentrations of dissolved oxygen. Anoxic (zero oxygen) values have been recorded in most summers in deeper water.
- Low water clarity; Secchi disc values less than one meter of depth are common.
- High concentrations of inorganic nitrogen
- High concentrations of total phosphorous

In addition, the following are typical characteristics of eutrophic lakes that are also common to Lake Elsinore:

- Shallow water that does not show permanent thermal stratification in summer (technically a polymictic or many-mixing lake). This allows nutrients released from the sediments to be rapidly carried to the algae growing at the lake surface.
- High ratio of watershed to lake surface area (greater than 100 indicates potential eutrophy). Lake Elsinore has a ratio of 167 (500,480 to 3,000 acres).
- Very warm dry conditions that provide maximum sunlight and favorable water temperatures for blue-green and other algae growth
- Warm water that shows daily or short-lived thermal stratification allowing total oxygen depletion in the lake bottom water and sediments even thought the lake frequently mixes top-to-bottom.
- Highly variable depth, including total dry out that eliminates shoreline vegetation that could modify planktonic algae blooms.

From the characteristics stated above, it follows that Lake Elsinore is likely to be eutrophic, even in the absence of human influences. Use of simple regression models such as the Vollenweider model that compare annual nutrient loading with some function of mean depth also shows that Lake Elsinore is likely to be eutrophic. Similarly, the Carlson Index shows a similar eutrophic state. However, these two models have limited applicability as they were developed for temperate zone, seasonally stratified lakes. Since Lake Elsinore is probably naturally eutrophic, restoration to its natural state may not serve the needs of the current lake users. A main factor in the eutrophication of Lake Elsinore is that sufficient nutrients exist in the lake to support the growth of large amounts of algae. The decay of algae creates an imbalance between the oxygen demand from decaying algae and the ability of the lake to provide sufficient oxygen. For lake users, this would not be aesthetically pleasing, and may pose public health risks during body contact or ingestion of lake water.

Fish Kills. Lake Elsinore has experienced several fish kills over the last decade. **Table 1-1** shows statistics on oxygen conditions, oxygen demand and lake volume as related to fish kills for Lake Elsinore in the period 1990-96.

Some lake experts have related fish kills to low lake levels and/or the collapse of algae blooms. Both these conditions can result in fish kills, but further examination of the more recent data indicates that the only correlation to fish kill is the season (i.e. high summer, July-August, see Table 1-1). During mid summer, the lake is at its warmest and most likely to show temporary thermal stratification. Measurements in Lake Elsinore and other very productive shallow lakes show that, in only a few days, thermal stratification can completely deplete dissolved oxygen in the bottom water. Hence one can conclude that fish kills are a threat any time temporary thermal stratification occurs. The resulting mixing would bring anoxic, ammonia- and sulfide-rich water to the surface with no refuge for the fish. Lake Elsinore has a high pH of around 8, so ammonia and hydrogen sulfide could be toxic. However, shallow water is not desirable for most beneficial uses in Lake Elsinore, so stabilization of the lake level would be a benefit even if the deeper water did not always prevent fish kills.

Table 1-1
Lake Elsinore Fish Kill Summary

Date	Initial DO (mg/L)	Final DO (mg/L)	Duration (days)	Oxygen Demand (mg/L/d)	Approximate Lake Volume (10^6 m^3)	Mass Based Oxygen Demand (t/d)	Fish Kill
July/Aug 1990	6	0	60	0.10	35	3.4	X
March 1991	7	0	30	0.23	35	8.1	
July/Aug 1991	9	0	100	0.09	35	3.2	
Feb 1992	14	9	30	0.17	94	16	
March 1992	9	6	30	0.10	126	13	
July/Aug 1992	6.5	2	60	0.08	112	9.0	X
Mar/Apr 1994	16	8	45	0.18	102	18	
Jun/Jul/Aug 1994	8.5	2.5	90	0.07	102	7.1	
May 1995	14.5	6	30	0.28	115	32	
June/July 1995	9	3	90	0.07	111	7.8	X
June 1996	9	5	30	0.15	93	12	

(Data summarized from Montgomery Watson Lake Elsinore NPDES Permit Feasibility Study, December 1997, Figures A-3, A-4 and A-5)

Lake Elsinore Management Project/Basin Modification. Constructed between 1988 and 1995, the Lake Elsinore Management Project/Basin Modification was a $40 million project funded mainly by the US Bureau of Reclamation (USBR). The project consisted of an earthen levee to reduce the lake's surface area (from about 6,000 acres to approximately 3,000 acres) in order to reduce evaporation. This project also includes an operations island for accessing three wells intended for domestic supply purposes and lake supplementation; riparian habitat and wetlands mitigation areas; a lake-type inlet that diverts flows from the San Jacinto River into the lake; and an overflow weir to manage flood waters during storm events.

An area of about 350 acres in the back basin at the historic terminus of the San Jacinto River was dedicated as a wetland to provide environmental mitigation for this construction, but it is currently too deep and devoid of vegetation to function as a wetland. This area and the entire eastern edge of the lake are currently undeveloped.

Tributary Drainage. Lake Elsinore is the terminal lake of the San Jacinto River Watershed in Western Riverside County. The 500,480-acre drainage basin includes the Canyon Lake reservoir, with a surface area of approximately 10,000 acre-ft. Canyon Lake intercepts most of the normal runoff and heavy sediments from upstream. Lake Elsinore receives inflows from the

San Jacinto River only when Canyon Lake spills, or during a major storm event. Lake Elsinore also receives direct runoff from the small adjacent watershed.

Lake Level Stabilization. Lake Elsinore has an annual water deficit of about 7,500 acre-feet, with a 4 1/2-foot elevation drop, in normal years and a deficit of about 15,000 acre-feet in dry years. Lake level stabilization can be achieved by the addition of a volume of water equal to each year's water deficit. The expected range of water elevation is four feet (1245 to1249 feet above mean sea level).

Water level stabilization can only be achieved by the addition of new water from external sources, such as pumped groundwater or recycled water. In a water-short area like southern California, use of potable quality groundwater for lake makeup is not the best solution. Nonetheless, the use of recycled water that contains nutrients also has its limitations because the lake is already eutrophic. However, the additional nutrient loading could be offset by nutrient reductions in other sources, thus minimizing the increase or even reducing lake eutrophication.

1.3 REGULATORY REQUIREMENTS

With respect to water quality, the RWQCB has established water quality objectives to protect designated beneficial uses of Lake Elsinore (body contact and non-body contact recreation, warm water aquatic habitat, and wildlife habitat). Based on water quality analyses performed by the US Environmental Protection Agency (EPA) in the early 1970s, Lake Elsinore was recognized as a eutrophic lake.

RWQCB is currently in the process of developing standards for Total Maximum Daily Loads (TMDLs) for nutrients in Lake Elsinore. The outcome of the TMDL process will impact the discharges to Lake Elsinore. A copy of the staff report on the problem statement for TMDL for nutrients in Lake Elsinore is attached (**Appendix A**) for reference. The project team held two meetings with the RWQCB staff during the course of this project to provide project updates and to receive input.

1.4 ORGANIZATION OF REPORT

The main body of the report includes the following sections:

Section 1 – Introduction

Section 2 – Recycled Water and San Jacinto River Flow Characteristics
- 2.1 Recycled Water Sources and Quantities
- 2.2 Recycled Water Nutrient Data
- 2.3 San Jacinto River Flow Characteristics

Section 3 – Recycled Water Conveyance Alternatives
- 3.1 Alternative No. 1 - Delivery via Cottonwood Creek and San Jacinto River
- 3.2 Alternative No. 2 - New Pipeline from Terminus of Temescal Pipeline

SECTION 2
RECYCLED WATER AND SAN JACINTO RIVER FLOW CHARACTERISTICS

Lake Elsinore receives inflows from the San Jacinto River only when water is released from Canyon Lake Dam or spills over during major storm events. To reliably maintain stable lake water levels in Lake Elsinore, new water must be added from external sources, such as local groundwater, surface water from Canyon Lake, purchased imported water, or recycled water. For this report, recycled water is defined as Title 22 water and can be used in California for any beneficial purpose except for direct drinking water supply. Up to 15,000 acre-ft per year (af/yr) of water may be required to make up for evaporative losses in Lake Elsinore.

This section describes the potential recycled water sources, their quantities and quality. Characteristics of the baseline San Jacinto River flows are also discussed.

2.1 RECYCLED WATER SOURCES AND QUANTITIES

Two potential recycled water sources for this project are the Eastern Municipal Water District (EMWD) recycled water conveyed through the Temescal Pipeline and the EVMWD Regional Plant. The 1997 Lake Elsinore NPDES Permit Feasibility Study by Montgomery Watson presented a technical evaluation utilizing recycled water from both sources.

2.1.1 EMWD

Table 2-1 summarizes EMWD's water recycling facilities, treatment processes, capacities and average flows in million gallons per day (mgd).

Table 2-1
EMWD Water Recycling Facilities

Recycling Facility	Level of Treatment	Biological Treatment Process	Capacity (mgd)	Flow (mgd)
Moreno Valley RWRF[a]				
Old Plant	Secondary	Conventional	8	2
New Plant	Tertiary	Bardenpho	8	8
Perris Valley RWRF				
Old Plant	Secondary	Conventional	3	0
New Plant	Tertiary	Bardenpho	8	8
Sun City RWRF	Tertiary	Conventional	2	0
Hemet/San Jacinto RWRF	Secondary	Conventional	11	7
Temecula Valley RWRF	Tertiary	A2O (BNR)[b]	10	7

[a] RWRF = Regional Water Reclamation Facility [b] BNR = Biological nutrient removal

2.1.2 EVMWD

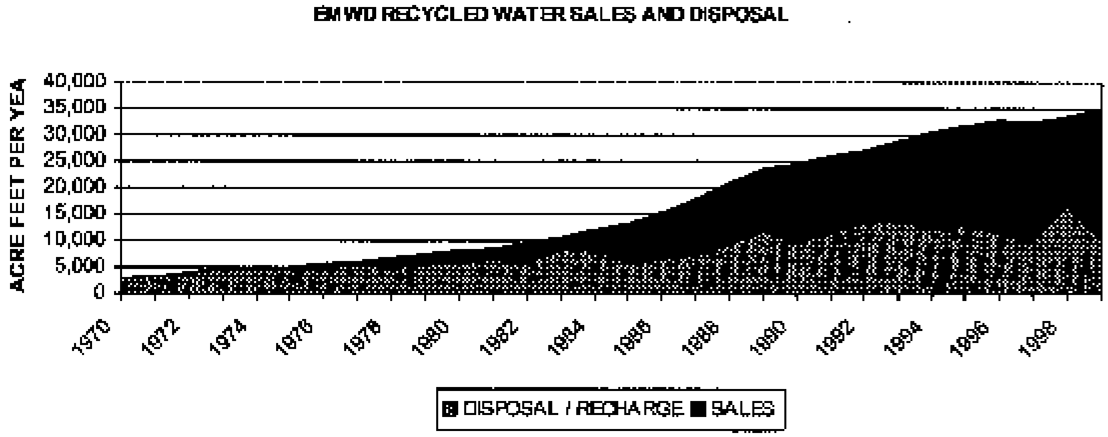
EVMWD's Regional Plant currently produces approximately 4 mgd of tertiary effluent treated to meet Title 22 requirements. In accordance with previous environmental analysis (Final EIR for the Regional Wastewater Reclamation Plant Expansion, January 1992), a minimum of 0.5 mgd of the effluent must be discharged to Temescal Creek to maintain downstream wetland and riparian habitat. Flows used for lake make-up water and other recycling efforts would come from effluent produced in excess of this volume. Note, the Regional Plant is currently being expanded from 4.0 to 8.0 mgd - construction is anticipated to be completed in fall 2002.

EVMWD entered into an agreement with EMWD in 1991 to purchase excess recycled water from the EMWD system for lake augmentation. The agreement provides for:

- Sale of 5,000 to 30,000 acre-ft per year of surplus recycled water;
- Base purchase price of $33 per acre-ft using a Consumer Price Index (CPI)-based formula for adjustment;
- Delivery from December 21 through March 21 in any given year;
- An option to purchase and extend deliveries when available;
- Water quality assurances to meet basin standards and health regulations for body contact;
- Right to refuse delivery should water fail to meet water quality standards;
- 20-year agreement with a five year notification for non-renewal; and
- EVMWD is to obtain an NPDES permit for discharge into Lake Elsinore.

EMWD's recycled water would be delivered to Lake Elsinore via the Temescal Pipeline, which was originally constructed to allow disposal of EMWD's excess flow from all its treatment plants to Temescal Creek, downstream of the lake. Thus, only tertiary treated effluent will be conveyed in this "outfall" pipeline. During the preparation of this study, Mike Garner of EMWD indicated that effluent from the Moreno Valley RWRF, the Perris Valley RWRF and the Temecula Valley RWRF would constitute the mix of recycled water to be delivered to Lake Elsinore. Mr. Garner further indicated that EMWD effluent is 100 percent reused in summer within the EMWD service area. The availability of excess flow in winter months is still under negotiation between the two agencies. For the purpose of facility sizing and nutrient loading calculations, it is assumed that 15,000 acre-ft per year of EMWD recycled water will be delivered to Lake Elsinore to offset annual evaporative losses. EMWD's recycled water sales and disposal quantities between 1970 and 1999 are shown on **Figure 2-1** for reference.

Figure 2-1



2.2 RECYCLED WATER NUTRIENT DATA

2.2.1 EMWD

Nutrient data were obtained from EMWD for the Moreno Valley RWRF, the Perris Valley RWRF and the Temecula Valley RWRF for the period between January 1997 and August 2000 (**Appendix B**). These data are summarized in **Table 2-2** below. Total dissolved solids (TDS) concentrations are also listed for reference.

Table 2-2
Perris Valley RWRF
Effluent Nutrients Analyses
(4/13/97 to 8/7/00)

(mg/L)	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
No. of Data	356	41	43	19	3	6	18
Minimum	0.1	0.01	0.01	0.2	1.2	0.3	425
Maximum	6.0	4.6	4.6	4.6	1.7	2.8	600
Average	0.2	0.4	0.91	0.8	1.5	0.8	502

Table 2-2 *(Continued)*
Temecula Valley RWRF
Effluent Nutrients Analyses
(1/1/97 to 8/8/00)

(mg/L)	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
No. of Data	904	257	366	45	1	6	137
Minimum	0.1	< 0.01	0.01	2.1	2.6	3.8	545
Maximum	6.2	14.0	16.0	10.0	2.6	4.3	962
Average	0.2	< 6.3	7.09	6.5	2.6	4.0	674

Table 2-2 *(Continued)*
Moreno Valley RWRF
Effluent Nutrients Analyses
(1/14/97 to 8/8/00)

(mg/L)	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
No. of Data	510	233	297	43	434	6	42
Minimum	0.1	0.01	0.01	1.1	0.1	0.2	349
Maximum	19.0	7.8	15.0	19.0	6.6	3.7	800
Average	3.6	2.7	4.10	7.3	1.7	2.0	437

EMWD presently has an NPDES discharge permit with a total inorganic nitrogen (TIN) limit of 8 mg/L for disposal of its recycled effluent into Temescal Creek. Since no total phosphorous (TP) limit is currently in place, only sporadic data were collected at the treatment plants. In addition, the treatment plants were not operated under the nutrient removal mode when data were collected. Mr. Garner indicated that EMWD would not provide additional phosphorus removal above current removal rates unless compensated for this effort, since phosphorus removal is not required in EMWD's discharge permit. **Table 2-3** lists the performance of EMWD's water recycling facilities versus their design capabilities when running in the nutrient removal mode.

Table 2-3
EMWD Water Recycling Facilities
Potential Nutrient Removal Levels
(Information Provided by EMWD, 2000)

Recycling Facility	Currently Operating Mode (mg/L)		Design Capability (mg/L)	
	TIN	TP	TIN	TP
Moreno Valley RWRF				
Old Plant	14	8	NA	NA
New Plant	2	2	1	0.5
Perris Valley RWRF				
Old Plant	14	8	NA	NA
New Plant	2	2	1	0.5
Sun City RWRF	14	8	NA	NA
Hemet/San Jacinto RWRF	14	8	NA	NA
Temecula Valley RWRF	3	6	1	1

As indicated in Table 2-3, currently some of the EMWD plants can achieve 0.5 mg/L TP, which would be satisfactory for discharge into Lake Elsinore without additional treatment. Both Moreno Valley RWRF and Perris Valley RWRF would be able to achieve the 0.5 mg/L TP limit when plant operation is optimized for nutrient removal. In any case, the recycled water quality objectives need to be affordable and agreeable to EMWD, EVMWD, and RWQCB.

2.2.2 EVMWD

Recent nutrient data were also collected for EVMWD's Regional Water Reclamation Plant between January 1997 and July 2000 (**Appendix C**). **Table 2-4** summarizes the data.

Table 2-4
EVMWD Regional Water Reclamation Plant
Effluent Nutrients Summary (mg/L)
(1/97 to 7/00)

	NH_4-N	NO_3-N	TIN	Ortho PO_4-P	TP
No. of Data	26	46	43	9	38
Minimum	0.1	1.4	1.6	0.39	0.12
Maximum	2.9	21	21	3.1	11
Average	1.1	4.9	5.4	1.6	2.3

2.3 SAN JACINTO RIVER FLOW CHARACTERISTICS

To compare the recycled water quality against the baseline San Jacinto River flows that enter Lake Elsinore, a full spectrum of flow and water quality data have been obtained from Riverside County Flood Control and Water Conservation District (RCFCWCD) (**Appendix D**). Samples were collected at RCFCD Station 827, located near the Lake Elsinore inlet on the northeast side of the lake. Approximately 80 percent of inflows to Lake Elsinore are contributed by flows in the San Jacinto River downstream of Canyon Lake. Canyon Lake only overflows into Lake Elsinore (via San Jacinto River) when the elevation of Canyon Lake exceeds the spillway level of 1381.76 feet MSL. Runoff to Canyon Lake comes from as far away as the urban areas of Hemet, San Jacinto, Perris, and Moreno Valley. **Table 2-5** presents a summary of selected parameters for San Jacinto River water.

Table 2-5
Water Quality Data – Selected Parameters
San Jacinto River Upstream of Lake Elsinore (RCFCD Station 827)
(Grab samples collected quarterly between 9/8/94 and 4/20/99)

(mg/L)	NH_4-N	NO_2-N	NO_3-N	Org-N	TN	TKN	TIN	Org-P	Ortho PO_4-P	TP	TDP	TDS	Flow (cfs)
No. of Samples	24	25	25	23	25	25	6	7	7	25	18	23	24
Minimum	<0.1	<0.1	0.1	0.1	0.2	0.2	0.4	0.05	0.05	<0.05	0.05	310	0
Maximum	6.8	0.3	2.7	3.3	8.3	8.2	6.9	0.15	2	2.7	0.62	1290	300
Average	0.42	0.11	0.95	0.89	2.2	1.25	1.75	0.06	0.62	0.56	0.32	932	13.5

Source: Riverside County, 2000

Approximately one quarter of the river flow data shown in Table 2-5 were collected during wet weather conditions. They do not represent storm flows as measured by integrating samples collected over a complete hydrograph. Specifically, large amounts of particulate nitrogen and phosphorus are probably transported in the few hours of the highest water flow but were not specifically sampled for in the data presented in Table 2-5. Thus high nutrient measurements did not necessarily correspond to high flows in the river. The nutrient inputs could be contributed by sources other than rainfall-induced flows within the tributary watershed, by erosion or other unknown sources. For example, there are numerous dairies in the San Jacinto watershed as well as housing developments and dirt roads.

2.4 SUMMARY

According to the data presented in the tables above, the design capability ranges for TIN, TP and TDS in effluent from each of the three EMWD recycled facilities are comparable to the average water quality of the San Jacinto River as defined in Table 2-5. Addition of true storm water values would greatly increase TN, TP and possibly TDP concentrations. Thus it appears that the proposed source of recycled water contains low enough nutrient concentrations to be a viable option for consideration as make up water for evaporative losses in Lake Elsinore.

In the highly variable inflow regime of Lake Elsinore, a single storm can bring in very large amounts of nutrients. Following wet El Nino years, for example, lake nutrients and water elevation may peak and then slowly decline. In many lakes, winter inflows improve water quality since the initial high nutrient "first flush" is washed through the lake and downstream. Such flood events do not benefit Lake Elsinore in this fashion. The lack of an outflow in most years and consequent retention of the first flush tends to make Lake Elsinore more eutrophic than would be expected from a simple nutrient-to-algae model.

SECTION 3
RECYCLED WATER CONVEYANCE ALTERNATIVES

The Temescal Pipeline was constructed to allow disposal of excess recycled water from EMWD's treatment facilities to the Temescal Wash in wet years and months with low recycled water demand. It also provides a convenient means for the delivery of EMWD's recycled water to Lake Elsinore. After leaving EMWD's Sun City RWRF, the 54-inch diameter Temescal Pipeline generally follows the Railroad Canyon Road, turns northwest after crossing the Interstate freeway I-15, continues along Casino Drive, Flint Street, Riley Street, Collier Avenue, and terminates at an energy dissipation facility south of Minthorn Street (see **Figure 3-1**). The terminus location is also known as "Wasson Sill," a high point located at the confluence of the Wasson Canyon channel and the Temescal Wash north of Lake Elsinore. The Wasson Canyon channel currently serves as the outflow channel for Lake Elsinore when lake level rises above 1255 ft above mean sea level (MSL).

Constructed in 1996, the energy dissipation facility was designed to reduce the pressure head of recycled water delivered from EMWD's Sun City reclaimed water pump station at a hydraulic grade line (HGL) of 1583 ft in order to discharge to the Temescal Wash at 1262 ft MSL. A motorized sleeve valve was installed to dissipate the energy for flows up to 36 mgd. Dechlorination was also planned at this facility for effluent disposal. However, the dechlorination function has been relocated to the Sun City reclaimed water pump station, which was designed to handle 20 mg/L of residual chlorine at 20 mgd capacity.

EVMWD's 1994 levee project modified the lake inlet, and it now diverts the last mile of San Jacinto River water directly to the lake. The historic San Jacinto River channel continues and ends at an existing wetland located at the southeast corner of Lake Elsinore. It is recommended that the recycled water be delivered directly to the historic river channel south of the lake inlet so that water can be further treated at the wetlands before lake discharge (the aspect of wetlands treatment is addressed in Sections 5 and 7). However, the river channel south of the lake inlet would need to be modified to accommodate the flow (addressed in Section 7). The river channel would also need to be lined to retard subsurface percolation due to a groundwater depression (the "Sedco Cone") within the middle portions of the channel.

Three alternatives have been identified and evaluated for the delivery of EMWD's recycled water to lake inlet for lake augmentation, as described in the following sections. All three alternatives are shown on Figure 3-1.

3.1 ALTERNATIVE NO. 1 - DELIVERY VIA COTTONWOOD CREEK AND SAN JACINTO RIVER

The concept of Alternative No. 1 employs natural means to dissipate the high pressure of the recycled water in the Temescal Pipeline. A 54-inch-diameter pipeline would be constructed along the Cottonwood Canyon Road located near the east end of the City of Lake Elsinore south of Canyon Lake, to convey the recycled water uphill to Cottonwood Creek, a tributary of San

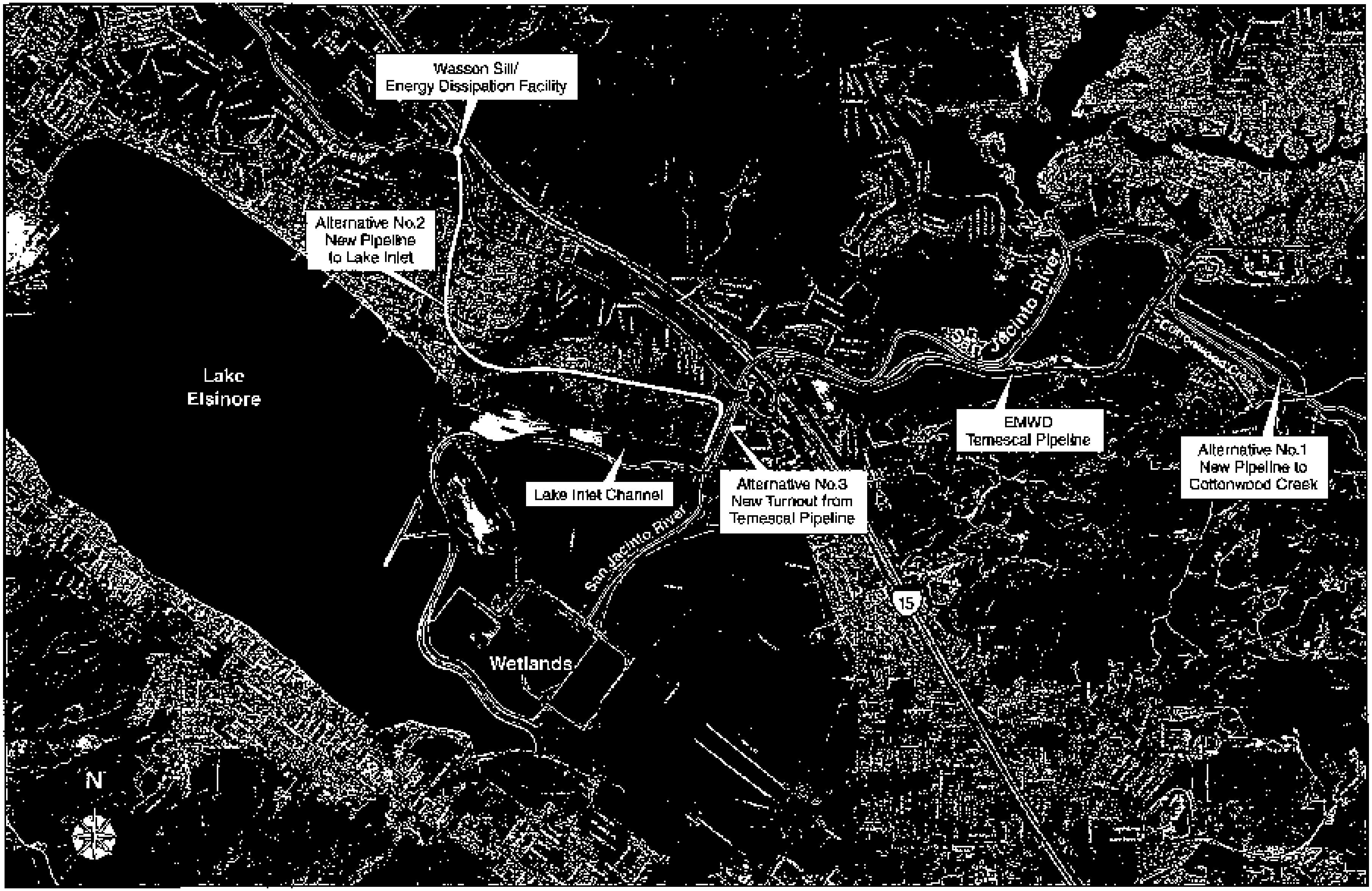


Figure 3-1

EMWD Recycled Water Conveyances Alternatives

Jacinto River. A 54-inch flow isolation valve would need to be installed downstream in the main Temescal Pipeline.

Since Cottonwood Canyon Road generally follows the alignment of Cottonwood Creek, the length of pipeline required should correlate closely to the topography of the creek in order to minimize the impact on the creek. Approximately 8,000 feet of pipeline are assumed at this time. Recycled water would be released from the pipeline, travel down the creek to the river, and eventually reach the lake inlet in its natural way.

3.2 ALTERNATIVE NO. 2 - NEW PIPELINE FROM TERMINUS OF TEMESCAL PIPELINE

Alternative No. 2 takes advantage of the existing energy dissipation facility at Wasson Sill. The Wasson Canyon channel cannot be used to convey the recycled water directly to Lake Elsinore at the current nutrient levels, unless permitted by the RWQCB. With Alternative No. 2, recycled water would be re-directed back to the lake inlet from the existing energy dissipation facility. There are a number of alternative routes for the new pipeline; the final alignment will depend on the results of a utility search. For the purpose of developing construction costs, 20,000 feet of 54-inch-diameter pipe are assumed.

3.3 ALTERNATIVE NO. 3 - NEW TURNOUT IN TEMESCAL PIPELINE NEAR LAKE INLET

Alternative No. 3 is intended to shorten the required length of new pipeline. A new turnout in the Temescal Pipeline near the intersection of Railroad Canyon Road and Casino Drive would allow a very short connection between the turnout and lake/river channel discharge. Approximately 2,700 feet of 54-inch-diameter pipeline would be required if the recycled water is to be delivered directly to the river channel south of lake inlet.

3.4 ALTERNATIVES EVALUATION

The three alternatives were evaluated on a cost basis. Implementation issues for each alternative were also identified. **Table 3-1** summarizes the evaluation. Costs of items common to all alternatives, such as river channel lining and lake inlet modifications, were not included in the comparison. Since the difference in annual operation and maintenance costs among these alternatives is insignificant, it will not impact the selection of alternatives.

Although Alternative No. 1 appears to have a reasonable construction cost, many implementation issues also need to be addressed. First, it would involve discharging a large quantity of water into the creek/river during winter months. Second, part of this discharge would percolate through the river channel bed and not reach the lake unless the channel is lined, a potentially expensive remedy. Last, the Water Quality Control Plan (Basin Plan) administered by the RWQCB imposes a total dissolved solids (TDS) limit of 450 mg/L for Reach 1 of the San Jacinto River (Lake Elsinore to Canyon Lake). The effluent TDS exceeds this figure. Alternative No. 1 would not likely be approved by the regulators unless mitigation is provided.

Table 3-1
EMWD Recycled Water Conveyance
Alternatives Evaluation

Recycled Water Delivery Alternative	Alternative No. 1 Delivery via Cottonwood Creek/ San Jacinto River	Alternative No. 2 New Pipeline from Terminus of Temescal Pipeline	Alternative No. 3 New Turnout in Temescal Pipeline Near Lake Inlet
Additional 54" Pipeline Installation Cost (1)	8,000 lin ft $2,400,000	20,000 lin ft $6,000,000	2,700 lin ft $810,000
54" Flow Isolation Valve Installation Cost (1)	At flow diversion $30,000	Not required None	At flow diversion $30,000
Energy Dissipation Facility (2) Installation Cost (3)	Not required None	Already in place None	Near river crossing $1,200,000
Total Installation Cost (4)	**$2,430,000**	**$6,000,000**	**$2,050,000**
TDS Offset	Required; may need to purchase desalter capacity	Not required	Not required
Other Issues	Pending RWQCB approval; water loss in creek/river; public acceptance issue	New pipeline in utility-congested streets	

Notes:

(1) Order-of-magnitude construction cost estimates are for comparison purposes only; administration, engineering, contingency, etc. are not included.

(2) EMWD provides dechlorination for 20 mgd of flow at Sun City RWRF. Additional dechlorination is required for flows beyond 20 mgd.

(3) Inflated original construction cost obtained from EMWD; including site work, block building, emergency generator, and motorized sleeve valve.

(4) Does not include costs of river channel lining, which is common to all and estimated at $1.3 million.

Alternative No. 2 is the most expensive option due to the length of new pipeline to re-direct the water back to the lake inlet. Finding a suitable alignment for this large diameter pipeline may also be difficult.

Alternative No. 3 appears to be the simplest and least expensive option to bring the recycled water to Lake Elsinore and is therefore the recommended alternative for this project.

SECTION 4
LAKE ELSINORE SEDIMENT-WATER INTERFACE & NUTRIENT ADDITION STUDIES

Numerous water quality studies have been performed on Lake Elsinore, each with a slightly different objective. This project intends to identify and address the mitigation of additional nutrient impacts on the lake resulting from the addition of recycled water to replace lake evaporative losses. In order to develop lake enhancement measures, additional data were required to better understand various components of oxygen demands in both the water column and sediments of the lake, as well as to quantify these demands for treatment facility sizing.

This section summarizes findings of previous studies pertinent to nutrient impacts, and the results of this study's field sampling program conducted from July to September, 2000. The complete Lake Elsinore Sediment-Water Interface Study report is attached (**Appendix E**).

4.1 SUMMARY OF PREVIOUS STUDIES

Several previous studies addressed the current issues of concern for this project. Of particular interest are the following:

1. Lake Elsinore Water Quality Monitoring Program Black & Veatch, 1996.

Results of lake water quality monitoring between May 1995 and July 1996 were presented. Phytoplankton enumeration, sediment testing, dissolved oxygen measurements, and various water quality parameters were included.

The Black and Veatch study reported that very low dissolved oxygen (DO) concentrations occurred in summer. The low DO was likely to cause release of soluble bio-available phosphate from the sediments to the water column, where it could stimulate algal growth. In addition, the same low DO levels were likely to cause the release of toxic ammonia and hydrogen sulfide.

2. Lake Elsinore NPDES Permit Feasibility Study, Final Phase 1 Technical Report Montgomery Watson, 1997.

This study investigated and modeled the hydrology and water quality of the lake and the potential effects of recycled water addition under various scenarios. Analyses of phosphorus release from lake sediment were performed as part of the study.

The 1997 Montgomery Watson study determined that internal nutrient loading and recycling between bottom sediments and the water column is the dominant source of phosphorus in the lake, especially in dry years. Because Lake Elsinore seldom overflows, nutrients accumulate in the lake and in the bottom sediments. The report also suggested that nutrient impacts from added recycled water would be insignificant at concentration levels of 4.5 mg/L nitrogen and 2.0 mg/L phosphorus.

3. Laboratory and Limnocosm-scale Evaluations of Restoration Alternatives for Lake Elsinore. Michael A. Anderson, University of California, Riverside, December 2000.

This study evaluated the impacts of two potential water quality improvement techniques: aeration and metal salt additions. The experiments were conducted in the fall of 2000. The laboratory microcosm study showed that addition of phosphate in the range of 0.1-0.3 mg/L stimulated fall (October) algal growth, while nitrate and ammonia addition did not. Nutrient flux measurement from lake sediments were carried out in the laboratory under low DO conditions. DO was shown to produce large amounts of algae-stimulating phosphate and also the fish toxicant ammonia in lake-sediment experiments in the laboratory. These experiments showed rates of releases of phosphate and ammonia compatible with the levels reported for the summer of the same year (Appendix E) and used for offset calculations (Section 8). The addition of alum, calcium and aeration (air containing the usual 21% of oxygen) all resulted in reduction of phosphate. Alum was most successful (~ 100%), calcium less so (65%) and aeration reduced phosphate by 35% under these conditions. Alum was predicted to "completely shut down internal loading of P, at least in the short term." Alum, calcium and aeration did not reduce ammonia, at least under the conditions of these short-term laboratory experiments.

In the in-lake limnocosms study, wastewater in a 20:1 dilution (lake: wastewater) was used in fixed columns that extended into the lake sediments. The 20:1 ratio approximated the concentrations expected in the reclaimed wastewater after dilution in the lake. The tests were carried out over 30 days, but results were greatly affected by algae growth on the walls of the limnocosms after 10 to 12 days. In this early period, a small stimulation from 12:1 recycled water was found on phytoplankton as shown by chlorophyll *a* pigment increases. Since this was not replicated, it was not confirmed whether the changes were real or due to random chance. Since the changes found were always in the same direction (increasing), it is likely that true, if small stimulation occurred.

Nutrients and wastewater increased algal growth in field enclosures (limnocosms). Wastewater combined with aeration showed the same results as wastewater and alum or calcium. Recycled wastewater used to stabilize the water levels in Lake Elsinore were calculated to be about one-quarter of the internal loading of phosphate from the anoxic sediments in normal years and more than one-quarter in drought years.

Three of the results from the UCR study are important for the restoration of Lake Elsinore. First, there was a dramatic improvement in water quality in the limnocosms after 10-12 days. Professor Anderson comments on the increased clarity, "It does underscore the benefits of a macrophyte and attached algae-based ecosystem as compared to the phytoplankton-based system presently in the lake." Thus, Dr. Anderson's comments fully support the bio-manipulation restoration technique recommended in this report. Biomanipulation uses a macrophyte-based attached algae nutrient and turbidity-based approach promoted by submerged vegetation.

The second significant finding was the apparent difference in nutrient response from the lake summer laboratory bioassays. The rapid depletion in nitrate in the limnocosms, but the fluctuating phosphate suggests nitrogen limitation. This finding is contrary to the laboratory studies that showed phosphate limitation. It would thus be wise to pursue both nitrogen and phosphorus reductions for Lake Elsinore.

Third, no differences were reported in the benefits to water clarity or chlorophyll from the addition of alum, alum plus calcium, or aeration, when measuring the effects of 20:1 recycled water. These findings again contrast with the differences (100, 65 and 35%) found in the less realistic laboratory studies. These data have been taken into account in calculating effects of proposed treatments and offsets in this report. Most significant in the context of offsets discussed in this document, an internal loading rate of phosphate of about 25,000 kg P/yr was estimated from the UCR study's preliminary data.

4. Comments on Calcium Addition as an Algal Treatment System for Lake Elsinore. William T. Berry, Cusick, Washington. 1995.

A series of comments and reports conclude that "Putting Ca^{++} into Lake Elsinore will compound the problem." Reduction and/or elimination of the source of the ortho-P (phosphate) were suggested as ways to correct the problems at Elsinore. By analogy, Professor Berry also excluded other in-lake phosphate chemical treatments, such as alum or Phosloc®.

5. Report on the advisability of adding alum to cure eutrophication problems in Lake Elsinore. G. Dennis Cooke, Kent State University, Ohio. Summer 2001.

Dr. Cooke is a leading expert on lake restoration and has studied alum applications in many lakes. He concluded that alum should not be added to Lake Elsinore and echoed Professor Berry's comments that P-sources should be reduced in lieu of using alum chemical sequestering of soluble P.

6. Internal Loading and Nutrient Cycling in Lake Elsinore. Michael A. Anderson, University of California, Riverside. August 2001.

This report expanded the fall 2000 UCR report (see item #3) and measured nutrient flux from the sediments, nutrient loading from field monitoring, sedimentation and particle-bound nutrient deposition. Sandy sediments were found in shallow (< 4 m deep) water, transitional sediments at 4-6 m depth, and fine organic sediments in water 6-7 m deep. The fine organic sediment was found to cover about 50% of the lakebed. Thus the area of organic and transitional sediments that would release ammonia and phosphate is about 66% of the lakebed, as assumed in the calculations made in this report in Appendix E and Section 8. Both ammonia and phosphate were released from the sediments over a range of temperature and oxygen conditions. Less phosphate was released under oxygenated conditions but releases still occurred. It should be noted that the degree of anoxia was not recorded, so greater releases of phosphate may occur in field conditions. A strong seasonal (as well as spatial) component was found for nutrient releases from the sediments with highest releases in the summer (phosphate = 12 $mg/m^2/d$, ammonia = 101 $mg/m^2/d$) and lowest releases in the winter (P = 26 $mg/m^2/d$, N = 7 $mg/m^2/d$).

Suspended sediments, as well as nutrient releases from bottom sediment, were found to contribute to internal loading. The degree of bio-availability of the suspended sediments was considered lower than the soluble sediment nutrient releases. Suspended sediment had a similar composition to bottom sediment and deposition rates ranged between 19 g/m^2/d at 3 m depth to about 80 g/m2/d on the lake bed. No clear seasonal or spatial trends were found, as might be expected in a warm-climate shallow lake. A lake nutrient budget was developed for the dry year of 2001 and showed low external loading (0.63 tons P, 5.3 tons N), high internal sediment releases (33 tons P, 197 tons N), and even higher, though less bio-available sediment re-suspension (51 tons P, 270 tons N).

A mathematic BATHTUB model was used to "predict limited increases in ... (algae) with modest additions of recycled water, although large additions were predicted to have a more significant effect." Air and alum additions were predicted to have a similar level of reduction in algae (27 and 32% respectively). The report concluded that "control of internal and, in wet years, external sources of nutrients in conjunction with lake level stabilization is necessary before significant improvements in water quality can be achieved."

The overall ratio of N:P for inflow and internal releases was 6:1, or 5.6 if sediment re-suspension is included. This would indicate nitrogen limitation overall. Since most of the particulate phosphate but only a fraction of the particulate nitrogen is bio-available, nitrogen limitation is confirmed for the overall lake budget. However, the dominance of the non-nitrogen fixing and ammonia favoring blue-green alga *Microcystis* indicates that nutrient limitation in the classic sense is not an applicable concept in Lake Elsinore at this time.

An important conclusion can be reached from Professor Anderson's findings in this dry year with little inflow. The conclusion is that, even with complete TMDL control in the watershed, the lake will continue to be eutrophic and have nuisance conditions such as algae blooms and occasional fish kills. Eventually, a complete TMDL control of nutrients might reverse the lake's trophic state. Currently, inflow of nutrients serves to periodically replenish the nutrient pool. The importance of an effective in-lake process to reduce internal loading of bio-available phosphate and ammonia is evident from the findings of this UCR study.

4.2 SUMMER 2000 SAMPLING PROGRAM

Field monitoring and sediment core experiments were conducted in Lake Elsinore during the summer of 2000. The goal of this work was to evaluate the magnitude and dynamics of various components of oxygen demand in the lake, and to examine the effects of oxygen on nutrient dynamics at the sediment-water interface.

Thermal stratification was observed in July and early August and surface water was supersaturated with dissolved oxygen (DO) as a result of phytoplankton activity. Below 2 meters depth, DO tended to decline with increasing depth. In late August and September, the water column was isothermal and undersaturated with DO. Relative to saturation, the lake exhibited a DO deficit of approximately 400 tons oxygen. Soluble reactive phosphorous (SRP) and nitrate were never detected in the lake. Ammonia was detected in July and early August in water below 2 meters at a concentration of 50-200 micrograms (μg)-N/L. In late August and September, ammonia was detected throughout the water column at about 300 μg-N/L. Though

SRP was not detected in bottom-water, a number of field observations suggest that the sediment-water interface was reduced (anoxic) and was a source of internal nutrient loading to the lake.

The oxygen demand of lake water was measured at 0.4-0.5 mg/L/day in July and 0.8-0.9 mg/L/day in August. Sediment oxygen demand (SOD) in July, August and September experimental chambers averaged 1.56, 1.34 and 0.51 grams per meter squared per day (g/m^2/day). Mixing at the sediment-water interface increased SOD at two of the three sites by 30-70 percent. Based on these experimental data, summertime oxygen demand in Lake Elsinore is approximately 80 tons/day. Much of this demand is satisfied by natural re-aeration from the atmosphere and from phytoplankton DO production. An analysis of eleven historical DO depletion episodes yielded DO consumption rates ranging from 3-32 tons/day with a median of 9 tons/day.

Nutrient release experiments showed that oxygenated conditions inhibited or reversed sediment release of SRP and ammonia. Anoxic SRP and ammonia release rates ranged from 7.7-26.6 mg-P/m^2/day and 41-119 mg-N/m^2/day. Release rates showed no spatial variability, but did show a significant decline between sampling dates. Estimated monthly internal loading of nutrients for July through September ranged from 3,500 to 5,800 kg-P and 16,300 to 26,000 kg-N.

Based on the results of the summer 2000 sampling program, the following has been recommended:

1) An aeration system should be installed in Lake Elsinore. Such a system would result in a number of water quality benefits.
2) An oxygenation system sized for 27 US tons/day should be used to inhibit fish kills. This includes a baseline delivery rate of 20 tons/day that would satisfy 90 percent of historical DO depletion episodes occurring between 1990 and 1996. It also includes an additional 7.5 tons/day to compensate for potential induced oxygen demand. Either a mixing system or an oxygenation system should be considered.
3) Additionally, an oxygenation system sized for 46 tons/day should be used to inhibit excessive internal nutrient loading. To meet this higher demand, a submerged oxygen-water contact chamber with a horizontal diffuser is recommended.
4) A value of 24.5 US tons-P per year can be used as an estimate for the internal loading offset that could be achieved via aeration. The offsets are further discussed in Section 8.

Dr. Michael Anderson of UC Riverside has recently performed other lake studies for the RWQCB, including the internal loading of P and the maximum nutrient input from recycled water to the lake without impairing beneficial uses. This project team coordinated with Dr. Anderson during the preparation of the study. The comprehensive recent work of Dr. Anderson is in broad agreement with the limited studies reported here. In particular, the UCR study's December 2000 estimate of internal loading is in agreement with the value shown in #4. However, this value may vary from year to year and in his second report he increases this value to about 33 tons/y, of which at least 27% (9 tons) would be inhibited by aeration or oxygenation. Improvements in technique could increase this value. These findings concerning the need for lake stabilization and the modest increase in lake algae (predicted by a mathematic model) from the typical recycled wastewater additions are in line with the findings and suggestions in this report.

Because Dr. Anderson carried out both field and laboratory tests aimed at assisting selection of restoration techniques, a more balanced view of the likely effectiveness of alum and aeration (or oxygenation) can be gained. It seems most probable that the higher sediment phosphate releases in summer, that occur prior to Dr. Anderson's 2000 study, saturate the aquatic ecosystem. Ammonia releases in the summer probably saturate the nitrogen component of the nutrient load as well. Because the main algae species in Lake Elsinore can store many generations worth of P as granules inside the cells, P-limitation, as measured by Dr. Anderson, must be quite strong. However, there was ample P available from the sediments in summer and fall 2000. Possibly, Dr. Anderson's laboratory microcosms contained rapidly growing algae, or those that had been isolated from deeper P-rich water by temporary thermal stratification. In contrast, the in-lake limnocosms studies would automatically sample a larger, and perhaps less stratified, phytoplankton population since they were in shallow water nearer the lake edge.

SECTION 5
LAKE ELSINORE
ENHANCEMENT ALTERNATIVES

5.1 GENERAL

As stated in Section 1, Lake Elsinore is eutrophic and experiences blue-green algae blooms resulting in low dissolved oxygen levels, occasional summer fish kills and malodors. These conditions and their probable causes addressed by lake management for Lake Elsinore are shown in **Table 5-1** below.

Table 5-1
Current Problems in Lake Elsinore

Problem to be Addressed	Probable Cause	Other Possible Causes
Fish kills	Entire water column mixing following temporary mid-summer thermal stratification (low dissolved oxygen, toxic ammonia, toxic hydrogen sulfide)	Low winds, very low water levels, algae bloom and die-off
Large water level fluctuations	Insufficient yearly inflow, 5 feet of evaporation each summer	Gently sloping shallow lake bed exacerbates effect
Malodors	Anoxia (no oxygen) on lake bed, hydrogen sulfide	Dead fish, algae
Algae	Excessive nutrients from watershed and anoxic lake bed in summer (internal loading)	Shallow lake mixes nutrients from sediments
High internal nutrient loading	Anoxia on lake bed, sediment re-suspension from wind action	
No lakeshore vegetation (emergent or submergent)	Desiccation of lakeshore vegetation due to large water level fluctuation, carp grub up sediments & plant roots of submergent plants, phytoplankton shade underwater plants	Hard substrate, wave action

The methods available for solving the problems listed in Table 5-1 are best divided into two categories: watershed management and in-lake treatment. This evaluation addresses five watershed management methods and seventeen in-lake treatment methods, which are described in the following sections.

5.2 WATERSHED MANAGEMENT METHODS

All lakes are directly impacted by their watersheds. Lake Elsinore's watershed encompasses a direct drainage area of 46 square miles, plus wet weather overflows from Canyon Lake, which has a drainage area of 780 square miles. Runoff transports the nutrients (particularly phosphorus) to Lake Elsinore via the San Jacinto River that are the cause of the lake's nuisance algae blooms. Five watershed management methods typically used to reduce pollutant input to the lake are discussed and evaluated below for the Lake Elsinore drainage basin.

Treat sewage. Tertiary treatment is currently provided for most of the wastewater collected by sewer systems in the developed areas in and around the city of Lake Elsinore. No sewage treatment plant effluent is currently discharged into Lake Elsinore or its tributary streams. Treated sewage is either recycled or discharged into Temescal Creek downstream of Lake Elsinore.

Divert non-point sewage. Non-point, diffuse sources of sewage are generally from septic tank leachfields around the lakeshore. If they are sited on large plots of land, septic tanks are acceptable methods of treatment for the oxygen-demanding components of sewage. However, septic systems are ineffective for nutrient removal of all waste components, even if there are sufficient trees in the vicinity of the leachfields to remove soluble nitrate. In winter, trees do not assimilate much water from the ground, which can contribute to soluble nutrients flowing to local groundwater and eventually to the lake. One method to reduce diffuse septic tank pollution is to intercept septic tank discharges and connect them directly to a sewer system. This method is applicable for some of the unsewered residential complexes near the lake.

Decrease landscape and agricultural fertilizer input. The other main diffuse source of nutrients in most drainages is "nuisance flows" from landscaping irrigation and runoff from farms. In the Lake Elsinore watershed, nuisance flows do exist and could be collected by the sanitary sewer system and treated. The volume of these flows and their effect on the lake nutrient budget are unknown.

In the dry climate of Lake Elsinore, runoff from agriculture is likely to occur only in winter season rain storms. Although occasional, such flow can contain high amounts of nutrients and pathogenic wastes. There are several dairies and other agricultural operations in the vast Lake Elsinore watershed. It is recommended that control of agricultural and other diffuse nutrient sources be mainly directed through RWQCB's ongoing TMDL process. EVMWD is also preparing an update to the San Jacinto River Basin Watershed Sanitary Survey, which will examine these "non-point" pollution sources and remediations.

Restrict entry of storm runoff and/or runoff sediment. Runoff that carries soil sediment contains nutrients at much higher concentrations than even eutrophic lake waters. The removal of storm runoff sediments is important since they contain sorbed nutrients that are released when the sediment particle contacts the lower nutrient setting of the lake. In addition, once in the lake, organic sediment particles can be decomposed by bacteria, releasing nutrients in summer and adding to the lake's internal nutrient loading.

Typically, Best Management Practices (BMPs) are used to control sediment losses. Contour plowing, improved road grading, and enforcement of runoff control measures during construction are examples of non-structural BMPs commonly used. Constructed detention ponds and wetlands to hold urban and agricultural runoff are examples of structural BMPs. It is recommended that BMPs be also considered in the TMDL process not directly dealt with in the management of Lake Elsinore.

Use of wetlands as "biological filters." Wetlands in wet or dry conditions have proven effective at removing sediment and soluble nutrients as well as heavy metals, organics, pesticides and pathogens. However, a detention time of one to four weeks is needed for soluble nutrient removal. Only a few hours are needed for sediment removal in wetlands. It is recommended that wetlands be employed in the drainage basin where possible. The existing 350-acre lakeside wetlands could be reconfigured to serve this role. Wetlands treatment is further discussed in the subsequent sections of this report.

5.3 SELECTION OF IN-LAKE TREATMENT METHODS

Seventeen in-lake treatment methods were considered for lake management, as listed below.

A. Physical Methods

Common and widely applicable methods

1. Dredging and disposal of lake-bottom sediment
2. Water level drawdown and water level fluctuation
3. Destratification and lake mixing
4. Macrophyte (water weed) harvesting
5. Wetland algae filters (off-line wetlands)

Minor or restricted methods

6. Algae (phytoplankton) harvesting
7. Selective withdrawal of hypolimnion water
8. Dilution/flushing
9. Sediment sealing (fabric liners, barriers)

B. Chemical Methods

10. Herbicides (for algae or macrophytes)
11. Oxygenation or aeration
12. Shading (dyes)
13. Sediment sealing (chemical; alum, Phosloc for PO_4 binding or calcium carbonate)

C. Biological Methods

Direct

14. Pathogens of algae or macrophytes (virus, bacteriophages, bacteria)
15. "Grazers" on algae or macrophytes (grass carp, *Tilapia*, beetles)
16. Nutrient harvesting

Indirect

17. Bio-manipulation ("top-down" controls of the aquatic food chain to favor algae-filtering *Daphnia (water flea)*). Includes harvesting excess small fish and bottom-grubbing carp.

The applicability of the above methods for Lake Elsinore is summarized in **Table 5-2**.

Table 5-2
Applicability Review of In-Lake Methods for Lake Elsinore

No.	Method	Applicability for Lake Elsinore	Use
1	**Dredging**	Too costly for a large lake where over 20 feet must be removed	No
2	**Water level fluctuation**	Stable lake level will improve shoreline for humans and riparian & submerged vegetation. Addition of recycled water is feasible from local sources. Nutrients added can be offset with oxygenation, wetlands and at-plant treatment. Is needed for bio-manipulation.	Yes
3	**Destratification and lake mixing**	Possible method using air mixing to move oxygenated surface water to anoxic sediments. Will require most energy when problems are worse. Not shown to work in warm climates	No
4	**Macrophyte (water weed) harvesting**	No weeds at present, mechanical harvesting may be needed along with herbicides in enhanced lake for inshore swimming/boating areas. Combine with bio-manipulation	Maybe
5	**Wetland algae filters (off-line wetlands)**	Good method for direct removal of algae using redesigned 350 acres of current lakebed "wetlands". High pumping cost, successful in tests in Florida. Discontinue after bio-manipulation	Yes
6	**Algae (phytoplankton) harvesting**	Cost is high unless algae are harvested and sold as high priced health food or food dye. Possible use with Oregon firms.	No
7	**Selective withdrawal of hypolimnion water**	No spare water to lose, would require a large siphon from the deeper lake to outlet	No
8	**Dilution/flushing**	No spare or clean water available in large amounts	No
9	**Sediment sealing (fabric liners, barriers)**	Lake too large for these methods. Could be used for weed control alongside docks, swim areas	Limited
10	**Herbicides (for algae or macrophytes)**	Will be needed to shape the expected vegetation growth following bio-manipulation. Combine with harvesting?	Yes
11	**Oxygenation or aeration**	Main method to prevent fish kill, odors, internal nutrient loading. Oxygenation only feasible method in Elsinore due to huge pipe runs needed for aeration in very shallow water. Reduce after bio-manip.	Yes
12	**Shading (dyes)**	Lake too large, dye lasts only a few months.	No
13	**Sediment sealing (alum, Phosloc or calcium carbonate)**	Lake very large for these methods, high cost, reserve for limited use if aeration/oxygenation is not fully effective for PO_4. Not recommended for Elsinore; increases toxicity and pH. Recent experiments show alum can be replaced with oxygenation.	No
14	**Pathogens of algae or macrophytes**	Ineffective for blue-green algae due to resistance buildup. None known for macrophytes	No
15	**Fish grazers on algae or macrophytes**	Not applicable, lake needs more submerged macrophytes, not less	No
16	**Nutrient harvesting from fish or other biota**	Many small fish and large carp will be harvested as part of the bio-manipulation process. N and P removal expected to be small relative to inflows. Combine with bio-manipulation	Yes
17	**Bio-manipulation**	Main sustainable method to remove nuisance algae, tie up nutrients, reduce sediment re-suspension	Yes

For Lake Elsinore, the three chosen methods for lake enhancement are:

- A5 Wetlands filtration
- B11 Deeper water oxygenation
- C17 Bio-manipulation

The application of oxygenation/aeration and wetlands treatment for Lake Elsinore requires more site-specific development and therefore will be addressed separately in Sections 6 and 7. Bio-manipulation is a relatively new method, which has had some significant successes in Europe, and is discussed in detail below.

5.4 BIO-MANIPULATION

Bio-manipulation, as its name suggests, is a lake management technique that relies on altering the lake's biology in order to change the water quality. Bio-manipulation has had some great success in shallow lakes in Europe, and research in the US has indicated that it could be successful here as well. Bio-manipulation for use in Lake Elsinore has several components.

- Increase in submerged plants in the shallow parts of the lake
- Increase in the effectiveness of algae-filtering zooplankton
- Balance between plankton-eating and fish-eating fish stocks
- Removal of bottom grubbing fish
- Initial large reduction in nutrient loads to the lake

The role of the plants is the overall key. First, the plant roots stabilize the sediments and reduce internal loading via sediment re-suspension. The shelter from the waves provided by the underwater stems and leaves also prevents sediment re-suspension. Second, the calm water between the stems is unfavorable to planktonic algae, which quickly sink, and die or are eaten thus increasing water clarity in the open water. Third, the dense underwater vegetation provides a daytime refuge for the small zooplankton that eat algae during the night when they venture out into the open water (most fish feed by sight and cannot see algae in the night).

Enhancing the nuisance algae-grazing potential of the zooplankter, *Daphnia*.

The theoretical concept of bio-manipulation has a main component that involves manipulating the lake ecosystem so that large zooplankton that filter large amounts of water and feed on algae are favored over small zooplankton that filter much less water. Large zooplankton are a favorite food for small fish, so reducing the excessive numbers of small fish usually found in eutrophic lakes is one method of bio-manipulation.

Instead of curing eutrophication by removing nutrients or killing the algae with chemical poisons, bio-manipulation uses changes in the upper part of the food web. This concept has been formalized in a modern ecological hypothesis, the "Top-down, Bottom-up" hypothesis, as shown below.

BOTTOM UP HYPOTHESIS

Nutrients → Algae → Lower water clarity → Problems

TOP DOWN HYPOTHESIS

- Big fish eat small fish
- Small fish eat big zooplankton
- Big zooplankton eat more phytoplankton
- Phytoplankton reduction is a desirable goal

The method was first attempted by simply adding large fish. The method worked in small lakes, but over-fishing, pollution and inability to control small fish populations limited the method in large lakes. The approach used by Europeans in large shallow lakes was the more practical method of removing small fish directly using nets. In the early stages of bio-manipulation, netting of fish had to be done quite frequently, as often as every two weeks. Less frequent netting is needed once the general fish population in stabilized. If any large fish or any desirable native or rare fish are netted, they are put back into the lake.

Large bottom grubbing fish, such as the introduced European carp, may inhibit bio-manipulation for two reasons. First, they disturb the sediments so that it is difficult for aquatic plants to germinate and grow. Second, carp eat sediments and pass algae nutrients into the water more quickly than native fish. Fishponds with carp are usually green with suspended algae and have few aquatic plants. The opposite is preferred for Lake Elsinore. It is proposed that, along with the regular summer netting of small trash fish, that large carp be eliminated as much as possible.

Modern shallow lake limnology indicates that there are two stable states for shallow lakes. One is an algae-filled turbid lake such as Lake Elsinore, the other is a clear water lake with about 40 percent of its shallow edge waters filled with aquatic vegetation. At the eutrophic state, addition of nutrients to a shallow lake causes overgrowth of aquatic plants and eventual death. The lake is then stable as a eutrophic lake.

For a clear water marsh, reduction of nutrients or removal of algae by increasing zooplankton grazing results in an increase in large zooplankton, especially *Daphnia*, and re-growth of aquatic plants. Note that <u>nutrient reduction alone will not achieve clear water</u> (e.g., Lake Sammamish upstream from Lake Washington, Seattle). Instead of hoping that natural large fish will eat sufficient small fish to allow for a *Daphnia* population explosion, it is possible to assist nature by removing some of the excess smaller fish. The results of removing small fish in a large shallow lake in Europe include:

- Increases in Secchi depth,
- Increases in *Daphnia*,
- Increases in littoral (shoreline) aquatic vegetation,
- Decreases in blue-green algae scums, and
- Best water quality aesthetics since 1920.

5.5 CURRENT FISH MANAGEMENT IN LAKE ELSINORE

Bio-manipulation requires balancing the ratio of fish that eat zooplankton (planktivores) and those that eat other fish (piscivores). Generally most sport fishing leans towards piscivores, so bio-manipulation should be easily compatible with typical fish management in lakes. Current fish stocking and other fish management practices are discussed below.

Lake Elsinore is the largest natural freshwater lake in southern California. Because the lake is shallow, nutrient enriched, and located in an area with ample sunshine, it is very productive biologically. Representative species found in this warm water fishery include largemouth bass, bluegill, bullhead, carp, channel catfish, crappie, and threadfin shad. In order to have a more comprehensive understanding of how to bio-manipulate the lake, Mr. Pat Kilroy, lake manager for the city of Lake Elsinore, provided the following information on current fish stocking practices at Lake Elsinore in a memorandum dated September 26, 2000 (see **Appendix F**).

Lake Elsinore's water quality has not always been favorable to support a sport fishery. Due to the periodic low oxygen levels caused by excess nutrients and algae, carp are the predominant species of large fish in Lake Elsinore throughout the year. With reasonably good water quality in the lake for the past five years, it has been reported that the sport fishery has significantly improved, especially the size and number of catfish and crappie. However, this contention was based on a few photographs and anecdotal information, with no fish population survey or creel counts. The city of Lake Elsinore and the California Department of Fish & Game (CDFG) have taken advantage of this good water quality in performing some minor fishery enhancement work and the initiation of a fish stocking program. There are unconfirmed reports that Lake Elsinore had not been stocked with fish for at least 15 years prior to 2001. CDFG has included Lake Elsinore in its "Put n' Take" Trout Fishery Program in an attempt to expand fishing opportunities for the general public, particularly during the winter months when the lake has high oxygen levels from the surface to the bottom waters. **Table 5-3** presents the stocking details of the 2000 fish stocking program.

Table 5-3
2000 Lake Elsinore Fish Stocking Program

Type of Fish	Stocking Date or Time Period	Total (pounds or number)	Size Range (pounds or inches)
Rainbow Trout	Feb. 2000	5,000 lbs.	1-6 lbs.
(scheduled trout stocking)	Nov-Dec. 2000	6,250 lbs.	0.5-6 lbs.
Channel Catfish	March-July 2000	8,550 lbs.	1-3 lbs.
Largemouth Bass fingerlings	June 2000	3,600 fish	2-inch

Note: "Just-4-Kids" Fishing Derby held in June, 2000.

SECTION 6
LAKE AERATION AND OXYGENATION SYSTEMS

6.1 GENERAL

Daily or short-lived thermal stratification exists in Lake Elsinore that allows total oxygen depletion in the lake bottom water and sediments, despite frequent top-to-bottom mixing of the lake. Since the lake is not permanently stratified in summer, nutrients released from the sediments are rapidly carried to the lake surface, which accelerates algae growth. Other compounds such as hydrogen sulfide and ammonia can also be released at low dissolved oxygen (DO) levels, which have the potential to cause fish kills.

As described in Section 4.2 of this report, an oxygenation rate of 27 tons per day to the lake bottom water is recommended to inhibit fish kills in Lake Elsinore. This includes a baseline delivery rate of 20 tons/day that would satisfy 90 percent of historical DO depletion episodes occurring between 1990 and 1996, and an additional 7 tons per day to compensate for potential induced oxygen demand. However, if the goal is to inhibit internal nutrient loading, a much larger delivery capacity of 46 tons per day oxygen may be needed to assure that a well-oxygenated sediment-water interface is maintained. For the purpose of this project, an aeration/oxygenation system will be sized at a capacity of 20 tons oxygen delivery per day. Expansion to the theoretical limit of 46 tons per day in order to meet the oxygen demands in the water column as well as the sediments is possible, but unlikely to be needed once the entire package of four in-lake and two watershed management systems are in place. Thus a professional judgment was made to limit the system capacity to 20 tons since some undersaturation of oxygen can be tolerated without producing fish kills. A similar professional judgment was made for the aeration/mixing scheme where the most extreme stratification will not be fully overcome on the hottest days.

Various methods of oxygenation, aeration and other modes of lake mixing are available to replace oxygen in eutrophic lakes where oxygen is depleted in deep water and sediments by decaying algae. The main advantage of aeration/oxygenation is that hydrogen sulfide production is inhibited and internal loading of phosphate and ammonia from the sediments is eliminated.

Five major methods including standard aeration, propeller mixing, diffused Mobley-TVA oxygen bubblers, Canning Pump (on-shore oxygenation) and a modified Speece Cone (Speece Well) system have been considered for this study. These methods were discussed and evaluated in a workshop on August 15, 2000. Results of the workshop and the logic behind the selections are summarized in **Appendix G**. In general those methods that worked best under conditions of temporary stratification (i.e. pre-cursor to fish kills) and had a horizontal distribution of oxygenated water over the sediments were favored over those that worked best in well mixed conditions, which have no danger of fish kills.

From the workshop, two methods were selected for further evaluation: pressure oxygenation with a Speece Well and some form of aeration/lake mixing. The Speece Well system contains some untested design segments, but these were considered to be small disadvantages since the main concept had been used in other lakes. The standard aeration method while too cumbersome and costly has a long track record. The two selected methods are discussed in detail below.

6.2 AERATION SYSTEM

Simple aeration is the most widely used method of lake management. but the technique mixes the lake, often with unwanted consequences. For permanently stratified lakes, hypolimnetic aeration or oxygenation is preferred. Current methods of simple aeration employ various kinds of mechanical devices, which range from enclosed airlift pump towers, to miles of perforated hose, to sophisticated underwater mixing systems. Only those methods applicable to shallow, traditionally unstratified lakes such as Lake Elsinore were considered. These techniques range from adding compressed air to a submerged pipe with holes along part of the length, to complex arrays of submerged air/water diffusers.

The main advantages of shallow lake aeration are:

- Aeration is non toxic
- Simple construction for small lakes (air compressor, pipes, diffusers)
- Gives rapid results for reduction of fish kills
- Should reduce internal loading of phosphate and ammonia
- Improves fishing for warm water species

The main disadvantages of shallow water aeration are:

- Large amount of piping and thus costly for large lakes
- Large air compressors are noisy and undesirable around peaceful lakes (noise reduction is available for approximately the cost of the compressors).
- System is subject to disturbance by boat anchors and fishing lines
- Aerated water motion is imparted in the vertical plane, not the desired horizontal plane
- Works worst under temporarily stratified conditions when fish kills are most likely
- Higher risk of increased turbidity through sediment resuspension

Most aeration schemes are designed either to add oxygen from the aeration bubbles to the deeper anoxic water, or to mix oxygen-rich surface water down into the deeper water. Lake Elsinore's surface water is supersaturated with oxygen during the day, due to photosynthesizing algae;, whereas, the bottom waters are often devoid of oxygen. Through aeration, the lake water could be vertically mixed and its oxygen content could be more uniformly re-distributed from top to bottom.

In shallow lakes, there is not enough contact time for the rising air bubbles to transfer oxygen into the water. A working guide for the optimum depth for bubbles to come to equilibrium with water is 100 feet; 50 feet is about the minimum depth. This is because the air bubbles rise quite quickly and it takes time for the oxygen transfer to occur. A 2-mm bubble will rise at 22 cm/sec in calm water, which means that even with 50 feet (15 m) of depth the bubble will rise to the surface in about one minute. The effective depth of anoxic or low-oxygen water is the measure that is of importance in the oxygen adsorption, not the total lake depth necessarily. In Lake Elsinore this depth is generally only 5-10 feet, although it may be as much as 15-20 feet in low wind conditions. Thus, air bubbles will only have about 10 seconds of transfer time to oxygenate

Lake Elsinore. Therefore, due to the shallow depth of the anoxic zone, lake mixing or destratification is the preferred aeration option for Lake Elsinore.

Conventional compressed air systems. These are available commercially (e.g. Aquarius Systems, Florida) and typically require either a flat lake bottom or one pipe to each diffuser. The concept is similar to the aeration basins of a wastewater treatment plant. If one diffuser is installed higher than another, air will flow to the shallower one that has lower pressure resistance for discharge of air flow. **Figure 6-1A** provides a conceptual layout of this conventional aeration system.

Air could be supplied from compressors at one central location or several locations along the lakeshore. The total capacity of compressors needed is about 5,200 scfm (4,400 m^3/hr), which may have to be further refined during design. For complete destratification of a 23 feet (7 m) deep lake the horizontal diameter of the primary mixing cell would be about 300 feet or 14 times the lake depth (see **Figure 6-2**). Thus diffusers should be located on 300-foot centers, which requires 1,000 individual diffusers for the entire 3,000 acre lake. Using 1,000 diffusers in Lake Elsinore would mean an enormous length of pipe (about 750,000 feet). In addition, the air distribution piping and diffusers are buoyant in water therefore would require extensive anchoring. The conceptual layout shown on **Figure 6-1A** considers a modified air piping arrangement that would utilize common headers to serve diffusers placed at the same depths in order to shorten the required pipe lengths and better balance air distribution.

The air pipes and anchors are subject to disturbance by boat anchors and fishing lines. Diffusers would also need to be serviced or replaced on a regular basis. The type of diffuser needs to be carefully selected to minimize clogging and maintenance effort.

The City of Lake Elsinore's Lake Operations Division has also independently investigated the lake aeration issue in order to improve the water quality and enhance beneficial uses of the lake. The effort was documented in a draft report titled "Aeration System for Lake Elsinore", which is attached (**Appendix H**) for reference.

Self-balancing compressed air systems. These systems would overcome the disadvantage of the conventional aeration system by providing self-balancing and more than one diffuser placed on one pipeline, even if there is a difference in elevation between the ends of the pipe. Such systems are now available as an option to a conventional system. However, self-balancing systems are proprietary at this time.

Different sized holes can be used in the air supply pipe to balance airflow distribution. However, the concept is not really applicable with diffusers. The key to the success of a self-balancing aeration system is a control device to regulate airflows coming out from each diffuser (i.e. balancing air distribution in pipe). Because more diffusers can be placed on the same header, the length of pipes could be significantly reduced to less than 20 percent of pipes required for the conventional system, depending on the lake configuration. As a result, the required compressor size and power consumption would also be reduced. A conceptual layout of a self-balancing aeration system is shown on **Figure 6-1B** (for reference only).

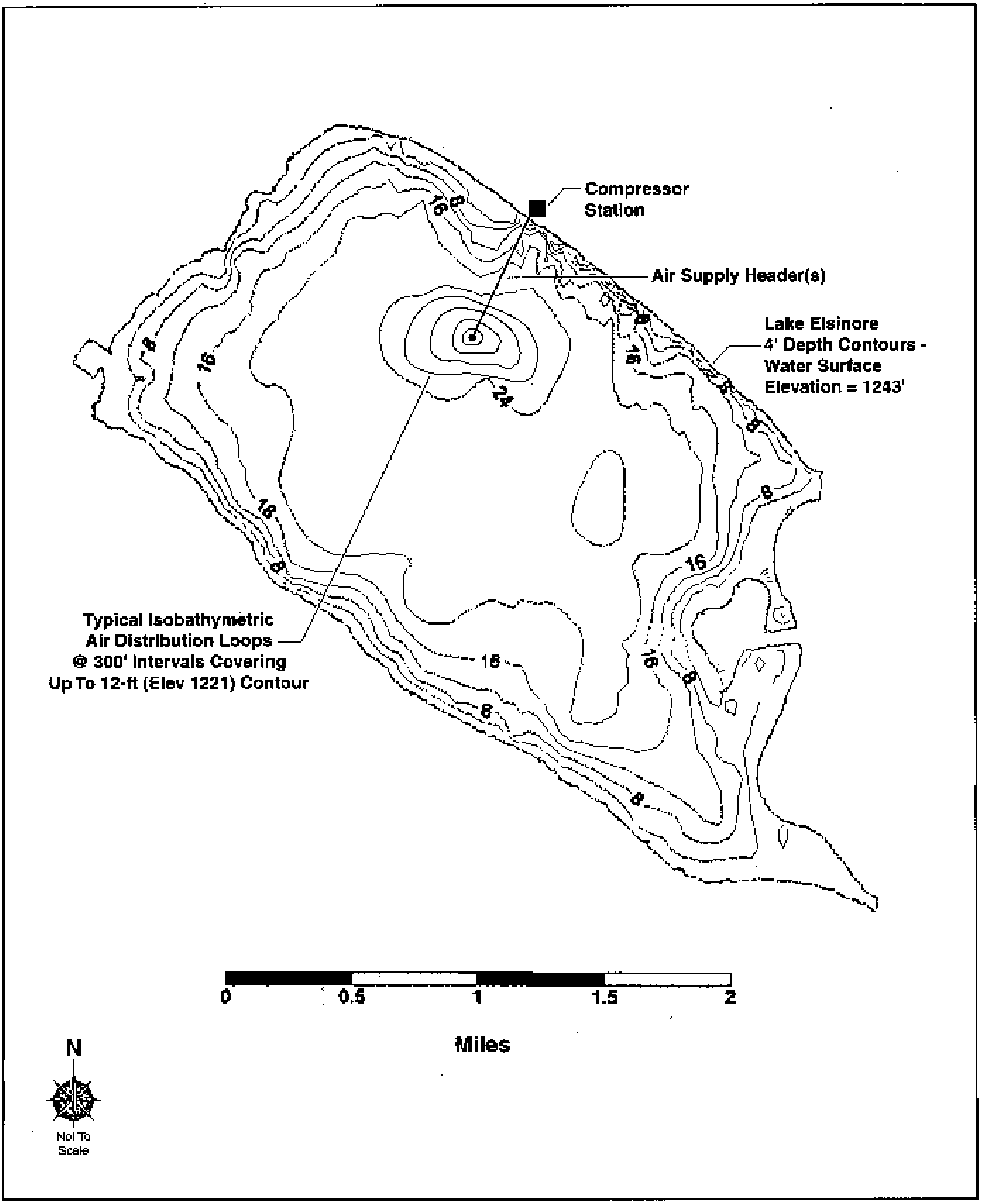


Figure 6-1A

Conventional Aeration System Conceptual Layout

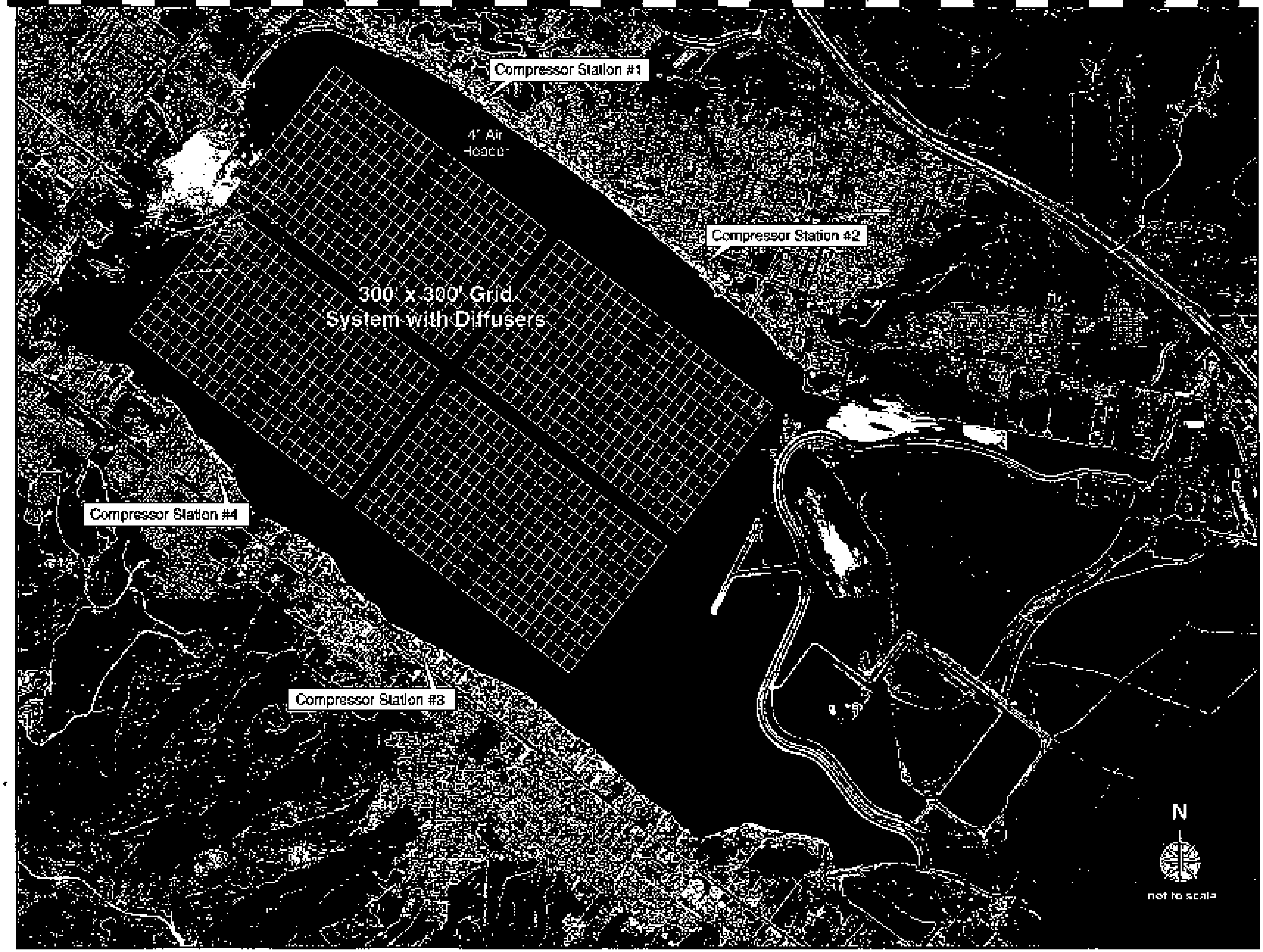


Figure 6-1B

Self-Balancing Aeration System Conceptual Layout

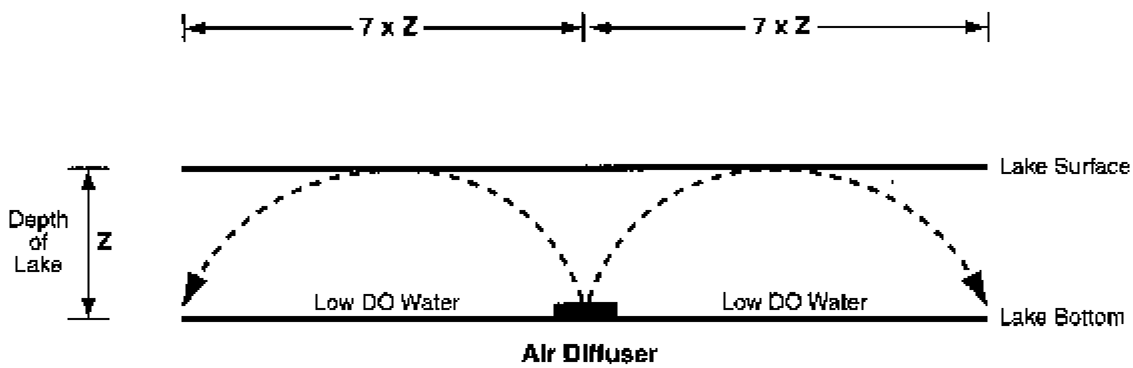


Figure 6-2
Lake Mixing Dynamics

The estimated total compressor capacity would be about 215 hp with 5,200 scfm of airflow supplied by eight compressors at four lakeshore locations. In addition, self-sinking hydraulic hoses made of wire-wound rubber could also be used for air distribution without anchoring. It should be noted that this system needs to be further defined, if this type of system is selected.

6.3 SPEECE WELL OXYGENATION SYSTEM

Oxygenation works by adding pure oxygen directly to those parts of the lake where dissolved oxygen in the water is low or absent. In general, pure oxygenation is theoretically superior to aeration as it is five times more efficient, since air contains only 20 percent oxygen.

The main advantages of oxygenation are:

- Non toxic, solves problem of oxygen deficiency directly
- Very simple system, liquid oxygen generates its own pressure as it evaporates
- Less noise generated (no noise if liquid oxygen system is used)
- Oxygenated water can be pushed horizontally over the sediments, exactly where it is needed. Motion is from water pump and natural lake motion.
- Works best under temporary stratification when pre-cursor conditions for fish kills are most likely
- Gives rapid results in terms of suppression of nutrient releases and eliminates phosphate, ammonia internal loading
- Has been shown to reduce algae in large lakes
- Improves fishing for warm water and cool water species.

The main disadvantages of oxygenation are:

- Liquid oxygen (LOX) would have to be shipped and stored on site unless pressure-swing adsorption technology is used.
- Speece Cone systems (but not Mobley-TVA bubble diffusers) require a large-size submersible pump.
- Some underwater construction is needed for the Speece Well, the submersible pump and water distribution manifold in the deep water zone.

Because Lake Elsinore is predominantly shallow, simply bubbling oxygen into the lake bottom via diffusers would be ineffective. Most of the oxygen would rise through the water so rapidly that little is dissolved in the water and the remaining pure oxygen would be lost to the atmosphere. Some method of retaining the bubbles or eliminating the need for bubbles is required. Most other shallow lakes (and rivers) are oxygenated by pumping a side-stream of water and providing counter-flow contact of oxygen and the side-stream in a closed vessel before the water is returned to the lake. This method, originally used in the 1960s and called side-stream pumping, was a success in some of the Tennessee Valley Authority (TVA) tailwaters from large warm reservoirs. The "Thames Bubbler", a mobile barge-based system capable of delivering up to 30 tons of oxygen per day, was used in the Thames River, England. A similar system is planned for the Swan River in Australia. Advances for the method recently have been use of Venturi mixers (Canning River, see Horne, 1998) and wells or holes in the river bank. These methods have been successful and the information has been used to size a system for Lake Elsinore.

The oxygenation system configuration that is well-suited for Lake Elsinore is a combination of the Speece Cone and the recent TVA riverside stream pumping methods. Deep lake water is pumped to the "cone" to contact with oxygen (supplied from the shoreline by a feeder pipe) within the structure. Oxygen gas is introduced part way down the cone and released. The counter-flow system (water flows down, oxygen gas flows up) dissolves the oxygen efficiently with minimal wasting. In previous installations, the cone is situated at the bottom of the water column to take advantage of the pressure at a depth of about 90 feet. Ninety feet depth is equivalent to three atmospheres pressure and thus much more oxygen can be packed into the water. Less water needs to be pumped and the energy costs are reduced.

The modification for Lake Elsinore, the Speece Well, consists of a standard Speece Cone placed in a deep well excavated in the lakebed. Lake Elsinore is very shallow so a conventional Speece Cone would only have a pressure head of 2/3 of an atmosphere. To obtain sufficient depth to supersaturate the carrier water with dissolved oxygen the Cone would be situated at the base of a 35 feet deep "well" on the lake bed in the deepest part of the lake (alternate is 70 feet). The well would be about 16 feet in diameter. The approximate location of the Speece Well is shown on **Figure 6-3**. There would be only one installation on shore for the Speece Well oxygenation system. The Speece Cone would be assembled on shore, barged/floated to the deepest point and installed. Because of the depth of well, the walls of the well would have to be reinforced. Temporary dewatering of the immediate area may also be required to install the Speece well.

Pure gaseous oxygen flows under its own pressure from a lakeside storage or on-site generation facility is delivered in a small size (estimated to be 1-inch-diameter) pipe to the Speece Cone mixing chamber. An electric-powered submersible pump sized at 150 ft^3/sec (or 75 ft^3/sec if the well is 70 feet deep) on the lakebed immediately adjacent to the deep well circulates water from near the lakebed to the Speece Cone. **Figures 6-4 and 6-5** provide a preliminary, conceptual layout of the Speece Well oxygenation system. The estimated pump size is 200 hp and could be reduced to 100 hp if deeper well is considered. After mixing, the water with supersaturated dissolved oxygen would flow to a manifold on the lakebed where it exits horizontally. The high oxygen concentrations are immediately reduced by at least ten fold as the manifold jet entrains adjacent low-oxygen water as it exits. Approximately 3,000 feet of oxygen supply pipes and power supply cables are required to support the operation of the Speece Well oxygenation system.

Oxygen must either be purchased as liquid oxygen (LOX), stored in two 13,000-gallon vertical tanks, or generated on site using a pressure-swing absorption (PSA) or a vacuum pressure swing adsorption (VPSA) device. The on-site PSA or VPSA generation of oxygen would not eliminate storage of backup LOX but would eliminate delivery of LOX. An evaporator about 20 feet high would be required for the LOX system. Following the evaporator, the gaseous oxygen will pass through a control manifold which contains temperature and pressure control valves. A typical LOX tank installation is shown on **Figure 6-6**. The LOX facilities need to be secured to prevent vandalism. The PSA/VPSA device will require a permanent sound proofed shed approximately 20 feet by 40 feet, and a 3-phase power supply. The VPSA system can produce oxygen from 25 percent to greater than 95 percent purity. However, a backup LOX storage tank would still be recommended.

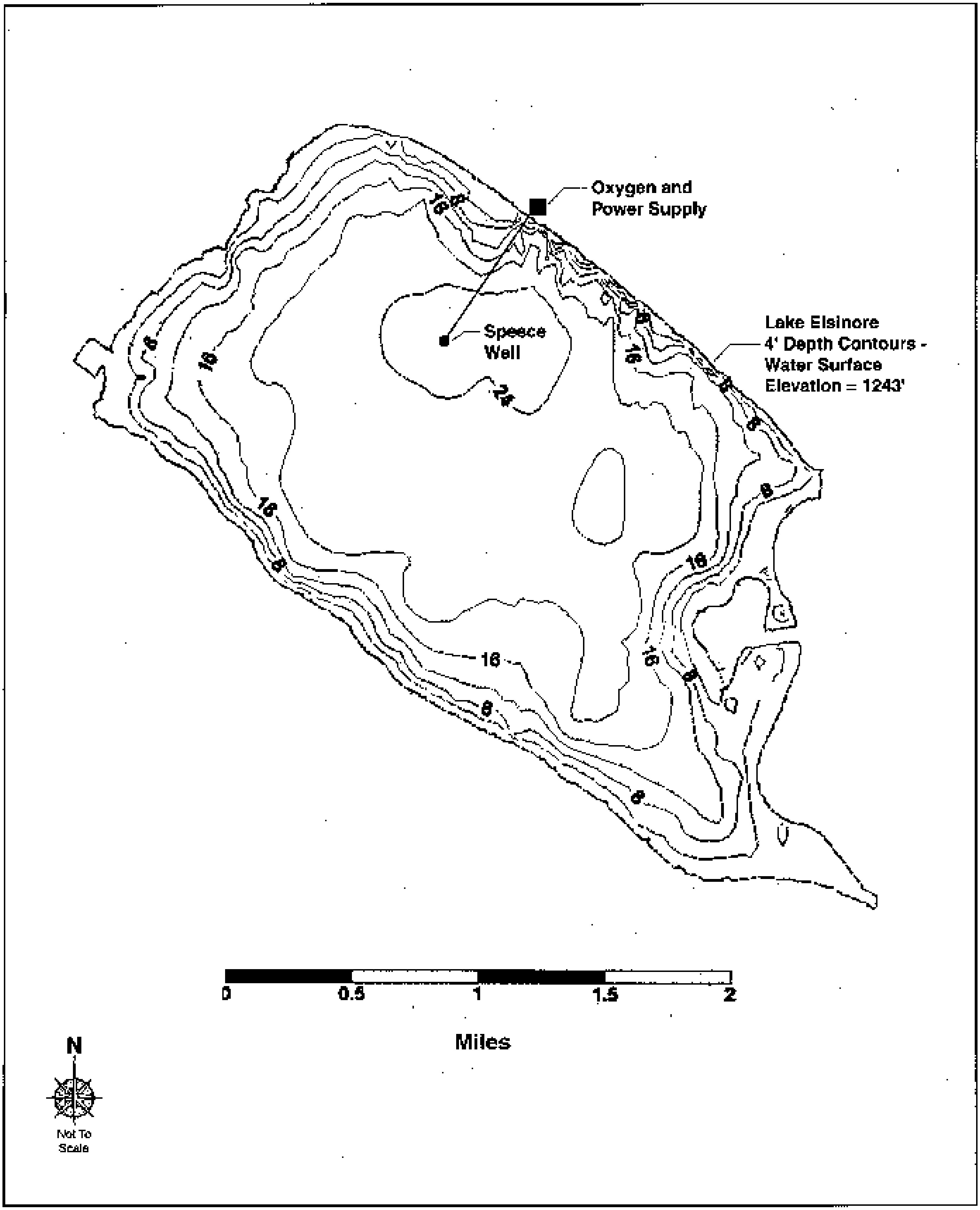


Figure 6-3

**Speece Well Oxygenation System
Location of Speece Well**

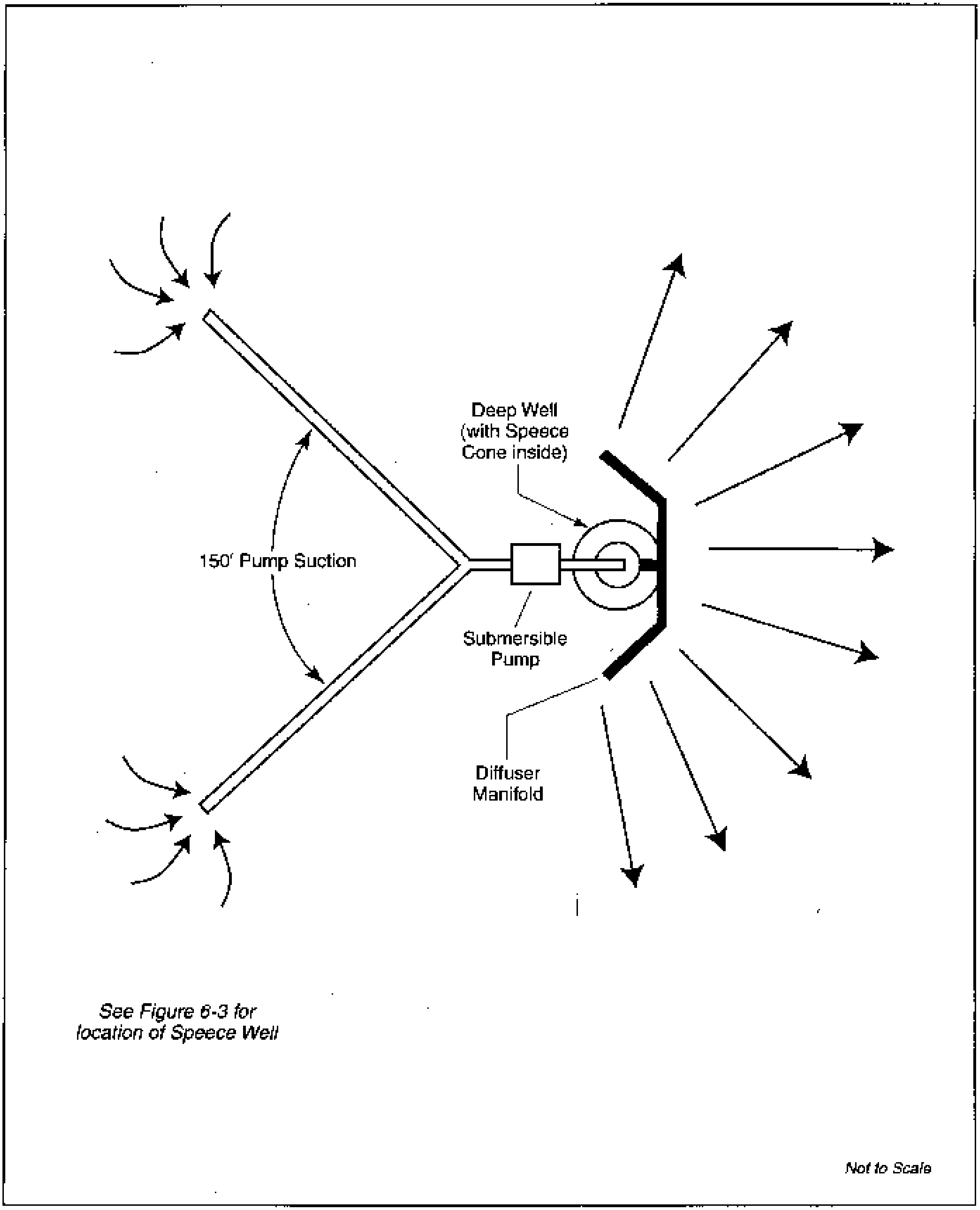


Figure 6-4

Speece Well Oxygenation System
Preliminary Layout (Top)

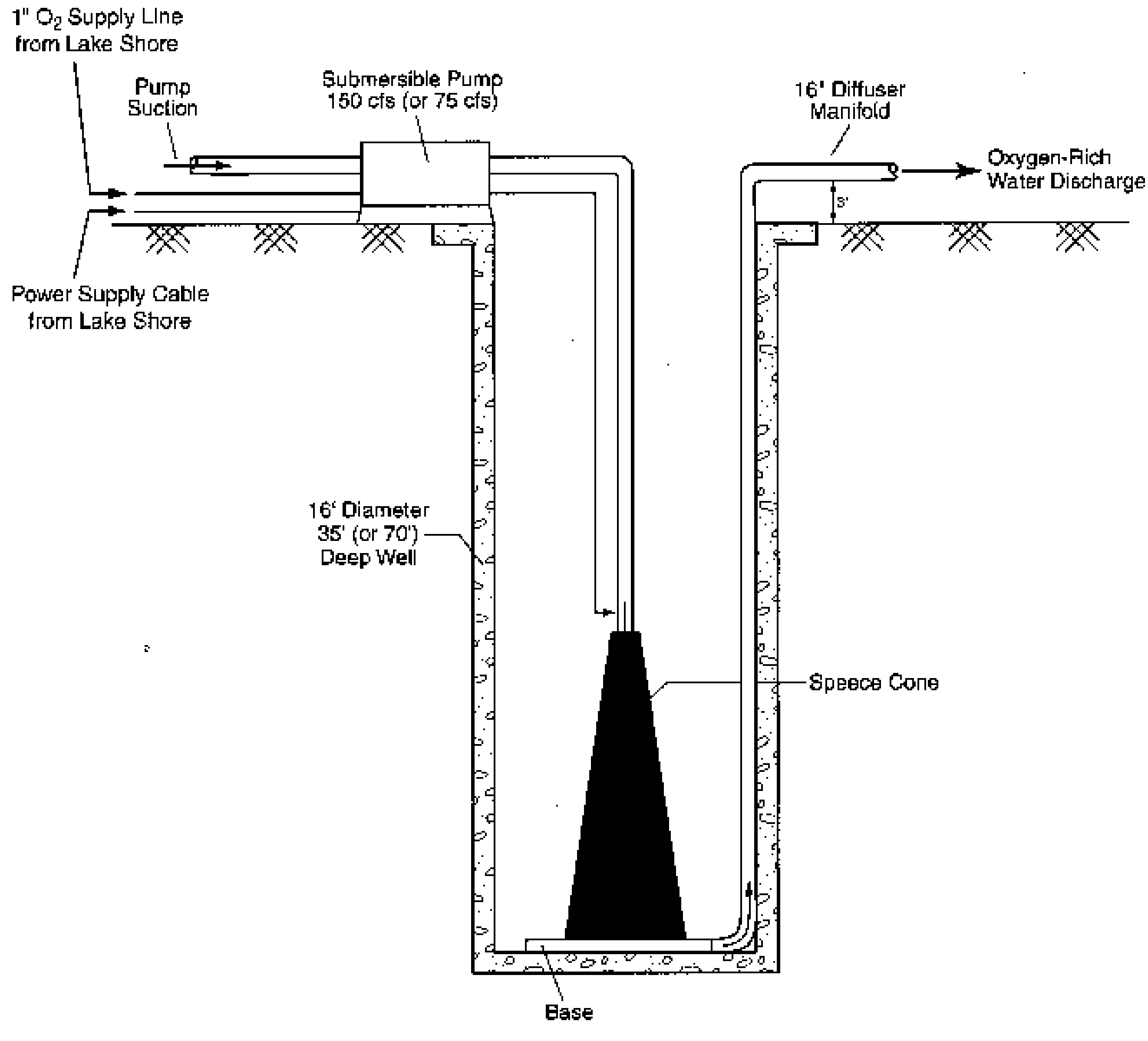


Figure 6-5

Speece Well Oxygenation System
Preliminary Layout (Section)

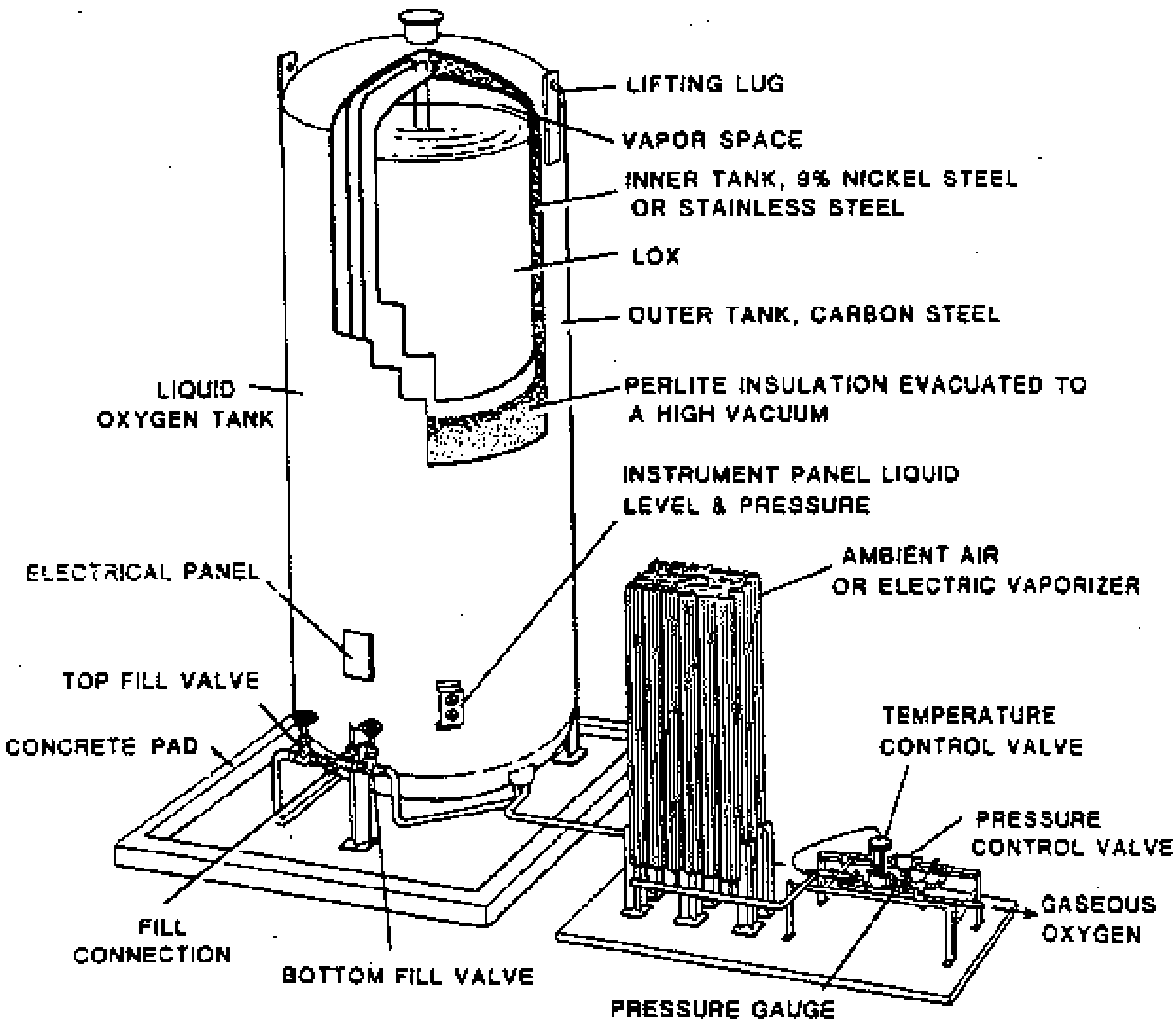


Figure 6-6
Typical Lox Tank Installation

Both the LOX and the VPSA/PSA equipment are available on a lease basis provided that concrete foundation, telephone line, power, lighting, and security enclosures are furnished. The minimum lease agreement would be 3-5 years for the LOX system and as long as 15 years for the VPSA/PSA system. Leasing is a common practice in the LOX industry. It has the advantage that capital costs are reduced and maintenance is performed by the tank supplier, but has the disadvantage that some of the facilities may not be accessible to the lake operations staff. Leasing terms may also not be optimal because the leases are normally paired with long-term LOX purchase agreements.

If the oxygen supply equipment is to be purchased, the LOX system would cost approximately $600,000 less than the VPSA system. This difference is just about the estimated annual operating cost for the LOX system. Operating cost for the VPSA system is about one third of the LOX system based on preliminary information furnished by the vendors. Because the actual usage of oxygen and required duration of lake oxygenation may vary from assumptions made by this study, final selection of the oxygen supply system is pending a more detailed life-cost analysis.

An outlet manifold for the outflowing water from the Speece Cone would be needed on the lakebed. The expected size is about 16 inches in diameter and 50 to 150 feet long (size and shape yet to be determined) with 2 inch holes every foot (this may also be modified). The manifold would sit about 3 feet above the lakebed (exact height still to be determined). Note that sizing of the Speece Well oxygenation system would need to be verified during design if this system is chosen.

6.4 PUMPED STORAGE TAILRACE OXYGENATION SYSTEM

EVMWD is currently investigating a 500 megawatt high-head pumped storage project located in the Cleveland National Forest south of Lake Elsinore that would use Lake Elsinore as the lower reservoir. The upper reservoir would be created in either Morrell Canyon or Decker Canyon. Water from Lake Elsinore would be pumped uphill by reversible turbines and stored in the upper reservoir at night when electricity is less expensive that at daytime rates. Then, during daylight hours when electricity demand increases, the stored water would be released downhill back into the lake to drive the reversible turbines and generate power to sell when electricity rates are higher. A maximum of 18 inches of daily lake level variance would be expected with this type of project.

If the pumped storage project was to be implemented, the lake enhancement project would benefit from the low-cost electric power and some shared facilities, especially the aeration/oxygenation system. A side-stream type of oxygenation system could be developed to couple with the pumped storage project. Oxygen could be injected in the water coming out of the turbines and return to the lake using the project's piping network. This potential oxygenation alternative cannot be fully developed at this time, because details of the pumped storage project are not yet finalized.

6.5 RECOMMENDATIONS

Based on the analysis performed above, it appears that the Speece Well oxygenation system is a preferred option for a shallow lake like Lake Elsinore, because much less subsurface facilities are involved. In addition, the Speece Well oxygenation system has the advantage of delivering highly oxygenated water directly into the deepest part of the lake water-sediment interface. Section 9 of this report provides a preliminary cost analysis of the aeration/oxygenation system, which shows that oxygenation is the cost effective alternative and is therefore recommended.

Theoretically, Lake Elsinore experiences low oxygen levels for about 120 days per year, between mid-June to mid-October. However, it is recommended that a system be designed to allow an average daily delivery of 20 tons of oxygen to the lake bottom for the first few years. Subsequent oxygen demand should decrease by up to two-thirds of the initial delivery/demand rate.

SECTION 7
WETLANDS TREATMENT

7.1 GENERAL

Natural or constructed wetlands have become increasingly popular in the United States for the treatment of municipal wastewater, industrial process water, stormwater, and agricultural runoff. They can provide both an enhanced aquatic wildlife habitat and a natural water purification process. A well planned and designed wetland ecosystem will not only remove a variety of pollutants from the water, but may also provide visual, ecological, cultural and recreational benefits. Of particular interest for this project is a wetland's sediment and nutrient-sink capabilities, attributes that have been demonstrated from decades of data collected at various wetland systems. Wetlands are here defined as shallow water areas (0.5 to 2.0 feet deep) occupied primarily by emergent and submergent plants such as reeds, bulrush, cattail, pondweed, and water lilies. The key mechanisms that make water quality improvement possible in wetlands include:

- Uptake (and harvesting) of emergent plants
- Subsurface bacterial nitrification and denitrification
- Screening/filtration of particulates
- Sedimentation (accelerated if coagulants are added)

Wetlands treatmentplays multiple roles for this project. Four tiers of treatment function are intended for wetlands treatment, including the following:

- **Recycled water "polishing."** In order to achieve one of this project's goals, an NPDES permit for discharging recycled water to Lake Elsinore for lake augmentation, nutrient levels in the recycled water may have to be reduced. Wetlands will remove total nitrogen (TN) and total phosphorus (TP) from the recycled water that is delivered in the winter months before it is introduced to the lake. The 500-acre treatment wetland at Prado Basin, in Riverside County, has provided data for calculation of removal of TN and TP.

- **Algae removal.** Wetlands can directly filter diverted lake surface water to remove nuisance algae and other large particulate detritus in the lake that causes problems in the summer. Eutrophication studies in the very large Lake Apopka in Florida, using a wetland of a similar size to the one proposed for Lake Elsinore, removed more than 90 percent of the TN and TP in an experimental full-scale performance test. Additional credits may be claimed by this project for the enhancement of lake water quality.

- **Nuisance flow treatment.** High levels of nutrients contained in the nuisance flows (e.g. irrigation and agricultural runoffs) that eventually drain into Lake Elsinore will increase the nutrient budget of the lake. Removing TN and TP from the nuisance flows would also be beneficial to this project.

- **Regulatory compliance.** The existing wetland at Lake Elsinore is currently not in compliance with the conditions established by the US Army Corps of Engineers (ACOE) for the mitigation of the levee project described earlier in Section 1.2. Measures must be taken to achieve permit compliance. Wetlands created by this project can also be designed to meet ACOE's mitigation requirements.

Advantages of wetlands

- Wetlands are fully compatible with all other uses including wildlife, recreation, education, and aesthetic enjoyment.
- Almost all of the nuisance algae are directly removed from the lake water in summer.
- System is self-maintaining (except for water conveyance).
- Quite a simple process and has been tested in large lakes.
- No toxicants added.
- Works in conjunction with all lakes.
- Will remove soluble nutrients as well as sediment if hydraulic residence time is long enough and temperature is greater than 15°C.
- Wetlands can be constructed where convenient.
- Will increase values of properties near wetlands.

Disadvantages of wetlands

- Need to move large volumes of water (but can use solar, wind or other sources of power). Water must be pumped in or out of the wetlands, depending on the design and the biological, metabolic activity in the wetland species.
- Some of the algae removed in summer will die and the nutrients eventually recycled back to the lake (probably in fall or winter), unless harvested or removed.
- Need to acquire considerable acreage of land for wetland construction, unless using the existing wetlands area is utilized.

7.2 EXISTING WETLANDS

As described earlier, a 350-acre wetland was constructed in the Back Basin at the historic terminus of the San Jacinto River southeast of Lake Elsinore in 1991, to mitigate the impact of levee construction that reduced the lake's surface area in order to reduce evaporation. The location of the existing wetland is shown on Figure 3-1. While the primary purpose was to provide habitat for migratory waterfowl, under appropriate water level conditions it can also function as shallow fish habitat linked to the main body of the lake by a 48-inch-diameter conduit through the levee. Other facilities were also constructed as part of the Lake Elsinore Management Project. The facilities are owned and operated by EVMWD. EVMWD entered into an agreement with the City of Lake Elsinore to maintain the wetlands, which includes periodic debris removal, replanting and inspection. The US Bureau of Reclamation (USBR), which provided primary funding for construction and transferred ownership to EVMWD in 1991, maintains an interest in the facility. The wetland has to meet environmental assessment conditions as well as special conditions established in the 404 Permit issued by Army Corps of Engineers (ACOE) and the 1601 Permit issued by the California Department of Fish and Game (CDFG). A summary of environmental commitment and mitigation requirements for the existing wetlands are provided in **Appendix I**.

The existing wetland consists of over 200 acres of water and three islands totaling over 100 acres. The bottom of the wetlands and top of the berm are at elevations of 1233 and 1248 feet MSL, respectively. Water level in the wetlands is to be maintained between elevation 1240 and 1243, providing a water depth of up to 10 feet. EVMWD has installed a water surface elevation marker as well as automatic water surface elevation sensors to monitor the water levels in the wetlands. When lake water or naturally occurring runoff is insufficient to maintain the water surface in this operational range, makeup water would be required. A wet well was constructed at the west end of the wetlands near the main levee to allow a pump installation in order to lower flood water levels after flooding periods. No pumps have been installed at this time.

The riparian habitat area, also known as the low flow channel, was established in the existing San Jacinto River bed downstream of the levee. This portion of the mitigation area was originally envisioned as a flow-through system whereby 3 cfs of water would make its way through a narrow low flow channel in the riverbed into the wetlands, thereby maintaining the wetland water level. However, a lake inlet system was constructed to redirect and convey the normal flows from the last mile of the San Jacinto River into the lake main body as part of the original Lake Elsinore Management Project. This restricts the availability of normal river water to flow to the wetlands. River water will only flow over the weir into the back basin during storm events.

EVMWD installed water ponding check structures adjacent to the wetlands to allow inundation of the entire width of the riverbed downstream of the levee. A pipeline was also constructed to supply makeup water to the riparian habitat from the Cereal Street wells on the northern edge of the wetlands. However, since the Cereal Street wells produce groundwater with very good quality they are currently used to meet EVMWD's potable water demands. Because no other suitable makeup supplies have been available, the low flow channel has been dry. EVMWD currently pumps lake water directly into the wetlands to maintain the water levels using temporary equipment. It should be noted also that water conveyed through the low flow channel will be partially lost to percolation caused by a groundwater depression (the "Sedco Cone") within the middle portion of the channel. EVMWD has plans to line this channel.

7.3 PROPOSED MODIFICATIONS

Although constructed wetlands can be located where convenient, the existing wetland site appears to be most feasible for this project at this time, unless other properties at more advantageous location in the Back Basin can be acquired. For the purpose of this study, it is assumed that the existing wetlands will be redesigned to meet the project goals as well as the mitigation requirements established by ACOE for levee construction. The redesigned wetlands will serve a dual purpose of mitigation and treatment.

The current wetland is too deep and devoid of aquatic plants and therefore has minimum water polishing capability and limited wildlife habitat value. A preliminary layout of the redesigned wetlands is shown on **Figure 7-1**. The modified system, starting from the water supply scheme, is described in detail below,

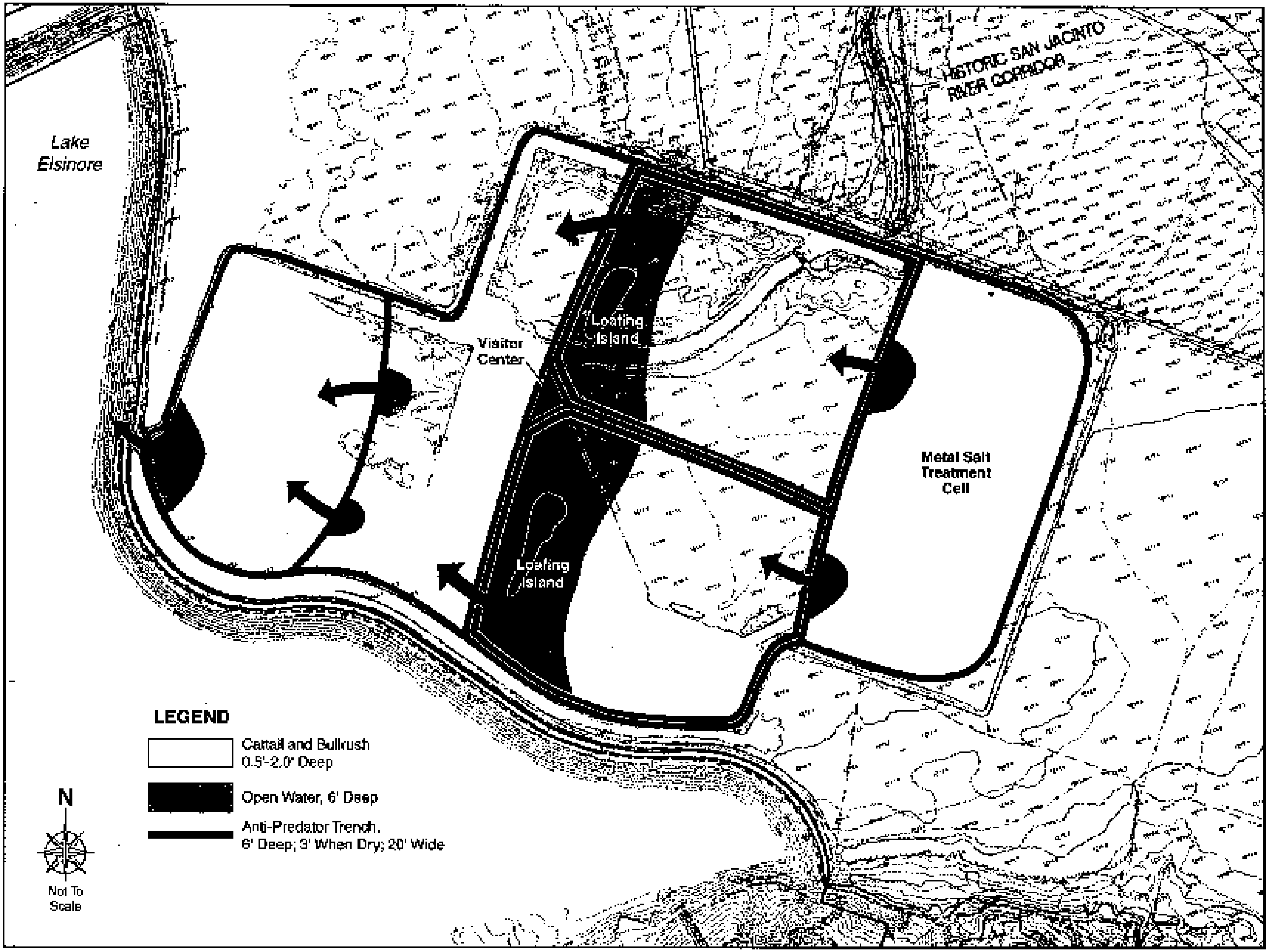


Figure 7-1

Modified Wetlands Plan

- The recycled water will be conveyed in a pipeline directly to the low flow channel (i.e. the last mile of historic San Jacinto River channel) during the winter months. However, the weir structure at the entrance to the low flow channel on the south side of lake inlet levee needs to be modified or rebuilt to allow lake surface water to enter the channel and reach the wetlands for algae filtration during the summer months. Although the operating level of the lake is to be maintained at 1240 feet MSL, the goal is to stabilize the lake level and maintain a minimum water surface level at 1245 feet after recycled water becomes available for lake augmentation. Provided that the lake water elevation is above 1245 feet, no additional pumping would be required to direct the lake surface water to the east end of lake inlet channel where the low flow channel begins.

- The low flow channel must be lowered and lined to allow conveyance of recycled water in the winter months (and lake surface water in summer months) to the wetlands for treatment. The channel needs to be re-graded to accommodate delivery of up to 15,000 acre-ft of recycled water in a 4-month period (about 40 mgd), and about 800 acre-ft/day (260 mgd) of algae-rich lake surface water in the summer. The summer flow estimate is based on circulating the entire photic (lighted) zone of the lake within 10 to 14 days. The actual volume of the photic zone is dependent on the lake water quality and may therefore vary. Suitable lining material such as pneumatically-applied concrete can be used to retard subsurface percolation within the channel to minimize water loss and protect the quality of underlying groundwater.

- With a more regular water supply to the wetlands, approximately 60 acres of riparian habitat can be established along the low flow channel, to gain additional wildlife and water treatment credits. This could translate to 600 lbs/year permanent removal of phosphorus based on 1 $g/m^2/yr$ removal, 1,500 lbs/yr seasonal storage of phosphorus, and 2 tons of nitrate removal based on 50 $mg/m^2/day$, within a 4-month period.

- Concepts similar to the original design were used in the redesign in order to minimize required modification work to the existing wetlands. The perimeter berms of the existing wetlands will remain unchanged. Shallow marsh areas (0.5 to 2.0 feet deep) as well as open water zones (6 feet deep) will be provided as shown on Figure 7-1. Five wetland cells are planned for this project with plug flow through the entire system. Deep trenches around the two middle cells protect wildlife against predators. The deeper zones and islands within the two middle cells are provided for waterfowl to take off and land. The other deeper areas are provided to keep the emergent vegetation clear of the water collection points within each cell and to keep water flowing through the system. The adoption of a multiple-cell system allows for periodic drawdown of individual cells, which is required for maintenance and interruption of vector (mosquito and midge) larvae development.

- Metal salts (e.g. ferric chloride, ferric sulfate, calcium carbonate) or Phosloc® can be added in the first wetland cell at low concentrations (2 to 10 mg/L, pending bench or pilot tests) to enhance and accelerate phosphorus removal from the incoming flows through precipitation, coagulation and settling. However, technical experts retained by the Lake Elsinore-San Jacinto Watershed Authority believe that the best option would be the use of calcium carbonate because of the high pH of the lake water.

- Based on preliminary calculations, the existing wetland bottom elevation of 1233 feet can be maintained for the deep zones in the redesigned wetlands, in order to minimize the required earthwork. The existing islands would have to be excavated to create deep zones and shallow marsh areas. Except for the top 6 inches, excavated material will be used to fill up other areas and create berms between cells. The required additional material can be hauled from the low flow channel, which needs to be lowered to allow lake water to circulate back through the wetlands. The goal is to balance the earthwork within the Back Basin so that no additional fill material is required.

- With the redesign proposed above, the water surface elevation in the wetlands would be at about 1240 feet. However, additional calculations using actual topographic information would be needed to confirm this number. The filtered lake surface water may have to be pumped back to the lake, if the water surface elevation exceeds 1240 feet. For planning purposes, three 80 mgd and one 40 mgd constant speed propeller pumps are assumed, each pump with 20 feet of total dynamic head (TDH). These pumps would also be able to manage the recycled water flows in the winter. The total pump power required is about 1,200 hp. A wet well with a 3-minute detention time at the maximum flow rate would also be required. When bio-manipulation takes hold, the larger zooplankton should filter larger volumes of lake water and reduce the volume of water necessary to be recirculated through the wetland. The pumps will discharge treated flow back to the lake via a 96-inch-diameter pipe. The length and exact location of discharge in lake can be determined at a later date.

- Since wetlands also provide recreational and educational opportunities, a visitor center near the redesigned wetlands could also be incorporated. Studies elsewhere (e.g. Arcata, CA) have shown that the economic benefit to providing good public access and education in wetlands can exceed the value of the treatment wetlands themselves. Similar visitor systems have proven successful at San Jacinto Wetland (IRWD, Orange County, CA) and are planned at the Prado Wetlands (OCWD, Riverside County, CA).

- CDFG requires that the initial plantings at the original wetlands be full density on 10-foot centers under the Lake Elsinore Management Project. Planting at 3-foot centers would speed the project and reduce costs for weed removal in the first few years. CDFG will again be consulted for the planting scheme of the redesigned wetlands.

SECTION 8
PROJECT OFFSETS

8.1 THE NEED FOR OFFSETS

As the problems of low water in summer 2001 have shown yet again, Lake Elsinore needs a more stable lake elevation if it is to become a popular destination for visitors and a desirable location for permanent lakeside dwellers. In addition, a more stable water level is essential for the submerged vegetation that forms the basis of the long-term lake management strategy of bio-manipulation. Finally, the desirable emergent riparian growth at the lake edges also requires a fairly stable water elevation. A good method to moderate the current water level fluctuations would be to add new water in winter from other sources than the natural drainage.

It is impossible to add water to a lake without adding at least some nutrients, and Lake Elsinore already has an excess of nutrients. In the Elsinore Valley the only reasonable source of large quantities of water is recycled wastewater, but this source has more nutrients than some other sources. As detailed in other sections of this report, the amount of bio-available nitrogen and phosphorus can be reduced though treatment down to about 1-2 mg/L. Since Lake Elsinore already has an excess of nutrients, the increase produced by the addition of a few thousand acre-feet of recycled makeup water has been experimentally demonstrated to make little difference to the trophic state of the lake. It is unlikely that any further degradation in the lake could be detected, and a more likely result is an improvement in the lake's beneficial uses. The lack of significant effect of moderate amounts of treated recycled water on the lake's trophic state is supported by two recent and substantial experimental studies (Montgomery Watson 1997, Anderson 2001).

Nonetheless, the Total Maximum Daily Load (TMDL) for Lake Elsinore requires a reduction in nutrient loading, even if beneficial use is not further impaired. For this lake, the best solution appears to be to offset the nutrients added in the makeup water by reducing nutrients elsewhere. In concept, the nutrient offset is an equal or greater amount of nutrients over those added by the recycled water. Offsets for nitrogen and phosphorus are needed since both these elements can be limiting in Lake Elsinore. In addition, if bio-manipulation is successful, nitrogen limitation is likely to become the norm in Lake Elsinore, partially due to denitrification among the stable sediments near the plant roots.

The main problem with the offsets is that a simple one-to-one swap does not seem appropriate. The reason for adding makeup water is to stabilize the lake level. If a one-to-one swap for nutrients added is made, no credit is given for the improvement in water quality due to the more stable water level. Presently there is no credit swap available between water level stability and added nutrients. However, this kind of credit exchange must be developed in arid regions where other solutions are inapplicable.

During project meetings with the RWQCB, Gerry Thibeault, Executive Officer of the Santa Region RWQCB, indicated that changing the management objectives of Lake Elsinore to allow recycled water discharge may be well justified (e.g. to support social/economic growth, gain maximum benefits) but could also be a lengthy process. He suggested that other measures be pursued, to maximize the potential nutrient offsets for nutrients added with recycled water.

These measures may include bio-manipulation, dry weather flow diversion in the watershed, treating lake water at wetlands, and other means, which have been discussed in the previous sections.

This section presents nutrient offsets that are quantifiable and identifies other potential offsets that are not quantifiable as a result of implementing various lake enhancement measures.

8.2 PHOSPHORUS OFFSETS THROUGH TREATMENT

Table 8-1A presents the offset values for phosphorus added in the recycled water when 7,500 acre-ft of flow are supplied to Lake Elsinore in the winter months. **Table 8-1B** presents the offset values for the most critical situation where 15,000 acre-ft per year are supplied, when no natural flows reach the lake. The phosphorus loading will be reduced proportionately to flow reductions for all but the internal load suppression, which will be similar for all years. At a flow of 15,000 acre-ft for four winter months, and with 1 mg/L phosphorus in the recycled water, the loading to Lake Elsinore will be 18.5 tons/yr. At 2 mg/L phosphorous concentration, the loading will be 37 tons per year. Since the maximum phosphorus retention rate would be exceeded, all additions are considered (winter, summer). The prediction for summer removal has been lowered to prevent over-estimation of annual phosphorus retention.

Table 8-1A
Phosphorus Offsets with
7,500 acre-ft Recycled Water Addition to Lake Elsinore
(All units shown in tons/yr)

Time Period	Winter Wetland[1]	Summer Wetland[1]	Metal Salt Treatment Wetland[2]	Internal Loading Suppression[3]	Total Offset	Total Loading	Phosphorus Removal
1-5 yrs[4]	7	7	13.5	12.5	40 +	18.5	**21.5**
1-5 yrs[5]	7	7	4.5	12.5	31 +	9.3	**21.7**
> 5 yrs[4,6]	1	1	13.5	12.5	28 +	18.5	**9.5**
> 5 yrs[5,6]	1	1	4.5	12.5	19 +	9.3	**9.7**

See footnotes under Table 8-1B.

Table 8-1B
Phosphorus Offsets with
15,000 acre-ft Recycled Water Addition to Lake Elsinore
(All units shown in tons/yr)

Time Period	Winter Wetland[1]	Summer Wetland[1]	Metal Salt Treatment Wetland[2]	Internal Loading Suppression[3]	Total Offset	Total Loading	Phosphorus Removal
1-5 yrs[4]	7	7	13.5	12.5	40 +	37	**3.0**
1-5 yrs[5]	7	7	4.5	12.5	31 +	18.5	**12.5**
> 5 yrs[4,6]	1	1	13.5	12.5	28 +	37	**- 9.0**
> 5 yrs[5,6]	1	1	4.5	12.5	19 +	18.5	**0.5**

1 Wetlands of 350 acres will be the reconfigured wetland now in existence as a shallow lake extension of Lake Elsinore. The wetlands will be designed to optimize shorebird and vegetation-loving birds. In four winter months recycled water at 15,000 acre-ft per winter will be passed through and in four summer months about 800 acre-ft/day will be pumped through to remove algae (summer lake TP is taken as 650 ug/L from historical data). Initial P-retention rates based on empirical data from Prado Wetlands in Riverside County during October-December period when 13-18 mg P m-2 y-1 was recorded (mean of 15 mg P m-2 y-1 is used here and pro-rated for 4 months).

2 Assumes inflow of 2 mg/L TP reduced to 0.5 mg/L (z = 3 feet, HRT = 3 days, 50% of inflow treated with alum or ferric, possibly with polymers. Estimated decrease in wetland life factor of two). If phosphorus is supplied at 1 mg/L, reduction will be 4.5 tons.

3 Based on empirical results for chambers containing Lake Elsinore sediments in summer 2000, literature reviews (see Beutel memo 14 September 2000), similar experiments in fall 2000 and summer fall 2001 by Dr. Anderson (see review in section 4), and consideration of calculations on mass loading by Pat Kilroy (memo Nov. 1997). Area of anoxic sediment is taken as 2000 acres, for six months. Recently, Dr. Anderson has estimated from laboratory studies that 33 tons of phosphate are released from the sediments and 27% or 9 tons would be suppressed by oxygenation. The mean suppression for all the world's lakes for aeration/oxygenation is 50% or 15 tons and values up to 95% have been recorded. The degree of anoxia (Redox potential) of the sediments in Dr. Anderson's laboratory enclosures was not recorded to it is not clear if the results are fully quantitatively applicable to Lake Elsinore. A meeting between Dr. Anderson, Dr. Buetel, Mr. Kilroy and Professor Horne in Madison Wisconsin it was agreed that an offset of 12.5 tons/y was the best current number for a phosphorous offset for an aerated or oxygenated lake.

4 Assumes that inflow will be 2 mg/L TP.

5 Assumes that inflow will be 1 mg/L TP

6 Rates greater than 5 years based on 2 mg P m-2 y-1 or twice the long term rates of Richardson for US wetlands. Greater retention based on designed wetlands of higher productively and thus greater long term storage potential than US average which includes natural wetlands of all kinds.

A sediment-soluble reactive phosphorus (SRP) release rate of 16.8 mg/m^2/day was found by Dr. Beutel and used for his estimate of the offset in internal phosphorus loading that could be achieved by an oxygenation system. This is the average of the July, August and adjusted September release rates multiplied by a factor of 0.95 to account for minor phosphorus releases observed under oxic conditions, and assuming an anoxic surface area of 2,000 acres yields a monthly release of 4,100 kg (4.5 tons)-P. Anoxia at the sediment-water interface likely occurs for six months during the summer and fall. Thus, Dr. Beutel's estimate of the internal loading offset that could be achieved in the lake is estimated at approximately 25,000 kg-P (27 tons) per year. This value is identical with the original estimate of Dr. Anderson but substantially less than the estimate of several hundred tons made earlier (with no laboratory data) by Mr. Kilroy. The second estimate made by Dr. Anderson was 33 tons/yr. At a meeting between Dr.

Anderson, Dr. Buetel, Mr. Kilroy and Professor Horne in Madison Wisconsin in November 2001, the latest results were reviewed. It was unanimously agreed that an offset of 12.5 tons P/y was the best estimate for a phosphorous offset for an aerated or oxygenated Lake Elsinore. The P offset number of 12.5 tons per year has therefore been incorporated into Tables 8-1A-B.

8.3 NITROGEN OFFSETS THROUGH TREATMENT

The offsets for nitrogen can be calculated in a similar fashion to that used for nitrogen. **Table 8-2A** presents the offsets for nitrogen added in the recycled water when 7,500 acre-ft of flow is supplied to Lake Elsinore in the winter months. **Table 8-2B** presents the offset values for the most critical situation where 15,000 acre-ft per year are supplied to the lake when no natural flows reach the lake. The nitrogen loading will be reduced proportionately to flow decreases for all but the internal load suppression, which will be similar for all years. At a flow of 15,000 acre-ft for four winter months and with 1 mg/L nitrogen in the recycled water the loading to Lake Elsinore will be 18.5 tons/yr. At 2 mg/L nitrogen concentration, the loading will be 37 tons per year. Unlike phosphorus removal, the maximum known rate of nitrogen removal for wetlands is not exceeded during additions of various summer and winter removal rates.

Table 8-2A
Nitrogen Offsets with
7,500 acre-ft Recycled Water Addition to Lake Elsinore
(All units shown in tons/yr)

Time Period	Winter Wetland[1]	Summer Wetland[1]	Metal Salt Treatment Wetland[2]	Internal Loading Suppression[3]	Total Offset	Total Loading	Nitrogen Removal
1-5 yrs[4]	~ 10	245	8	75	338+	18.5	320
1-5 yrs[5]	15	245	8	75	343+	9.3	334
> 5 yrs[4,6]	15	245	17[7]	75	352+	18.5	334
> 5 yrs[5,6]	29	245	17[7]	75	366+	9.3	357

See footnotes under Table 8-1B.

Table 8-2B
Nitrogen Offsets with
15,000 acre-ft Recycled Water Addition to Lake Elsinore
(All units shown in tons/yr)

Time Period	Winter Wetland[1]	Summer Wetland[1]	Metal Salt Treatment Wetland[2]	Internal Loading Suppression[3]	Total Offset	Total Loading	Nitrogen Removal
1-5 yrs[4]	~10	245	8	75	338+	37	301
1-5 yrs[5]	15	245	8	75	343+	18.5	327
> 5 yrs[4,6]	15	245	17[7]	75	352+	37	315
> 5 yrs[5,6]	29	245	17[7]	75	366+	18.5	348

1 Wetlands of 350 acres will be the reformed wetland now in existence as a shallow lake extension of Lake Elsinore. The wetlands will be designed to optimize shorebird and vegetation-loving birds. In four winter months recycled water at 15,000 acre-ft per winter will be passed through and in four summer months about 800 acre-ft/day will be pumped through to remove algae (summer lake TN is taken as 2,077 ug/L from historical data (but see Table 8-3 for alternate values). Also assumes 50% recycle that may not occur since there is capacity in the wetlands to denitrify all the added-N. TN removal rates based on tests on similar-sized wetlands at Lake Apopka, Florida. Denitrification rates based on empirical data from Prado and IRWD Wetlands in Riverside & Orange Counties.

2 Based on expected removal of inorganic N (supplied as nitrate or ammonia) in lake water using a low rate based on Prado and IRWD wetlands of 50 $mgN/m^2/d$. Assumes winter nitrogen inflow of 2 mg/L nitrate and ammonia.

3 Based primarily on empirical results for chambers containing Lake Elsinore sediments in summer 2000, literature reviews (see Beutel memo 14 September 2000) and consideration of calculations on mass loading by Pat Kilroy (memo Nov. 1997). Area of anoxic sediment is taken as 2000 acres, for six months.

4 Assumes that inflow will be 2 mg/L nitrate.

5 Assumes that winter nitrogen inflow will be 1 mg/L nitrate and ammonia

6 Rates of denitrification in the summer will be greater after 5 years due to the accumulation of plant litter.

Total nitrogen (TN) as algae will be almost completely retained by the wetlands acting as a physical filter. Unlike phosphorus, where recycling and subsequent release to the lake of a majority of the originally retained TP is possible, most of the retained TN should never reach the lake. Because of the highly dynamic nature of nitrogen cycling at the sediment-water interface, it is not as straight-forward to directly estimate the decrease in nitrogen internal loading that would be achieved as a result of oxygenation. Experimental results suggest that in the wetlands, sediment nitrogen release would shift from ammonia to nitrate, a nitrogen species that is non-toxic to fish. Total sediment nitrogen release is expected to decrease since nitrate is susceptible to denitrification. TN recycling is less than TP and there is sufficient denitrification capacity in the wetlands to denitrify all the TN removed. Any recycled TN will be transformed to ammonia then to nitrate and then removed as nitrogen gas. However, conservative assumptions have been made assuming that the TN removal process will only range from 33 to 50 percent.

Table 8-3 shows the TN removal rates based on different recycle rates. Various assumptions based on 1990 and more recent TN data and assumptions on recycling rates of algae (TN) removed in wetlands were used.

Table 8-3
Nitrogen Removal through Wetlands Filtration in Summer for Lake Elsinore
(All units in tons)

Flow Passed through Wetlands in Summer	TN = 6000 ug/L 50% Recycle Rate	TN = 2,077 ug/L 50% Recycle Rate	TN = 2,077 ug/L 67% Recycle Rate
400 acre-ft/day	700	245	204
800 acre-ft/day	350	123	102

8.4 LAKE LEVEL STABILIZATION CREDITS

As mentioned above, there is no direct credit for water level stabilization and nutrients added. For Lake Elsinore and ideal way to manage water levels for biomanipulation and people would be so that the extreme variation (+35 feet to dry lake) in Lake Elsinore is reduced to +/- 2.5 feet

(5 foot range) or preferably +/- 1.25 feet (2.5 foot range). However, since there is five feet of evaporation each summer and water is only available in winter, a five-foot range is the best that can be expected with current recycled water inputs. Currently, recycled water can be added to make up the lake volume lost to evaporation as long as the added nutrients can be offset by other means. Maintaining a stable lake level will have the following advantages, which should also be considered as credits for this project:

- Recreation is improved, docks are easier to use, and extensive mud flats do not form in summer. People prefer a stable lake level.
- Shoreline emergent and submergent vegetation can grow (but needs to be controlled in high use areas). Stable level makes lake aesthetically more pleasing and natural.
- Suspended sediments are reduced as submerged and emergent plants stabilize the soil and reduce the stirring action of the waves.
- Bio-manipulation is enhanced since the submerged plants provide daylight refuges for the zooplankton including *Daphnia* and also juvenile sport fish. In turn *Daphnia* eat algae during the night.

The quantification of lake level stabilization credits has not previously been attempted. In principle the benefits of lake stabilization can be converted to dollar values. The cost to remove nitrogen from a range of 6 to 8 mg/L down to 4 mg/L and phosphorus from 4 to 2.5 mg/L can also be estimated. The balance between the two can provide a basis for credit offsets. The value of 4 mg/L for total nitrogen and 2.5 mg/L for total phosphorous are used as targets because this level of treatment can be accomplished on a consistent basis through biological nutrient removal technology.

8.4 OTHER CREDITS

Although not easily quantifiable, diversion and treatment of nuisance flows should also be deemed as credits for this project. Nuisance flow removal will consist of diverting these flows from storm drain/open drain to sanitary sewer to wastewater treatment facilities (if collectable) or treating these flows directly at the wetlands (carried by runoff).

SECTION 9
COST ANALYSES

This section presents estimates of makeup water, potential cost benefits to the lake, and costs of lake management. Construction and operation/maintenance (O&M) costs are associated with the incorporation of various lake enhancement measures that would allow recycled water discharge to Lake Elsinore for lake level stabilization.

9.1 COST OF MAKEUP WATER SUPPLIES

The need for makeup water for Lake Elsinore could be met by potentially potable water from wells, as is the case for many small (20-100 acre shallow lakes in southern California. Other sources are imported drinking water from the Metropolitan Water District of Southern California (MWD) that supplies much of the Los Angeles region. However, the State of California has decreed that potable water can only be used to replenish potable waters sources. In droughts, when the situation is most critical in Lake Elsinore, drinking water is in great demand in Southern California that imports waters from both Colorado River to the east and the Sacramento River to the north. Non-potable well water is a possible makeup source but several possible wells contain high levels of nutrients or salts. Thus reclaimed municipal effluents is a good potential source of makeup water in terms of volume as long as the nutrients present do not affect other beneficial uses of the lake. Balancing the supply are the costs (Table 9-1).

Costs for non-recycled water in the region (Table 9-1) vary from $125/af (local wells) and $266/af (MWD agricultural grade) to $475/af (treated MWD Colorado River). Local wells are unlikely to produce an adequate supply so the annual costs for makeup water are $4 to $7.1 million (15,000 af) and $0.66 to $1.2 million (2,500 af/yr). The 2,500 af volume is based on the likely amount of available recycled water in the early years. Recycled water costs are $106/af giving a cost of 1.6 million for droughts and $0.26 million in most years. Recycled water is the only viable option based on the volumes needed, legal considerations on the most appropriate use of drinking water supplies, economics and beneficial use considerations.

Table 9-1
Costs of Various Water Supplies to Lake Elsinore
Including Potable and Reclaimed Sources (1999 dollars)
(Source, EVMWD, May 3, 2000)

Water source	Dollar cost per acre-foot	Annual dollar costs for 2,500 af/yr	Annual dollar costs for 15,000 af/yr
Local wells[1]	> 125	> 312,500	1,875,000
MWD agricultural grade	266	665,000	3,990,000
Uninterrupted MWD supply	350	625,000	5,250,000
Treated MWD water	475	1,187,500	7,125,000
Reclaimed water, municipal supply	106	265,000	1,590,000

[1] Costs for local wells were not adjusted for the recent approximate doubling in electricity needed for pumping.

The economic advantage of using a reclaimed supply is obvious from Table 9-1. The current population in the area is 85,000 and is estimated to rise to 173,000 by 2020 due to the attractiveness of the area for retirees. Thus the strain on local and imported potable water supplies would make unavailable even the costly sources listed in Table 9-1. The amount of reclaimed water would, however rise with the population (Fig. 2) and the amount available to fill the lake in winter would not be threatened by other reuse needs.

9.2 ECONOMIC BENEFITS OF USING RECYCLED WATER FOR LAKE LEVEL STABILIZATION

Without makeup water Lake Elsinore could dry up completely once every 10 to 20 years with average rainfall distribution. In the 1990s the two El Nino years provided an above normal water supply. The lake was expected to dry up in 1991 but late rains resulted in an inflow of 18,000 af of water from the San Jacinto River. This unusual inflow raised the lake level over 6 feet.

The cost of a desiccated lake to local businesses has been estimated at $20 million (Lake Elsinore Management Authority, 1993). Assuming a dry lake on average every ten years the cost benefit from a stabilized lake is $2 million per year.

Assuming the costs of a variable lake elevation are proportional to the costs for complete desiccation a value of the water in the lake to local businesses is about $800,000 per foot assuming that the lake is full at 1255 feet elevation (maximum depth ~ 25 feet). The desirable level for recreation has been established at 1240-1249 feet so that cost benefit can only be claimed for water elevation stabilization below 1249 feet. With a dry lake every 10 years, the lake elevation will be below 1249 feet about half of the time resulting in a dollar loss of $3.3 million (5 x $800,000) or $400,000/y over five years.

The economic benefit of lake stabilization between 1240 and 1248 feet can thus be summed as $23.3 million per decade or about $2.4 million/y. This cost benefit can be compared with the one-time construction costs of the proposed restoration (~ 12 million) and O & M costs of about $1 million including pumping of lake and makeup water (see below).

9.3 COSTS OF THE PROPOSED RECYCLED WATER SUPPLY AND LAKE MANAGEMENT TECHNIQUES

The probable construction and O&M costs of various components required to bring recycled water from EMWD to Lake Elsinore are summarized below. The three selected in-lake management schemes are shown in Table 9-2 and some contenders that were eliminated from final consideration are shown for comparison in Table 9-3. These costs are based on information presented in the previous sections of this report. Present worth of the project is also included based on a 20-year duration and 8 percent interest rate. Key assumptions are also listed in the table for clarification. The presented estimates are "reconnaissance level" opinion of probable costs which are expected to have an accuracy of +30 percent to -30 percent.

As shown in Table 9-2, the present worth of the oxygenation system is several million dollars less than the aeration system. Thus, oxygenation is the recommended alternative.

Table 9-2
Lake Elsinore Enhancement Preliminary Cost Estimates
Three Recommended In-lake and Two Watershed Techniques

	Facility Description	Capital Cost	Annual O&M Cost	Present Worth (1)
A	**Recycled Water Conveyance** 54" pipe to lake inlet; flow isolation valve; new energy dissipation facility; lake inlet/weir structure modification; low flow (river) channel excavation and haul; channel lining	$3.3 M	$20 k	$3.5 M
B	**Redesigned Wetlands** Earth work; flow distribution structures; wetlands and littoral planting; metal salt feed facility; 260 mgd constant speed propeller pumps operating at 40 mgd for 4 winter months and 260 mgd for 4 summer months; pump wet well; electrical & control; visitor center; system maintenance	$7.1 M	$400 k (2) ($186k on power)	$10.9 M
C	**Bio-manipulation** Fish netting	$100 k	$30 k	$387 k
D	**Oxygenation System (SDOC)** Liquid oxygen storage and feed facility, walled, feeding 20 tons/day oxygen for 8 months per year(4); 16-inch-diameter Speece well, 35 feet below lake bottom; 200 hp submersible pump; 54" pump suction pipes; Speece cone and base; outlet manifold; anchored oxygen supply and electrical cable from lake shore to lake bottom; LOX consumption; system maintenance	$1.7 M	$570 k (3) ($452k on LOX, $95k on power)	$7.1 M
E	**Aeration System (Conventional)** 8-650 scfm, 2.2 bars compressors with acoustic enclosures, fenced, operating at 80% design flow for 8 months per year (4); electrical & control; anchored air headers to lake central location; anchored 600,000 LF air distribution lines and 1000 diffusers throughout the lake; system maintenance	$11.1 M	$350 k (3) ($146k on power, $180k on maintenance of air lines)	$14.4 M
	Total Cost with Oxygenation System (A+B+C+D)	$12.2 M	$1.02 M	$21.89 M
	Total Cost with Aeration System (A+B+C+E)	$21.6 M	$0.8 M	$29.19 M

(1) Present worth is calculated based on a 20-year duration and 8% interest rate.
(2) Cost will be substantially lowered when biomanipulation is in place.

(3) O&M cost expected to decline by 50 to 70% after the first 3-5 years of operation.
(4) 8 months of operation is the likely maximum, once the initial few algal blooms, time of actual operation in 3-5 years could be as little as 4 months.
(5) Present worth is calculated based on a 20-year duration and 8% interest rate.
(6) Cost will be substantially lowered when biomanipulation is in place.
(7) O&M cost expected to decline by 50 to 70% after the first 3-5 years of operation.
(8) 8 months of operation is the likely maximum, once the initial few algal blooms, time of actual operation in 3-5 years could be as little as 4 months.

Table 9-3
Lake Elsinore Enhancement: Preliminary Cost Estimates for In-lake Management Options Not Recommended for Reasons of Cost and Efficiency
Presented for Comparison

	Facility Description	Capital Cost	Annual O&M Cost	Present Worth (1)
F	**Calcium Carbonate addition** Calcium carbonate addition to 2,000 acres of P-releasing organic sediments. One-time application, barges and lakeside storage and delivery system.	$3.0 M	One-time capital cost	$3.0 M

9.4 BALANCE BETWEEN COSTS AND BENEFITS OF THE PROJECT

The cost of the proposed lake stabilization project to be carried out in association with this NPDES permit application should consider both the capital and O & M costs of in-lake and watershed restoration projects. The total cost for the new recycled water pipeline modification, redesigned wetlands, biomanipulation, and lake oxygenation systems was estimated at $12.2 million (capital cost) with annual O & M costs of approximately $1 million (See Table 9-2). The benefits are estimated at $2.4 per year. The cost-benefit ratio for O & M and direct recreational benefits is thus 1:2.4 on the positive side. These benefits exclude any multiplier effect on the local economy and the public good will that may increase, for example, the cost of lakeside property by will increase by a factor of between one and a half to three.

APPENDIX A

RWQCB Staff Report

Problem Statement
for
Total Maximum Daily Load
for
Nutrients in Lake Elsinore

California Regional Water Quality Control Board

Santa Ana Region

STAFF REPORT

PROBLEM STATEMENT FOR TOTAL MAXIMUM DAILY LOAD FOR NUTRIENTS

In

LAKE ELSINORE

California Regional Water Quality Control Board

Santa Ana Region

Winston H. Hickox
Secretary for Environmental Protection

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Phone (909) 782-4130 - FAX (909) 781-6288

Gray Davis
Governor

September 26, 2000

TO: LAKE ELSINORE TOTAL MAXIMUM DAILY LOAD (TMDL) MAILING LIST

TRANSIMITTAL OF THE LAKE ELSINORE NUTRIENT TMDL PROBLEM STATEMENT

Enclosed is a copy of the staff report for the Lake Elsinore Nutrient TMDL Problem Statement. This staff report will be presented to the Regional Board on October 6, 2000 at the regularly scheduled Regional Board Meeting. The Regional Board meeting time and location is as follows:

DATE:	**October 6, 2000**
TIME:	**9:00 a.m.**
LOCATION:	**City Council Chambers, Loma Linda** **25541 Barton Road** **Loma Linda, California**

Should you have any questions regarding the staff report, please feel free to contact me at (909)782-4493 or you may contact Cindy Li at (909)782-4906.

Sincerely,

Hope A. Smythe

Hope A. Smythe, Chief
Planning Section, Inland Waters

enclosure

FILE:HAS;MEMLETS;ELSINORETRANSMIT.DOC

Executive Summary

Clean Water Act Section 303(d) requires that States identify waters that do not or are not expected to meet the water quality standards (beneficial uses, water quality objectives) with the implementation of technology-based controls. Once a waterbody has been listed on the 303(d) list of impaired waters, states are then required to develop a Total Maximum Daily Load (TMDL) for the pollutant causing impairment. A TMDL is defined as the sum of the individual waste load allocations for point sources, load allocations for nonpoint sources and natural background. TMDLs must also address seasonal variations and include a margin of safety. In 1994, the Regional Board identified Lake Elsinore as impaired due, in part, to excessive levels of nutrients. As a result of the listing, the Regional Board has initiated the development of the Lake Elsinore nutrient TMDL.

This report provides an overview of the Lake Elsinore watershed, a history of the algal bloom and fish kill problems of Lake Elsinore, a summary of the lake eutrophication processes, and past studies conducted on Lake Elsinore. The report also summarizes proposed numeric targets for the Lake Elsinore nutrient TMDL, as well as activities to be undertaken by Regional Board staff and other agencies to develop the nutrient TMDL and restore Lake Elsinore.

Regional Board staff is not proposing that any formal action by the Regional Board on the Lake Elsinore nutrient TMDL be taken at this time. The intent of this report is to provide the Board and the public with background information and staff's initial strategy and ideas for development of the Lake Elsinore nutrient TMDL.

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1.0 Description of Lake Elsinore and the San Jacinto River Watershed

Lake Elsinore lies 60 miles southeast of Los Angeles and 22 miles southwest of the City of Riverside. The Lake is located within the City of Lake Elsinore in Riverside County, and is a natural low point of the San Jacinto River and its drainage basin (Figure 1). The total drainage basin of the San Jacinto River watershed is approximately 782 square miles. Over 90 percent of the watershed (735 square miles) drains first into Railroad Canyon Reservoir (Canyon Lake). Lake Elsinore is the terminus of the San Jacinto River watershed. The local tributary area to Lake Elsinore, consisting of drainage from the Santa Ana Mountains to the west and the City of Lake Elsinore, is 47 square miles.

1.1 San Jacinto River Watershed – Geological and Hydrological Features

The San Jacinto River watershed is bounded by two strike-slip fault zones, the San Jacinto fault zone to the northeast and the Elsinore fault zone to the southwest (Figure 2). The San Jacinto Valley is among the most seismically active of the major strike-slip fault zones in southern California, and also the site of rapid subsidence (20 mm per year) due to tectonic activity and groundwater withdrawal (Morton, 1999). The rapid rate of subsidence has resulted in the formation of a strike-slip "pull-apart basin" or graben that has developed along parallel fault strands in the fault zone. The Elsinore fault zone is also a strike-slip fault zone and the subsidence along the fault formed Lake Elsinore.

Flow to the San Jacinto River begins in the San Jacinto Mountains. Water flows down the San Jacinto Mountains and then northwest along the San Jacinto fault zone. Most of the flows from the mountain infiltrates into the ground during low flow years. The extremely high subsidence rate of the San Jacinto Valley along the fault zone has resulted in a closed depression periodically filling with water to form the ephemeral Mystic Lake. In very wet years, the surface area of Mystic Lake can expand up to 400 acres. The river makes a 90 degree turn and flows west at the Mystic Lake. The very low river gradient westward from Mystic Lake forms a broad fluvial plain. The River then flows through the narrow Railroad Canyon, Canyon Lake and exits the Perris Block into the lower Elsinore basin created by the Elsinore fault zone.

The major waterbodies and tributaries of the San Jacinto River Watershed include Lake Hemet, Strawberry Creek, Bautista Creek, "Mystic Lake", Perris Valley Storm Drain, Salt Greek, Canyon Lake (Railroad Reservoir), and Lake Elsinore.

The San Jacinto River channel has been heavily altered by man for flood control, farming and water supply purposes. In the late 19th century, Metropolitan Water District constructed the Colorado River Aqueduct through the San Jacinto Mountains to convey Colorado River water to Southern California. As a result of de-watering during aqueduct construction, a large amount of groundwater was lost through the tunnel in the mountains. Early in the 20th century, the U.S. Army Corps of Engineers and the Riverside Flood Control and Water Conservation District constructed a levee along the San Jacinto River north of the City of San Jacinto to provide flood protection. Construction of the levee resulted in the accumulation of sediment in the river channel, causing the river bed to be at a higher elevation than the City, thereby exacerbating the flooding potential. Farmers in the watershed have diverted flow away from its natural path into Mystic Lake, leaving the old river bed dry. The new river channel bypasses the graben basin, thus cutting off the sediment supply that would have compensated for the rapid subsidence. Consequently, the area of the depression is expanding. Groundwater in the basin has also been withdrawn for agricultural and domestic supply purposes in the last century. As a result of all of the human engineering activities to the San Jacinto River, the surface flow in the San Jacinto River has been significantly reduced. Only in extremely wet years does water from the San Jacinto River reach Canyon Lake and Lake Elsinore.

1.2 Land Use

The majority of land in the San Jacinto basin consists of federally, state or privately owned open space areas. According to 1993 landuse data from the Southern California Association of Governments (SCAG), land use in the watershed includes vacant land (66%), agricultural land (18%, including Confined Animal Operations such as dairies and chicken ranches, and irrigated cropland), and residential landuse (9%) (Table 1). Vacant/open space is being converted to residential uses as the population in the area expands. The major municipalities in the watershed include the cities of San Jacinto, Hemet, Sun City, Perris, Canyon Lake, Lake Elsinore and portions of Moreno Valley and Beaumont.

Table 1
San Jacinto Watershed 1993 Land Use

Land Use Classification	Acres	Total %
Vacant	304,194	66
Agricultural	83,157	18
Residential	41,521	9
Military	5,745	1
Transportation & Utilities	4,867	1
Water & Flood Plain	3,688	1
Open Space and Preserve	2,954	1
Commercial	2,256	0.5

Data source: Montgomery Watson, 1996.

1.3 Characteristics of Lake Elsinore

Lake Elsinore is a relatively shallow lake with a large surface area. At the current lake outlet sill elevation of 1,255 feet, the lake has an average depth of 24.7 feet and a surface area of 3500 acres. Annual average precipitation in the Lake Elsinore watershed is approximately 11.6 inches; average annual evaporative loss is 56.2 inches (Montgomery & Watson, 1997). This excessive evaporation loss compared to natural inflow results in very low lake levels. At the extreme, Lake Elsinore was completely dry in the 1950s and 1960s (Figure 3). Only in extremely wet years does Lake Elsinore overflow into Temescal Creek. In the last century, Lake Elsinore only overflowed five times (1919, 1981, 1983, 1993, and 1995) causing extensive flooding to the City of Lake Elsinore.

To prevent the Lake from drying out and also to mitigate the flooding potential, the US Bureau of Land Management, the U.S. Army Corps of Engineers and the County of Riverside Flood Control and Water Conservation District developed the Lake Elsinore Management Project (LEMP). Three major projects were implemented through the LEMP: 1) construction of a levee to separate the main Lake from the back basin to reduce the Lake surface area and thereby prevent significant evaporative losses; 2) realignment of the Lake inlet channel to bring natural runoff from the San Jacinto River; and, 3) lowering of the Lake outlet channel to increase outflow to Temescal Creek when the Lake level exceeds an elevation of 1,255 feet. The LEMP also called for the introduction of supplemental makeup water to maintain Lake levels at an adopted operation range of 1,240 to 1,249 feet. Highlights of the LEMP are shown in Figure 4.

1.4 Lake Elsinore Beneficial Uses and Water Quality Objectives

The beneficial uses of Lake Elsinore as identified in the 1995 Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) are as follows:

- Warm Freshwater Aquatic Habitat – **(WARM)**
- Body Contact Recreation – **(REC1)**
- Non Body Contact Recreation – **(REC2)**
- Wildlife Habitat – **(WILD)**

The Basin Plan specifies both numeric and narrative water quality objectives for Lake Elsinore that relate to nutrient impairment. These objectives are as follows:

- Total Inorganic Nitrogen (TIN) – 1.5 mg/L[1]

[1] TIN is the sum of nitrate, nitrite and ammonia forms of nitrogen. The TIN water quality objective was established based on the TIN historical average in the lake prior to 1975. Given the eutrophication problems in Lake Elsinore, Regional Board staff believes this value may need to be revised.

- Algae -- Waste discharges shall not contribute to excessive algal growth in receiving waters.
- Un-ionized Ammonium-N (UIA) – 0.822 mg/L
- Dissolved Oxygen – the dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated **WARM**
- pH – 8.5 to 6.5

The Basin Plan does not specify a phosphorus water quality objective for Lake Elsinore. As will be discussed further, phosphorus concentrations greatly affect algae growth in Lake Elsinore and, therefore, it may be appropriate for the Regional Board to consider developing a phosphorus objective for the lake.

2.0 Eutrophication of Lake Elsinore – Background and Historical Data

The following section discusses the eutrophication processes in lakes, and summarizes the past studies on Lake Elsinore water quality.

2.1 The Eutrophication Processes

Eutrophication of a waterbody is a process in which nutrient enrichment occurs, and phytoplankton production is high. Eutrophication of a lake due to natural processes (filled in by sediments, accumulation of organic matter) may take thousands of years (US EPA, 1990). However, human-induced eutrophication can occur when nutrients from urban runoff, fertilizers and organic matter from animal wastes are discharged to a lake.

There are three stages in the trophic continuum of lake eutrophication: oligotrophy, mesotrophy, and eutrophy. An oligotrophic lake has low nutrient concentrations, and low biologic productivity. Consequently, the water is very clear. Mesotrophy is the first stage of lake moving toward a eutrophic condition. Nutrient concentrations and biological productivity begin to increase. An eutrophic lake typically has high nutrient concentrations and high algal productivity. It contains an undesirable abundance of plant growth, particularly, phytoplankton (free floating microscopic algae), periphyton (attached algae), and macrophytes (large aquatic plants). If the nutrient levels and algal productivity of a lake are higher than exists for a eutrophic lake, the lake is considered hypereutrophic.

The two most common nutrients are phosphorus and nitrogen. Figure 5 depicts the phosphorus cycle in a lake system. Phosphorus (in the form of phosphate) can be carried into a lake by river inflow either as the soluble reactive form or bound to sediments. The soluble form of phosphorus can be taken up directly by algae and is then converted to organic phosphorus. Organic phosphorus can either move up through the food chain until it is removed by fish or birds, or, as the algae die, the organic phosphorus settles into the sediment and partially binds to calcium and iron ions to form phosphate minerals over time. The calcium bound phosphate is relatively stable and will remain permanently bound to calcium. On the other hand, the phosphate bound to iron remains in the sediment only if there is sufficient dissolved oxygen present (oxic conditions). Under anoxic conditions (low dissolved oxygen), the iron will be reduced to the soluble form, resulting in the release of phosphorus back into the water column.

Another important process in the phosphorus cycle occurs in alkaline (high pH) lakes such as Lake Elsinore. In an alkaline lake, the co-precipitation of phosphate with calcium occurs. When the concentrations of phosphate and calcium ions exceed their solubility, a mineral, hydroxyapatite, will precipitate out. In addition, phosphate ions can be adsorbed by calcite particles and be removed from the water column. The high alkalinity of Lake Elsinore provides a self-cleansing mechanism for the lake.

The nitrogen cycle in a lake system is more complex than the phosphorus cycle in that there are more forms of nitrogen. Nitrogen gas and ammonia gas, the soluble nitrogen forms of nitrate, nitrite, and ammonium, and organic nitrogen are all present in a lake system. The nitrogen cycle, as depicted in Figure 6, consists of nitrogen fixation, ammonification, nitrification, and denitrification.
All four of these processes occur in Lake Elsinore. Nitrogen fixation in a lake system occurs when certain blue-green algal species, such as *Anabaena* and *Nodularia*, fix nitrogen from the atmosphere. Under anoxic conditions, the organic nitrogen bound in detrital organic matter goes through mineralization to produce ammonium. Ammonium can be readily taken up by algae or, under alkaline (high pH) conditions, the ammonia gas and ammonium ion equilibrium is shifted to produce ammonia gas (un-ionized ammonia). At high enough concentrations, un-ionized ammonia is toxic to fish. Nitrification is the process by which bacteria oxidize ammonium to nitrate in the presence of oxygen. In the denitrification process, sediment bacteria convert nitrate ions into nitrogen gas that is then released to air. This process occurs in the sediment/water column interface under anoxic conditions.

The ratio of total nitrogen (TN) to total phosphorus (TP) has been used to estimate which of the two nutrients is the limiting factor for algal growth. If the TN/TP ratio is greater than 10, phosphorus is considered the limiting nutrient. If the TN/TP ratio is less than 10, nitrogen is then the limiting nutrient. In other words, the factor that is in short supply relative to the needs of algae will limit the growth of those plants. Therefore, control measures can be developed to address the limiting nutrient. In the case of Lake Elsinore, the limiting nutrient changes through time (see Section 3.3). Therefore, both nutrients need to be controlled.

2.2 Lake Elsinore Eutrophic Survey by US EPA (1975)

In 1975, US EPA conducted a eutrophic survey among 24 lakes and reservoirs in the western United States, including Lake Elsinore. The study placed Lake Elsinore into the hypereutrophic state due to high levels of chlorophyll a[2], total phosphorus, total nitrogen, and low Secchi depth[3] readings. These results are summarized in Table 4.

As part of the EPA study, an effort was made to determine whether the limiting nutrient was nitrogen or phosphorus. The study consisted of using an algal growth test (assay) on the algae *Selenastrum capricornutum*. Results indicated that at that time, nitrogen was the limiting nutrient (US EPA, 1978). A survey of phytoplankton indicated a dominance of flagellate-green, blue-green algae and diatoms. The abundance of the algal cells increased the turbidity of the water column. The presence of the blue-green algae suggested that nitrogen fixation was a process for the blue-green algae to utilize nitrogen directly from the atmosphere.

Table 4 EPA EUTROPHIC SURVEY (1975) RESULTS OF LAKE ELSINORE

Sampling Date	Chlorophyll a (ug/L)	TOT-P (mg/L)	Ortho-P (mg/L)	Inorg-N (mg/L)	SECCHI (m)
3/10/75	52.1	0.515	0.254	0.079	0.3
6/23/75	41.9	0.469	0.086	0.123	0.2
11/13/75	117.7	0.366	0.046	0.241	0.3
Mean	**70.57**	**0.45**	**0.13**	**0.15**	**0.27**

2.3 Black & Veatch Studies (Clean Lakes Study and Lake Elsinore Water Quality Monitoring Program) (1992-1997)

In 1993, the Santa Ana Watershed Project Authority (SAWPA) was awarded a Clean Water Act Section 314 grant (Clean Lakes Study) to conduct a water quality study of Lake Elsinore. The consulting firm of Black & Veatch was retained by SAWPA to conduct the study. As a follow-up to the LEMP, Black & Veatch conducted a water quality monitoring program under the contract with the then Lake Elsinore Management Authority (LEMA) from 1994 through 1997. The results and findings of the two studies were reported in Black & Veatch (1994, 1996). The results and findings of the nutrient and algae analyses are summarized below.

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[2] chlorophyll a is a measure of the algae biomass

[3] secchi depth is a measure of the clarity of water. The greater the secchi depth, the greater the water clarity.

Dissolved Oxygen

The average dissolved oxygen concentrations for the Lake Elsinore stations (measured at the top, middle and bottom of the water column) from March 1994 to June 1996 are shown in Figure 7. Dissolved oxygen concentrations in Lake Elsinore varied both seasonally and vertically. The high dissolved oxygen at the surface suggested that algae photosynthesis was supersaturating the water with dissolved oxygen most of the time. Extremely low dissolved oxygen near the bottom during the summer time indicates that there was a high oxygen demand from the sediment. In addition, during the two-week period in September 1995, approximately 10 tons of fish died as a result of oxygen depletion. At that time, the dissolved oxygen concentrations at the top, middle and bottom were all below 5 mg/L.

Secchi Disk Depth

Secchi Disk depth is an indicator for water clarity. High secchi readings indicate clear, less turbid water. Low depth readings indicate muddy, turbid water that is often caused by the presence of abundant algal cells. Secchi depth has been used as one of the eutrophication indices. Secchi depth in Lake Elsinore was measured biweekly from March 1994 through June 1996 (Figure 8). In March 1994 the water in Lake Elsinore had a Secchi depth of 130 inches. By July 1994 the Secchi depth had dropped to approximately 20 inches. The Secchi depth remained stable through to the end of the monitoring program, ranging from 17 to 35 inches (0.4 to 0.9m), which is very low.

Phosphorus and Nitrogen

Total phosphorus includes orthophosphate and organic phosphorus. Orthophosphate is the soluble reactive form that algae can take up directly from the water column. When the sample includes a significant amount of algal cells, the organic phosphorus is primarily the phosphorus content of the algal cells.

The phosphorus data from 1992 through 1997 are shown in Figure 9. Prior to January 1993, orthophosphate concentrations in Lake Elsinore were below the detection limit. In January of 1993, Canyon Lake overflowed. This overflow greatly altered the phosphorus concentrations in Lake Elsinore. After the Canyon Lake overflow, both orthophosphate and total phosphorus increased dramatically; orthophosphate increased from non-detect to 0.5 mg/L, and total phosphorous increased from 0.5 mg/L to 1.2 mg/L. The increase in phosphorus more than likely came from the San Jacinto River as Canyon Lake overflowed.

Both forms of phosphorus decreased from 1994 through 1997. By the summer of 1997, the total phosphorus concentration was approximately 0.2 mg/L, and the orthophosphorus was below the detection limit. This decrease may be explained by the settling of the algal particles and the mineral precipitation of phosphate to the lake sediment.

All of the forms of nitrogen were analyzed in the Clean Lakes Study and the follow-up monitoring; nitrate nitrite, ammonium, and total kjeldahl nitrogen[4]. As shown in Figure 10, in Lake Elsinore, the major form of nitrogen exists as organic nitrogen. Prior to the Canyon Lake overflow in January 1993, the total kjeldahl nitrogen concentration was as high as 13 mg/L. After the overflow, both parameters dropped dramatically to 2 mg/L. There was an increase in total kjeldahl nitrogen concentration (mostly the organic nitrogen) in October 1993, up to 6 mg/L, possibly due to an algal bloom. There is no data for total kjeldahl nitrogen concentrations in 1994; analyses resumed in 1995 and the total kjeldahl nitrogen concentrations remained stable from 1995 through 1997 at approximately 3 mg/L.

As discussed previously, an evaluation of the ratio of total nitrogen (TN) to total phosphorus (TP) can be used to determine whether the limiting nutrient is nitrogen or phosphorus. Once the limiting nutrient is identified, specific control measures targeted at that nutrient can be identified and implemented. A plot of the ratio of total nitrogen to total phosphorus from 1992 to 1997 in Lake Elsinore is shown in Figure 11. Phosphorus was the limiting nutrient from 1992 to the 1993 before the overflow of Canyon Lake. After Canyon Lake overflowed, nitrogen became the limiting nutrient in Lake Elsinore. There was no data collected during 1994. From 1995 to 1997, the phosphorus became the limiting nutrient once again. It is apparent from evaluation of the data during both wet and dry conditions, that both nitrogen and phosphorus are critical nutrients with regards to algal growth in Lake Elsinore. Because the limiting nutrient can vary depending on the hydrologic conditions, it is necessary that the TMDL address both nutrients.

Chlorophyll a

Chlorophyll a is an indicator for algal biomass. It is also an important indicator for eutrophication status. In general, a lake with an average chlorophyll a concentration over 20 ug/L is considered eutrophic (US EPA, 2000).

Chlorophyll a concentrations in Lake Elsinore are shown in Figure 12. In October 1993, chlorophyll a concentrations were as high as 950 ug/L. This also coincides with high organic nitrogen concentrations (see Figure 11).

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[4] Total kjeldahl nitrogen is the sum of organic nitrogen and ammonium nitrogen; total nitrogen is the sum of ammonium, nitrate, nitrite and organic forms of nitrogen; total inorganic nitrogen excludes the organic forms of nitrogen.

From 1995 to1997, chlorophyll a concentrations did display a seasonal variation; during July to November concentrations ranged from 100 ug/L to 624 ug/L, and during December to May, chlorophyll a concentrations ranged from non-detect to 65 ug/L. The low winter/spring chlorophyll a concentrations are likely correlated with reduced temperature and light conditions which limit algal growth.

Trophic State Index (TSI) was developed by Carson (1977) to determine and to classify lakes based on the levels of eutrophication.

$$TSI = 30.6 + 9.81 * \ln(\text{chlorophyll a})$$

Most of the oligotrophic lakes measured had a TSI below 40, mesotrophic lakes had TSI between 35 and 45, while most eutrophic lakes had TSI greater than 45. Based upon the 1993-1997 data, the TSI values for Lake Elsinore ranged from 53 to 93 (Table 5) – clearly eutrophic.

Algal Taxonomy

Taxonomic evaluations of algae species were performed on samples collected in September and October 1993, then monthly from May 1995 to July 1996. The dominant species of algae in Lake Elsinore are blue-green algae, *Oscillatoria* and *Anabaena*. Diatoms, and flagellate-green algae were also abundant. The cell counts ranged from a high of 77,417 cells per mL on July 10, 1996 to a low of 126 cells per mL on December 12, 1995. The abundance of the phytoplanktonic algae is the cause of low Secchi depth readings in Lake Elsinore; the algal cells absorb, scatter, and disperse the light from passing through the water column, making the lake water pitch dark 2-3 feet below the surface.

Table 3. Chlorophyll a concentration and TSI values for Lake Elsinore.

[illegible]	[illegible]	[illegible]	[illegible]	
3/10/75	52.13	69.39		
6/23/75	49.94	68.97		
11/13/75	141.12	79.16	47.80 Winter-Spring	
11/23/92	50	68.98		
1/5/93	23	61.36		
1/22/93	59	70.6		
2/11/93	64	71.4	163.69 Summer-Fall	
3/25/93	N.D.			
4/15/93	N.D.			
4/30/93	N.D.			
5/12/93	N.D.			
5/26/93	20	59.99	TSI =	30.6+9.81ln(chl)
6/16/93	16	57.8		
6/29/93	20	59.99		
7/29/93	327	87.4		
8/13/93	10	53.19		
9/21/93	260	85.15		
9/28/93	228	83.86		
10/20/93	954	93.74		
5/25/95	28	63.29		
6/6/95	40	66.79		
6/29/95	34	65.19		
7/13/95	101	75.87		
7/25/95	116	77.23		
8/10/95	103	76.07		
8/31/95	165	80.69		
9/14/95	116	77.23		
9/26/95	119	77.48		
10/12/95	196	82.33		
10/26/95	140	79.08		
11/14/95	143	79.29		
12/12/95	52	69.36		
1/12/96	65	71.55		
2/15/96	76	73.08		
3/22/96	42	67.27		
4/24/96	52	69.36		
5/16/96	57	70.26		
5/30/96	52	69.36		
6/13/96	62	71.09		
6/25/96	49	68.78		
7/10/96	170	80.98		
7/15/96	18	58.95		
7/23/96	71	72.42		
5/1/97	63	71.24		
7/31/97	28	63.29		

3.0 Lake Elsinore Nutrient TMDL – Problem Statement/Numeric Targets

The most distinct water quality problem of Lake Elsinore is hypereutrophication. The hypereutrophic condition means that the lake is enriched with nutrients (phosphorus and nitrogen), resulting in high algal productivity, mostly planktonic algae. As shown in Table 2, there have been reports of algal blooms and fish kills in Lake Elsinore since the 1930s (EDAW Inc., 1974)[5]. The cause cited for the fish kills was the depletion of oxygen in the water column. Algae respiration and decay uses the dissolved oxygen in water column; excessive oxygen depletion adversely affects other aquatic biota, including fish. The decay of dead algae and fish also produces offensive odors and an unsightly lakeshore, adversely affecting use of the Lake for recreational purposes. In addition, the massive amount of algal cells causes high turbidity in the lake, making the water an uninviting murky green color at times.

Comparing the fish kill record to rainfall and lake levels, the fish kills seem to coincide with either very shallow lake levels or flooding. This indicates that lake levels and inputs of nutrients to the Lake during very wet conditions are both important factors that affect the health of Lake Elsinore.

As a result of the history of fish kills and algae blooms in Lake Elsinore, in 1994, the Regional Board placed Lake Elsinore on the Clean Water Act Section 303(d) list of impaired waterbodies. For any waterbody listed as impaired, federal law requires that a total maximum daily load (TMDL) be established to address the impairment.

Pursuant to the federal TMDL requirements, quantifiable and measurable numeric targets that will ensure compliance with water quality standards (beneficial uses and water quality objectives) must be established in the TMDL (US EPA, 1999). For Lake Elsinore, the warm freshwater aquatic habitat (WARM) and body and non- body contact recreation (REC1 and REC2) are the beneficial uses that are impaired by the nutrient input. The TMDL and its numeric targets must be structured to assure protection of the WARM and REC1 and REC2 beneficial uses and attainment of the nutrient related water quality objectives specified in the Basin Plan (see Section 1.4). Regional Board staff believes that the WARM beneficial use is the most sensitive with respect to nutrients and that if the TMDL ensures protection of the WARM beneficial use, then the recreation beneficial uses will be protected as well.

[5] It is possible that additional fish kills occurred that are not shown on the Table 2. What is tabulated reflects the fish kill records that were available to Regional Board staff.

Table 4

Fish Kill Record in Lake Elsinore

Year	Description
1933	Fish kills and algal bloom in April, reported by State Bureau of Sanitary Engineering
1940	Fish kills reported by State Bureau of Fish Conservation
1941	Fish Kills reported by State Department of Fish and Game
1948	"Aug. 31-Sept. 2 300-500 tons of carp" reported by State Department of Fish and Game
1950	"There are no fish in the Lake" reported by Riverside County Health Department
1966	"An Extensive die-off of fish" reported by State Department of Fish and Game
1972	"During the last Week of August, and continued through September, tons of fish were buried or taken to the dump, mostly thread-fin shad" - reported by State Department of Fish and Game
1991	"120 thousands tons of fish killed by algae" – reported by The Press Enterprise
1992	"August 17, 12-15 tons fish kill" – reported by The Press Enterprise
1993	"More than 100,000 tons of fish died" - Black & Veatch
1995	"In September, 10 tons of fish killed, shad, bluegill" – reported by The Press Enterprise
1996	"In August, smaller fish die-off" – by The Press Enterprise
1997	"On April, 7 tons of shad died of oxygen depletion" – reported by The Press Enterprise
1998	200 tons Fish kill reported by Press Enterprise

As described below, staff proposes at this time that numeric targets for dissolved oxygen, chlorophyll a and total inorganic nitrogen be included in the Lake Elsinore nutrient TMDL. Staff believes that if these numeric targets are met, then the water quality standards of Lake Elsinore will be achieved. Staff would also like to emphasize that this is staff's initial assessment of appropriate numeric targets for the Lake Elsinore nutrient TMDL. With additional data that are to be collected in the next year, staff may propose additional numeric targets or revise those discussed here.

Dissolved Oxygen

As previously stated, the Basin Plan specifies a dissolved oxygen narrative water quality objective of:

The dissolved oxygen content of surface waters shall not be depressed below 5
mg/L for waters designated as WARM.

The proposed Lake Elsinore nutrient TMDL numeric target for dissolved oxygen is as follows:

- monthly average dissolved oxygen (measured biweekly during summer-fall, and monthly during winter-spring) be greater that 5 mg/L at the hypolimnetic[8] zone, when the lake stratifies; and
- Average dissolved oxygen over depth should be no less than 5 mg/L when the lake is well mixed from top to bottom.

It could be argued that some fish species in Lake Elsinore could survive at lower levels of dissolved oxygen, such as carp and shad. However, the Lake has been stocked with other , more sensitive species of fish as well. Furthermore, it is evident from the fish kill record that dissolved oxygen levels need to be maintained at 5 mg/L or greater in order to prevent fish kills.

Average

Chlorophyll a

Currently, there are insufficient data to determine the chlorophyll a concentration that would result in no excessive algal blooms in Lake Elsinore. For an interim goal, staff proposes that the numeric target for chlorophyll a be as follows:

- mean chlorophyll a concentrations shall be no greater than 40 ug/L during the growth season (July through November).

Specify peak! 80 ug/L

[8] The lower, colder water zone in a stratified lake.

As more data become available that allow a better relationship between chlorophyll a concentrations and algal blooms to be developed, the numeric target will be re-evaluated.

Total Inorganic Nitrogen

As previously stated, the Basin Plan specifies a total inorganic nitrogen objective for Lake Elsinore of 1.5 mg/L. Staff is proposing that this objective also serve as a numeric target. As noted earlier in this report (footnote 1, Section 1.4), this objective may need to be revised in the future. If it is revised, then the numeric target in the TMDL would be revised accordingly.

4.0 Other Management Activities In Lake Elsinore and the San Jacinto Watershed

It is important to note that TMDL development by the Regional Board is only one of the MANY efforts to restore the beneficial uses of Lake Elsinore. Federal, state, local governments and the general public have been working to pool funds and to evaluate various lake management alternatives for a number of years. US EPA has granted the City of Lake Elsinore $475,000 for Lake restoration, and the US Army Corps of Engineers is conducting a reconnaissance study of the San Jacinto Watershed. In March 1999, the voters of California passed Proposition 13. One of the provisions in the bond was an award of $15,000,000 for restoration of Lake Elsinore and the San Jacinto River Watershed. A Joint Powers Agency (JPA) was formed to manage and plan for Lake and watershed restoration activities using these funds. The members of the JPA include the City of Lake Elsinore, the City of Canyon Lake, SAWPA, the County of Riverside, and Elsinore Valley MWD. Under the supervision of the JPA Board, a Technical Advisory Committee (TAC) was formed from the JPA member agencies. Regional Board staff have been active participants at the JPA TAC since the TMDL related activities are directly related to the Lake and watershed restoration activities.

Among possible Lake management alternatives, several are being considered by the JPA for Lake Elsinore restoration, including alum treatment, metal salt addition, treatment wetland construction, biomanipulation and supplement water supply to the Lake. A summary of each management alternative is provided below.

Alum treatment

Alum treatment consists of the addition of aluminum sulfate (alum) to the lake water. Alum combines with the phosphate ions in the water column and precipitates on the lake bottom. If an appropriate dosage of alum is added, the soluble phosphate ions will be removed from the water column. The precipitate forms a thin layer on the top of the lake sediment acting as a barrier to prevent the release of phosphate to the water column under anoxic conditions. However, there are limitations on the long-term benefits of alum treatment. When a new source of phosphate is introduced, or the existing source of phosphate in the watershed is not controlled, the alum layers will be buried underneath the new lake sediment that is rich in phosphate and thus, the effect of the alum treatment is lost. The success of alum treatment on other lakes demonstrates that if the other sources of phosphate are not controlled, alum treatment loses 70% of its effectiveness in five years, and 100% of its effectiveness in seven years (Robertson D.M., 2000, oral presentation). ?

Metal Salt Addition

Other metal salts, such as calcium chloride, can be added to lake water, much in the same manner as in alum treatment. Phosphate will combine with the calcium ions and precipitate to the lake bottom. The difference between alum treatment and metal salt addition is the stoichiometric ratio and the impact on water pH. Calcium is an alkaline metal and its addition raises the pH of the water. The addition of Alum will lowers the pH of the Lake.

no effect on pH

Treatment Wetland Construction

Treatment wetlands, such as Prado wetland in Riverside County and San Joaquin Marsh in Orange County, have been effective in removing nitrate, particularly during the summer. Wetlands are able to reduce nitrate concentrations from up to 10 mg/L (inflow) to as low as 2 mg/L (outflow) (Reilly, Horne and Miller, 2000). The removal of phosphate by wetland is less effective, and, at times can even be problematic. Overall, total phosphate is removed as part of the sediment being trapped in wetland, but over a long period of time, soluble phosphorus can be released from the wetland via mechanisms similar to the way lake sediments release phosphorus under anoxic conditions. Research by scientists at Duke University in the Everglades has shown that the addition of a low dose of chemicals, such as metals, can enhance the phosphate removal rate by wetlands (Bachant, P., oral communication).

Biomanipulation

Due to the hypereutrophic conditions of Lake Elsinore, the biologic community has shifted to species that could adapt or survive under the harsh conditions. For example, the fish community is dominated by shad, a bottom scavenger that can tolerate low dissolved oxygen conditions. Shad heavily grazes on zooplankton such as *Daphnia* that dwell on the lake-bottom. A preliminary algal survey conducted by UC Riverside this summer showed that the number of zooplankton on Lake Elsinore lake bottom is about one-hundredth to one-thousandth of that of Lake Perris in the same watershed. In a healthy ecosystem, one of the important functions of zooplankton is to graze on the algae (phytoplankton) and thus, significant algal blooms are prevented. Biomanipulation, consisting of one of two approaches, aims to alter this unhealthy cycle.

The first approach, termed "bottom-up", begins with implementation of changes at the bottom of the food chain – the phytoplankton. In this case, control of phytoplankton is achieved by reducing the amount nutrients required for algal growth. Examples of the "bottom-up" approach include alum treatment and wetlands treatment.

The second approach, termed "top-down", as its name suggests, begins at the top of the food chain (big fish and humans). Big fish such as catfish and bass are stocked in a lake to graze on smaller fish such as shad. By fishing, humans can help reduce the smaller fish populations as well. The reduction in small fish allows the zooplankton population to recover and increase. As the zooplankton population increases, the grazing of the phytoplankton also increases, thereby reducing the presence of algae.

Supplement Water Supply to Lake Elsinore

Lake Elsinore can lose approximately 4.5 feet of water, or 11,000 acre-feet of water due to evaporation in a year. In many years, there is insufficient water coming from the watershed to compensate for the loss (see Figure 3). As a result, Lake Elsinore can become dry such as occurred during the 1950 and 1960s. Despite the existence of agreements going back to 1927 (Tilly agreement), there has been no effort to maintain the water level at 1240 feet as proposed by the agreement. In 1967, the State Parks and Recreation District (Department) installed three deep wells to pump groundwater to provide supplemental water to lake. After the State relinquished its ownership of Lake Elsinore to the City of Lake Elsinore in 1992, the three wells were handed over to the Elsinore Valley MWD. The source of supplemental water to the Lake has been uncertain ever since. In order to restore and maintain the beneficial uses of Lake Elsinore, it is critical to maintain a stable water level. Regional Board staff believes that without maintaining a stable water level, implementation of any of the restoration alternatives being considered would be futile.

The citizens of Elsinore Valley formed a Task Force to explore the sources of supplemental water supply, including the use of recycled water. The Task Force committee members include citizens of City of Lake Elsinore, City of Lake Elsinore officials, Elsinore Valley MWD Board members, and Regional Board staff. In 1997, a white paper was prepared by the Task Force evaluating the recycled water alternative. The use of recycled water as a source of supplemental water supply for the Lake was agreed upon by all members as long as the following conditions are met:

> Total *phosphorus not exceed 0.2 mg/L, and that nitrogen and phosphorus criteria for recycled water not exceed minimum background nutrient levels that naturally occur in the lake.* (The Recycled Water Task Force, 1997)

Currently, Elsinore Valley MWD is in the process of conducting a study to evaluate the feasibility of using of recycled water as a supplemental water supply for Lake Elsinore. Regional Board staff have been working very closely with Elsinore Valley MWD, the City of Lake Elsinore and their consultants in evaluating potential water quality impacts from using recycled water in Lake Elsinore.

Limnocosm-Scale Evaluations of Restoration Alternatives for Lake Elsinore

In order to evaluate the effectiveness of the various alternatives for Lake Elsinore restoration, the JPA contracted with UC Riverside's Dr. Michael Anderson to conduct both limnocosm experiments in the Lake and special laboratory studies. A series of 10 limnocosm tanks have been constructed and placed in the western portion of Lake Elsinore. The impacts of aeration, metal salt addition, biomanipulation, and recycled water addition on water quality in Lake Elsinore are being studied in the limnocosms. Monitoring is being conducted to measure nutrient levels and algal response when aeration, alum treatment, metal salt addition and recycled water addition are applied to the limnocosms. In the laboratory studies, nutrient release from intact sediment cores following aeration, alum treatment, calcium oxide treatment, or combined alum/calcium oxide additions will be compared with nutrient releases from untreated sediment cores. Laboratory studies consisting of the addition of solutions of known nitrogen, phosphorus and recycled water to Lake Elsinore water column samples to quantify the algal response to external nutrient input to the lake. These types of assessments are critical to providing an evaluation of the most feasible and viable solutions to addressing the impairment of Lake Elsinore.

5.0 Regional Board Planned Activities for TMDL Development

Regional Board staff initiated the Lake Elsinore nutrient TMDL development process in the fall of 1999. As shown in Table 6, development of the TMDL will continue through 2003. One of the first steps in developing the TMDL is to determine all of the nutrient sources and the nutrient loads associated with each source. In an effort to obtain the source and loading information, Regional Board staff obtained monitoring data from various agencies in the Lake Elsinore watershed. Unfortunately, nutrient sources were not quantified in any of the reports or data reviewed. Again, these data are critical for TMDL development. Therefore, Regional Board staff, in coordination with watershed stakeholders, has developed and is in the process of implementing an extensive watershed-wide monitoring program. To develop the monitoring program, Board staff evaluated the watershed to determine potential inputs to Lake Elsinore. Potential nutrient inputs to Lake Elsinore were identified to be San Jacinto River below the Canyon Lake Dam, Cottonwood Creek, local area storm drains, groundwater, internal sediment nutrient loading, septic systems around Lake Elsinore and atmospheric deposition. Because Lake Elsinore is also affected by the San Jacinto River upstream of Canyon Lake during heavy runoff periods, Regional Board staff is also evaluating potential nutrient sources to Canyon Lake that include confined animal facilities (including dairies, non dairy sites such as duck ranches and chicken ranches, sites where manure is disposed to land but not for the purpose of growing crops, and crop land located within the dairy property for the purpose of growing crops), urban uses (including residential, commercial and industrial), irrigated agriculture, imported water, and open space[1]. The JPA is assisting the Regional Board in the monitoring program by providing funding support.

Monitoring began this summer and will continue though next summer/fall. Once nutrient sources have been identified and quantified, the proposed TMDL and allocations for all sources will be developed. The proposed TMDL will also include an implementation program and a monitoring program for TMDL compliance evaluation. Board staff anticipates providing an additional status report to the Regional Board in the summer of 2000 and bringing a proposed Lake Elsinore nutrient TMDL for Regional Board consideration in 2003/2004.

In addition to the monitoring activities, in January 2000, Regional Board staff convened a technical TMDL workgroup to assist staff in the development of the nutrient TMDL. The workgroup includes representative from the city of Lake Elsinore and other watershed municipalities, Riverside County Flood Control and Water Conservation District, the County of Riverside, Elsinore Valley MWD, SAWPA, Eastern MWD, San Jacinto Resource Conservation District, dairy industry representatives (Milk Producers Council and Western Dairymen Association), The Farm Bureau and the public. The workgroup has been instrumental in assisting Regional Board staff in the development of the TMDL monitoring program and has also provided input on the proposed numeric targets. Regional Board staff will continue to meet with and solicit input from the TMDL workgroup on a regular basis throughout the TMDL development process.

Finally, as previously mentioned, Board staff is an active participant on the JPA Technical Advisory Committee and the Task Force 2000. Staff believes that it is important to coordinate the TMDL development activities with the activities of other agencies in the watershed because some or all of the lake restoration alternatives being considered may be included in the implementation plan of the nutrient TMDL.

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[1] Like Lake Elsinore, Canyon Lake is also listed as impaired due to nutrients. Monitoring of the San Jacinto River watershed upstream of Canyon Lake for nutrient sources is also necessary for development of the Canyon Lake nutrient TMDL.

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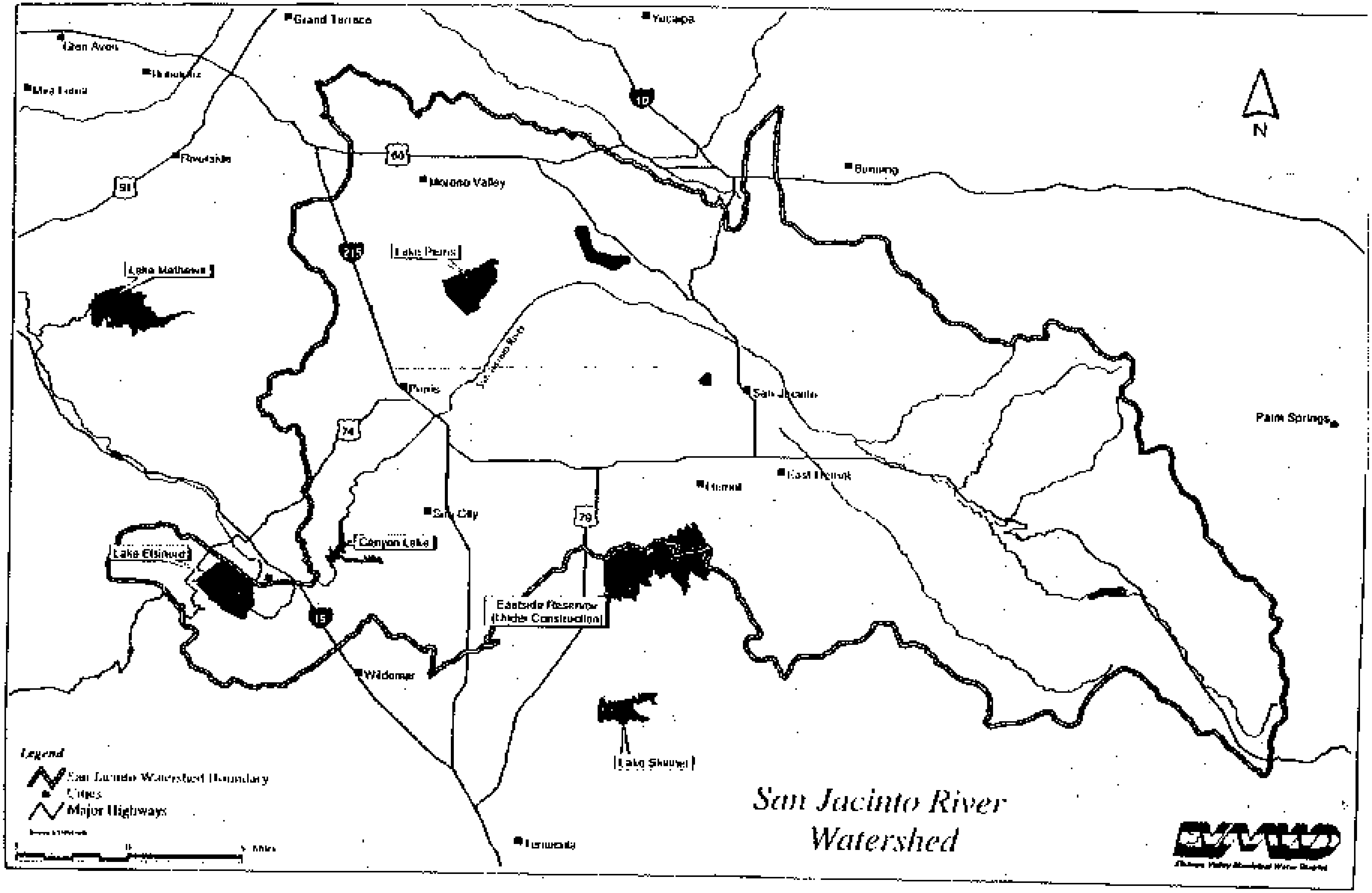


Figure 1. Map of the San Jacinto Watershed

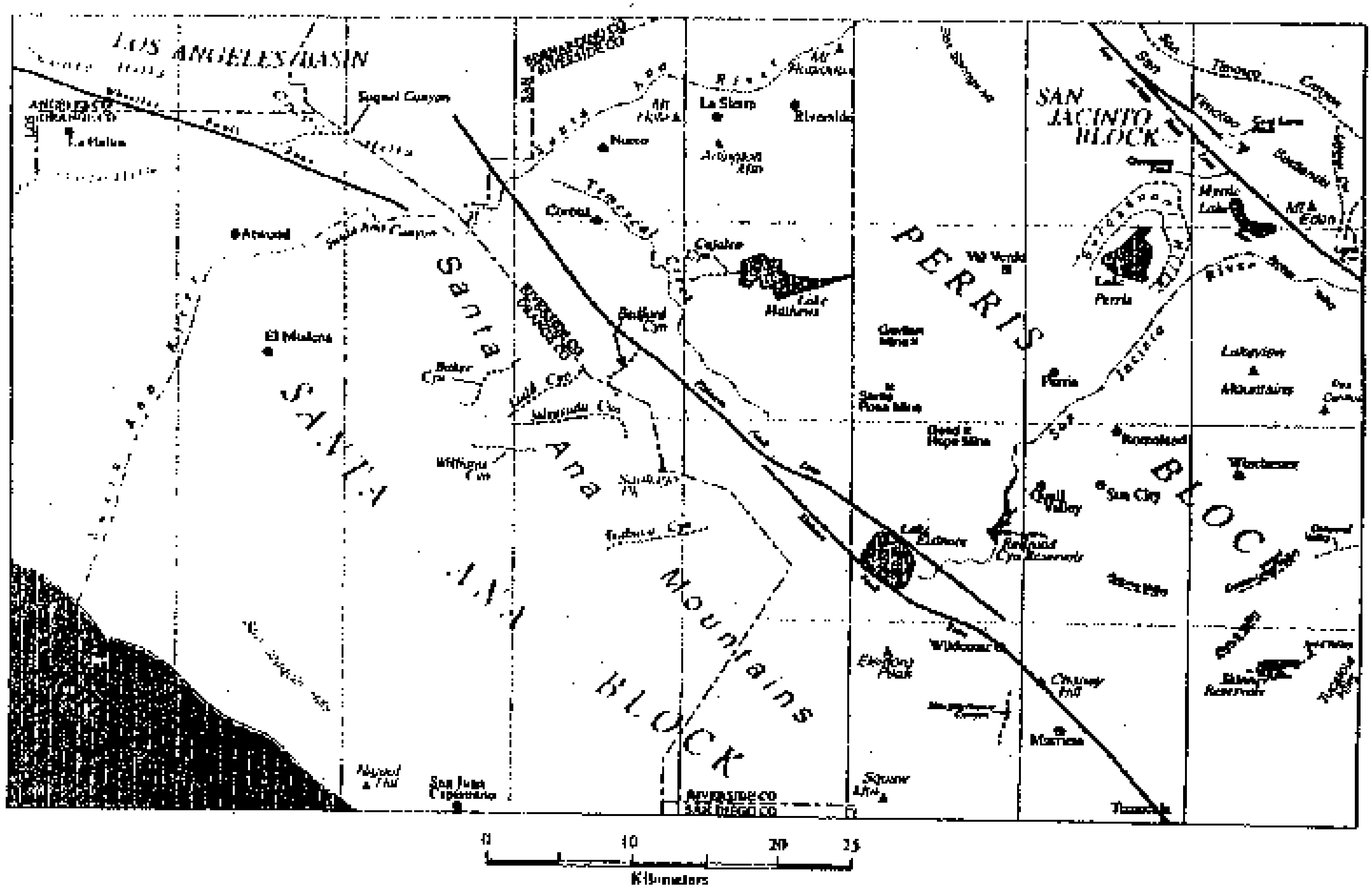
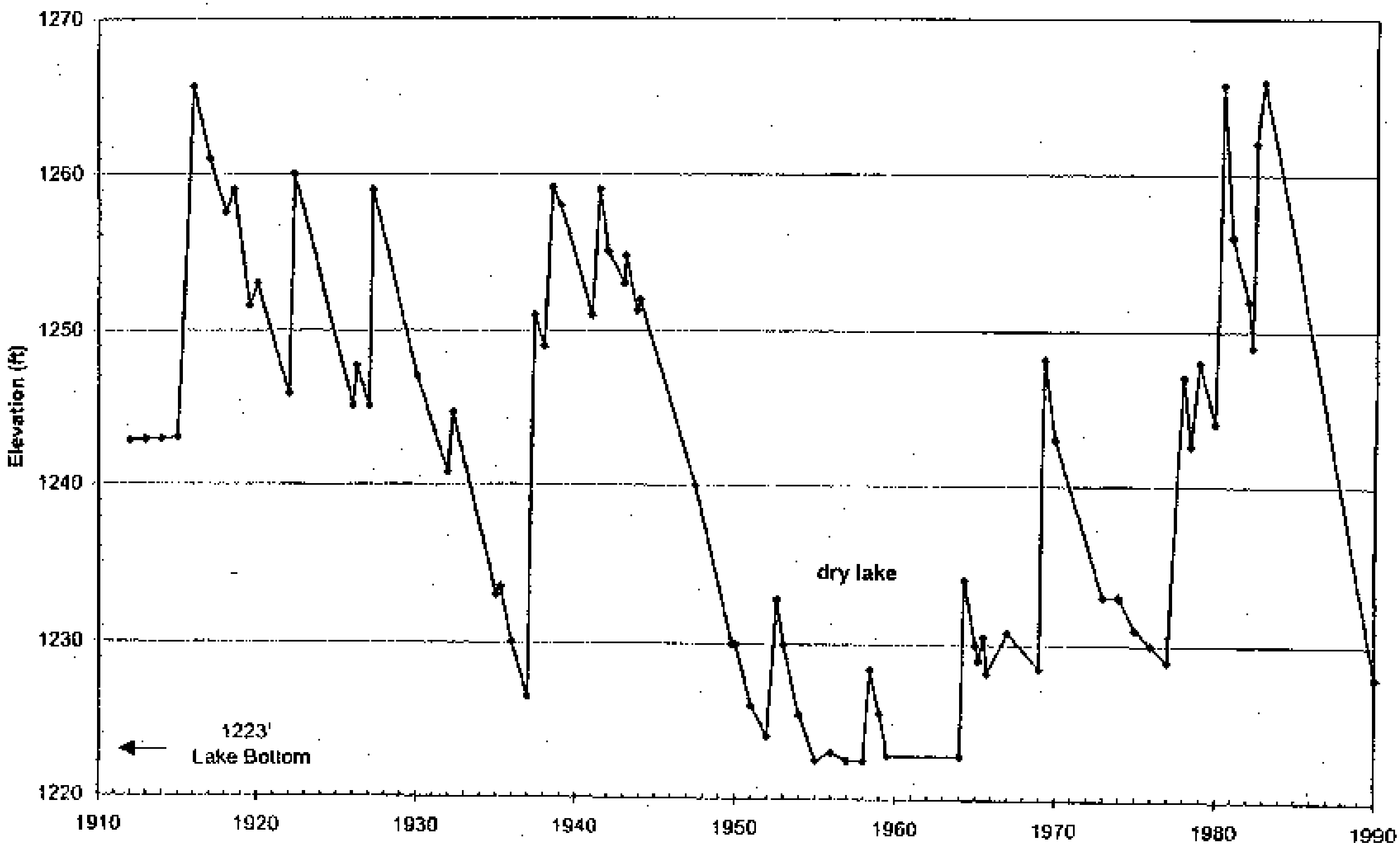


Figure 1. Map of Santa Ana 30' X 60' quadrangle showing geographic, cultural, and selected geologic and geomorphic features referred to in the text. ●, town; ▲, mountain peak; ■, specific feature.

Figure 2. Santa Ana 30' x 60' quadrangle map showing geologic and geomorphic features in the area

Figure 3. Lake Elsinore Elevation 1912-1990



Data Source: Riverside County Flood Control and Water Conservation District

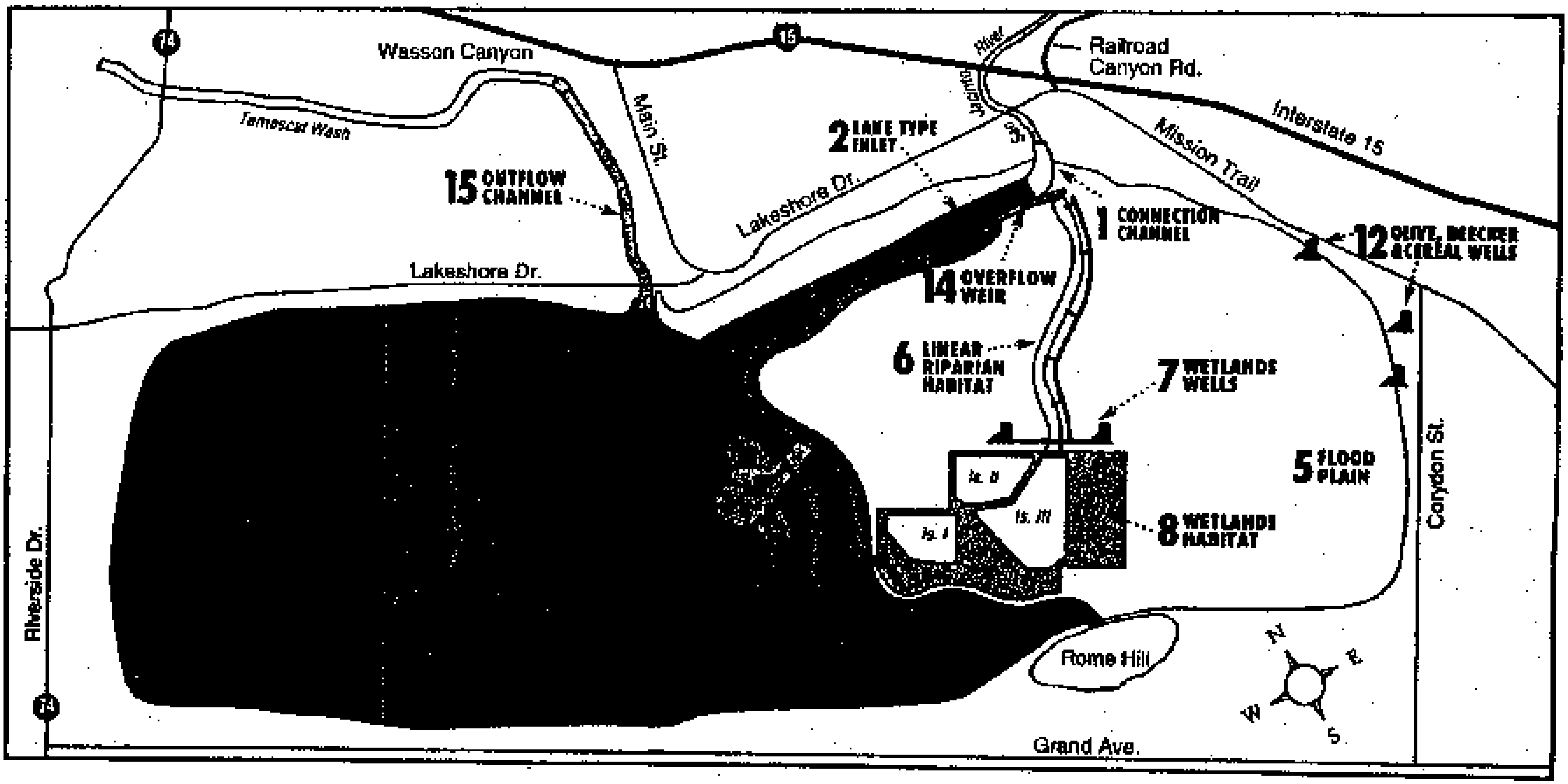


Figure 4. Lake Elsinore Management Project highlights

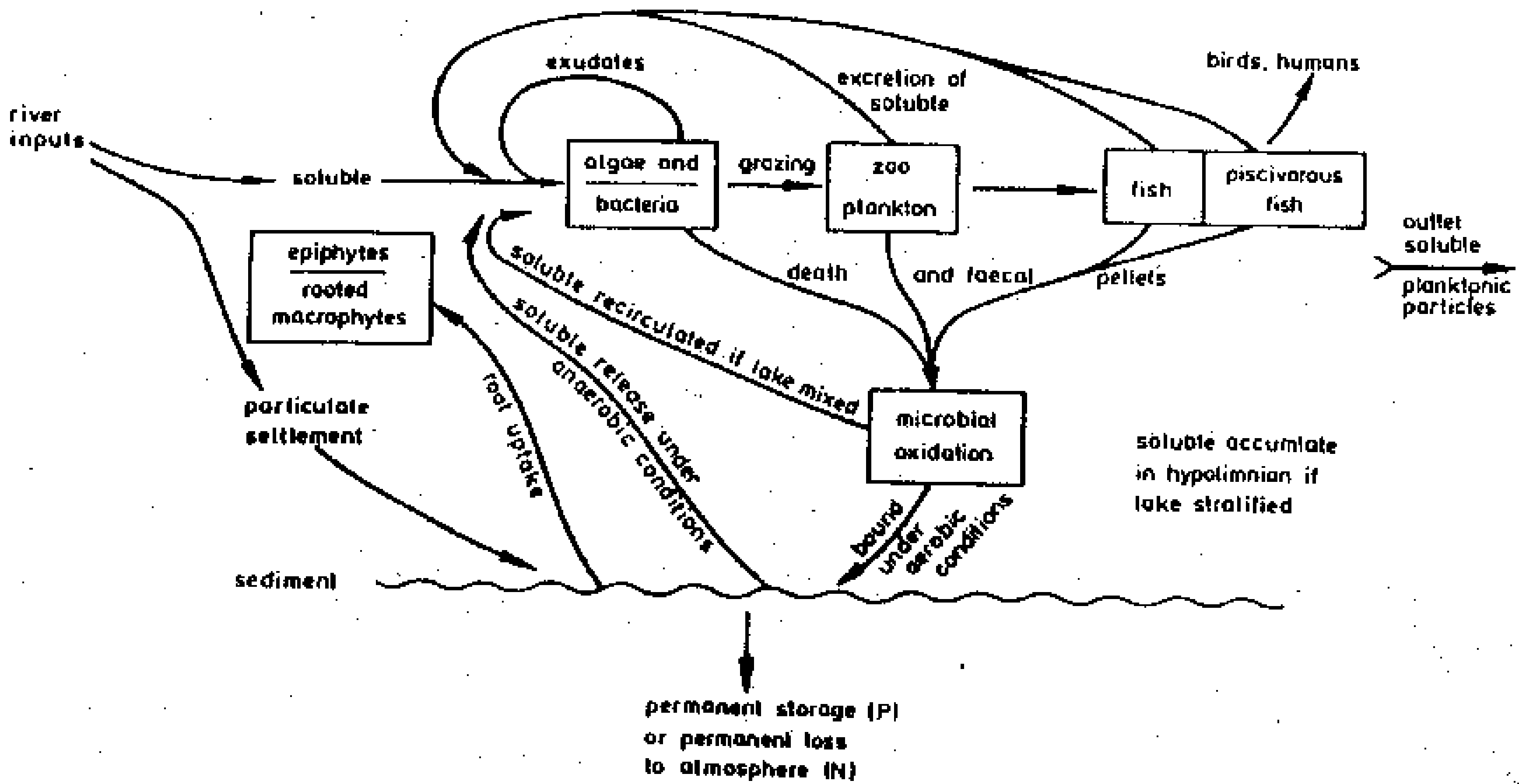


Figure 5. Phosphorus cycles in a lake system (from Harpper, D. 1992)

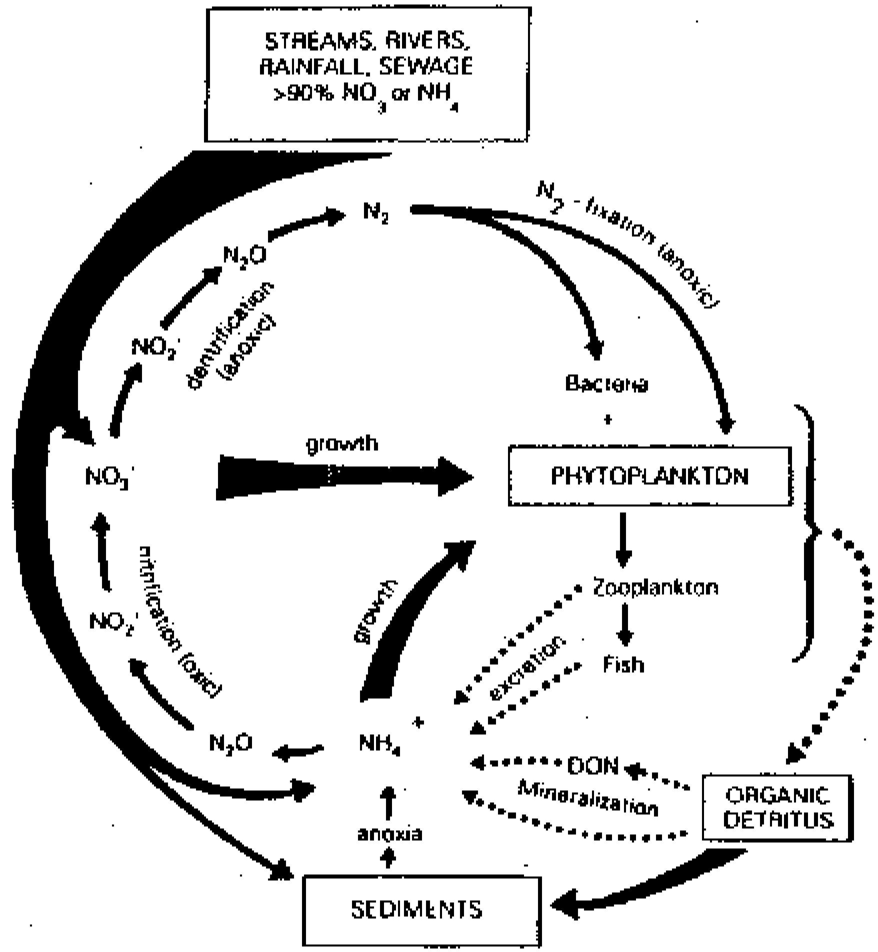
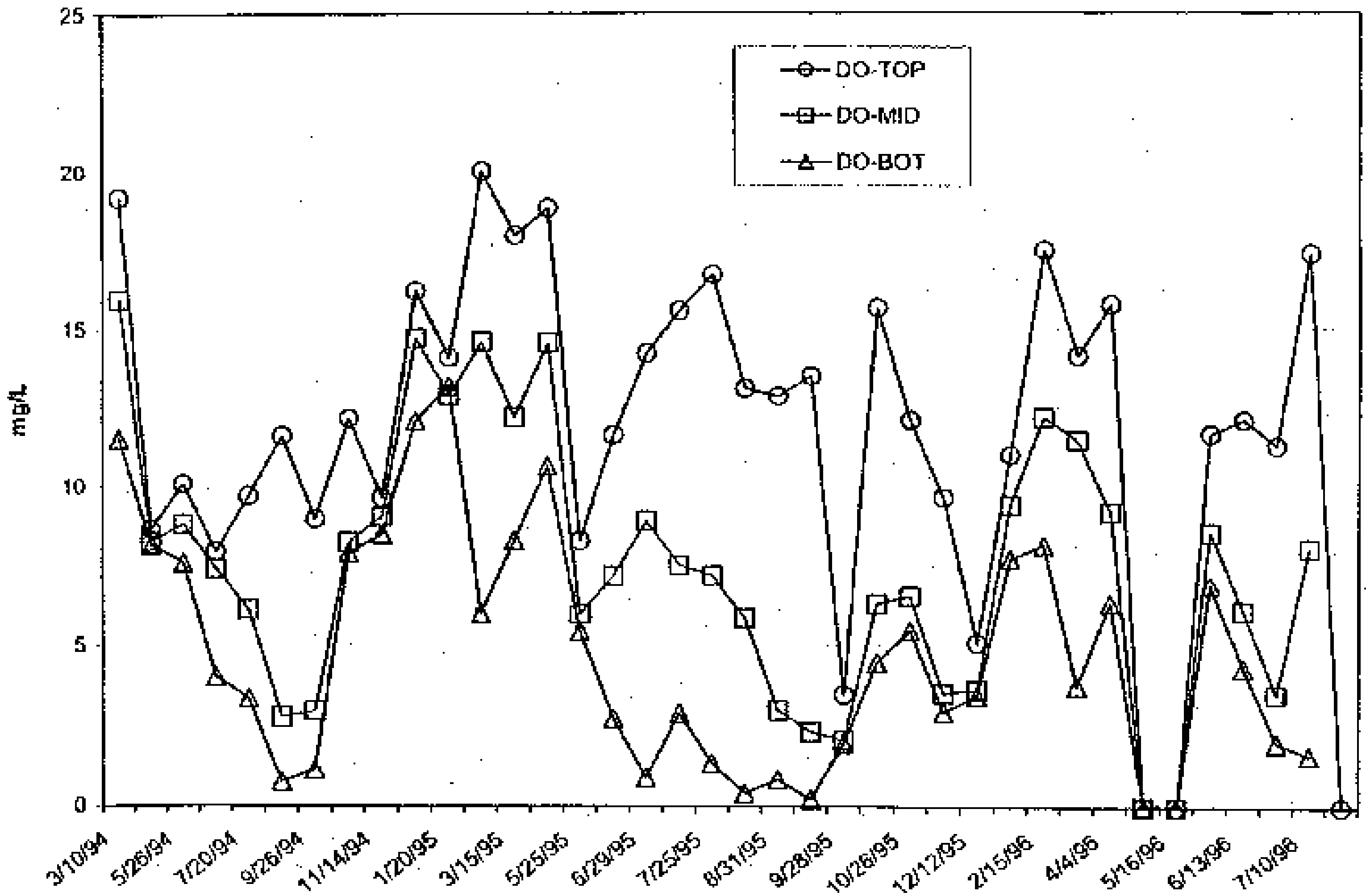


FIGURE 8-1 The nitrogen cycle in freshwater aquatic ecosystems. Thick black lines indicate the main pathways in terms of mass transfer; dotted lines, those involving recycling and mineralization in the water column. Most biologically available nitrogen is present as nitrate, which passes from rain to rivers and lakes, where much of it is taken up by algae, used for growth, and then deposited in the sediments. Nitrogen in algae eaten by zooplankton (lakes) and insect larvae (lake benthos and streams) is excreted as ammonia, which is recycled back to algae in the summer. Note the two anoxic sections of the cycle (N_2 fixation and denitrification), which involve blue-green algae and bacteria, in contrast to the rest of the cycle that occurs under oxygenated conditions. Most N_2 fixation occurs in the plankton, whereas most denitrification occurs in the sediments, especially in estuaries and wetlands. Most organic nitrogen in aquatic ecosystems is present as plant or animal nitrogen and organic detritus (particulate or DON = dissolved organic nitrogen).

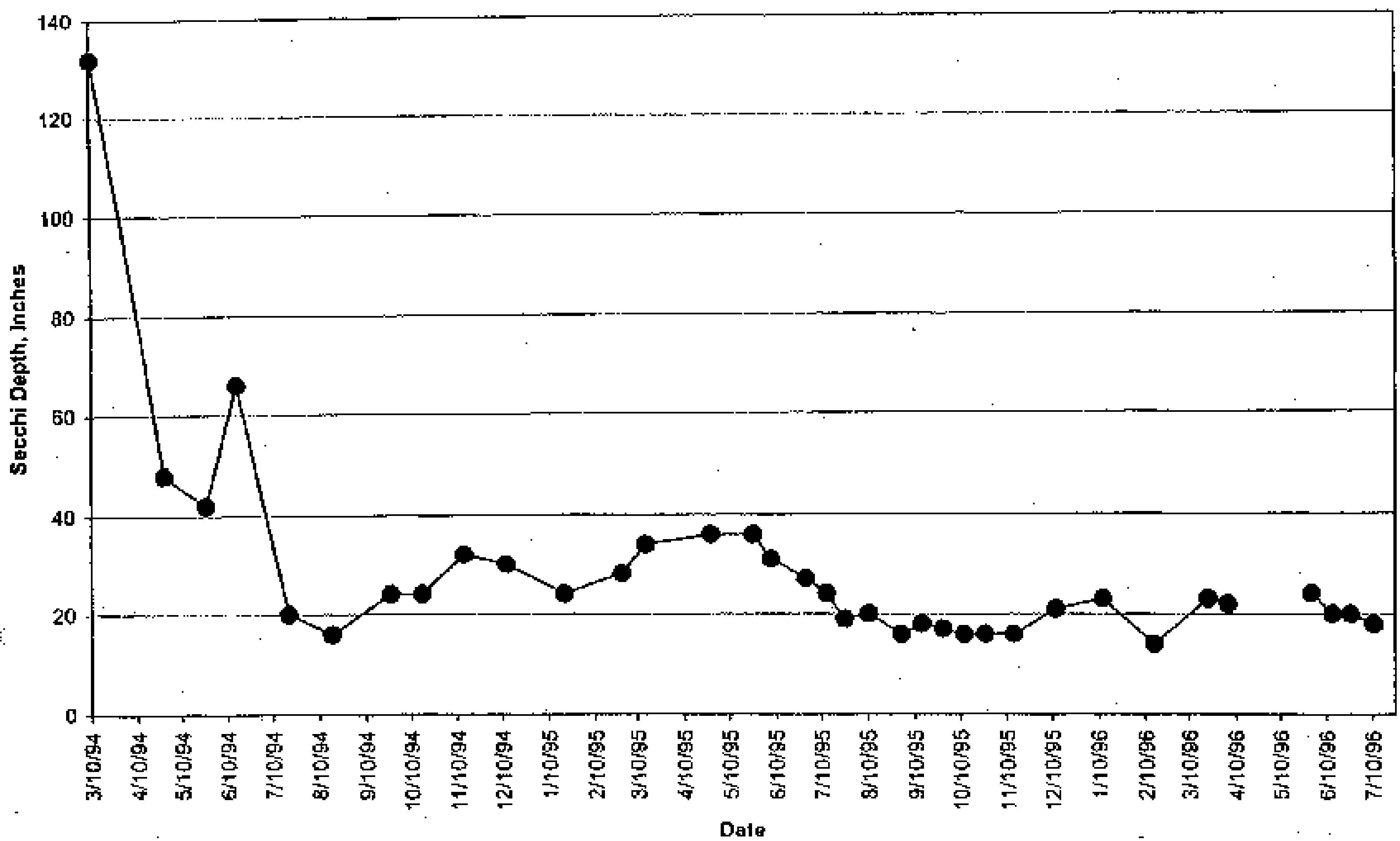
Figure 6. Nitrogen cycles in a lake ecosystem (from Horne and Goldman, 1994)

Figure 7. Dissolved Oxygen Concentrations in Lake Elsinore (1994-1996)



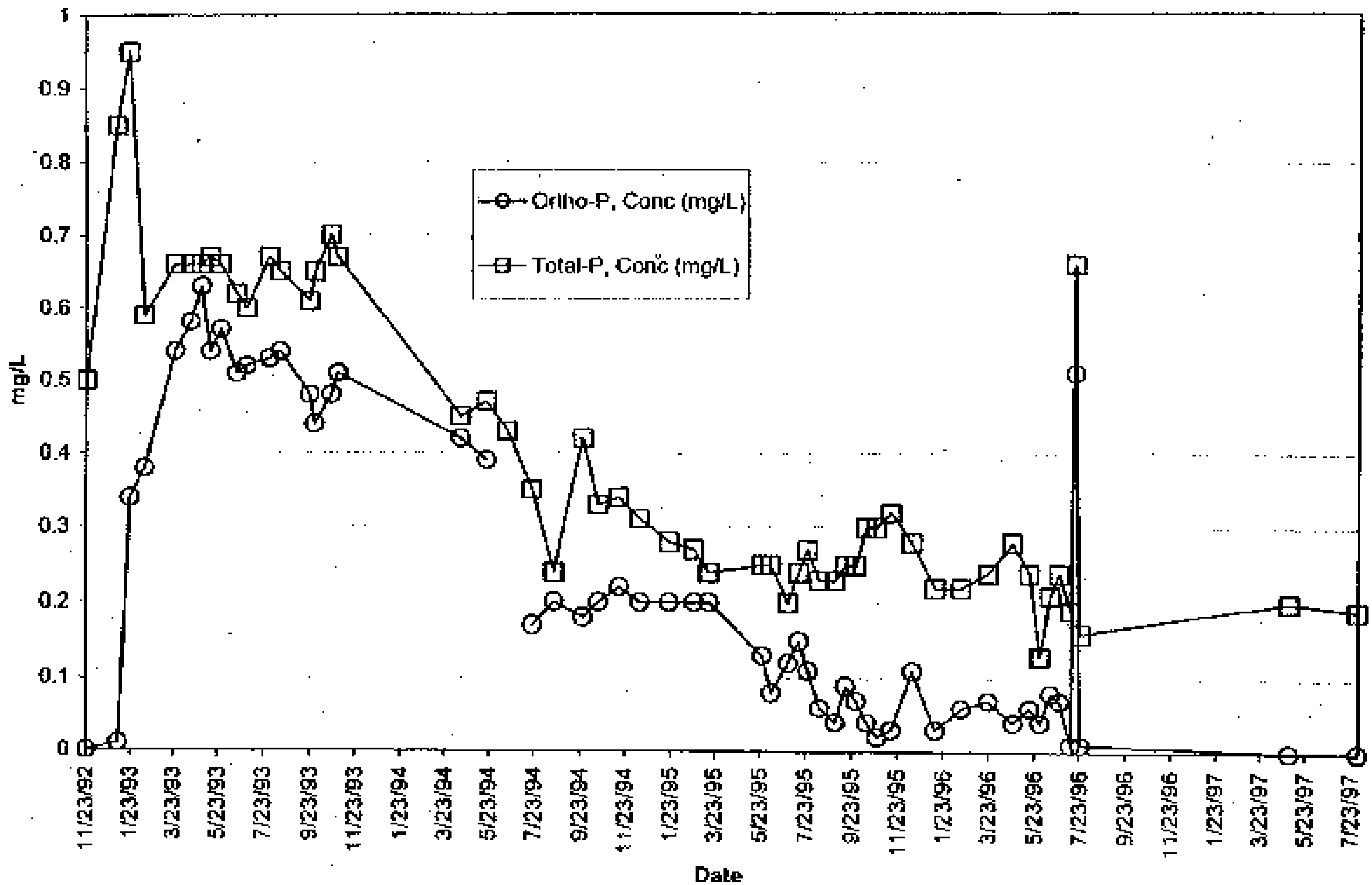
Data Source: Black Veatch (1996) Lake Elsinore Water Quality Monitoring Program

Figure 8. Lake Elsinore Secchi Depth (1994-1996)



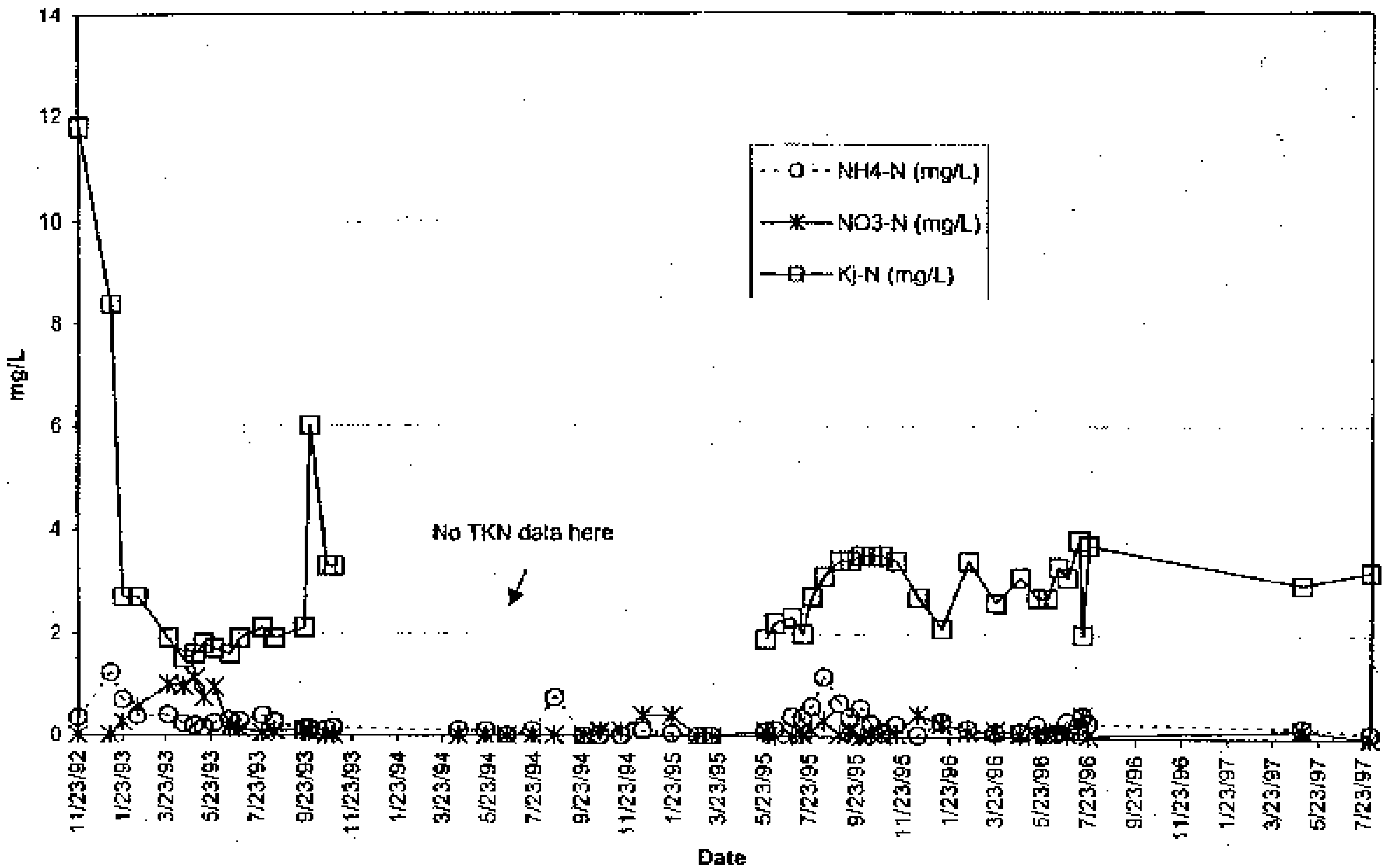
Data Source: Black Vealch (1996) Lake Elsinore Water Quality Monitoring Program

Figure 9. Lake Elsinore Phosphorus Concentrations (1992-1997)



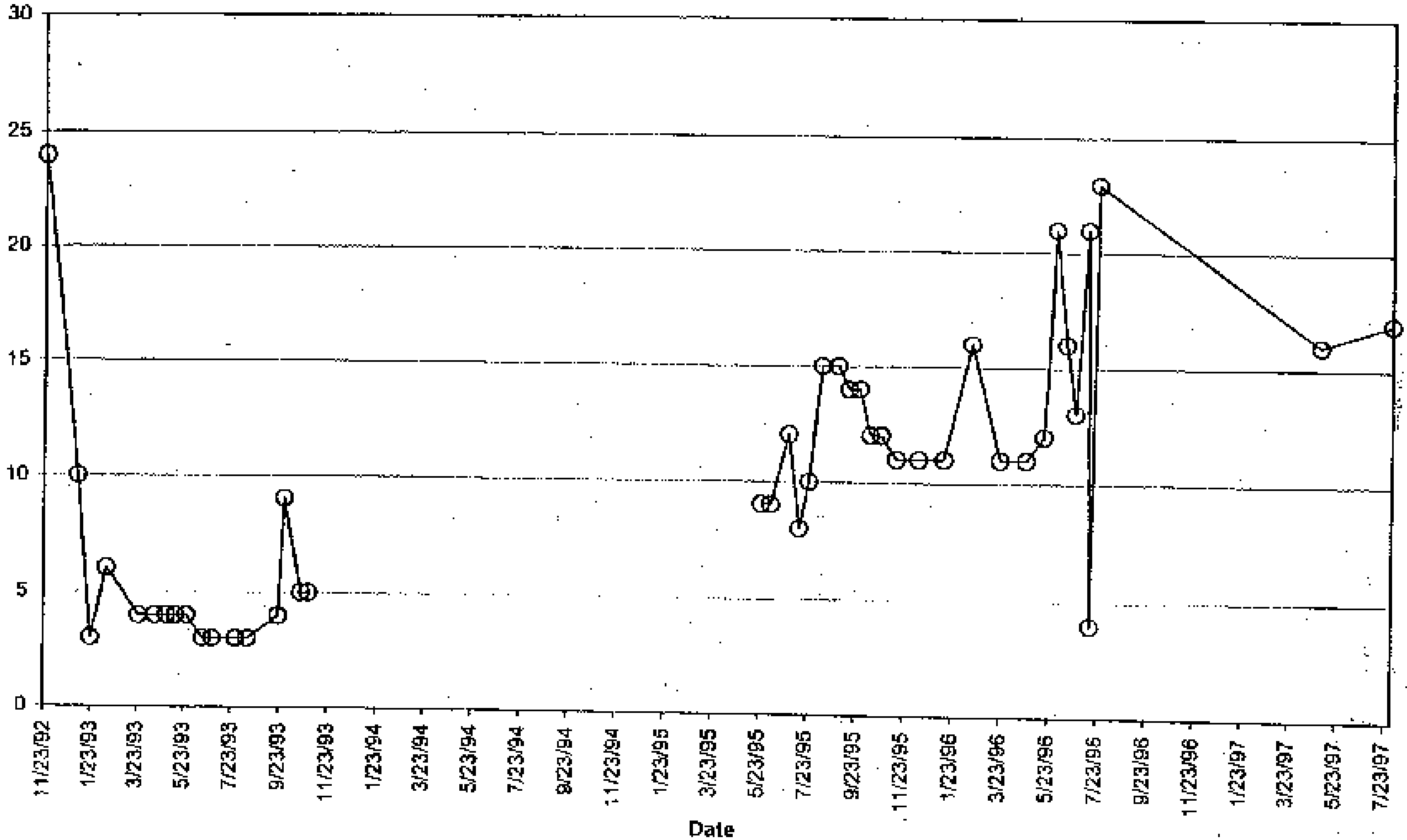
Data Source: Black Veatch (1996) Lake Elsinore Water Quality Monitoring Program

Figure 10. TKN, Ammonium-N, Nitrate-N Concentrations



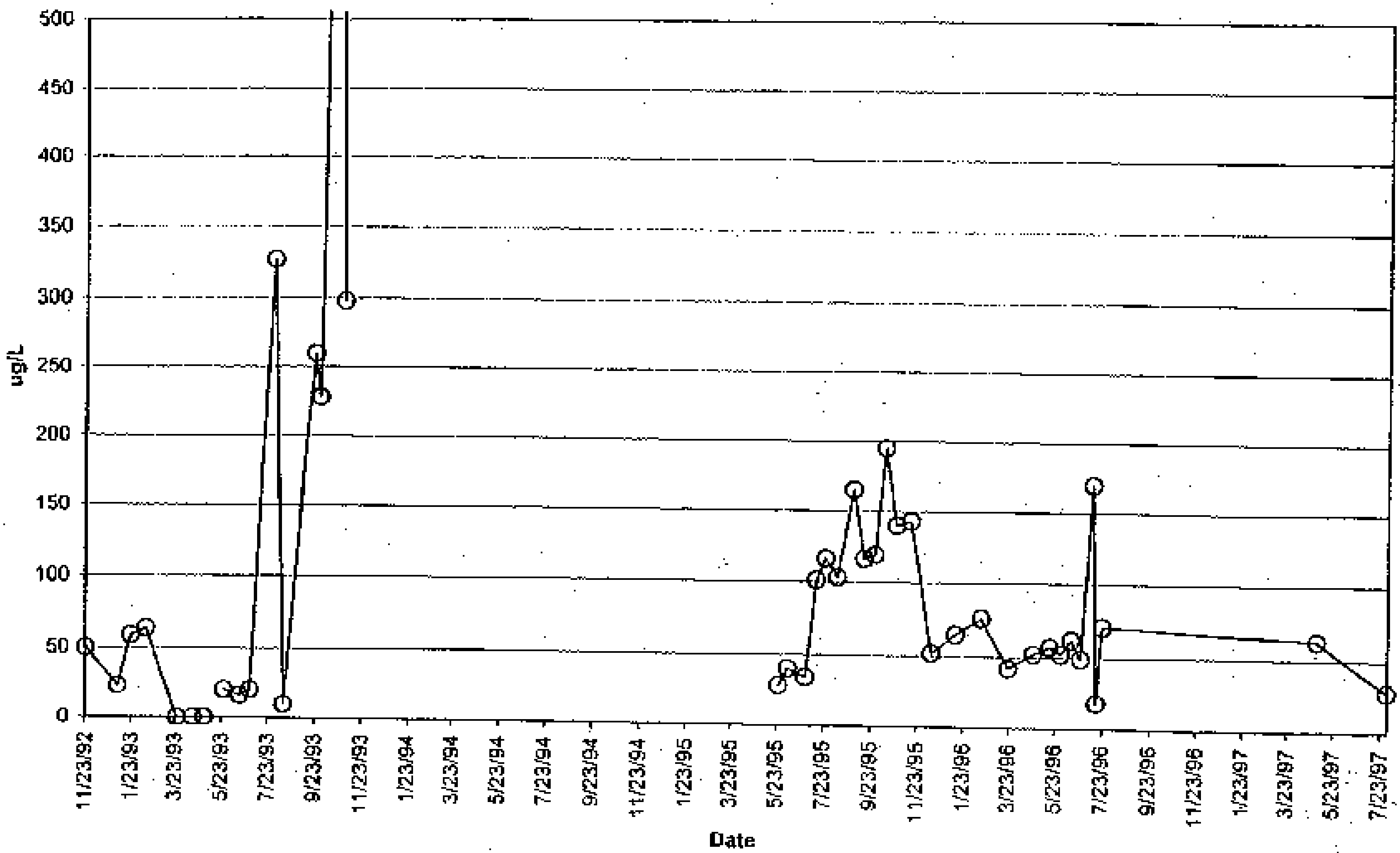
Data Source: Black Veatch (1996) Lake Elsinore Water Quality Monitoring Program

Figure 11. Lake Elsinore Total Nitrogen/Total Phosphorus Ratio (1992-1997)



Data Source: Black Veatch (1996) Lake Elsinore Water Quality Monitoring Program

Figure 12. Algae Biomass, Chl-a (ug/L)



Data Source: Black Veatch (1996) Lake Elsinore Water Quality Monitoring Program

APPENDIX B

Eastern MWD Recycled Water Nutrients Data

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
1/14/97	0.1	0.1	4.8	4.8			800
2/11/97	0.2	0.1	7.6	7.8			560
3/5/97	0.1						
3/11/97	2.9	0.1	6.1	9			580
3/11/97							
4/8/97	1.1	0.1	7.2	8.3			390
5/1/97	0.1		5		1.3		
5/4/97	1.3		4.1		1.9		
5/6/97	0.1		6.5		1.8		
5/8/97	0.1		4.9		1.1		
5/11/97	3		3.8		1.5		
5/13/97	0.1	0.1	5.8	5.9			460
5/13/97	0.1		6.1		1.7		
5/15/97	0.1		7		1.4		
5/18/97	5.1		1.5		1.9		
5/20/97	5.2		3.2		2		
5/22/97	1.4		5.5		2.4		
5/27/97	2		2.3		2.2		
5/29/97	0.9		2.8		1.9		
6/1/97	3.1		2.3		3.3		
6/3/97	0.1		1.4		2.6		
6/5/97	3.3		2.2		2.8		
6/8/97	5.4		1.6		2.5		
6/10/97	5	0.1	1.7	6.6			440
6/10/97	3.9		1.8		2.4		
6/11/97							
6/12/97	2.1		2.5		1.9		
6/15/97	4.3		2		2		
6/17/97	1.9		2.4		2		
6/19/97	1		3.4		1.9		
6/22/97	3.2		2.3		3.6		
6/24/97	2.2		3		4.8		
6/26/97	0.5		2.7		4.7		
6/29/97	0.1		2.8		3.1		
7/1/97	0.1		2.8		2.9		
7/6/97	4.7		2.4		1.3		
7/8/97	3.7	0.1	1.9	6.5			460
7/8/97	0.8		2.6		0.5		
7/10/97	0.1		2.9		1.5		
7/13/97	2.2		1.9		1.4		
7/15/97	1.4		2.7		0.9		
7/17/97	0.2		3.2		1.1		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
7/20/97	1.3		3.5		1.3		
7/22/97	0.1		2.9		0.4		
7/24/97	0.1		2.2		0.6		
7/27/97	0.1		2.9		1.3		
7/29/97	1.1		3.2		0.9		
7/31/97	0.1		3		0.6		
8/3/97	0.1		4.1		0.7		
8/5/97	0.1		3.1		0.1		
8/7/97	1.2		2.8		1.2		
8/10/97	14		2.1		0.6		
8/12/97	14	0.1	1	15			440
8/12/97	11		1		1.9		
8/14/97	17		0.6		4.1		
8/17/97	10		3.2		2.6		
8/21/97	6.1		2.5		1.5		
8/24/97	0.1		1.7		0.2		
8/26/97	0.1		6.7		0.7		
8/28/97	0.4		4.2		1.5		
9/2/97	2.6		1.8		0.9		
9/4/97	1		2.9		1.1		
9/7/97	2.4		2.1		1.3		
9/9/97	5.3	0.1	1.4	6.6			430
9/9/97	9.3		0.9		2		
9/11/97							
9/11/97			0.9		2.7		
9/14/97	7.5		1.6		1.2		
9/16/97	4.4		1		0.5		
9/18/97	5.8		1		0.5		
9/21/97			2.4		0.1		
9/23/97	2.7		3.2		0.1		
9/25/97	0.2		3		0.7		
9/28/97	0.1		2.7		1.2		
9/30/97	0.1		5.4		1.3		
10/2/97	1.2		3.7		2.6		
10/5/97	0.1		6.3		3		
10/7/97	0.1		8.2		4.1		
10/9/97	1.7		6.6		4.5		
10/12/97	19		4		3.5		
10/14/97	4.5	0.01	4.6	9			370
10/14/97	9.2		1.6		4.4		
10/16/97	5.9		4		2.7		
10/21/97	6.4		3.2		3		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
10/23/97	1.1		4.9		3.3		
10/26/97	0.7		5.9		1.7		
10/28/97	0.1		5.9		1.7		
10/30/97	0.1		6.8		2.7		
11/2/97	0.1		4.5		2.4		
11/4/97	0.5		4.6		3		
11/6/97	0.1		7.9		3.9		
11/9/97	0.8		6.6		4.9		
11/11/97	0.1		4.5		2.7		
11/12/97	0.4	0.01	5.9	6.3			391
11/13/97	0.4		5.4		2.5		
11/16/97	0.2		3.3		1.8		
11/18/97	0.1		3.2		1.8		
11/20/97	0.1		3.4		2		
11/23/97	0.1		3.1		1.4		
11/25/97	0.1		3.2		1.6		
11/30/97	0.1		2.6		0.4		
12/2/97	0.1		3.5		0.9		
12/4/97	0.1		2.9		1.3		
12/7/97	0.1		6.8		2		
12/9/97	0.1	0.01	7.3	7.3			539
12/9/97	0.1		7.3		2.3		
12/11/97							
12/11/97	0.1		10		2.9		
12/14/97	0.1		6.2		2		
12/16/97	0.1		5.3		2.1		
12/18/97	0.1		7.6		2.8		
12/21/97	0.1		6.6		2.1		
12/23/97	0.1		6		2.3		
12/28/97	0.3		3		1.3		
12/30/97	4.2		2.8		2.4		
1/4/98	3.3		3.6		2.2		
1/6/98	2.3		7.5		2.8		
1/8/98	0.2		10		2.6		
1/11/98	0.6		7.8		2.2		
1/13/98	1.9	0.01	7.3	9.2			470
1/13/98	1.5		8.8		2.5		
1/15/98	1.2		9.2		2.9		
1/18/98	1.5		7.5		2.8		
1/20/98	1.4		7.6		2.7		
1/22/98	0.7		8.6		2.7		
1/25/98	2.4		9		2.3		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
1/27/98	4.6		7.7		2.6		
1/29/98	3.2		9.7		3		
2/1/98	3.1		5.9		2		
2/3/98	4.1		5.4		2.1		
2/5/98	4.5		5.7		1.9		
2/8/98	7.8		4.5		1.6		
2/10/98	7.5	0.01	4.5	12			429
2/10/98	7.7		3.6		1.7		
2/12/98	6.9		4.2		1.2		
2/17/98	12		2		1.6		
2/19/98	12		2.8				
2/22/98	12		2.9		1.7		
2/24/98	14		0.8		3.7		
2/26/98	17		1.1				
3/1/98	9.2		2				
3/3/98	8.1		1.2		1.1		
3/5/98	9.2		1		0.3		
3/8/98	5.8		6.4		2.1		
3/10/98	7.4	0.01	5.2	13			420
3/10/98	6.1		5.3		2.6		
3/11/98							
3/12/98	1.7		6		2.8		
3/15/98	5.6		2.7		1.6		
3/17/98	2.6		5.5		2.2		
3/19/98	6		2.4		2.5		
3/22/98	7.3		1.9		2.1		
3/26/98	5.5		1.5		2.2		
3/29/98	5.1		2.1		1.6		
3/31/98	1.3		1.6		0.4		
4/2/98	0.9		1.4		0.1		
4/5/98	1.8		3.1		0.9		
4/7/98	4.4		7.6		2.2		
4/9/98	6.4		9.8		2.4		
4/12/98	7.1		6.7		2.3		
4/14/98	6	0.01	7.8	14			507
4/14/98	4.2		8.7		2.2		
4/16/98	4.7		7.5		1.3		
4/19/98	5.5		9.1		1.7		
4/21/98	7.8		7.8		2.6		
4/23/98	9.9						
4/26/98	8.9		8.5		2		
4/28/98	6.9		10		1.9		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_3-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
4/30/98	6		7.1		1.9		
5/3/98	8.2		7.8		1.4		
5/5/98	8.4		8		1.4		
5/7/98	6.2		12		1.2		
5/10/98	8.6		10		1.6		
5/12/98	8.4	0.01	11	19			425
5/12/98	7.9		12		2.1		
5/14/98	4.9		12		1.9		
5/17/98	7.5		8		1.8		
5/19/98	9.6		4.4		1.8		
5/21/98	7.8		6.8		1.9		
5/26/98	8.7		5.7		1.9		
5/28/98	9		8.1		1.7		
5/31/98	8.6		10		1.6		
6/2/98	12		4		1.3		
6/4/98	14		0.5				
6/7/98	10		7.3		1.8		
6/9/98	9.2	0.01	6.6	16			405
6/9/98	13		7.3		1.7		
6/11/98							
6/11/98	19		9.4		1.5		
6/14/98	9.6		5.7				
6/16/98	3.7		13				
6/18/98	8		3.4		2		
6/21/98	12		3.3		1.7		
6/23/98	6.7		4.8		1.9		
6/25/98	9.6		6.8		2.2		
6/28/98	12		4.2		2.8		
6/30/98	10		1.3		3.4		
7/5/98	13		3.9		3.1		
7/7/98	9.8		6		2.6		
7/12/98	9		5.6		2		
7/14/98	8.4	0.01	5.3	14			349
7/14/98	9.7		4		1		
7/16/98	3.2		4.7		1.8		
7/19/98	6.2		6.2		3		
7/21/98	12		2.8		3.8		
7/23/98	5.4		3.9		2.7		
7/26/98	12		0.6		2.4		
7/28/98	14		0.4		2.4		
7/30/98	4.6		6.3		1.8		
8/2/98	4.2		6		2.6		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
8/4/98	1.5		7.4		2.7		
8/6/98	2.9		2.5		2.6		
8/9/98	3.5		3		3.1		
8/11/98	3.3	0.01	1.7	5			358
8/11/98	2.5		2.3		3.6		
8/13/98	3.8		1.7		2.1		
8/16/98	9.7		2.4		4		
8/18/98	11		2.4		2.5		
8/20/98	3.1		4.1		2.6		
8/23/98	2.5		3.3		2		
8/25/98	0.3		4.7		2.2		
8/27/98	0.1		8.4		2.4		
8/30/98	0.1		9.1		2		
9/1/98	0.1		8.6		2		
9/3/98	0.1		6.5		1.7		
9/8/98	1.8	0.5	4.4	8.5			418
9/8/98	0.1		5.1		2.3		
9/10/98	0.1		8.2		2.8		
9/13/98	0.1		8.5		3.4		
9/15/98	0.1		9.2		2.1		
9/17/98	0.1		9.9		1.6		
9/20/98	0.1		12		2.6		
9/22/98	0.1		14		2.6		
9/24/98	0.3		15		2.4		
9/27/98	1.8		12		2.6		
9/29/98	1.2		8.6		2		
10/1/98	5		4.9		2.2		
10/4/98	2.7		1.8		0.8		
10/6/98	4.5		1.7		0.4		
10/8/98	8.6		1.8		1		
10/11/98	8.4		1.5		2.8		
10/13/98	9	0.1	1.5	10			370
10/13/98	7.2		1.1		2.2		
10/15/98	7.8		0.8		3.3		
10/18/98	6.5		0.8		1.3		
10/20/98	9.2		0.5		1.2		
10/22/98	13		0.5		2		
10/25/98	2.9		1.3		0.3		
10/27/98	11		0.9		1.6		
10/29/98	7.1		1.6		1.4		
11/1/98	9.2		1.2		0.9		
11/3/98	7.5		1.5		0.5		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
11/5/98	3.9		4.3		0.1		
11/8/98	6.5		2.3		0.5		
11/10/98	6.1	0.01	2	8.1			360
11/12/98	4.4		3.7		0.5		
11/15/98	5		1.6		1.5		
11/17/98	3.9		2.1		0.8		
11/19/98	2.5		1.9		0.5		
11/22/98	3.3		2.5		0.7		
11/24/98	3.8		1.6		1.2		
11/29/98	9.9		1.6		0.4		
12/1/98	9.5		1.7		0.5		
12/3/98	8.5		1.6		0.4		
12/6/98	7.6		1.9		0.6		
12/7/98	7.2	0.05	2.1	9.4			365
12/8/98	7.8		1.7		0.6		
12/10/98	2.3		2.8		1.5		
12/13/98	6.9		2.6		5.7		
12/15/98	6		1.4		3.3		
12/17/98	8.1		0.9		4.3		
12/20/98	8.2		1		1.4		
12/22/98	9.4		1.2		0.7		
12/27/98	10		1.1		0.7		
12/29/98	13		0.6		2		
1/3/99	19		0.4		0.8		
1/5/99	19		0.4		0.6		
1/7/99	12		0.8		0.4		
1/10/99	8.6		0.9		2.9		
1/12/99	3.7	0.01	1.4	5.1			385
1/12/99	12		1.2		1.8		
1/14/99	9.8		2.1		1.1		
1/17/99	8.3		2.9		1.1		
1/19/99	7.6		1.7		0.5		
1/21/99	10		2.7		0.3		
1/26/99	5.7		3.9		0.3		
1/28/99	0.1		3.6				
2/1/99	3.1	4					
2/3/99	3.6	4.3					
2/5/99	2	4.9			1.5		
2/8/99	0.2	2.1			0.1		
2/9/99	0.2	1.6	0.01	1.6			380
2/10/99	0.2	1.1			0.1		
2/12/99	4.4	5.9			1.1		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
2/17/99	2.2	5.3			1.7		
2/19/99	3.5	5.8			1.9		
2/22/99	1.5	3.6			1.8		
2/24/99	2.2	4.4			1.5		
2/26/99	2	3.3			2.3		
3/1/99	1.5	2.6			2.8		
3/3/99	2.4	1.9			1.5		
3/5/99	4.8	1.9			1.7		
3/8/99	1.5	2.7			2.9		
3/9/99	4	2	0.01	6			385
3/10/99	6.3	1.8			1.9		
3/12/99	2.9	3.9			2.3		
3/15/99	4.5	2.6			2.7		
3/17/99	2.5	3.5			0.96		
3/19/99	2	1.8			1.6		
3/22/99	6	4.4			1.1		
3/24/99	4.8	2.7			1		
3/26/99	4	3.3			1.7		
3/29/99	3	4.1			2.9		
3/31/99	7.9	1.8			1.9		
4/2/99	7.2	2.9			1.4		
4/5/99	3.7	3			2.2		
4/7/99	4.7	3.5			1.5		
4/9/99	6.1	4.3			1.8		
4/12/99	4.4	4.3			2.5		
4/13/99	4.7	3.8	0.01	8.4			380
4/14/99	3.4	3.6			1.5		
4/16/99	6.6	1.8			2		
4/19/99	5.9	3.2			2.8		
4/21/99	9.8	2.3			1.5		
4/23/99	7.8	2.7			1.4		
4/26/99	9.4	3			1.5		
4/28/99	8.9	2.6			1.2		
4/30/99	10	3.2			2.1		
5/3/99	7	3.6			4.3		
5/5/99	5.1	4			2.1		
5/7/99	4.5	3.7			1.3		
5/10/99	8.6	2.1			2.1		
5/11/99	7	2.7	0.01	9.7			410
5/12/99	8.2	3.1			1.7		
5/14/99	7.1	2.6			1.2		
5/17/99	3.9	4.7			1.8		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
5/19/99	5.4	3.5			1.6		
5/21/99	8.3	2.8			1.8		
5/24/99	9.6	2.4			1.1		
5/26/99	8.5	1.1			0.1		
5/28/99	5.1	0.9			0.3		
6/2/99	8	1.6			0.6		
6/4/99	2.5	3.8			0.1		
6/7/99	0.2	2.3			0.35		
6/8/99	1.6	1.4	0.1	3			440
6/9/99	0.2	2.2			0.2		
6/11/99	0.2	3.3			0.4		
6/14/99	1.3	3.9			0.4		
6/16/99	3	3.3			0.4		
6/18/99	0.2	3.2			0.1		
6/23/99	2.8	2.7			0.2		
6/25/99	1.2	3.3			0.33		
6/28/99	1.4	3.9			0.4		
6/30/99	2.4	2.4			0.96		
7/2/99	5.5	3.9			0.3		
7/7/99	5.7	1.5			0.8		
7/9/99	1.2	1			0.4		
7/12/99	1.4	1.2			0.2		
7/13/99	7.6	0.8	0.01	8.4			425
7/14/99	13	0.4			3.4		
7/16/99	6.3	0.5			1.2		
7/19/99	12	0.5			2.7		
7/21/99	0.2	0.6			0.3		
7/23/99	3.7	3.1			0.3		
7/26/99	0.9	2.8			1		
7/28/99	2	2.5			0.4		
7/30/99	0.2	4.6			0.4		
8/2/99	1	3.8			1.2		
8/4/99	0.6	3.6			0.7		
8/6/99	0.6	3.5			0.8		
8/9/99	3.3	4.7			2.4		
8/10/99	0.2	3.9	0.01	3.9			415
8/11/99	0.2	3.6			0.8		
8/12/99						2.8	
8/13/99	0.2	3.3			2.9		
8/16/99	0.2	3.8			3.4		
8/18/99	0.2	3.8			1.9		
8/19/99						2	

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_3-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
8/20/99	0.2	3.5			2.1		
8/23/99	0.2	1.8			3.3		
8/25/99	1.5	3.8			1.1		
8/26/99						0.2	
8/27/99	1	4.4			1.4		
8/30/99	0.5	3.9			0.4		
8/31/99	0.2	4.3			0.6		
9/1/99						1.6	
9/2/99	0.2	7.2			2		
9/7/99	0.2	2.8			1		
9/8/99						1.4	
9/9/99	2	2.3			2.8		
9/12/99	0.2	3.1			1.5		
9/13/99	1.8	1.3	0.1	3.2			370
9/14/99	0.2	2			1.3		
9/15/99						3.7	
9/16/99	0.2	3			1.3		
9/19/99	0.2	2.1			0.8		
9/21/99	2	1			1.2		
9/23/99	4	1.2			1.3		
9/26/99	0.2	1.9			1.8		
9/28/99	0.2	1.9			0.8		
10/3/99	0.2	1			1.4		
10/5/99	0.2	1.9			0.5		
10/7/99	0.2	3.2			1.7		
10/10/99	0.2	2.4			1.5		
10/11/99	0.1	1.1	0.1	1.1			400
10/12/99	0.2	1.9			0.7		
10/14/99	0.2	2.5			1.3		
10/17/99	0.2	2.8			2.6		
10/19/99	0.2	2.6			2.2		
10/24/99	1.7	4			3		
10/26/99	0.2	3.1			2.1		
10/28/99	0.2	4			3.4		
10/31/99	0.5	2.8			3.2		
11/2/99	0.2	3.1			1.8		
11/4/99	0.2	3.6			1.8		
11/7/99	0.2	2.6			1.1		
11/8/99	0.2	2.6	0.01	2.6			435
11/9/99	0.2	2.8			0.6		
11/11/99	0.2	4			1		
11/14/99	0.2	4.5			1.9		

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
11/16/99	0.2	4.4			1.8		
11/18/99	0.2	6.1			2.3		
11/21/99	0.2	4.2			2.5		
11/23/99	0.2	3.8			1.8		
11/28/99	0.2	2.1			0.3		
11/30/99	0.2	2.8			0.8		
12/2/99	0.2	3.3			1.3		
12/5/99	0.2	3			6.6		
12/7/99	0.2	1.4			6.4		
12/9/99	0.2	2.9			2.8		
12/12/99	0.2	3.2			1.4		
12/13/99	0.2	2.3	0.01	2.3			435
12/14/99	0.2	2.4			1		
12/16/99	0.5	2.1			1.9		
12/19/99	1.4	1.2			1		
12/21/99	0.9	1.6			0.3		
12/26/99	0.5	1.3			0.6		
12/28/99	0.2	2.3			0.2		
2/1/00	0.2	4.7			1.9		
2/3/00	0.2	6.5			2.9		
2/6/00	0.2	6.2			3.6		
2/7/00	0.2	4.8	0.01	4.8			535
2/8/00	0.2	5.5			3.2		
2/10/00	0.2	7.8			3.5		
2/13/00	0.2	5.2			2.2		
2/15/00	0.2	4.3			1.4		
2/17/00	0.2	3.9			1		
2/22/00	1.9	2.7			0.6		
2/24/00	2.8	2.8			0.8		
2/27/00	6.8	2.2			0.8		
2/29/00	8.8	2.1			0.8		
3/2/00	8.2	2.7			1.1		
3/5/00	8.7	2.5			0.6		
3/7/00	6.9	2.9			0.7		
3/9/00	6.8	2.4			0.7		
3/12/00	1.9	2.3			0.2		
3/13/00	2.2	2.1	0.1	4.3			480
3/14/00	2.5	2.4			0.2		
3/16/00	5.5	1.6			0.2		
3/19/00	4.5						
3/21/00							
3/23/00	0.2						

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
3/26/00	0.2						
3/28/00	0.2						
3/30/00	0.2						
4/2/00	0.2						
4/4/00	0.2						
4/6/00	0.2						
4/9/00	0.2						
4/10/00	0.1	1.5	0.1	1.4			410
4/11/00	0.2						
4/13/00	0.2						
4/17/00	0.2	5			1.3		
4/18/00	0.2	7.3			1.8		
4/20/00	0.2	6.2					
4/23/00	0.2	3.3			1.3		
4/25/00	0.2	2.6			1.3		
4/27/00	0.2	3.3			1.5		
4/30/00	0.2	5.2			1.5		
5/2/00	0.5	4.2			1.4		
5/4/00	0.2	2.9			1.6		
5/7/00	0.2	4.5			1.8		
5/8/00	3.5	1.5	0.01	5			450
5/9/00	9.2	0.7			2.3		
5/11/00	0.2	3.2			0.2		
5/14/00	0.2	3.5			1.1		
5/16/00	0.2	3			1.4		
5/18/00	0.2	2.1			0.7		
5/21/00	0.2	2			0.5		
5/23/00	0.2	1.8			0.25		
5/25/00	0.2	4.2			1.2		
5/30/00	0.2	3.9			1.8		
6/1/00	0.2	5.4			2.1		
6/4/00	0.2						
6/6/00	0.2						
6/8/00	2.5						
6/11/00	0.2						
6/12/00	0.1	4.7	0.1	4.7			450
6/13/00	0.2						
6/15/00	0.2						
6/18/00	0.2						
6/20/00	0.2						
6/22/00	0.2						
6/25/00	0.2						

Moreno Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
6/27/00	0.2						
6/29/00	0.2	3			0.43		
7/2/00	0.2	2.3			0.3		
7/4/00	1	1.7			0.69		
7/6/00	0.2	1.5			0.2		
7/9/00	0.2	1.4			0.5		
7/10/00	0.2	1.8	0.01	1.8			430
7/11/00	0.2	2.7			0.3		
7/13/00	0.2	2.3			0.4		
7/16/00	0.2	2.9			0.6		
7/18/00	0.2	2.8			1.2		
7/20/00	0.2	2.8			0.9		
7/23/00	0.2	4.3			1.3		
7/25/00	0.2	3.1			1.7		
7/27/00	0.2	3.2			1.7		
7/30/00	0.2	3.9			0.7		
8/1/00	0.2	3.5			2.1		
8/3/00	0.2						
8/6/00	0.2	3.4			1.1		
8/7/00	0.2	3.6	0.01	3.6			
8/8/00	0.2	3.9			1.6		
No. of Data	510	233	297	43	434	6	42
Minimum	0.1	0.01	0.01	1.1	0.1	0.2	349
Maximum	19	7.8	15.00	19	6.6	3.7	800
Average	3.6	2.7	4.10	7.3	1.7	2.0	437

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
01/01/97	0.1						
01/02/97							664
01/02/97	0.1		4.3				
01/05/97	0.1		1.3				
01/06/97	0.1						
01/07/97	0.1		6.8				
01/08/97	0.1						
01/09/97	0.1						
01/12/97	0.1						
01/13/97	0.1						
01/14/97	0.1	< 0.1	7.8	7.8			600
01/14/97	0.1						
01/15/97	0.1						
01/16/97	0.1						
01/19/97	0.1						
01/20/97	0.1						
01/21/97	0.1						
01/22/97	0.1						
01/23/97	0.1						
01/26/97	0.1						
01/27/97	0.1						
01/28/97			5				610
01/28/97	0.1		7.9				
01/29/97	0.1						
01/30/97	0.1		8				
02/02/97	0.1						
02/03/97	0.1						
02/04/97	0.1		11				
02/05/97							715
02/05/97							733
02/05/97							
02/05/97							734
02/05/97	0.1						
02/06/97	0.1		10				
02/09/97	0.1		9				
02/10/97	0.1						
02/11/97	0.1	< 0.1	5.3	5.4			660
02/11/97	0.1		4.3				
02/12/97	0.1						
02/13/97	0.1		5.8				
02/17/97	0.1						
02/18/97	0.1		6.3				
02/19/97	0.1						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
02/20/97	0.1			8.4				
02/23/97	0.2			6.6				
02/24/97	0.1							
02/25/97				5				650
02/25/97	0.1			7.5				
02/26/97	0.1							
02/27/97	0.1							
03/02/97	0.1			6.7				
03/03/97	0.1							
03/04/97	0.1			7.3				
03/05/97								670
03/05/97								703
03/05/97	0.1							
03/06/97	0.1			11				
03/09/97	0.1							
03/10/97	0.1							
03/11/97	0.1	<	0.1	5.8	5.9			620
03/11/97	0.1			6.2				
03/12/97	0.1							
03/13/97	0.1			9.3				
03/16/97	0.2			5.9				
03/17/97	0.1							
03/18/97	0.1			9				
03/19/97	0.1							
03/20/97	0.1			8				
03/23/97	0.1			6.5				
03/24/97	0.1							
03/25/97				6.6				720
03/25/97	0.1			6.3				
03/26/97	0.1							
03/27/97	0.1			5.2				
03/30/97	0.1			3.4				
03/31/97	0.1							
04/01/97	0.1			6.8				
04/02/97								642
04/02/97								709
04/02/97	0.1							
04/03/97	0.1			12				
04/06/97	0.3			2.9				
04/07/97	0.1							
04/08/97	0.1	<	0.1	4	4.1			560
04/08/97	0.1			5.2				
04/09/97	0.1							

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
04/10/97	0.1			8				
04/13/97	0.2			4.1				
04/14/97	0.1							
04/15/97	0.1			4.7				
04/16/97	0.1							
04/17/97	0.1			5.4				
04/20/97	0.1			6.1				
04/21/97	0.1							
04/22/97	0.2			5.9				
04/23/97	0.1							
04/24/97	0.1			7.9				
04/27/97	0.1			7.1				
04/28/97	0.1							
04/29/97				5				620
04/29/97	0.1			8.3				
04/30/97	0.1							
05/01/97	0.1			13				
05/04/97	0.1			9.1				
05/05/97	0.1							
05/05/97								688
05/06/97	0.1			8.1				
05/07/97								696
05/07/97								710
05/07/97	0.1							
05/08/97	0.1			7.5				
05/11/97	0.1			5				
05/12/97	0.3							
05/13/97	6.2	<	0.1	5.3	5.9			670
05/13/97	0.1			6.1				
05/14/97	0.1							
05/15/97	0.1			7.3				
05/18/97	0.1			5.2				
05/19/97	0.1							
05/20/97	0.1			4.8				
05/21/97	0.1							
05/22/97	0.1			5				
05/26/97	0.1							
05/27/97				5.8				620
05/27/97	0.5			5.6				
05/28/97	0.1							
05/29/97	0.1			5.4				
06/01/97	0.1			5				
06/02/97	0.1							

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
06/03/97	0.1		4.9				
06/04/97							727
06/04/97							761
06/04/97	0.1						
06/05/97	0.1		3.4				
06/08/97	0.1		3.3				
06/09/97	0.1						
06/10/97	0.1	< 0.1	2	2.1			620
06/10/97	0.1		4.4				
06/11/97	0.1						
06/12/97	0.1		5.4				
06/15/97	0.1		4.1				
06/16/97	5.8						
06/17/97	0.1		5.1				
06/18/97	2.9						
06/19/97	0.1		5.7				
06/22/97	0.1		5				
06/23/97	0.1						
06/24/97			2.5				680
06/24/97	0.1		5.1				
06/25/97	0.1						
06/26/97	0.1		6				
06/29/97	0.1		3.6				
06/30/97	0.1						
07/01/97	0.1		1.6				
07/02/97							758
07/02/97							765
07/02/97	0.1						
07/06/97	0.1		4.7				
07/07/97	0.1						
07/08/97	0.1	< 0.1	5.6	5.7			640
07/08/97	0.1		6.5				
07/09/97	0.1						
07/10/97	0.1		5				
07/13/97	0.1		4.4				
07/14/97	0.1						
07/15/97	0.1		6.4				
07/16/97	0.1						
07/17/97	0.1		7.6				
07/20/97	0.1		5.5				
07/21/97	0.1						
07/22/97	0.1		8.6				
07/23/97	0.1						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
07/24/97	0.1			7.8				
07/27/97	0.1			5.3				
07/28/97	0.1							
07/29/97				4.7				630
07/29/97	0.1			5				
07/30/97	0.1							
07/31/97	0.1			9.1				
08/03/97	0.1			5.4				
08/04/97	0.1							
08/05/97	0.1			5.7				
08/06/97	0.1							
08/07/97	0.1			7.2				
08/10/97	0.1			5.5				
08/11/97	0.1							
08/12/97	0.1	<	0.1	6.2	6.3			630
08/12/97	0.1			4.9				
08/13/97	0.1							
08/14/97	0.1			4.6				
08/17/97	0.1			5.4				
08/18/97	0.1							
08/19/97	0.1			7.7				
08/20/97	0.1							
08/21/97	0.1			5.1				
08/24/97	0.1			6.8				
08/25/97	0.1							
08/26/97				6				740
08/26/97	0.1			6.2				
08/27/97	0.1							
08/28/97	0.1			6.9				
09/01/97	0.1							
09/02/97	0.1			7.1				
09/03/97								854
09/03/97								811
09/03/97	0.1							
09/04/97	0.1			5.8				
09/07/97	0.1			5.2				
09/08/97	0.1							
09/09/97	0.1	<	0.1	5.8	6			730
09/09/97	0.1			7.1				
09/10/97	0.1							
09/11/97	0.3			7.3				
09/14/97	0.1			7				
09/15/97	0.1							

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
09/16/97	0.1			6.7				
09/17/97	0.1							
09/18/97	0.1			6.6				
09/21/97				6				
09/22/97	0.1							
09/23/97	0.1			7.1				
09/24/97	0.1							
09/25/97	0.1			7.4				
09/28/97	0.1			5.3				
09/29/97	0.1							
09/30/97		<	0.01	4.5				606
09/30/97	0.1			5.6				
10/01/97								808
10/01/97								713
10/01/97	0.1							
10/02/97	0.1			5.2				
10/05/97	0.1			5.6				
10/06/97	0.1							
10/07/97	0.1			6.4				
10/08/97	0.1							
10/09/97	0.1			7				
10/12/97	0.1			6.4				
10/13/97	0.6							
10/14/97	0.6	<	0.01	5.2	6			545
10/14/97	0.1			6.4				
10/15/97	0.1							
10/16/97	0.1			7.3				
10/19/97	0.1			6.2				
10/20/97	0.1							
10/21/97	0.1			7				
10/22/97	0.1							
10/23/97	0.1			5.9				
10/26/97	0.1			5.9				
10/27/97	0.1							
10/28/97				5.3				610
10/28/97	0.1			6.2				
10/29/97	0.1							
10/30/97	0.1			7.7				
11/02/97	0.1			6.6				
11/03/97	0.2							
11/04/97	0.1			6				
11/05/97								863
11/05/97								962

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
11/05/97	0.1						
11/06/97	0.1		7.3				
11/09/97	0.1		6.9				
11/11/97	0.1		7.2				
11/12/97	0.1	< 0.01	7.2	7.2			620
11/12/97	0.3						
11/13/97	0.2		7.3				
11/16/97	0.2		5.9				
11/17/97	0.1						
11/18/97	0.1		7.7				
11/19/97	0.1						699
11/20/97	0.1		7.8				
11/23/97	0.1		5.6				
11/24/97	0.1						
11/25/97			5.5				680
11/25/97	0.1		7.7				
11/30/97	0.1		6.2				
12/01/97	0.1						
12/02/97	0.8		6.2				
12/03/97	0.9						
12/04/97	1.1		7.2				
12/07/97	0.1		7.4				
12/08/97	0.1						
12/09/97	0.1	< 0.01	5.5	5.5			635
12/09/97	0.1		4.5				
12/10/97	0.1						
12/11/97	0.1		7.2				
12/14/97	0.1		6.6				
12/15/97	0.1						
12/16/97	0.1		8.4				
12/17/97							720
12/17/97							660
12/17/97	0.1						
12/18/97	0.1		9.2				
12/21/97	0.1		7.2				
12/22/97	0.1						
12/23/97	0.1		8				
12/28/97	0.1		6.9				
12/29/97	0.1						
12/30/97			6.6				611
12/30/97	0.1		5.8				
01/04/98	0.1		8.3				
01/05/98	0.1						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
01/06/98	0.1			8.1				
01/07/98								700
01/07/98								660
01/07/98	0.1							
01/08/98	0.1			9.2				
01/11/98	0.1			8.4				
01/12/98	0.1							
01/13/98	0.1	<	0.01	6.9	7			680
01/13/98	0.1			7.4				
01/14/98	0.1							
01/15/98	0.1			9.6				
01/18/98	0.1			7.5				
01/19/98	0.1							
01/20/98	0.1			12				
01/21/98	0.1							
01/22/98	0.1			12				
01/25/98	0.1			15				
01/26/98	0.1							
01/27/98				11				635
01/27/98	0.1			9.3				
01/28/98	0.1							
01/29/98	0.1			14				
02/01/98	0.1			11				
02/02/98	0.1							
02/03/98	0.1			13				
02/04/98								650
02/04/98								630
02/05/98	0.1			16				
02/08/98	0.1			11				
02/09/98	0.1							
02/10/98	0.1	<	0.01	9	9			635
02/10/98	0.1			9.9				
02/11/98								
02/11/98	0.1							
02/12/98	0.1			14				
02/16/98	0.1							
02/17/98	0.1			10				
02/18/98	0.1							
02/19/98	0.1			15				
02/22/98	0.1			11				
02/23/98	0.1							
02/24/98				9.8				624
02/24/98	2.3			4.7				

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
02/25/98	0.1							
02/26/98	0.1			12				
03/01/98	0.3			9.6				
03/02/98	0.1							
03/03/98	0.3			7.8				
03/04/98								700
03/04/98								670
03/04/98	0.1							
03/05/98	0.1			11				
03/08/98	0.1			11				
03/09/98	0.1							
03/10/98	0.1	<	0.01	8.7	8.7			679
03/10/98	0.1			9.5				
03/11/98	0.1							
03/12/98	0.1			11				
03/15/98	0.1			8.7				
03/16/98	0.1							
03/17/98	0.1			12				
03/18/98	0.1							
03/19/98	0.1			12				
03/22/98	0.1			13				
03/23/98	0.1							
03/24/98	0.2			10	10	2.6		700
03/24/98	0.1			9.4				
03/25/98	0.1							
03/26/98	0.1			9.7				
03/29/98	0.1			10				
03/30/98	0.1							
03/31/98	0.1			11				
04/01/98								710
04/01/98								690
04/01/98	0.1							
04/02/98	0.1			12				
04/05/98	0.1			10				
04/06/98	0.2							
04/07/98	0.1			9.9				
04/08/98								
04/09/98	0.1			12				
04/12/98	0.3			8.1				
04/13/98	0.1							
04/14/98	0.1	<	0.01	10	10			820
04/14/98	0.1			10				
04/15/98	0.4							

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
04/16/98	0.1		11				
04/19/98	0.1		9.2				
04/20/98	0.2						
04/21/98	0.1		8				
04/22/98	0.1						
04/23/98	0.1						
04/26/98	0.1		9.9				
04/27/98	0.1						
04/28/98			6.3				671
04/28/98	0.1		7.6				
04/29/98	0.2						
04/30/98	0.1		9.1				
05/03/98	0.1		6.8				
05/04/98	0.1						
05/05/98	0.1		7.7				
05/06/98							670
05/06/98							630
05/06/98	0.1						
05/07/98	0.1		5.6				
05/10/98	0.1		9				
05/11/98	0.1						
05/12/98	0.1	< 0.01	6.9	6.9			685
05/13/98	0.1						
05/14/98	0.1		13				
05/17/98	0.1		7.8				
05/18/98	0.1						
05/19/98							
05/19/98	0.1		8.4				
05/20/98	0.1						
05/21/98	0.1		12				
05/25/98	0.1						
05/26/98			8.3				670
05/26/98	0.1		7.7				
05/27/98	0.1						
05/28/98	0.1		8.9				
05/31/98	0.1		11				
06/01/98	0.1						
06/02/98	0.1		8.8				
06/03/98							670
06/03/98							630
06/03/98	0.1						
06/04/98	0.5		12				
06/07/98	0.1		8				

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
06/08/98	0.1						
06/09/98	0.1	< 0.01	8.9	8.9			686
06/09/98	0.1		10				
06/10/98	0.2						
06/11/98	0.1		11				
06/14/98	0.1		8.7				
06/15/98	0.1						
06/16/98	0.1		8.5				
06/17/98	0.1						
06/18/98	0.1		6.3				
06/21/98	0.1		6				
06/22/98	0.1						
06/23/98	0.1		6				
06/24/98	0.1						
06/25/98	0.1		6.7				
06/28/98	0.1		6				
06/29/98	0.1						
06/30/98			5.2				733
06/30/98	0.2		6.9				
07/01/98	0.2						
07/02/98							710
07/02/98							700
07/05/98	0.1		9.3				
07/06/98	0.2						
07/07/98	0.1		6.6				
07/08/98	0.1						
07/09/98	0.1		7.9				
07/12/98	0.1		6.2				
07/13/98	0.1						
07/14/98	0.1	< 0.01	6.4	6.5			663
07/14/98	0.1		8.7				
07/15/98	0.1						
07/16/98	0.1		6				
07/19/98	0.1		4.9				
07/20/98	0.1						
07/21/98	0.1		7.5				
07/22/98	0.1						
07/23/98	0.8		9.5				
07/26/98	0.1		5.5				
07/27/98	0.1						
07/28/98			7				679
07/28/98	0.1		8.5				
07/29/98	0.1						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
07/30/98	0.3			5.6				
08/02/98	0.1			8.7				
08/03/98	0.1							
08/04/98	0.1			9.2				680
08/05/98								690
08/05/98								700
08/05/98	0.1							
08/05/98								690
08/06/98	0.1			9.2				
08/09/98	0.1			7.3				
08/10/98	0.1							
08/11/98	0.1	<	0.01	6.3	6.3			681
08/11/98	0.1			7.5				
08/12/98	0.1							
08/13/98	0.1			8.8				
08/16/98	0.1			7.6				
08/17/98	0.1							
08/18/98	0.1			7.8				
08/19/98	0.1							
08/20/98	0.6			9.7				
08/23/98	0.1			8				
08/24/98	0.1							
08/25/98				5.4				680
08/25/98	0.1			6.9				
08/26/98	0.1							
08/27/98	0.1			10				
08/30/98	0.1			7				
08/31/98	0.1							
09/01/98	0.1			8.5				
09/02/98								740
09/02/98								790
09/02/98	0.1							
09/03/98	0.1			8				
09/07/98	0.1							
09/08/98	0.1	<	0.01	5.8	5.8			690
09/08/98	0.1			6				
09/09/98	0.1							
09/10/98	0.1			10				
09/13/98	0.1			6				
09/14/98	0.2							
09/15/98	0.1			7.8				
09/16/98	0.1							
09/17/98	0.1			11				

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
09/20/98	0.1		8.7				
09/21/98	0.1						
09/22/98	0.1		11				
09/23/98	0.1						
09/24/98	0.1		12				
09/27/98	0.1		11				
09/28/98	1.3						
09/29/98			7.6				675
09/29/98	0.1		9.4				
09/30/98	0.1						
10/01/98	0.1		11				
10/04/98	0.1		10				
10/05/98	0.1						
10/06/98	0.1		9.9				
10/07/98							665
10/07/98							695
10/07/98	0.1						
10/08/98	0.7		13				
10/11/98	0.1		7.5				
10/12/98	0.1						
10/13/98	0.1	< 0.1	9.8	9.8			600
10/13/98	0.1		9				
10/15/98	0.1						
10/15/98	0.1		13				
10/18/98	0.1		9.1				
10/19/98	0.1						
10/20/98	0.1		8.8				
10/21/98	0.1						
10/22/98	0.1		9.9				
10/25/98	0.1		8				
10/26/98	0.1						
10/27/98			8.8				630
10/29/98	0.1		8.9				
11/01/98	0.1		9.7				
11/02/98	0.1						
11/03/98	0.1		8.6				
11/04/98	0.1						
11/05/98	0.1		11				
11/08/98	0.1		9.9				
11/09/98	0.1						
11/10/98	0.1	< 0.01	8.1	8.1			590
11/11/98	0.1						
11/12/98	0.1		11				

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
11/15/98	1.2			6.6				
11/16/98	0.1							
11/17/98	0.1			7.9				
11/18/98	0.1							
11/19/98	0.1			8.3				
11/22/98	0.1			7				
11/23/98	0.1							
11/24/98				6.9				630
11/24/98	0.1			6.9				
11/29/98	0.1			4.1				
11/30/98	0.1							
12/01/98	0.1			4				
12/02/98	0.1							
12/03/98	0.1			6				
12/06/98	0.1			7				
12/07/98	0.2							
12/07/98	0.2	<	0.01	4.9	5.1			685
12/08/98	0.1			7.6				
12/09/98	0.1							
12/10/98	0.1			6.9				
12/13/98	0.1			7.2				
12/14/98	0.1							
12/15/98	0.1			8.7				
12/16/98	0.1							
12/17/98	0.1			6.4				
12/20/98	0.1			4.7				
12/21/98	0.1							
12/22/98				3.5				685
12/22/98	0.1			5.5				
12/23/98	0.1							
12/24/98								655
12/24/98								595
12/27/98	0.1			5.3				
12/28/98	0.1							
12/29/98	0.1			4.6				
12/30/98	0.1							
01/03/99	0.1			4.4				
01/04/99	0.1							
01/05/99	0.1			6.1				
01/06/99								675
01/06/99								610
01/06/99	0.1							
01/07/99	0.1			9.5				

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N		NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
01/10/99	0.1			5.1				
01/11/99	0.4							
01/12/99	0.4	<	0.01	4.8	5.2			640
01/12/99	0.1			6.3				
01/13/99	0.1							
01/14/99	0.1			9				
01/17/99	0.1			7.2				
01/18/99	0.1							
01/19/99				4.7				685
01/19/99	0.1			6.2				
01/20/99	0.1							
01/21/99	0.1			7.6				
01/26/99	0.1			9.1				
01/27/99	0.1							
01/28/99	0.1			7.9				
02/04/99								680
02/04/99								680
02/06/00	0.2		5.8					
02/07/00	0.2		4.6	0.01	4.6			660
02/08/00	0.2		6.5					
02/09/00	0.2							
02/10/00	0.2		7.5					
02/13/00	0.2		7.2					
02/14/00	0.2							
02/14/00			6.8					680
02/15/00	0.2		6.4					
02/16/00								690
02/16/00	0.2							
02/17/00	0.2		9.8					
02/21/00	0.2							
02/22/00	0.2		9.8					
02/23/00	0.2							
02/24/00	0.2		14					
02/27/00	0.2		7.4					
02/28/00	0.2							
02/29/00	0.2		8.4					
03/01/00	0.2							
03/02/00	0.2		12					
03/05/00	0.2		8.2					
03/06/00	0.2							
03/07/00	0.2		9.2					
03/08/00	0.2							
03/09/00	0.2		8.2					

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
03/12/00	0.2	4.3					
03/13/00	0.2						
03/13/00	0.1	4.6	0.1	4.6			720
03/14/00	0.2	6.1					
03/15/00	0.2						
03/16/00	0.2	7					
03/19/00	0.2						
03/20/00							
03/20/00		5.4					670
03/21/00							
03/22/00	0.2						
03/23/00	0.2						
03/26/00	0.2						
03/27/00	0.2						
03/28/00	0.2						
03/29/00	0.2						
03/30/00	0.7						
04/02/00	0.2	3.9					
04/03/00	0.5						
04/04/00	0.2						
04/05/00	0.2						
04/06/00	0.3						
04/09/00	0.2						
04/10/00	0.1	5.3	0.1	5.3			650
04/11/00	0.2						
04/12/00	0.2						
04/13/00	0.2						
04/16/00	0.2	5.7					
04/17/00	0.2						
04/17/00		4.1					670
04/18/00	0.2	6.6					
04/19/00	0.2						
04/20/00	0.2	6.4					
04/23/00	0.2	4.7					
04/24/00	0.2						
04/25/00	0.2	5.9					
04/26/00	0.2						
04/27/00	0.2	5.8					
04/30/00	0.2	4.7					
05/01/00	0.2						
05/02/00	0.2	5.4					
05/03/00	0.2						
05/04/00	0.2	7.7					

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
05/07/00	0.2	6.7					
05/08/00	0.2	6.8	0.01	6.8			690
05/09/00	0.2	7.4					
05/10/00	0.2						
05/10/00							690
05/11/00	0.2	9.2					
05/14/00	0.2	5.9					
05/15/00	0.2						
05/15/00		5.5					660
05/16/00	0.2	6.3					
05/17/00	2.9						
05/18/00	0.2	7.1					
05/21/00	0.2	3.9					
05/22/00	0.2						
05/23/00	0.2	6.4					
05/24/00	0.2						
05/25/00	0.2	8.1					
05/29/00	0.2						
05/30/00	0.2	5					
05/31/00	0.2						
06/01/00	0.2	7.2					
06/04/00	0.2						
06/05/00	0.2						
06/06/00	0.2						
06/07/00	0.2						
06/08/00	2.5						
06/11/00	0.2						
06/12/00	0.2						
06/12/00	0.1	4.9	0.1	4.9			680
06/13/00	0.2	7.3					
06/14/00	0.2	7					
06/15/00	0.2						
06/18/00	0.2	5.4					
06/19/00	0.2						
06/19/00		4.2					700
06/20/00	0.2	5.6					
06/21/00	0.2						
06/22/00	0.2	4.9					
06/25/00	0.2	4.6					
06/26/00	0.2	5.9					
06/27/00	0.2						
06/28/00	0.2						
06/29/00	0.2	6.4					

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
07/02/00	0.2	7.8					
07/04/00	0.2	7					
07/05/00	0.2						
07/06/00	0.2	7.6					
07/09/00	0.2	7.8					
07/10/00	0.2						
07/10/00	0.2	7.1	0.01	7.1			690
07/11/00	0.2	7.2					
07/12/00	0.2						
07/13/00	0.2	7					
07/16/00	0.2	6					
07/17/00	0.2						
07/17/00		6.5					680
07/18/00		6.3					
07/19/00	0.2						
07/20/00	0.2	6.5					
07/23/00	0.2	6.3					
07/24/00	0.2						
07/25/00	0.2	6.8					
07/26/00	0.2						
07/27/00	0.2	5.6					
07/30/00	0.2	4.8					
07/31/00	1						
08/01/00	0.2	5.2					
08/02/00	0.2						
08/03/00	0.2						
08/06/00	0.5	5.2					
08/07/00	0.2	4.6	0.01	4.6			
08/08/00	0.2	5.6					
03/26/99	0.2	8.8					
03/29/99	0.2	8.7					
03/30/99	0.2						
03/31/99	0.2	7.6					
04/01/99	0.2						
04/02/99	0.2	10					
04/05/99	0.2	5.7					
04/06/99	0.2						
04/07/99	0.2	5.5					
04/08/99	0.2						
04/09/99	0.2	9.4					
04/12/99	0.2	7.4					
04/13/99	0.2	8.2	0.01	8.3			560
04/14/99	0.2	9.6					

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
04/15/99	0.2						
04/16/99	0.2	8.4					
04/19/99	0.2	7.2					
04/20/99	0.2						
04/20/99		5.4					655
04/21/99	0.2	6.8					
04/22/99	0.2						
04/23/99	0.2	9.4					
04/26/99	0.2	6.1					
04/27/99	0.2						
04/28/99	0.2	7					
04/29/99	0.2						
04/30/99	0.2	9.6					
05/03/99	0.2	7.8					
05/04/99	0.2						
05/05/99	0.2	9.9					
05/06/99	0.2						
05/07/99	0.2	9					
05/10/99	0.2	5.9					
05/11/99	0.2	6.1	0.01	6.1			650
05/12/99	0.2	7.3					
05/13/99							
05/13/99							645
05/14/99	0.2	7.5					
05/17/99	0.2	5.7					
05/18/99	0.2						
05/18/99		6.1					635
05/19/99	0.2	6.1					
05/20/99	0.2						
05/21/99	0.2	8.7					
05/24/99	0.2	8.8					
05/25/99	0.2						
05/26/99	0.2	8.1					
05/27/99	0.2						
05/28/99	0.2	11					
06/01/99	0.2						
06/02/99	0.2	8					
06/03/99	0.2						
06/04/99	0.2	9					
06/07/99	0.2	8.3					
06/09/99		8					
06/09/99	0.1	8.3	0.1	8.3			650
06/10/99	0.2						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
06/11/99	0.2	9.3					
06/14/99	0.2	6.1					
06/15/99	0.2						
06/15/99	0.1	5.6	0.1	5.6			700
06/16/99	0.2	6.3					
06/17/99	1.3						
06/18/99	0.2	6.6					
06/21/99	0.2	4.9					
06/22/99	0.2						
06/23/99	0.2	6.2					
06/24/99	0.2						
06/25/99	0.2	6.4					
06/28/99	0.2	5.4					
06/29/99	0.2						
06/30/99	0.2	5.2					
07/01/99	0.2						
07/02/99	0.2	7.3					
07/06/99	0.2						
07/07/99	0.2	3.8					
07/08/99	0.2						
07/09/99	0.2	5.5					
07/12/99	0.2	3.3					
07/13/99	0.2	4	0.01	4			615
07/14/99	0.2	4.7					
07/15/99	0.2						
07/16/99	0.2	3.8					
07/19/99	0.2	4.4					
07/20/99	0.2						
07/21/99	0.2	8.4					
07/21/99		8.4					570
07/22/99	0.2						
07/23/99	0.2	8.2					
07/26/99	0.2	5.7					
07/27/99	0.2						
07/28/99	0.2	4.8					
07/29/99	0.2						
07/30/99	0.2	4.8					
08/02/99	0.2	7.6					
08/03/99	0.2						
08/04/99	0.2	8.3					
08/05/99	0.2						
08/06/99	0.2	10					
08/09/99	0.2	10					

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
08/10/99	0.2	10	0.01	10			650
08/11/99	0.2	11					
08/12/99	0.2					3.8	
08/12/99							645
08/13/99	0.2	11					
08/16/99	0.2	9.7					
08/17/99	0.2						
08/17/99		7.1					665
08/18/99	0.2	7.2					
08/19/99	0.2					3.9	
08/20/99	0.2	7.5					
08/23/99	0.2	6.3					
08/24/99	0.2						
08/25/99	0.2	7.5					
08/26/99	0.2					3.9	
08/27/99	0.2	6.6					
08/30/99	0.2	5.4					
08/31/99	0.2						
08/31/99	0.2	8					
09/01/99	0.2					4.2	
09/02/99	0.2	9					
09/06/99	0.2						
09/07/99	0.2	5.7					
09/08/99	0.2					4	
09/09/99	0.2	8.8					
09/12/99	0.2	6.3					
09/13/99	0.1	5.2	0.1	5.2			620
09/14/99	0.2	7.8					
09/15/99	0.2					4.3	
09/16/99	0.2	9.5					
09/19/99	0.2	6.4					
09/20/99	0.2						
09/21/99		6.2	0.1				650
09/21/99	0.2	7.2					
09/22/99	0.2						
09/23/99	0.2	8.8					
09/26/99	0.2	4.7					
09/27/99	0.2						
09/28/99	0.2	7.1					
09/29/99	0.2						
09/30/99	0.2	5.6					
10/03/99	0.2	5.6					
10/04/99	0.2						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
10/05/99	0.2	5.4					
10/06/99	0.2						
10/07/99	0.2	8.3					
10/10/99	0.2	5.6					
10/11/99	0.1	4.4	0.1	4.4			650
10/12/99	0.2	5.6					
10/13/99	0.2						
10/14/99	0.2	8.2					
10/17/99	0.2	7.7					
10/18/99	0.2						
10/19/99		6.8					620
10/19/99	0.2	7.5					
10/20/99	0.2						
10/21/99	0.2	8.7					
10/24/99	0.2	6.5					
10/25/99	0.2						
10/26/99	0.2	6.4					
10/27/99	0.2						
10/28/99	0.2	10					
10/31/99	0.2	4.9					
11/01/99	0.2						
11/02/99	0.2	7.6					
11/03/99	0.2						
11/04/99	0.2	10					
11/07/99	0.2	7.9					
11/08/99	0.2	6.3	0.01	6.3			650
11/09/99	0.2	6.6					
11/11/99	0.2	9.3					
11/14/99	0.2	5.1					
11/15/99	0.2						
11/16/99		5.5					645
11/16/99	0.2	6.6					
11/17/99	0.2						
11/18/99	0.2	8.5					
11/21/99	0.2	6.8					
11/22/99	0.2						
11/23/99	0.2	8					
11/28/99	0.2	4.5					
11/29/99	0.2						
11/30/99	0.2	6.7					
12/01/99	0.2						
12/02/99	0.2	4.6					
12/05/99	0.2	5.2					

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
12/06/99	0.2						
12/07/99	0.2	6.8					
12/08/99	0.2						
12/09/99	0.2	9.3					
12/12/99	0.2	6.9					
12/13/99	0.2	6.4	0.01	6.4			660
12/14/99	0.2	7.3					
12/15/99	0.2						
12/16/99	0.2	7.4					
12/19/99	0.2	5.2					
12/20/99	0.2						
12/20/99		5.2					640
12/21/99	0.2	5.9					
12/22/99	0.2						
12/26/99	0.2	3.5					
12/27/99	0.6						
12/28/99	0.7	4.6					
12/29/99	0.2						
02/01/99	0.2	7.3					
02/02/99	0.2						
02/03/99	0.2	6					
02/04/99	0.2						
02/05/99	0.2	9.4					
02/08/99	0.2	8.7					
02/09/99	0.2						
02/09/99	0.2	6.7	0.01	6.7			720
02/10/99	0.2	7.7					
02/11/99	0.1						
02/12/99	0.2	10					
02/16/99	0.2						
02/16/99	0.2	7.4					695
02/17/99	0.2	5.8					
02/18/99	0.2						
02/19/99	0.2	8.2					
02/22/99	0.2	6.6					
02/23/99	0.2						
02/24/99	0.2	7.1					
02/25/99	0.2						
02/26/99	0.2	7.4					
03/01/99	0.2	6.5					
03/02/99	0.2						
03/03/99	0.2	6.8					
03/04/99	0.2						

Temecula Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
03/05/99	0.2	11					
03/08/99	0.2	7.7					
03/09/99	0.2						
03/09/99	0.2	6.6	0.01	6.7			640
03/10/99	0.2	8					
03/11/99	0.2						
03/12/99	0.2	12					
03/15/99	0.2	6.8					
03/16/99	0.2						
03/16/99	0.2	7.6	0.01				630
03/17/99	0.2	11					
03/18/99	0.2						
03/19/99	0.2	10					
03/22/99	0.2	11					
03/23/99	0.2						
03/24/99	0.2	6.8					
03/25/99	0.2						
No. of Data	904	257	366	45	1	6	137
Minimum	0.1	< 0.01	0.01	2.1	2.6	3.8	545
Maximum	6	14.0	16	10	2.6	4.3	962
Average	0.2	< 6.3	7.1	6.5	2.6	4.0	674

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
04/13/97	0.1						
04/17/97	0.1						
04/20/97	0.1						
04/24/97	0.1						
04/27/97	0.1						
05/01/97	0.1						
05/04/97	0.1						
05/08/97	0.1						
05/11/97	0.2						
05/13/97	0.1	0.1	0.8				
05/15/97	0.1						
05/18/97	0.1						
05/22/97	0.4						
05/29/97	0.1						
06/01/97	0.1						
06/05/97	0.1						
06/08/97	4.6						
06/10/97	0.1	0.1	1.3				
06/11/97							
06/12/97	0.3						
06/15/97	0.1						
06/19/97	0.1						
06/22/97	0.1						
06/26/97	0.1						
06/29/97	0.1						
07/06/97	0.1						
07/08/97	0.1	0.5	0.9				
07/10/97	0.1						
07/13/97	0.1						
07/17/97	0.1						
07/20/97	0.1						
07/24/97	0.1						
07/27/97	0.1						
07/31/97	0.1						
08/03/97	0.1						
08/07/97	0.1						
08/10/97	0.1						
08/12/97	0.1	0.1	2.1				
08/14/97	0.1						
08/17/97	0.1						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
08/21/97	0.1						
08/24/97	0.1						
08/28/97	0.1						
09/04/97	0.1						
09/07/97	0.1						
09/09/97	0.1	0.1	4.1				
09/11/97							
09/11/97	0.1						
09/14/97	0.1						
09/18/97	0.1						
09/25/97	0.1						
09/28/97	0.1						
10/02/97	0.1						
10/05/97	0.1						
10/09/97	0.1						
10/12/97	0.1						
10/14/97	0.1	0.01	2.1				
10/16/97	0.1						
10/19/97	0.1						
10/23/97	0.1						
10/26/97	0.1						
10/30/97	0.2						
11/02/97	0.1						
11/06/97	0.1						
11/09/97	0.1						
11/12/97	0.1	0.01	2.1				
11/13/97	0.3						
11/16/97	0.2						
11/20/97	0.1						
11/23/97	0.1						
11/30/97	0.1						
12/04/97	0.1						
12/07/97	0.1						
12/09/97	0.1	0.01	2.5				
12/11/97							
12/11/97	0.1						
12/14/97	0.1						
12/18/97	0.1						
12/21/97	0.1						
12/28/97	0.1						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	T/N	Ortho PO_4-P	TP	TDS
01/04/98	0.1						
01/08/98	0.1						
01/11/98	0.1						
01/13/98	0.1	0.01	1.6				
01/15/98	0.1						
01/18/98	0.1						
01/22/98	0.1						
01/29/98	0.1						
02/01/98	0.1						
02/05/98	0.1						
02/08/98	0.1						
02/10/98	0.4	0.01	2				
02/12/98	0.1						
02/19/98	0.1						
02/22/98	0.1						
02/26/98	0.1						
03/01/98	0.3						
03/05/98	0.5						
03/05/98	0.1						
03/08/98	0.1						
03/10/98	0.1	0.01	1.2				
03/11/98	0.5						
03/12/98							
03/12/98	0.1						
03/13/98	0.5						
03/15/98	0.1						
03/16/98	0.4	0.02	4.6		1.7		
03/17/98	0.4						
03/18/98							
03/19/98	0.4						
03/19/98	0.1						
03/20/98							
03/22/98	0.1						
03/23/98							
03/24/98	1.3						
03/25/98							
03/26/98	0.9						
03/26/98	0.1						
03/27/98							
03/29/98	0.1						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
03/30/98							
03/31/98			0.7				
03/31/98	0.1						
04/01/98							
04/02/98	0.1						
04/02/98	0.1						
04/03/98							
04/05/98	0.3						
04/06/98							
04/07/98	0.1						
04/08/98	0.2		1.5		1.2		
04/09/98	0.2						
04/10/98							
04/12/98	0.4						
04/14/98	0.1	0.01	1.7				
04/16/98	0.1						
04/19/98	0.1						
04/21/98	0.3	0.42	3		1.5		
04/21/98	0.5						
04/22/98							
04/23/98	0.5						
04/23/98	0.1						
04/24/98							
04/26/98	0.1						
04/27/98							
04/30/98	0.1						
05/03/98	0.2						
05/07/98	0.1						
05/10/98	0.7						
05/12/98	0.1	0.01	0.6				
05/14/98	0.1						
05/17/98	0.1						
05/21/98	0.1						
05/28/98	0.1						
05/31/98	0.1						
06/04/98	0.1						
06/07/98	0.1						
06/09/98	0.1	0.01	0.7				
06/11/98							
06/11/98	6						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
06/14/98	0.1						
06/18/98	0.1						
06/21/98	0.1						
06/25/98	0.1						
06/28/98	0.1						
07/05/98	0.1						
07/09/98	0.1						
07/12/98	0.1						
07/14/98	0.1	0.01	0.6				
07/16/98	0.1						
07/19/98	0.1						
07/23/98	0.1						
07/26/98	0.1						
07/30/98	0.1						
08/02/98	0.1						
08/06/98	0.1						
08/09/98	0.1						
08/11/98	0.1	0.01	1				
08/13/98	0.1						
08/16/98	0.1						
08/20/98	0.1						
08/23/98	0.1						
08/27/98	0.1						
08/30/98	0.1						
09/03/98	0.1						
09/08/98	0.1	0.01	0.5				
09/17/98	0.1						
09/20/98	0.1						
09/24/98	0.1						
09/27/98	0.1						
10/04/98	0.1						
10/08/98	0.1						
10/11/98	0.1						
10/13/98	0.1	0.1	1.7				
10/15/98	0.1						
10/18/98	0.1						
10/22/98	0.1						
10/25/98	0.1						
10/29/98	0.1						
11/01/98	0.1						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
11/05/98	0.1						
11/08/98	0.1						
11/10/98	0.1	0.01	0.8				
11/12/98	0.1						
11/15/98	0.1						
11/19/98	0.1						
11/22/98	0.1						
11/29/98	0.1						
12/03/98	0.1						
12/06/98	0.1						
12/07/98	0.1	0.01	0.5				
12/10/98	0.1						
12/13/98	0.1						
12/20/98	0.1						
12/27/98	0.1						
01/03/99	0.1						
01/07/99	0.1						
01/09/00	0.2						
01/10/00	0.2	0.1	0.01	0.2			575
01/13/00	0.2						
01/16/00	0.2						
01/20/00	0.2						
01/23/00	0.2						
01/27/00	0.2						
01/30/00	0.2						
02/03/00	0.2						
02/06/00	0.2						
02/07/00	0.2	0.4	0.01	0.4			540
02/10/00							
02/13/00	0.2						
02/17/00	0.2						
02/24/00	0.2						
02/27/00	0.2						
03/02/00	0.2						
03/05/00	0.2						
03/09/00	0.2						
03/12/00	0.2						
03/13/00	0.1	0.6	0.1	0.6			530
03/16/00	0.2						
03/19/00	0.2						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
03/23/00	0.2						
03/30/00	0.2						
04/02/00	0.2						
04/06/00	0.2						
04/09/00	0.2						
04/10/00	0.1	0.3	0.1	0.3			480
04/13/00	0.2						
04/16/00	0.2						
04/20/00	0.2						
04/23/00	0.2						
04/27/00	0.2						
04/30/00	0.2						
05/04/00	0.2						
05/07/00	0.2						
05/08/00	0.2	0.6	0.01	0.6			470
05/11/00	0.2						
05/14/00	0.2						
05/18/00	0.2						
05/21/00	0.2						
05/25/00	0.2						
06/01/00	0.2						
06/04/00	0.2						
06/08/00	0.6						
06/11/00	0.2						
06/12/00	0.1	0.2	0.1	0.2			490
06/15/00	0.2						
06/18/00	0.3						
06/22/00	0.2						
06/25/00	0.2						
06/29/00	0.2						
07/02/00	0.2						
07/06/00	0.2						
07/09/00	0.2						
07/10/00	0.2	0.3	0.01	0.3			500
07/13/00	0.2						
07/16/00	0.2						
07/20/00	0.2						
07/23/00	0.2						
07/27/00	0.2						
07/30/00	0.2						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
08/03/00	0.2						
08/06/00	0.2						
08/07/00	0.2	0.3	0.01	0.3			
03/26/99	0.2						
03/29/99	0.2						
04/02/99	0.2						
04/05/99	0.2						
04/09/99	0.2						
04/12/99	0.2						
04/14/99	0.2	0.3	0.01	0.4			430
04/16/99	0.2						
04/19/99	0.2						
04/23/99	0.2						
04/26/99	0.2						
04/30/99	0.2						
05/03/99	0.2						
05/07/99	0.2						
05/10/99	0.2						
05/11/99	0.2	1.1	0.01	1.1			460
05/14/99	0.2						
05/17/99	0.2						
05/21/99	0.2						
05/24/99	0.2						
05/28/99	0.2						
06/04/99	0.2						
06/08/99	0.1	0.4	0.1	0.4			510
06/11/99	0.2						
06/14/99	0.2						
06/18/99	0.2						
06/21/99	0.2						
06/28/99	0.2						
07/02/99	0.2						
07/09/99	0.2						
07/12/99	0.2						
07/13/99	0.2	0.4	0.01	0.4			475
07/16/99	0.2						
07/19/99	0.2						
07/23/99	0.2						
07/26/99	0.2						
07/30/99	0.2						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
08/02/99	0.2						
08/06/99	0.2						
08/09/99	0.2						
08/10/99	0.2	4.6	0.01	4.6			500
08/12/99						2.8	
08/13/99	0.2						
08/16/99	0.2						
08/19/99						0.3	
08/20/99	0.2						
08/23/99	0.2						
08/26/99						0.3	
08/27/99	0.2						
08/30/99	0.2						
09/01/99						0.5	
09/02/99	0.2						
09/08/99						0.4	
09/09/99	0.2						
09/12/99	0.2						
09/13/99	0.1	0.2	0.1	0.2			520
09/15/99						0.5	
09/16/99	0.2						
09/19/99	0.2						
09/23/99	0.2						
09/26/99	0.2						
09/30/99	0.2						
10/03/99	0.2						
10/07/99	0.2						
10/10/99	0.2						
10/11/99	0.1	0.7	0.1	0.7			470
10/17/99	0.2						
10/24/99	0.2						
10/28/99	0.2						
10/31/99	0.2						
11/04/99	0.2						
11/07/99	0.2						
11/08/99	0.2	1.1	0.01	1.1			425
11/11/99	0.2						
11/14/99	0.2						
11/18/99	0.2						
11/21/99	0.2						

Perris Valley RWRF Effluent
Nutrients Analysis

Date	NH_4-N	NO_2-N	NO_3-N	TIN	Ortho PO_4-P	TP	TDS
11/28/99							
12/02/99	0.2						
12/05/99	0.2						
12/09/99	0.2						
12/12/99							
12/13/99	0.2	1.4	0.01	1.4			495
12/16/99							
12/19/99	0.2						
12/26/99	0.2						
02/01/99	0.2						
02/05/99	0.2						
02/08/99	0.2						
02/09/99	0.2	1.2	0.01	1.2			560
02/12/99	0.2						
02/19/99	0.2						
02/22/99	0.2						
02/26/99	0.2						
03/01/99	0.2						
03/05/99	0.2						
03/08/99	0.2						
03/09/99	0.2	1.2	0.01	1.2			600
03/12/99	0.2						
03/15/99	0.2						
03/19/99	0.2						
03/22/99	0.2						
No. of Data	356	41	43	19	3	6	18
Minimum	0.1	0.01	0.01	0.2	1.2	0.3	425
Maximum	6.0	4.6	4.6	4.6	1.7	2.8	600
Average	0.2	0.4	0.91	0.8	1.5	0.8	502

APPENDIX C

Elsinore Valley MWD Recycled Water Nutrients Data

EVMWD
Regional Water Reclamation Plant
Nutrients Analysis

Month	Ortho-P (mg/L)	Total P (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	TIN (mg/L)	TKN (mg/L)
Jan-97	3.1		0.2	2.3	2.5	
Feb-97		2	0.3	2.6	2.8	
Mar-97		2.9	2.9	9.3	11	
Apr-97		11	ND	1.7	2.2	
May-97	1.9		0.1	2.7	3.1	
Jun-97		1.2	ND	1.6	1.6	
Jul-97	2.6		1.2	3.7	5.1	
Aug-97	0.86		ND	4.8	5.2	
Sep-97	0.43		ND	2.6	2.6	
Oct-97	0.39		ND	4.9	5.2	
Nov-97		1.3	2.3	2.6	2.9	
Dec-97		1.5	1.1	5.8	7.1	
Jan-98		0.62	ND	3	3.6	
Feb-98		0.35	0.2	3	3.2	
Mar-98		ND	0.5	3.1	3.5	
03/04/98	1.4	3.1		3.7		1.5
03/05/98	1.8	3.2		3.6		1.6
03/06/98	2	3.3		3.4		1.5
Apr-98		0.19	0.5	5.3	5.5	
May-98		0.12	0.9	2	2.5	
Jun-98		ND	1.3	2.2	2.9	
Jul-98		0.85	ND	9	9	
Aug-98		0.82	0.8	1.4	1.8	
Sep-98		1.7	ND	3.5	5.2	
Oct-98		1.1	2.5	6.8	7.3	
Nov-98		0.95	ND	6.3	6.6	
Dec-98		1.7	ND	3.5	5.2	
Jan-99		2.2	ND	21	21	
Feb-99		3.3	ND	17	17	
Mar-99		3.4	0.8	7.6	7.8	
Apr-99		7.1	0.1	8.2	8.3	
May-99		3.6	ND	12	12	
Jun-99		3	1.5	7.5	8.4	
Jul-99		3.3	1.9	4	4.5	
Aug-99		2.4	1.7	2.5	2.8	
Sep-99		1.8	0.2	4.5	4.6	
Oct-99		1.4	ND	3.3	3.5	
Nov-99		2.5	0.2	3.5	3.8	
Dec-99		1.5	ND	3.9	4.1	
Jan-00		1.1	2	4.7	4.9	
Feb-00		1.9	0.1	4.1	4.5	
Mar-00		1.4	ND	2.7	2.9	
Apr-00		2.5	2	2.8	3.5	
May-00		2.9	1.4	2.5	3.1	
Jun-00		2.6	1.6	3.6	4.2	
Jul-00		2.6	ND	5.6	5.6	
No. of Data	9	38	26	46	43	3
Minimum	0.39	0.12	0.10	1.40	1.60	1.50
Maximum	3.10	11.00	2.90	21.00	21.00	1.60
Average	1.61	2.33	1.09	4.90	5.44	1.53

Elsinore Valley Municipal Water District

31315 Chaney St.
Lake Elsinore, CA 92531
Ph: 909 674-3146 ext. 203
Fax: 909 245-5946

FAX TRANSMITTAL

DATE: August 22, 2000	
TO: Ajit Bhamrah	FROM: Ted Eich
COMPANY: MW.	Elsinore Valley Municipal Water District
FAX NO: (626) 568-6278	cc:
SUBJECT: Sample Data Requested	No. of pages (including cover page): 5

Ajit- sorry for the delay I had to dig this information up. I hope its legible TED

Gloria:
FYI.

2000 - YEAR

	ORTHO-P	TOTAL P	NH_3	NO_3	TIN
Jan	N/S	1.1	2.0	4.7	4.9
Feb	N/S	1.9	0.1	4.1	4.5
Mar	N/S	1.4	N/D	2.7	2.9
Apr	N/S	2.5	2.0	2.8	3.5
May	N/S	2.9	1.4	2.5	3.1
Jun	N/S	2.6	1.6	3.6	4.2
Jul	N/S	2.6	N/D	5.6	5.6
Aug					
Sep					
Oct					
Nov					
Dec					

N/S - not Sampled
N/D - not Detected

99 - year

	ortho-P	TOTAL P	NH_3	NO_3	TIN
jan	N/S	2.2	N/D	21	21
feb	N/S	8.3	N/D	17	17
mar	N/S	3.4	0.8	7.6	7.8
Apr	N/S	7.1	0.1	8.2	8.3
may	N/S	3.6	N/D	12	12
Jun	N/S	3.0	1.5	7.5	8.4
July	N/S	3.3	1.9	4.0	4.5
Aug	N/S	2.4	1.7	2.5	2.8
Sep	N/S	1.8	0.2	4.5	4.6
Oct	N/S	1.4	N/D	3.3	3.5
Nov	N/S	2.5	0.2	3.5	3.8
Dec	N/S	1.5	N/D	3.9	4.1

N/S - not Sampled
N/D not Detected.

98 - Year

	Ortho-P	Total-P	NH_3	NO_3	TIN
Jan	N/S	0.62	N/D	8.0	3.6
Feb	N/S	0.35	0.2	3.0	3.2
Mar	N/S	N/D	0.5	3.1	3.5
April	N/S	0.19	0.5	5.3	5.5
May	N/S	0.12	0.9	2.0	2.5
Jun	N/S	N/D	1.3	2.2	2.9
July	N/S	0.85	N/D	9.0	9.0
August	N/S	0.82	0.8	1.4	1.8
Sep	N/S	1.7	N/D	3.5	5.2
Oct	N/S	1.1	2.5	6.8	7.3
Nov	N/S	0.95	N/D	6.3	6.6
Dec	N/S	1.7	N/D	3.5	5.2

Special Samples Runs

- End of Pipe

	Ortho-P	Total P	NH_3	NO_3	TIN	Kjeldahl-N
3/4	1.4	3.1	N/S	3.7	N/S	1.5
3/6	2.0	3.3	N/S	3.4	N/S	1.5
3/5	1.8	3.2	N/S	3.6	N/S	1.6

N/S - Not Sampled
N/D - Not Detected

97 - year

	ortho-P	TOTAL P	NH_3	NO_3	[illegible]
Jan	3.1 mg/L	N/S	0.2	2.3	2.5
Feb	N/S	2.0	0.3	2.6	2.8
Mar	N/S	2.9	2.9	9.3	11
April	N/S	11.0	N/D	1.7	2.2
May	1.9	N/S	0.1	2.7	3.1
Jun	N/S	1.2	N/D	1.6	1.6
July	2.6	N/S	1.2	3.7	5.1
Aug	0.86	N/S	N/D	4.8	5.2
Sept.	0.43	N/S	N/D	2.6	2.6
Oct	0.39	N/S	N/D	4.9	5.2
Nov	N/S	1.3	2.3	2.6	2.9
Dec	N/S	1.5	1.1	5.8	7.1

N/D - None Detected
N/S - Not Sampled or Not Ran

APPENDIX D

San Jacinto River (at Lake Elsinore) Water Quality Summary

Water Quality Data
San Jacinto River North of Lake Elsinore
(Riverside County Flood Control Dept. Station 827)

Sample Date	Level (ft)	Discharge (cfs)	Ambient Temp (F)	Alkalinity (mg/L)		NH4-N (mg/L)		Arsenic (mg/L)		Barium (mg/L)	HCO3 (mg/L)	Boron (mg/L)		Cadmium (mg/L)	Calcium (mg/L)	TOC (mg/L)
9/8/94	0.00	0.50		280		6.80		0.02		0.20	317	0.3	<	0.010	121.00	12.0
12/21/94	0.00	0.25		290		0.10	<	0.01	<	0.10	354	0.2	<	0.010	161.00	5.5
1/5/95	0.00	0		128	<	0.10	<	0.01		0.10	156	0.1	<	0.010	88.00	15.0
3/7/95	0.00	0		95	<	0.10	<	0.01	<	0.10	116	0.1	<	0.010	41.00	7.9
3/22/95	5.06	300		140		0.20	<	0.01		0.10	171	0.2	<	0.010	34.00	15.0
6/21/95	0.26	5		160		0.20	<	0.01		0.10	195	0.1	<	0.010	72.00	12.0
9/12/95	2.28	0.5		280		0.10	<	0.01		0.10	342	0.3	<	0.010	152.00	4.0
12/12/95	2.34	0.5		280	<	0.10	<	0.01	<	0.10	342	0.2	<	0.010	151.00	3.7
1/25/96	2.38	2.0			<	0.10										
2/21/96	2.87	10.0		160		0.20	<	0.01	<	0.10	190	0.2	<	0.010	84.00	9.3
3/13/96	2.51	0.75														
4/4/96	2.34	0.50		280		0.10	<	0.01	<	0.10	340	0.2	<	0.010	140.00	4.5
6/6/96	2.25	0.20		290	<	0.10	<	0.01		0.10	350	0.2	<	0.010	150.00	10.0
9/17/96	0.25	0.75		290	<	0.10	<	0.01		0.10	350	0.3	<	0.010	140.00	15.0
11/22/96	0.00	0		98		0.20		0.01		0.30	120	0.1	<	0.010	64.00	17.0
12/4/96	2.33	0.50		330		0.20	<	0.01		0.10	400	0.3	<	0.010	160.00	3.6
3/19/97	2.33	1.0		280	<	0.10	<	0.01	<	0.10	340	0.2	<	0.010	130.00	3.1
6/10/97	0.00	0.25		320		0.10	<	0.01		0.10	380	0.3	<	0.010	150.00	3.4
9/23/97	0.00	0		310		0.60	<	0.01		0.10	380	0.2	<	0.010	110.00	9.6
1/8/98	0.50	1.0		300	<	0.10	<	0.01	<	0.10	360	0.2	<	0.010	160.00	5.2
4/21/98	0.00	0		270	<	0.10	<	0.01		0.10	330	0.2	<	0.010	130.00	6.2
6/10/98	0.00	0		290	<	0.10		0.01		0.09	350	0.2	<	0.002	140.00	7.7
9/23/98	0.25	0.45	70	340		0.10		0.01		0.10	410	0.3	<	0.002	170.00	3.7
12/29/98			53	300	<	0.10		0.01		0.10	370	0.2	<	0.002	150.00	2.9
4/20/99		1.0	77	260	<	0.10		0.01		0.12	310	0.2	<	0.002	120.00	3.0
No.	23	24	3	23		24		23		23	23	23		23	23	23
Min.	0.00	0	53	95	<	0.1	<	0.007	<	0.09	116	0.1	<	0.002	34	2.9
Max.	5.06	300	77	340		6.8		0.02		0.3	410	0.3		0.01	170	17
Avg.	1.21	13.5	67	250		0.42		0.01		0.11	303	0.21		0.01	123	7.8

Water Quality Data
San Jacinto River North of Lake Elsinore
(Riverside County Flood Control Dept. Station 827)

Sample Date	CO3 (mg/L)	Chloride (mg/L)	Chromium (mg/L)	Color	Sp. Conductance Field (uS/cm)	Sp. Conductance - Lab (uS/cm)	Copper (mg/L)	Detergent (MBA) (mg/L)	Electro Chemical Balance (me/L)	Fluoride (mg/L)	Total Hardness (mg/L)
9/8/94	< 3	230	< 0.02	50	1490	1520	< 0.01	< 0.05	0.08	0.5	469
12/21/94	< 3	310	< 0.02	15	1616	1960	< 0.01	0.17	-0.22	0.5	615
1/5/95	< 3	200	< 0.02	30		1300	< 0.01	0.13	0.10	0.3	341
3/7/95	< 3	65	< 0.02	90		530	< 0.01	0.07	-0.40	0.2	149
3/22/95	< 3	61	< 0.02	75	522	560	< 0.01	0.05	0.09	0.3	123
6/21/95	< 3	43	< 0.02	30	664	620	< 0.01	< 0.05	-0.26	0.3	222
9/12/95	< 3	240	< 0.02	25	1820	1650	< 0.01	0.06	0.62	0.5	584
12/12/95	< 3	300	< 0.02	15	1810	1760	< 0.01	0.11	-0.93	0.5	578
1/25/96											
2/21/96	< 3	180	< 0.02	35		1110	< 0.01	0.07	-0.22	0.3	330
3/13/96						1290					
4/4/96	< 3	260	< 0.02	20	1430	1580	< 0.01	< 0.05	-0.51	0.5	550
6/6/96	< 3	260	< 0.02	25	1530	1640	< 0.01	0.19	-0.51	0.5	560
9/17/96	< 3	260	< 0.02	20	1500	1690	< 0.01	0.05	-0.29	0.5	550
11/22/96	< 3	32	0.05	40		390	0.07	< 0.05	2.80	0.4	250
12/4/96	< 3	340	< 0.02	15	1850	2000	< 0.01	< 0.05	-1.03	0.6	650
3/19/97	< 3	250	< 0.02	20	1460	1670	< 0.01	0.14	-1.19	0.6	500
6/10/97	< 3	290	< 0.02	20	1550	1790	< 0.01	< 0.05	-0.91	0.6	590
9/23/97	9	150	< 0.02	35	1340	1310	< 0.01	0.09	0.37	0.7	430
1/8/98	< 3	280	< 0.02	25	1960	2000	< 0.01	< 0.05	< 0.05	0.6	630
4/21/98	< 3	230	< 0.02	20	1530	1500	< 0.01	< 0.05	< 0.05	0.4	500
6/10/98	< 3	250	< 0.02	20	1580	1520	< 0.01	< 0.05	< 0.05	0.3	500
9/23/98	< 3	300	< 0.02	20	1870	1750	< 0.01	< 0.05	< 0.05	0.3	550
12/29/98	< 3	240	< 0.02	15	1780	1740	< 0.01	0.14	0.06	0.5	660
4/20/99	< 3	240	< 0.02	15	2	1480	< 0.01	0.08	< 0.01	0.3	480
No.	23	23	23	23	19	24	23	23	23	23	23
Min.	< 3	32	< 0.02	15	1.55	390	< 0.01	< 0.05	-1.19	0.2	123
Max.	9	340	0.05	90	1960	2000	0.07	0.19	2.8	0.7	660
Avg.	3.3	218	0.02	29	1437	1432	0.01	0.08	-0.05	0.45	474

Water Quality Data
San Jacinto River North of Lake Elsinore
(Riverside County Flood Control Dept. Station 827)

Sample Date	Petroleum Hydrocarbons (mg/L)	Hydroxide (mg/L)	Lead (mg/L)	Magnesium (mg/L)	Mercury (mg/L)	Nickel (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	Organic Nitrogen (mg/L)	Total Nitrogen (mg/L)	TKN (mg/L)
9/8/94	< 1	< 3	< 0.01	40	< 0.001		0.1	< 0.1	1.4	8.3	8.2
12/21/94	< 1	< 3	< 0.01	51	< 0.001		1.2	< 0.1	0.3	1.6	0.4
1/5/95	< 1	< 3	< 0.01	29	< 0.001		0.6	< 0.1	3.2	3.8	3.2
3/7/95	< 1	< 3	< 0.01	11	< 0.001		0.4	< 0.1	1.2	1.6	1.2
3/22/95	< 1	< 3	< 0.01	9	< 0.001		0.4	< 0.1	1.1	1.7	1.3
6/21/95	< 1	< 3	< 0.01	10	< 0.001		0.5	< 0.1	0.9	1.6	1.1
9/12/95	< 1	< 3	< 0.01	49	< 0.001		< 0.2	< 0.1	0.1	0.2	0.2
12/12/95	< 1	< 3	< 0.01	48	< 0.001	< 0.01	1.3	< 0.1	0.4	1.7	0.4
1/25/96							1.6	0.1		2.2	0.5
2/21/96	< 1	< 3	< 0.01	29	< 0.001	< 0.02	0.9	< 0.1	0.8	1.9	1.0
3/13/96							0.9	< 0.1		1.8	0.9
4/4/96	< 1	< 3	< 0.01	48	< 0.001	< 0.02	1.6	< 0.1	0.7	2.5	0.9
6/6/96	< 1	< 3	< 0.01	47	< 0.001	< 0.02	0.9	< 0.1	0.9	1.9	0.9
9/17/96	< 1	< 3	< 0.01	45	< 0.001	< 0.02	0.3	< 0.1	0.8	1.1	0.8
11/22/96	< 1	< 3	0.04	22	< 0.001	0.03	2.1	0.3	3.3	6.0	3.5
12/4/96	< 1	< 3	< 0.01	58	< 0.001	< 0.02	0.8	< 0.1	0.4	1.5	0.6
3/19/97	< 1	< 3	< 0.01	41	< 0.001	< 0.02	1.1	< 0.1	0.4	1.5	0.4
6/10/97	< 1	< 3	< 0.01	51	< 0.001	< 0.02	0.2	< 0.1	0.4	0.7	0.6
9/23/97	< 1	< 3	< 0.01	36	< 0.001	< 0.02	< 0.2	< 0.1	1.5	2.2	2.1
1/6/98	< 1	< 3	< 0.01	55	< 0.001	< 0.02	1.4	< 0.1	0.5	2.0	0.6
4/21/98	< 1	< 3	< 0.01	41	< 0.001	< 0.02	1.4	< 0.1	0.4	1.9	0.5
6/10/98	< 1	< 3	< 0.01	46	< 0.001	< 0.02	0.9	< 0.1	0.6	1.5	0.6
9/23/98	< 1	< 3	< 0.01	55	< 0.001	< 0.02	0.8	< 0.1	0.3	1.3	0.5
12/29/98	< 1	< 3	< 0.01	48	< 0.001	< 0.02	1.3	< 0.1	0.3	1.6	0.5
4/20/99	< 1	< 3	< 0.01	42	< 0.001	< 0.02	2.7	< 0.1	0.5	3.2	0.3
No.	23	23	23	23	23	16	25	25	23	25	25
Min.	< 1	< 3	< 0.01	9	< 0.0005	< 0.01	0.1	< 0.1	0.1	0.2	0.2
Max.	1	3	0.04	58	0.001	0.03	2.7	0.3	3.3	8.3	8.2
Avg.	1	3	0	40	0.0009	0.02	0.95	0.11	0.89	2.21	1.25

Water Quality Data
San Jacinto River North of Lake Elsinore
(Riverside County Flood Control Dept. Station 827)

Sample Date	TIN (mg/L)	Unionized Ammonia - N (mg/L)	Odor (TON)	Oil & Grease (mg/L)	BOD (mg/L)	COD (mg/L)	DO - field (mg/L)	Oxygen Saturation (%)	Phenols (mg/L)	Organic Phosphorus (mg/L)	Ortho Phosphorus (mg/L)
9/8/94	6.9	0.340	< 1	< 1	8	45	5.06	64	0.03	< 0.05	2.20
12/21/94	1.3	0.002	< 1	2	< 5	15	8.49	74	0.01	< 0.05	0.45
1/5/95	0.6	< 0.010	< 1	1	19	85			0.15	0.15	0.50
3/7/95	0.4	< 0.010	< 1	1	7	50			0.03	< 0.05	0.20
3/22/95	0.6	0.014	< 1	< 1	8	70	7.47	80	0.04	0.05	0.60
6/21/95	0.7	0.026	< 1	5	6	10	6.15	73	0.02	< 0.05	< 0.05
9/12/95			< 1	< 1	< 5	30	5.80	68	0.02	0.05	0.35
12/12/95			< 1	< 1	< 5	< 10	8.55	83	< 0.01		
1/25/96											
2/21/96			< 1	< 1	< 5	20			< 0.01		
3/13/96											
4/4/96			< 1	< 1	5	12	10.10	104	< 0.01		
6/6/96			< 1	3	8	20	5.35	62	< 0.01		
9/17/96			< 1	< 1	5	20	7.75	92	< 0.01		
11/22/96			< 1	< 1	11	76			0.02		
12/4/96			< 1	< 1	< 5	12	10.85	99	< 0.01		
3/19/97			< 1	3	< 5	< 10	9.67	102	0.04		
6/10/97			< 1	< 1	5	12	6.02	72	0.01		
9/23/97			< 1	4	13	47	0.35	5	0.02		
1/8/98			< 1	< 1	5	46	8.50	77	< 0.02		
4/21/98			< 1	< 1	< 5	23	7.38	89	< 0.02		
6/10/98			< 1	< 1	13	28	9.28	102	< 0.02		
9/23/98			< 1	< 1	< 5	28			< 0.02		
12/29/98			< 1	4	< 5	19	8.30		< 0.02		
4/20/99			< 1	< 1	11	< 10	8.15		< 0.02		
No.	6	6	23	23	23	23	18	16	23	7	7
Min.	0.4	0.002	< 1	< 1	< 5	< 10	0.35	5	0.01	0.05	0.05
Max.	6.9	0.34	1	5	19	85	10.85	104	0.15	0.15	2.2
Avg.	1.75	0.07	1	1.65	7.35	30	7.4	78	0.02	0.06	0.62

Water Quality Data
San Jacinto River North of Lake Elsinore
(Riverside County Flood Control Dept. Station 627)

Sample Date	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Total Insoluble Phosphorus (mg/L)	Potassium (mg/L)	Redox Potential (mV)	Salinity (ppt)	Selenium (mg/L)	Silver (mg/L)	Sodium (mg/L)	Total Solids (mg/L)	TDS (mg/L)
9/8/94	2.70			14			< 0.01	< 0.01	156		1020
12/21/94	0.45			4	235		< 0.01	< 0.01	152	1140	1170
1/5/95	0.95			14			< 0.01	< 0.01	108		800
3/7/95	0.35			6			< 0.01	< 0.01	38		320
3/22/95	0.75			12	195		< 0.01	< 0.01	63		375
6/21/95	< 0.05			3	155		< 0.01	< 0.01	34		380
9/12/95	0.50			5			< 0.01	< 0.01	134		1080
12/12/95	0.45	0.42	< 0.05	4			< 0.01	< 0.01	144		1090
1/25/96	0.38	0.36	< 0.05								
2/21/96	0.46	0.31	0.15	5			< 0.01	< 0.01	89	730	640
3/13/96	0.33	0.31	0.02								
4/4/96	0.37	0.34	< 0.05	3			< 0.01	< 0.01	130	1100	1040
6/6/96	0.43	0.40	< 0.05	4			< 0.01	< 0.01	140	1200	1080
9/17/96	0.33	0.28	0.05	4			< 0.01	< 0.01	140	1140	1100
11/22/96	2.30	0.62	1.70	14			< 0.01	< 0.01	31	2100	310
12/4/96	0.28	0.28	< 0.05	4			< 0.01	< 0.01	180	1410	1260
3/19/97	0.29	0.27	< 0.05	3			< 0.01	< 0.01	140	1100	1060
6/10/97	0.45	0.44	< 0.05	3			< 0.01	< 0.01	140	1300	1160
9/23/97	0.54	0.34	0.20	4			< 0.01	< 0.01	110	930	850
1/8/98	0.12	0.05	0.07	3			0.01	< 0.01	150	1370	1290
4/21/98	0.35	0.33	< 0.05	4			0.01	< 0.01	120	1210	1150
6/10/98	0.08	0.07	< 0.05	3			0.01	< 0.01	120	1120	980
9/23/98	0.60	0.43	0.17	3			0.01	< 0.01	150	1420	1170
12/29/98	0.30	0.24	0.07	3			0.01	< 0.01	140	1170	1100
4/20/99	0.26	0.26	< 0.05	3		0.07	0.01	< 0.01	130	1140	1000
No.	25	18	18	23	3	1	23	23	23	18	23
Min.	< 0.05	0.05	< 0.02	3	155	0.07	< 0.005	< 0.01	31	730	310
Max.	2.7	0.62	1.7	14	235	0.07	0.013	0.01	180	2100	1290
Avg.	0.56	0.32	0.16	5.43	195	0.07	0.01	0.01	119	1224	932

Water Quality Data
San Jacinto River North of Lake Elsinore
(Riverside County Flood Control Dept. Station 827)

Sample Date		TSS (mg/L)	Sulfate (mg/L)	Temp (Deg C)	Temp (Deg F)	Total Anions (me/L)	Total Cations (me/L)	Turbidity - field (NTU)	Turbidity - lab (NTU)		Zinc (mg/L)	pH - field	pH - lab	Wet Weather
9/8/94		55	250	24.3		16.93	17.01		23.0		0.01	7.99	8	0
12/21/94		10	220	8.9		19.23	19.01		0.4	<	0.01	8.11	8	0
1/5/95		240	170			11.78	11.88		234.0		0.03		8	1
3/7/95		130	67			5.17	4.77		21.0		0.01		8	1
3/22/95		20	41	17.3		5.42	5.51	81	53.0	<	0.01	8.43	8	0
6/21/95		20	86	22.4		6.26	6.00	26	20.0	<	0.01	8.43	8	0
9/12/95		20	230	21.7		17.03	17.65	15	7.0	<	0.01	8.93	8	0
12/12/95		6	220	12.6		18.84	17.91	1	1.4	<	0.01	8.99	8	0
1/25/96														1
2/21/96		48	130			10.87	10.65		51.0		0.01		7	1
3/13/96					56.00				16.0				8	1
4/4/96		9	210	15.5		17.44	16.93	15	5.2	<	0.01	7.98	8	0
6/6/96		7	220	20.9		17.78	17.27	18	15.0	<	0.01	8.14	8	0
9/17/96	<	5	200	22.1		17.37	17.08	3	1.7	<	0.01	8.24	8	0
11/22/96		1700	38			3.86	6.66		61.0		0.17		8	1
12/4/96	<	5	270	9.9		21.75	20.72		0.7	<	0.01	8.09	8	0
3/19/97	<	5	210	16.3		17.19	16.00	2	2.4		0.02	8.18	8	0
6/10/97	<	5	210	23.0		18.80	17.89	16	1.1	<	0.01	7.75	8	0
9/23/97		100	130	28.5		13.21	13.58	2	64.0		0.02	7.94	8	0
1/8/98	<	5	260	9.5		19.48	19.35	14	2.2	<	0.01	7.60	8	0
4/21/98		5	170	23.2		15.52	15.28	4	13.0	<	0.01	7.81	8	0
6/10/98	<	5	190	18.4		16.76	16.40	6	6.5	<	0.01	7.80	8	0
9/23/98	<	5	200	18.2		19.49	19.55	3	4.0	<	0.01	7.69	8	
12/29/98	<	5	180	10.2		16.79	17.89	1	1.0	<	0.01	8.06	8	
4/20/99		57	190	15.7		15.98	15.42	4	19.0		0.01	7.75	8	
No.		23	23	19	1	23	23	16	24		23	19	24	22
Min.	<	5	38	8.9	56	3.86	4.77	1	0.4	<	0.01	7.6	7.4	0
Max.		1700	270	28.5	56	21.75	20.72	81	234		0.17	8.99	8.3	1
Avg.		107	178	17.8	56	14.9	14.8	13.2	26.0		0.02	8.10	7.98	0.27

APPENDIX E

Lake Elsinore
Sediment-Water Interface Study

October 2000

LAKE ELSINORE
SEDIMENT-WATER INTERFACE STUDY

FINAL REPORT

By

Marc Beutel, Ph.D.

for

Montgomery Watson & Alex Horne Associates

October 2000

SUMMARY

Study Goals

Field monitoring and sediment core experiments were conducted on Lake Elsinore during the summer of 2000. The goal of the study was to evaluate the magnitude and dynamics of various components of oxygen demand in the lake, and to examine the effects of oxygen on nutrient dynamics at the sediment-water interface.

Field Monitoring

Thermal stratification was observed in July and early August and surface water was supersaturated with dissolved oxygen (DO) as a result of phytoplankton activity. DO below 2 m tended to decline with increasing depth. In late August and September the water column was isothermal and undersaturated with DO. Relative to saturation, the lake exhibited a DO deficit of approximately 400 t. Soluble reactive phosphorous (SRP) and nitrate were never detected in the lake. Ammonia was detected in July and early August in water below 2 m (50-200 μg-N/L). In late August and September ammonia was detected throughout the water column (~300 μg-N/L). Though SRP was not detected in bottom-water, a number of field observations suggest that the sediment-water interface was reduced and was a source of internal nutrient loading to the lake.

Oxygen Demand

Water oxygen demand was 0.4-0.5 mg/L/d in July and 0.8-0.9 mg/L/d in August. Sediment oxygen demand (SOD) in July, August and September experimental chambers averaged 1.56, 1.34 and 0.51 g/m^2/d. Mixing at the sediment-water interface increased SOD at two of the three sites by 30-70%. Based on this experimental data, summertime oxygen demand in Lake Elsinore is 80 t/d. Much of this demand is made up by natural reaeration from the atmosphere and from phytoplankton DO production. An analysis of eleven historical DO depletion episodes yielded DO consumption rates ranging from 3-32 t/d with median of 9 t/d.

Nutrient Release Experiments

Nutrient release experiments showed that oxygenated conditions inhibited or reversed sediment release of SRP and ammonia. Anoxic SRP and ammonia release rates ranged from 7.7-26.6 mg-P/m^2/d and 41-119 mg-N/m^2/d. Release rates showed no spatial variability, but did show a significant decline between sampling dates. Estimated monthly internal loading of nutrients for July through September ranged from 3,500 to 5,800 kg-P and 16,300 to 26,000 kg-N.

Recommendations

Based on the results of this study I recommend the following: 1) An aeration system should be installed in Lake Elsinore. Such a system would result in a number of water quality benefits. 2) An oxygen delivery rate of 27.5 t/d should be used to inhibit fish kills. Either a mixing system or an oxygenation system should be adequate. 3) An oxygen delivery rate of 46 t/d should be used to inhibit internal nutrient loading. To meet this higher demand, a submerged oxygen-water contact chamber with a horizontal diffuser should be employed. 4) A value of 25,000 kg-P per year should be used as an estimate for the internal loading offset that could be achieved via aeration.

METHODS

Field Monitoring

Nutrients, dissolved oxygen (DO) and temperature were monitored at Lake Elsinore on July 7, August 3, August 29 and September 22, 2000. DO and temperature were monitored using a Hydrolab meter and probe at the North, Mid and South Stations. Nutrient profile samples were collected at the deepest station (North). Nutrient samples were collected every 2 m in depth using a 1.5 L Van Dorn sampling bottle. Water samples were filtered through prewashed 0.45 μm filters once back in the laboratory, then frozen for later analysis. Deep-water samples were collected on July 7 and August 29 from all stations to measure water oxygen demand. Figure 1 shows the location of the three sampling stations.

Core Collection

On July 7, August 29 and September 22, 2000, two sediment cores were collected at each station, one for SOD experimentation and the other for nutrient release incubations. Cores were initially collected using a 15 by 15 cm Eckman dredge. Once at the lake surface, a 5-7 cm thick sediment core with 100-200 ml of overlying water was sub-sampled from the dredge into a specially designed cylindrical Plexiglas chamber (Figure 2). To collect the sediment-water interface sample, the chamber top was slowly pushed down into the water and sediment captured in the dredge. A cap and gasket were then mated with the bottom of the chamber by hand while the chamber was still in the sediment. The capped chamber was then pulled out of the dredge, rinsed off, and bolted onto a round Plexiglas base. The water tight chambers were gently flooded with bottom water and carefully transported to the laboratory.

Water Oxygen Demand

To measure water oxygen demand (WOD), deep-water samples were incubated in BOD bottles in the dark at *in situ* temperature (24°C for July and 27°C for August) and DO was monitored with time. Incubations included a composite of water from 4 and 6 m deep at the North and Mid stations and water from 4 m deep at the South station. July incubations were performed in triplicate while August incubations were performed in duplicate. WOD (mg/L/d) was calculated as the linear best-fit of DO versus time.

Sediment Oxygen Demand

Unmixed sediment oxygen demand (SOD) was measured in chambers from all stations on all three dates when cores were collected. Chambers were topped off with de-ionized water to avoid gas exchange with the headspace and DO in water overlying sediment was measured with time using a YSI meter/probe. Chambers collected in July and August were incubated in the dark at *in situ* temperature (24°C for July and 27°C for August). September chambers were incubated at room temperature (21°C) which was slightly cooler than *in situ* temperature (24°C). Water from each chamber was also incubated in BOD bottles and DO consumption was measured. SOD was calculated as the total chamber DO depletion rate minus the chamber water DO depletion rate. Both depletion rates were calculated as the linear best-fit of DO versus time yielding units of mg/L/d. SOD was converted to a flux (g/m²/d) by multiplying by the volume of chamber water and dividing by the chamber surface area (71.3 cm²).

After the unmixed SOD experiment, mixed SOD was measured in July and August chambers. Moderate water current at the sediment-water interface was achieved via a recirculating peristaltic pump that drew water out the top of the chamber and discharged it out a small nozzle 2-3 cm above the sediment-water interface. Velocity out of the discharge nozzle was 4-5 cm/s. No sediment was resuspended during the experiment. The mixing experiment was performed to estimate induced oxygen demand as a result of aeration system operation. Induced oxygen demand is the increase in SOD generally observed with increased mixing at the sediment-water interface. Mixing tends to decrease the diffusional boundary layer at the sediment-water interface, thereby increasing the flux of oxygen from overlying water into the sediment

There were some minor difficulties with the September SOD experiment. Chamber water DO consumption data was misplaced. So, based on earlier experiments a DO consumption rate of 10% of the total chamber DO consumption rate was used to calculate September SOD. In addition, September SOD was incubated below *in situ* temperature. SOD was adjusted from 21 to 24°C using the formula: $(SOD)_{T1} = (SOD)_{T2}\ \theta^{(T1-T2)}$, where θ equals 1.065 (Veenstra and Nolen, Wat. Res., 25:351-354, 1991). This yields an increase in SOD by a factor of 1.208.

Nutrient Release Rates

Chambers were incubated with 1 L of water overlaying the sediments and 100-200 ml of headspace. Chambers were aerated for 8-12 days, then turned anoxic for 8-12 days by bubbling chambers with nitrogen. July and August chambers were reaerated for 6-10 days. Gas injection rates were around 5 ml/min. This maintained a gently mixed water column while never resuspending sediment. I intended to incubate the September chambers with gas containing 10% oxygen and the remainder nitrogen to examine the effect of low DO conditions on sediment nutrient release. Unfortunately the gas tank containing this gas mixture was accidentally emptied during a previous experiment, and this incubation phase could not be performed.

The incubations were semi-batch in nature. Samples of 60-200 ml were withdrawn with a syringe out of the gas inlet port every 2-3 days. Synthetic make-up water consisting of de-ionized water and appropriate salts (1,000 mg/L TDS and pH of 9.0) was used to maintain a constant chamber water volume. Make-up water was added to chambers through the water sampling port. During sampling in anoxic chambers, positive pressure was maintained in the headspace with nitrogen gas to avoid oxygen contamination. In addition, make-up water added to the anoxic chambers was deoxygenated by bubbling it with nitrogen gas prior to injection into the chambers.

Overlaying chamber water was monitored for ammonia, nitrate, SRP and Oxidation Reduction Potential (ORP). Nutrient samples were filtered through prewashed 0.45 μm filters once back in the laboratory, then frozen for later analysis. Nutrient release rates (mg/m²/d) were calculated as the linear best-fit of the accumulated nutrient mass versus time multiplied by the chamber water volume and divided by the surface area of the chamber. ORP of chamber water was measured with a permanently installed hand-made electrode and a Corning calomel reference electrode brought into contact with chamber water at the time of sampling. The two electrodes were connected to a Beckman Expandomatic SS-2 voltmeter, and a reading was recorded after 5-10 minutes. Standard ORP was measured in ZoBell's solution and ORP values were calculated relative to the standard hydrogen electrode using the equation in Standard Methods. DO was also monitored during aerated phases using a YSI meter and probe. Sulfide concentration was monitored in the July chambers. Samples were preserved with zinc acetate and NaOH. During the August and September incubations sulfide was qualitatively monitored by smelling water samples.

Analytical Wet Chemistry

Standard colorimetric analytical methods were used to measure ammonia (phenate method), nitrate (cadmium reduction) and SRP (ascorbic acid method). Absorbence was measured at the appropriate wavelength on a Bausch and Lomb Spectronic 21 spectrophotometer using a cuvet with a path-length of 1 cm. Detection limits for ammonia, nitrate and SRP were 30 μg/L. Sulfide was measured using the iodometric method, and the method had a detection limit of 0.5 mg/L. In this study non-detect samples are reported as one-half of their detection limit.

RESULTS

Lake Water Quality

Figures 3 and 4 show summertime temperature and DO profiles in Lake Elsinore. Slight thermal stratification was observed in the upper 1-2 m of the water column in July and August with surface waters 1-2°C warmer than underlying water. Water temperatures increased from around 25 to 28°C between July and early August, then decreased to around 24°C in September. July and early August surface water was supersaturated with DO, presumably the result of intense phytoplankton productivity. Below 1-2 m, July DO ranged from 7-8 mg/L while early August DO ranged from 2-6 mg/L. Late August and September DO was below saturation throughout the water column and ranged from 3-6 mg/L.

Ammonia, nitrate and SRP were monitored in Lake Elsinore at the North Station, the deepest of the three stations. Only ammonia was detected in the water column (Figure 5). In July and early August low levels of ammonia (50-100 μg-N/L) were detected in bottom water. In late August and September, ammonia was around 300 μg-N/L throughout the water column.

Lake Oxygen Demand

Oxygen demand is made up of two components: water oxygen demand (WOD) and sediment oxygen demand (SOD). WOD is exerted in the water column by respiring pelagic organisms such as bacteria, phytoplankton, and zooplankton. SOD is the oxygen demand exerted by microorganisms consuming organic matter that has settled to the sediment-water interface. SOD also includes the demand exerted by the oxidation of reduced compounds (sulfide, methane, ferrous iron) diffusing from underlying sediments.

WOD was measured in bottom water samples (4-6 m deep) collected in July and early August. July WOD ranged from 0.46-0.53 mg/L/d and August WOD ranged from 0.80-0.94 mg/L/d. SOD data is summarized in Figure 6. Unmixed SOD showed no consistent spatial pattern, but SOD was significantly lower in September than in July and August. July, August and September unmixed SOD ranged from 1.47-1.65, 0.92-1.80, and 0.34-0.70 $g/m^2/d$, respectively. Note that mixing enhanced SOD in Mid and South sediments in both July and August by 30-70%.

Sediment Nutrient Release Dynamics

Figures 7 A, B and C show results of nutrient release incubations for July, August and September. For the most part, the three sets of incubations responded similarly to experimental manipulation. Results are discussed by phase below, then nutrient release rates are reviewed in detail.

<u>Oxic Phase</u>

During the aeration phase, DO levels ranged from 6-7 mg/L and ORP remained around 400-500 mV. August and September chambers initially had depressed ORP, but ORP increased as oxygenated conditions were established. SRP showed low to moderate increases and generally ranged from 100-600 μg-P/L. Ammonia and nitrate were much more dynamic. In July and August chambers ammonia initially increased to 4-6 mg-N/L then decreased to non-detect. The ammonia decrease was coupled with an increase in nitrate. In September chambers ammonia declined from 3-5 mg/L to non-detect, and nitrate steadily increased from non-detect to around 1 mg/L. During the aeration phase sulfide was not detected accept initially in August chambers.

Anoxic Phase

With the onset of anoxic conditions ORP dropped rapidly in all chambers and remained below 0 mV throughout the anoxic phase. ORP in September chambers was slower to respond to anoxia then July and August chambers. SRP and ammonia immediately began to accumulate in chamber water while nitrate decreased rapidly. SRP concentrations increased from 100-600 to 500-1,200 μg-P/L, and ammonia levels increased from non-detect to 2-5 mg-N/L. SRP and ammonia levels were higher in the July and August chambers compared to the September chambers. Sulfide odor was detected in all chambers, and total sulfide ranged from 4-10 mg/L in July chambers. During the anoxic phase, most chambers developed a white biomat at the sediment-water interface.

Reaeration Phase

July and August chambers were reaerated after the anoxic phase. ORP rebounded immediately to around 400 mV and DO levels ranged from 6-7 mg/L. SRP decreased then stabilized at around 400 μg-P/L in the July chambers and 700 μg-P/L in the August chambers. Ammonia levels dropped dramatically from 3-7 mg-N/L to non-detect in a few days with a corresponding increase in nitrate. Note that nitrate in August chambers, which had a longer reaeration phase, tended to decrease after the initial increase. Sulfide was no longer detected, and the white biomat vanished with the onset of oxygenated conditions.

Release Rates

Note that Figures 7 A, B and C show concentration and do not account for dilution as a result of chamber water sampling. These figures tend to visually de-emphasize nutrient accumulation while enhancing uptake. A clearer picture of sediment nutrient dynamics can be determined by examining cumulative nutrient mass with time. Cumulative mass is the current mass contained in chamber water plus mass removed during previous water sampling. Based on the slope of these curves, sediment release rates can be determined.

Figure 8 shows cumulative mass of nutrients with time for a single experimental chamber. Under oxic conditions SRP shows a low linear release of 1.72 mg-P/m^2/d. Under anoxic conditions the release increases to 24.5 mg-P/m^2/d. Reaeration leads to a linear uptake at a rate of –8.34 mg-P/m^2/d. Oxic ammonia and nitrate release is more dynamic and less linear in nature than SRP. But under anoxic conditions ammonia is released continuously at 105 mg-N/m^2/d, while nitrate is rapidly depleted at –37.2 mg-P/m^2/d. Reaeration results in shift in these dynamics with an ammonia uptake and nitrate release of approximately the same magnitude (80-90 mg-N/m^2/d). Release rates for all chambers are summarized in Table 1.

Figure 9 summarizes oxic versus anoxic release rates of SRP, the primary nutrient of concern in this study. SRP release rates showed little spatial variability.

Rates were similar at all sites on each sampling date. Temporal variability was substantial with SRP release rates decreasing significantly between sampling dates. July, August and September rates of SRP release under anoxic conditions ranged from 21.1-26.6, 16.9-18.0, and 7.7-10.9 mg-P/m^2/d, respectively. Note that release rates for August are approximately 20% lower than *in situ* levels since experimental cores were incubated under a slightly cooler temperature than *in situ* conditions.

Parameter	Oxic Phase			Anoxic Phase			Reaeration Phase		
	North	Mid	South	North	Mid	South	North	Mid	South
July Chambers									
ORP, mV	490	460	490	-290	-320	-310	320	410	370
SRP release	1.69 (0.99)	1.72 (0.95)	1.23 (0.99)	26.6 (0.96)	24.5 (0.99)	21.1 (0.94)	-	-8.34 (0.93)	-10.1 (0.89)
Ammonia release	+, -	+, -	+, -	101 (0.98)	105 (1.00)	116 (1.00)	-78.2 (0.80)	-87.8 (0.76)	-98.7 (0.83)
Nitrate release	0, +	0, +	0, +	-50.8 (1.00)	-37.2 (0.77)	-65.0 (0.93)	74.6 (0.95)	78.4 (0.93)	57.1 (0.93)
Sulfide release	0	0	0	129 (0.90)	201 (0.72)	185 (0.96)	0	0	0
August Chambers									
ORP, mV	510	420	470	-305	-150	-220	430	430	420
SRP release	4.59 (0.96)	+	5.44 (0.84)	16.9 (0.96)	17.4 (0.96)	18.0 (0.97)	-	-2.12 (0.81)	-3.69 (0.90)
Ammonia release	+, -	+, -	+, -	119 (1.00)	91.8 (0.98)	78.7 (0.90)	-109 (0.80)	-75.9 (1.00)	-
Nitrate release	0, +, -	0, +, -	0, +, -	-67.9 (0.77)	-70.7 (0.96)	-115 (0.99)	+, -	+, -	+, -
Sulfide odor	at beginning of incubation			yes	yes	yes	no	no	no
September Chambers									
ORP, mV	490	460	490	-290	-320	-310	NM	NM	NM
SRP release	0.87 (0.75)	+	0.10 (0.90)	7.68 (0.81)	9.97 (0.98)	10.9 (0.80)	NM	NM	NM
Ammonia release	-74.0 (0.95)	-, +, -	+, -	55.9 (0.87)	40.7 (0.85)	105 (0.85)	NM	NM	NM
Nitrate release	21.4 (0.82)	23.2 (0.97)	28.0 (0.97)	-27.9 (0.92)	-33.7 (0.75)	-27.2 (0.87)	NM	NM	NM
Sulfide odor	no	no	no	yes	yes	yes	NM	NM	NM

Table 1- Summary of Lake Elsinore Experimental Chambers. Reported ORP is at end of phase. All release rates are in mg /m^2/d. Value in parentheses is r^2 of linear fit of release rate. "+" represents a release while "-" represent an uptake. These symbols are used for phase where the response of a parameter was variable (e.g. a release followed by an uptake) or was not linear (r^2 less than 0.70).

DISCUSSION

Lake Water Quality

The goal of the field monitoring was to determine if sediment was releasing SRP to overlaying water. This is a relatively easy task in deep, stratified lake where released nutrients accumulate within a relatively isolated hypolimnion. However, in shallow, polymictic lakes it is difficult since released nutrients may be intermittently mixed into the entire water column, resulting in dilution and facilitating algal uptake. In Lake Elsinore, SRP did not accumulate in bottom water. This suggests that DO in overlaying water was high enough to maintain an oxidized sediment-water interface that acted as a barrier to the release of reduced iron and SRP. Sulfide odor was never detected in bottom water samples, which further suggests that the sediment-water interface was not highly reduced. However, as explained above, the lack of an observed accumulation of SRP in bottom water does not necessarily mean that sediment was not releasing SRP. A number of lines of evidence suggest the contrary.

Unlike SRP, ammonia was detected in bottom water in July and early August indicating that the sediment-water interface was reduced and was releasing nutrients to overlying water. In late August and September ammonia was detected throughout the water column, further suggesting that anoxic sediments were a source of internal nutrient loading. The fact that no nitrate was detected implies that there is little oxygen penetration into the sediments since this would stimulate nitrification, the oxic biological conversion of ammonia to nitrate, and would result is a nitrate flux out of the sediments. Recall that in all chamber experiments, under oxic conditions ammonia rapidly decreased with a concurrent increase in nitrate.

Observations during core collection also indicate that the sediment-water interface was reduced, and thus a source of internal nutrient loading. During core collection, sediments appeared dark and highly odorous indicating reduced conditions. In addition, in some samples a white, web-like biomat was observed at the sediment-water interface. This mat is likely *Beggiatoa sp.*, a microaerophillic (low oxygen loving) bacteria that utilizes sulfide as its electron donor and oxygen as its electron acceptor. It is common in freshwater and marine sediments. The presence of *Beggiatoa* indicates that the sediment-water interface is only slightly oxygenated, with sulfide diffusing upwards to the sediment-water interface. Thus, oxygen penetration into the sediments is low or non-existent, conditions that favor SRP release. In conclusion, while no SRP was observed in deep water, field observations suggest that the sediment-water interface in Lake Elsinore is reduced and that sediment is releasing SRP and ammonia to overlaying water. Once released to overlaying water, the nutrients appear to be diluted into the water column and/or are taken up by phytoplankton.

Lake Oxygen Demand

WOD values measured in July (~0.5 mg/L/d) and August (~0.9 mg/L/d) are lower than those determined in earlier water quality studies (Lake Elsinore NPDES Permit Feasibility Study, December 1997, Appendix F). Average May through October WOD, based on BOD_5 data, in 1993, 1995 and 1996 were 1.9, 2.6 and 1.2 mg/L/d. It is possible that these earlier WOD values were measured in surface samples that included high amounts of respiring phytoplankton, thereby elevating oxygen demand. It is also possible that the limited monitoring in this study missed peak WOD episodes that may occur after the crash of large phytoplankton blooms. The SOD values measured during this study (0.34-1.8 $g/m^2/d$) are similar to those measured in other shallow, warm lakes (1.6 $g/m^2/d$ in Lake Apopka, Florida; 1.5-4.7 $g/m^2/d$ in five Southwestern U.S. lakes).

This experimental oxygen demand data can be used to estimate the overall oxygen demand in Lake Elsinore. Assuming a water column depth of 5 m, a WOD of 1.0 g/L/d can be converted to an aerial oxygen demand of 5.0 $g/m^2/d$. Adding a SOD of 1.5 $g/m^2/d$ yields a total oxygen demand of 6.5 $g/m^2/d$. Multiplying by an approximate lake surface area of 3,000 acres (12.1 million m^2) yields a daily oxygen demand of around 80 metric t/d. Much of this demand must be made up by reaeration from the atmosphere and from phytoplankton oxygen production. If no natural reaeration of Lake Elsinore was taking place and assuming a starting DO concentration of 8 mg/L and a DO demand of 80 t/d, the lake would go anoxic in about one week.

Historical Oxygen Demand

Table 2 summarizes DO depletion episodes based on previous water quality studies (Lake Elsinore NPDES Permit Feasibility Study, December 1997, Figures A-3, A-4 and A-5). Multiplying the concentration-based oxygen demand by the volume of the lake, we can estimate the mass based oxygen demand for each episode. Oxygen demand for the eleven episodes ranged over an order of magnitude from 3.2 to 32 t/d. The median oxygen demand was 9 t/d. The fact that the observed oxygen demands are much lower than the estimated total oxygen (80 t/d) confirms that much of the oxygen demand in Lake Elsinore is made up via natural reaeration.

Patterns of oxygen demand and reaeration can be examined using field data collected during this study. In July and early August the upper 2 m of water were supersaturated with oxygen while underlying water was under-saturated. Relative to DO saturation, the upper 2 m of Lake Elsinore contained a surplus 30 t of oxygen as a result of reaeration via the atmosphere and/or phytoplankton productivity. However, the remainder of the water column had a deficit of 140 t. This deficit increased to around 400 t in late August and September when the entire water column was under-saturated by approximately 4 mg/L of DO.

Note from Table 2 that fish kills do not correlate with peak oxygen demand episodes or with lake volume. Instead, they correlate with season, all occurring in mid to late summer. One explanation for this seasonal relationship is that the lake temporarily stratifies during calm summer periods. This isolates bottom water from reaeration in a number of ways. It is no longer in contact with the atmosphere so gains no oxygen from this potential source. Since the photic zone is only 1-2 meters, bottom water also gains little DO from phytoplankton activity. Finally, DO produced by phytoplankton in surface water does not mix down into bottom water due to thermal stratification. Warm summer temperatures also stimulates respiring organisms in the sediments and water column leading to high oxygen depletion rates. I suspect that a lack of reaeration coupled with high rates of oxygen consumption results in bottom-water anoxia and subsequent fish kills.

Date	Initial DO (mg/L)	Final DO (mg/L)	Duration (days)	Oxygen Demand (mg/L/d)	Approx. Lake Volume (10^6 m^3)	Mass Based Oxygen Demand (t/d)	Fish Kill
July/Aug 1990	6	0	60	0.10	35	3.4	X
March 1991	7	0	30	0.23	35	8.1	
July/Aug 1991	9	0	100	0.09	35	3.2	
Feb 1992	14	9	30	0.17	94	16	
March 1992	9	6	30	0.10	126	13	
July/Aug 1992	6.5	2	60	0.08	112	9.0	X
Mar/Apr 1994	16	8	45	0.18	102	18	
Jun/Jul/Aug 1994	8.5	2.5	90	0.07	102	7.1	
May 1995	14.5	6	30	0.28	115	32	
June/July 1995	9	3	90	0.07	111	7.8	X
June 1996	9	5	30	0.15	93	12	

Table 2 - Historical DO declines in Lake Elsinore.

Sediment Nutrient Release Dynamics

Experimental results from this study predict that maintenance of a well-oxygenated sediment-water interface in Lake Elsinore will decrease the release of nutrients from sediment to overlaying water, and decrease the potential for sediment release of compounds toxic to lake biota. In all experimental chamber incubations, SRP and ammonia release was significantly lower under oxic versus anoxic conditions. In addition, reaeration after the anoxic phase slowed or reversed the release of SRP and ammonia. During the oxic phase and during reaeration ammonia was converted to nitrate. This is beneficial in two ways. Firstly, nitrate is much less toxic to aquatic organisms than ammonia, especially since the high pH of the lake favors the formation of highly toxic un-ionized ammonia. Secondly, nitrate unlike ammonia may undergo denitrification to nitrogen gas in deeper anoxic sediments, thereby being permanently removed from the lake ecosystem and unavailable to stimulate phytoplankton growth. Denitrification was responsible for the decline in nitrate observed at the tail end of the oxic and reaeration phases in August chamber incubations. Finally, sulfide, a highly toxic compound, was never detected in any well-oxygenated chamber.

SRP release rates measured in this study (7.7-26.6 mg-P/m^2/d) are similar to those from other studies. A literature review of data from hypereutrophic lakes worldwide found that anoxic sediment P release rates ranged from 10 to 40 mg-P/m^2/d and averaged around 20 mg-P/m^2/d (Nürnberg, Limnol. Oceanogr., 29:111-124, 1988). Ammonia fluxes in this study (40.7-119 mg-N/m^2/d) are somewhat higher than the few published studies that have examined this phenomena.

The release rates measured in this study can be used to estimate the magnitude of internal nutrient loading in Lake Elsinore, and the subsequent decrease in loading as a result of in-lake management strategies. For example, assuming an anoxic surface area of 2000 acres (8.09 million m^2) and average anoxic release rates measured in experimental chambers, internal loading in Lake Elsinore was 5,800 kg-P and 26,000 kg-N in July, 5,000 kg-P and 23,500 kg-N in August, and 3,500 kg-P and 16,300 kg-N in

September. August flux rates were adjusted by a factor of 1.2 to account for the lower experimental versus *in situ* temperature. These estimates are a bit lower than monthly P loading estimated from a mass balance developed for Lake Elsinore based on water quality data for 1995 and 1996 (Beutel, October 17, 2000 memo to Montgomery Watson). That study calculated monthly fluxes generally ranging from 4,000 to 13,000 kg-P. Estimating the magnitude of annual internal loading is more difficult since it requires knowledge of the extent and duration of anoxia at the sediment-water interface.

RECOMMENDATIONS

The goal of this study was to evaluate the magnitude and dynamics of various components of oxygen demand in the lake, and to examine the effects of oxygen on nutrient dynamics at the sediment-water interface. Based on this study I offer the following engineering recommendations.

Project Implementation

I recommend that an aeration system be installed in Lake Elsinore. Experimental results indicate that maintenance of an oxygenated water column and sediment-water interface will result in a number of water quality benefits. These benefits include: decreasing the potential for fish kills, decreasing the potential for sediment release of toxic sulfide, converting sediment release of nitrogen from toxic ammonia to nitrate, promoting nitrogen loss from the lake by enhancing denitrification, and decreasing internal loading of phosphorus.

System Design Capacity: Fish Kills

If the goal of the aeration system is primarily to inhibit fish kills, a delivery rate of 27.5 t/d is recommended. This includes a base delivery rate of 20 t/d that would satisfy 90% of historical DO depletion episodes occurring between 1990 and 1996. It also includes an additional 7.5 t/d to compensate for potential induced oxygen demand. Recall that mixing increased SOD by an average factor of 1.5 in Mid and South chambers, and SOD accounts for roughly 25% of the total oxygen demand in the lake. Thus estimated oxygen demand due to increased mixing is 20 t/d multiplied by 25% (the SOD component of overall oxygen demand) multiplied by 1.5. A properly designed mixing system using compressed air or a pure oxygenation system using a submerged contact chamber or a diffuser network could adequately supply this demand.

System Design Capacity: Internal Nutrient Loading

If the goal of the aeration system is to inhibit internal nutrient loading, a larger delivery capacity may be needed to assure that a well-oxygenated sediment-water interface is maintained. The system must be adequately sized and designed to not only meet water column oxygen demand, but sediment oxygen demand as well. Assume a summertime episode in which the lake stratifies and bottom-water receives no natural reaeration. The aeration system will need to meet a WOD of 0.94 mg/L/d (peak August experimental value) and a SOD of 1.95 $g/m^2/d$ (July average of mixed SOD). Assuming a water column depth below the thermocline of 4 m and a surface area of 2,000 acres, the resulting oxygen demand is approximately 46 t/d. I suggest that this value be used as an upper limit for the design capacity of an aeration system with the goal of inhibiting internal loading.

The most appropriate aeration system to meet the management goal of reducing internal loading is a submerged oxygen-water contact chamber coupled with horizontal distribution of highly oxygenated water across the sediment-water interface. Compared to mixing via compressed air or oxygenation via diffusers, this system has the advantage of delivering highly oxygenated water directly to the sediment-water interface.

Internal Nutrient Offsets

I recommend using a sediment SRP release rate of 16.8 $mg/m^2/d$ to estimate the offset in internal P loading that could be achieved by an oxygenation system. This is the average of the July, August and adjusted September release rates multiplied by a factor of 0.95 to account for minor P releases observed under oxic conditions. Assuming an anoxic surface area of 2000 acres yields a monthly release of 4,100 kg-P. Anoxia at the sediment-water interface likely occurs around six months during the summer and fall. Thus, I estimate the internal loading offset that could be achieved in the lake at approximately 25,000 kg-P per year.

Because of the highly dynamic nature of nitrogen cycling at the sediment-water interface, it is not possible to directly estimate the decrease in nitrogen internal loading that would be achieved as a result of oxygenation. However, experimental results suggest that sediment nitrogen release would shift from ammonia to nitrate, a non-toxic nitrogen species. Total sediment nitrogen release is expected to decrease since nitrate is susceptible to denitrification.

AKNOWLEDGEMENTS

I would like to thank Pete Dawson of Pro Marine for the free use of his boats and facilities during this study. Dr. Drew Hanson assisted with the August chamber incubations, and Ryan Barth and Scott Stoller assisted with September chamber incubations. Finally, I would like to thank Ajit Bhamrah and Gloria Lai-Blüml of Montgomery Watson and Dr. Alex Horne for providing me with background reports, water quality data, and guidance during the project. Note that all raw data from this study is available from the author upon request.

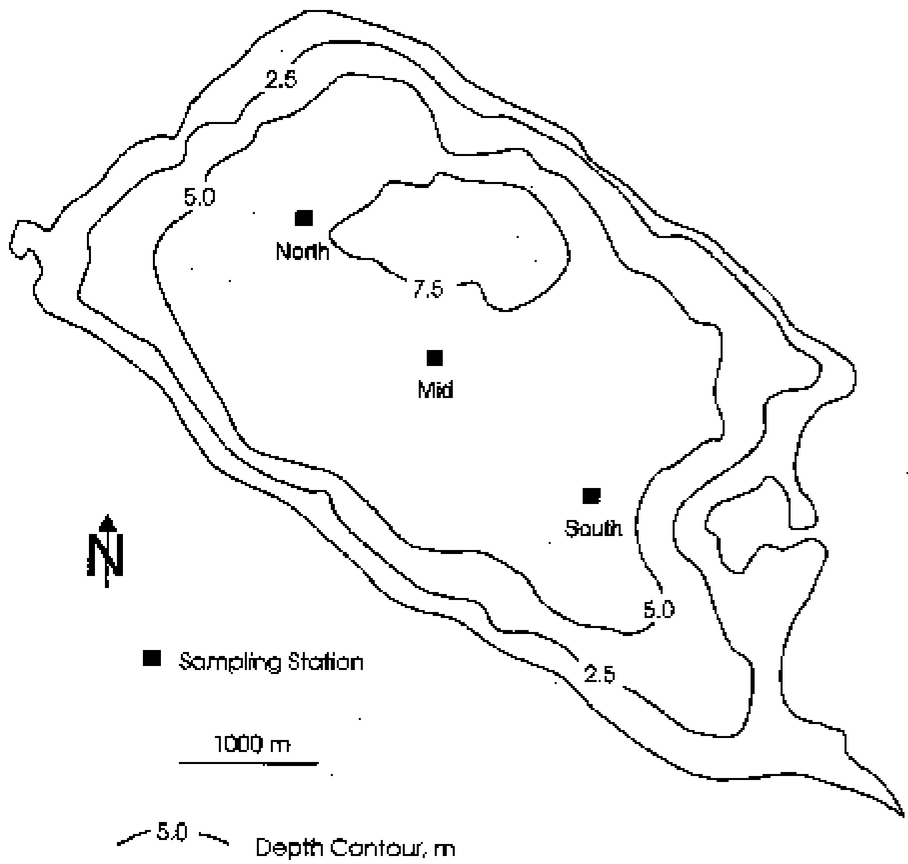


Figure 1 - Depth Contours and Sampling Stations in Lake Elsinore.

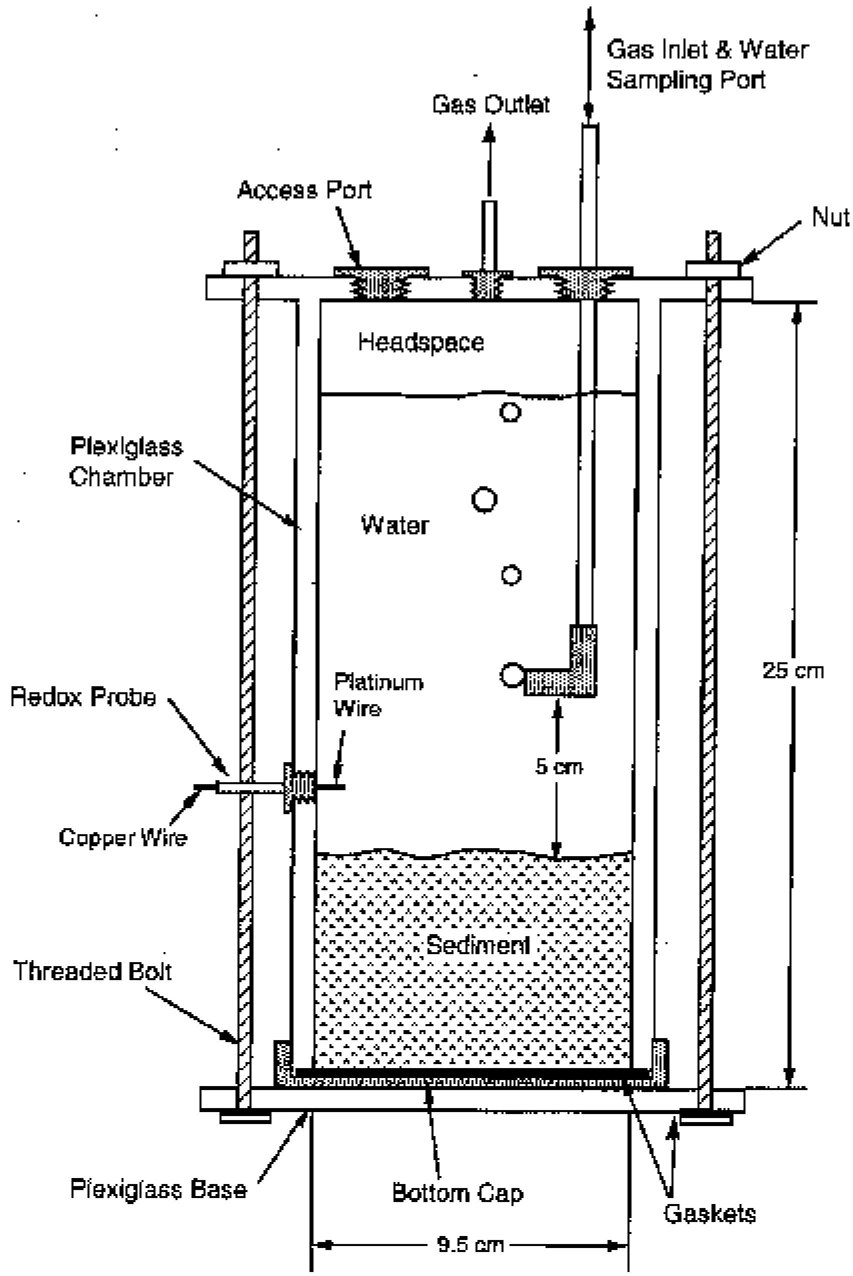


Figure 2 – Schematic of experimental sediment-water chambers used in Lake Elsinore study.

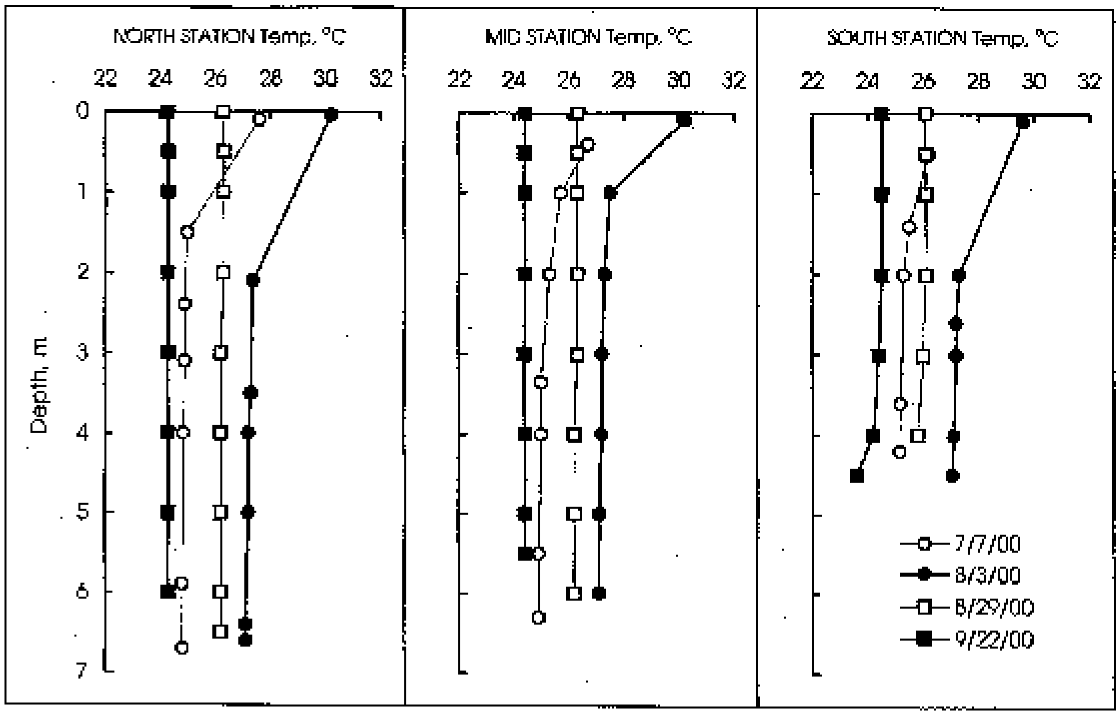


Figure 3 - Temperature in Lake Elsinore, Summer 2000.

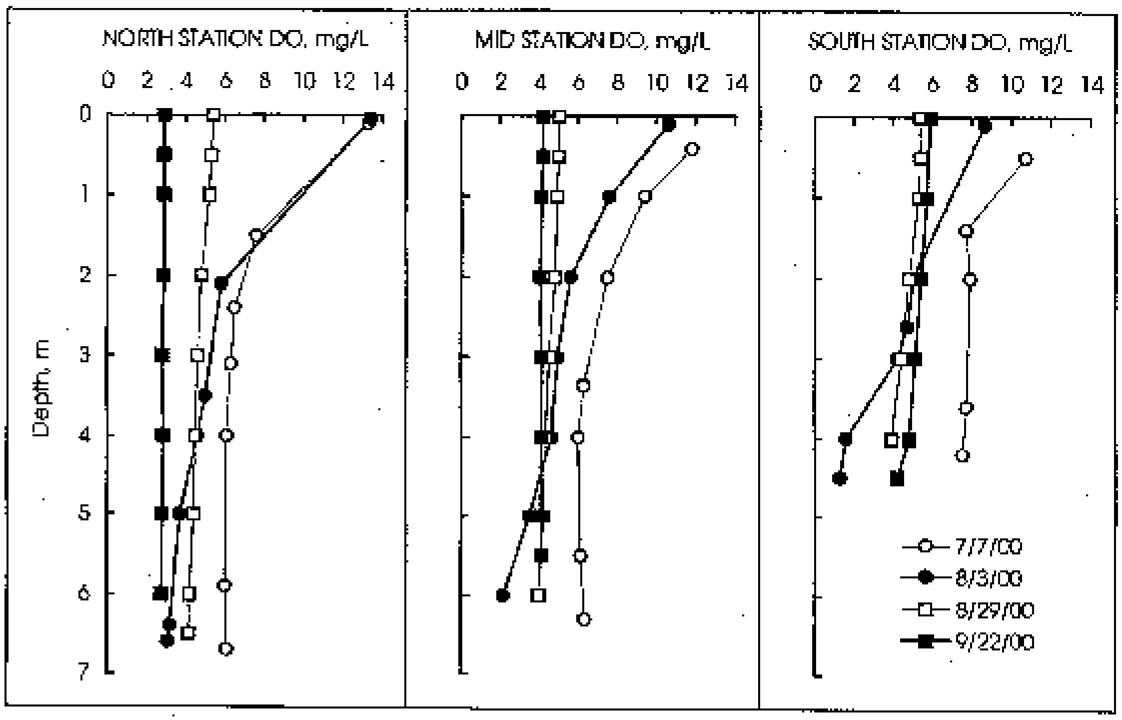


Figure 4 - Dissolved Oxygen in Lake Elsinore, Summer 2000.

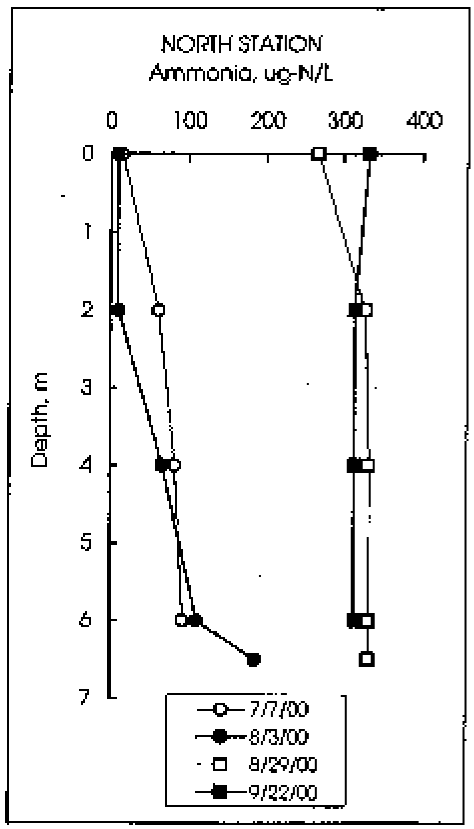


Figure 5 - Ammonia Profiles at Lake Elsinore North Station, Summer 2000. Note that SRP and nitrate were not detected in any samples.

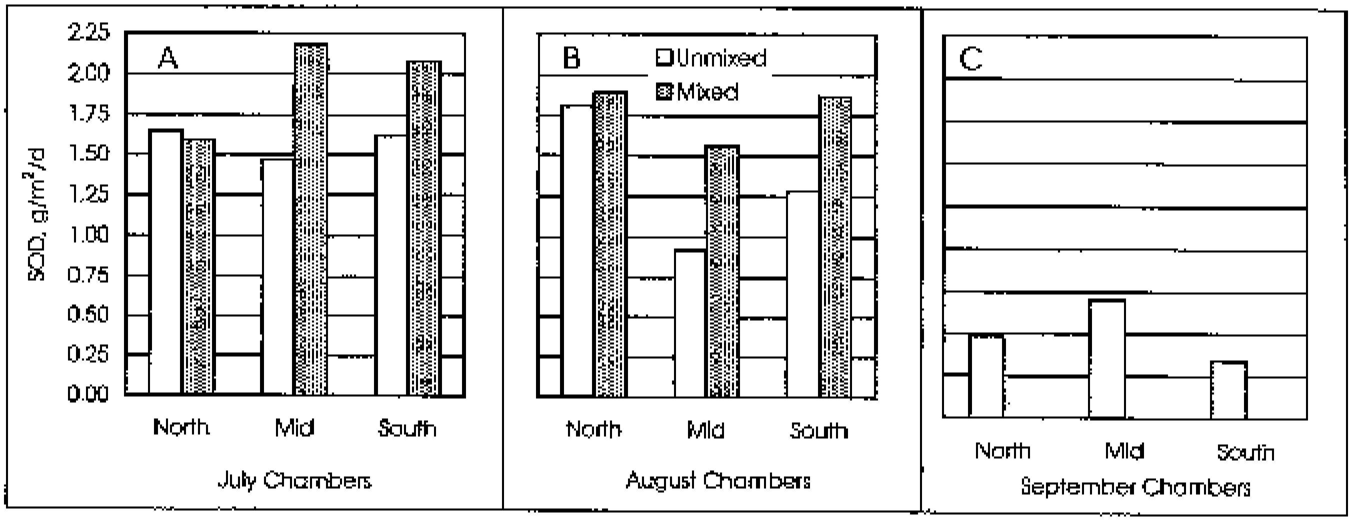


Figure 6 - Sediment Oxygen Demand (SOD) in Lake Elsinore Experimental Chambers. Measurements were made using sediment from three stations under unmixed (clear) followed by mixed (shaded) conditions. A. July chambers, B. August chambers, and C. September chambers, unmixed SOD only.

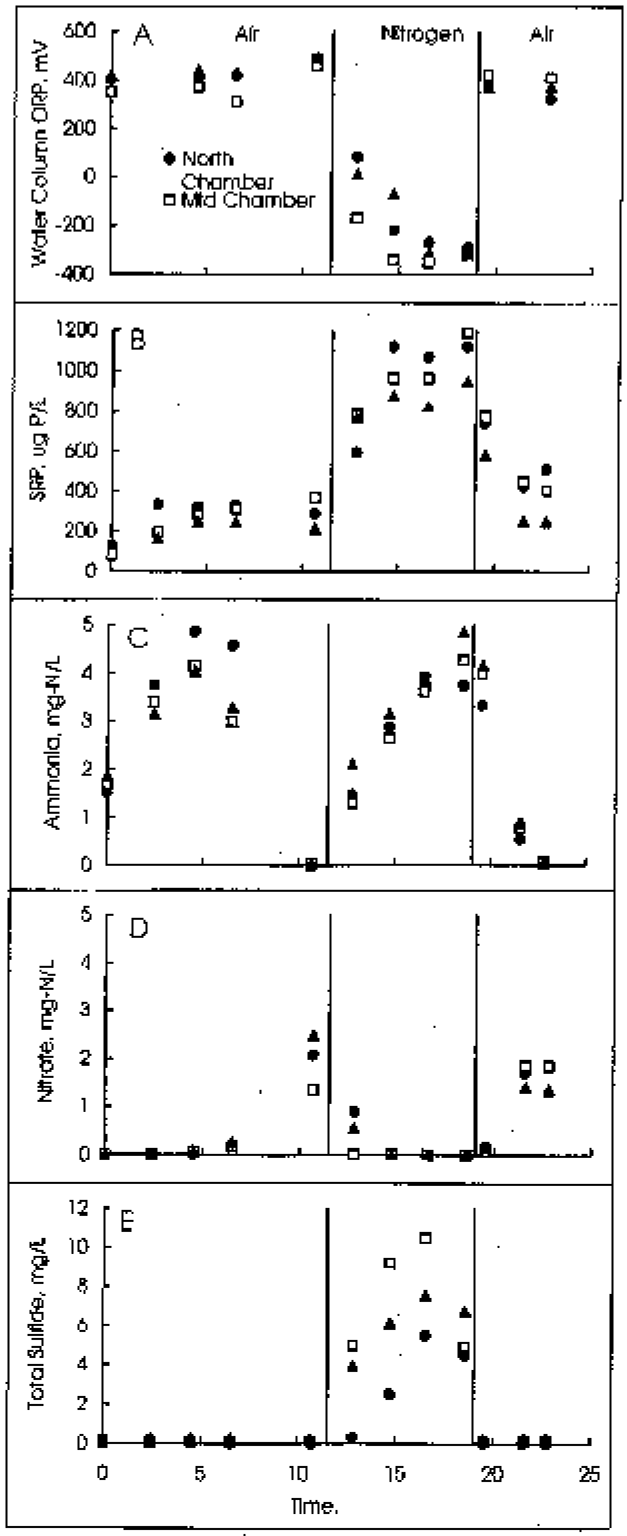


Figure 7A - Results of July Lake Elsinore Experimental Chamber Incubations. A. Water column ORP, B) SRP, C) ammonia, D) nitrate, and E) total sulfide. Chambers were aerated for 12 days, bubbled with nitrogen gas for 9 days, then reaerated for 6 days.

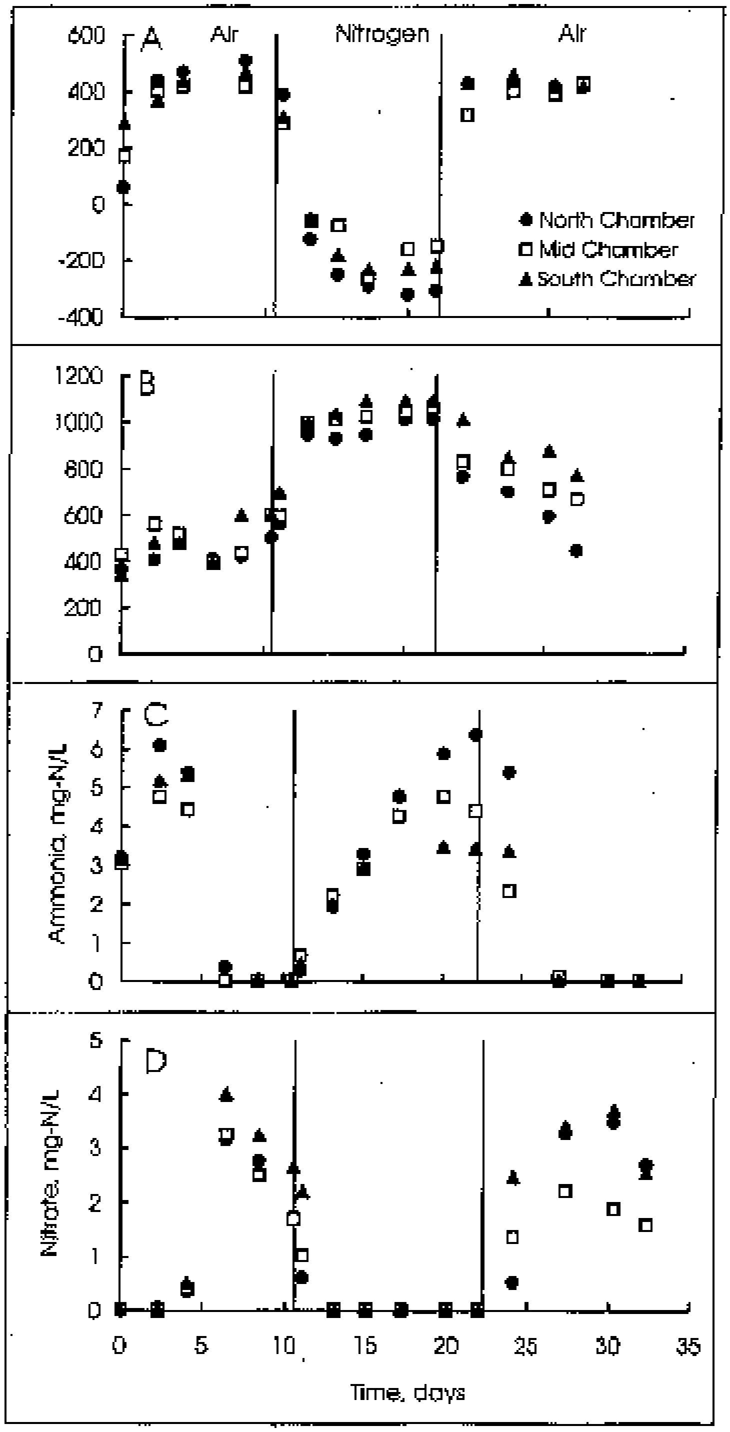


Figure 7B - Results of August Lake Elsinore Experimental Chamber Incubations. A. Water column ORP, B) SRP, C) ammonia, and D) nitrate. Chambers were aerated for 11 days, bubbled with nitrogen gas for 11 days, then reaerated for 10 days.

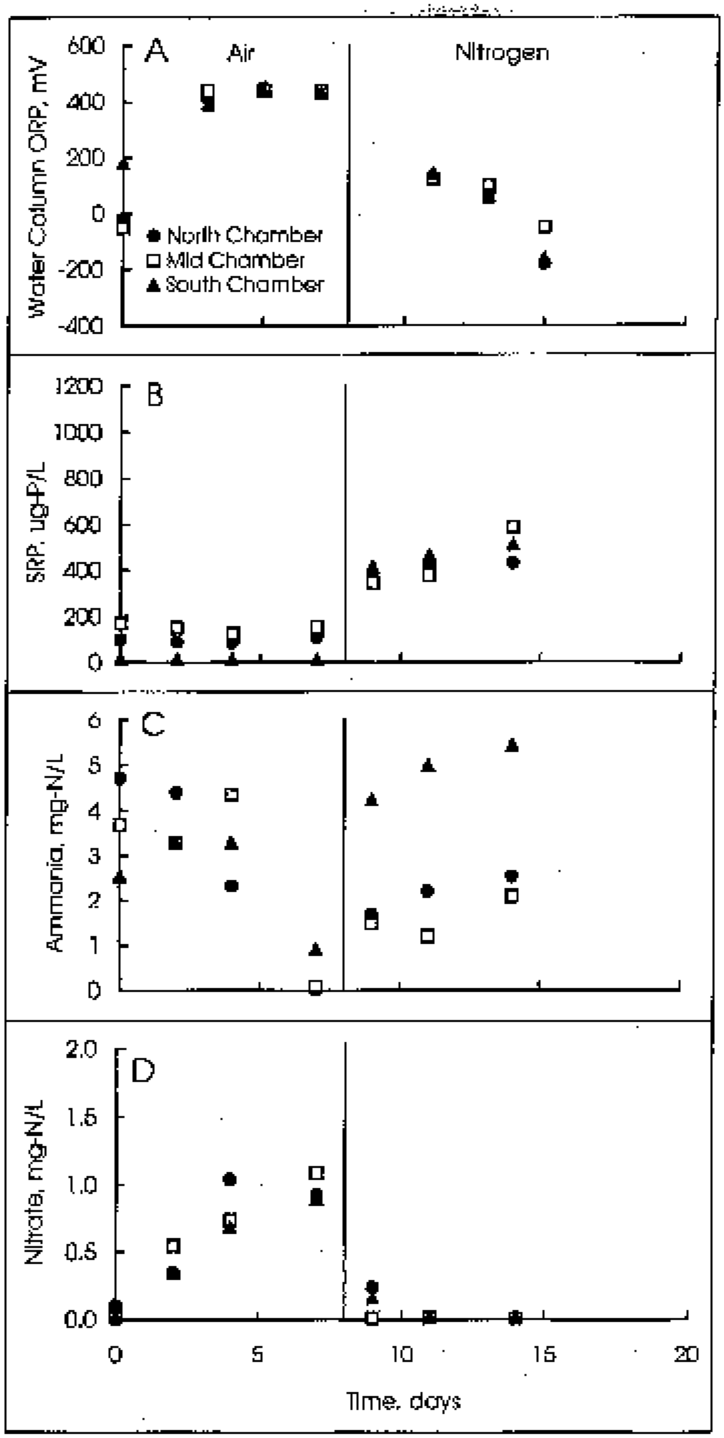


Figure 7C - Results of September Lake Elsinore Experimental Chamber Incubations. A. Water column ORP, B) SRP, C) ammonia, and D) nitrate. Chambers were aerated for 8 days then bubbled with nitrogen gas for 7 days.

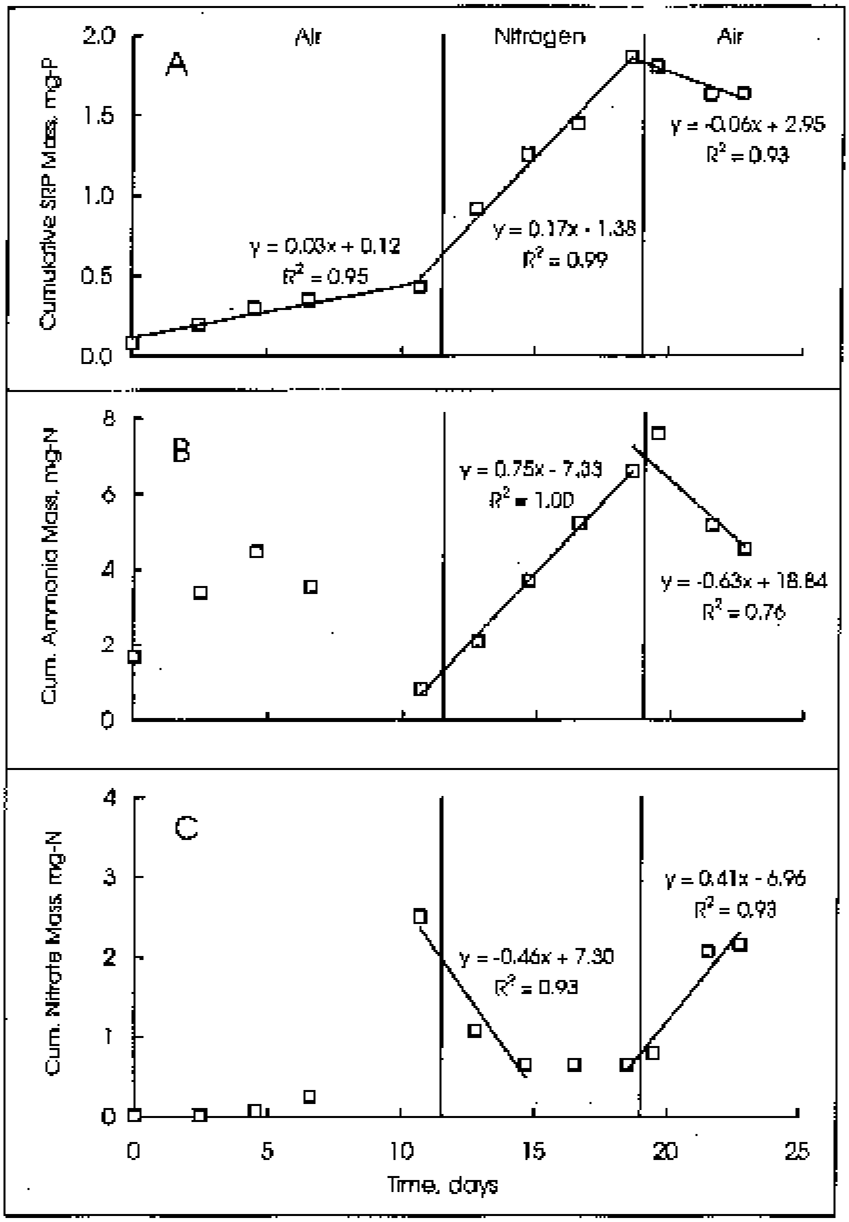


Figure 8 - Example Calculation of Sediment Release Rates. Graphs show cumulative mass in July Mid Chambers for A. SRP, B. ammonia, and C. nitrate. The slope of the linear regression of mass versus time (mg/d) is calculated for each phase starting with the final data point in the previous phase and ending either at the end of the phase or when the concentration reaches zero. Release rate is then calculated by divided this slope by the surface area of the chamber (71.3 square cm). Where rates were variable (e.g., ammonia and nitrate in the oxic phase) or non-linear over the treatment phase, release rates were not calculated. Instead, releases are reported qualitatively (see Table 2) as positive (+) or negative (-). For example, the oxic ammonia phase shown here was reported as "+ , -", a release followed by an uptake.

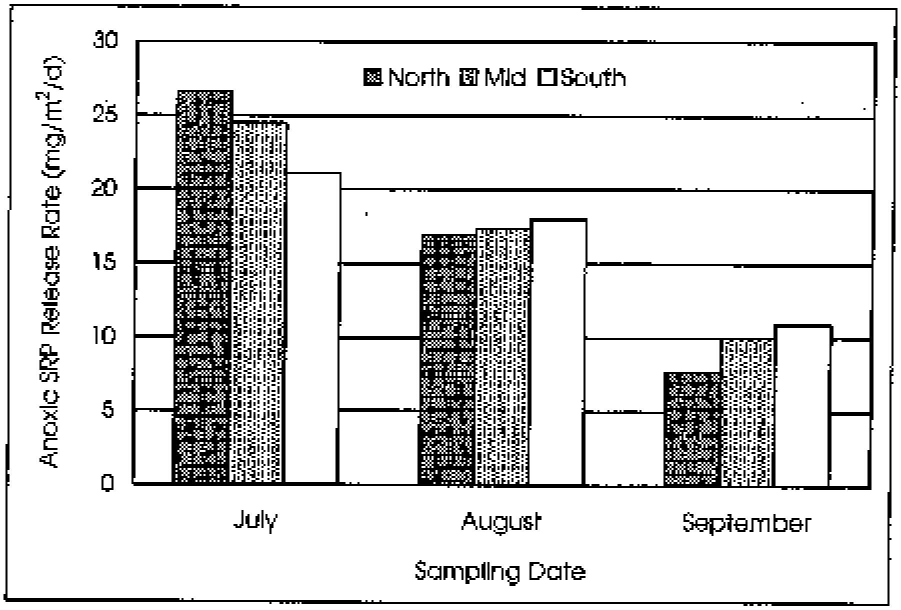


Figure 9 - Summary of Anoxic SRP Release Rates. Release rates were measured in experimental chambers incubated under anoxic conditions.

APPENDIX F

Lake Elsinore
Fish Stocking Program

CITY OF LAKE ELSINORE
MEMORANDUM

TO: Gloria Lai-Bluml, Montgomery-Watson

FROM: Pat Kilroy, Lake Operations Manager

DATE: September 26, 2000

SUBJECT: Lake Elsinore Fish Stocking Program

Lake Elsinore is classified as a warmwater fishery with the following representative species…

- Largemouth Bass
- Bluegill
- Bullheads (Brown & Black)
- Carp (Wild, Common, Leather & Mirror)
- Channel Catfish
- Crappie (White & Black)
- Threadfin Shad

As you are probably already aware, Lake Elsinore's water quality has not always been favorable in supporting a Sport Fishery. However, the Lake's water quality has been reasonable for the past five years, with no significant die-off of Sport Fish since 1995. The Lake's Sport Fishery has significantly improved during this period of good water quality, especially the size and number of Catfish & Crappie. Only a few photographs and anecdotal information supports this contention, with no fish population survey or creel counts performed by the City or CDF&G.

The City of Lake Elsinore and the California Department of Fish & Game have taken advantage of this good water quality by performing some minor fishery enhancement work and the initiation of a Fish Stocking Program. Unconfirmed reports state that Lake Elsinore had not been stocked with fish for at least 15-years prior to this year.

Lake Elsinore's best water quality occurs during the winter months, from November to March. During this time period the Lake has high oxygen levels from the surface to the bottom waters. Therefore, CDF&G has included Lake Elsinore in it's "Put n' Take" Trout Fishery Program in an attempt to expand fishing opportunities for the general public.

As you requested, the following information about this year's Fish Stocking Program is provided below.

Type of Fish	Stocking Date or Time Period	Total (pounds or number)	Size Range (pounds or inches)
Rainbow Trout	Feb. 2000	5,000 lbs.	1-6 lbs.
(scheduled trout stocking)	Nov-Dec. 2000	6,250 lbs.	0.5-6 lbs.
Channel Catfish	March-July 2000	8,550 lbs.	1-3 lbs.
Largemouth Bass fingerlings	June 2000	3,600 fish	2-inch

Note: "Just 4-Kids" Fishing Derby held in June, 2000.

APPENDIX G

Evaluation of Aeration/Oxygenation Methods for Lake Elsinore

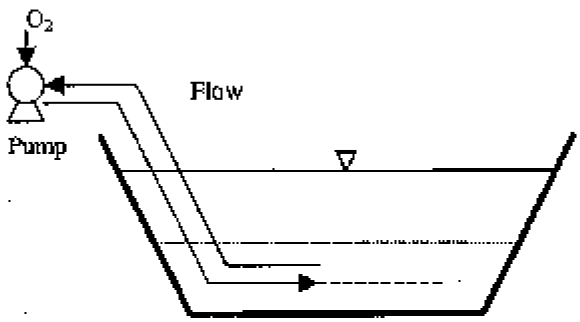
August 15, 2000

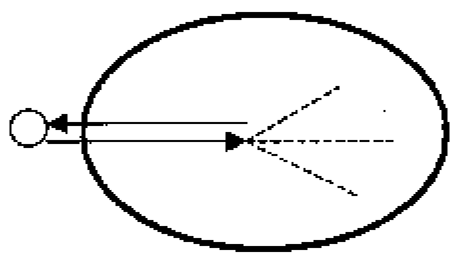
LAKE ELSINORE
AERATION/OXYGENATION SYSTEM EVALUATION
A summary of the August 15, 2000 workshop discussion

System Evaluation Criteria

- Prevent fish kill
- Causes: low winds, low water level
- Goals: lower H_2S, lower NH_3 (NH_4OH), deliver O_2 to sediments and water column
- Prevent smell/odor (H_2S and others)
- Reduce algae (inhibit PO_4 release) – does the system deliver oxygenated water to sediment-water interface ?
- Assist biomanipulation
- Compatible with recreation

A. Canning Pump





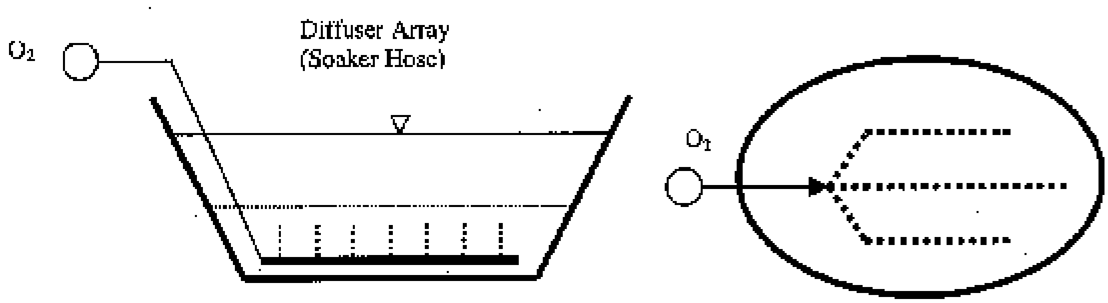
System Requirements

- Contact chamber
- Oxygen source (100 mg/L O_2, 20 ton/day)
- Venturi/U tube (30 ft deep) on shore at ground level for oxygen contact
- 3-ft or larger diameter pipe at 10 cfs
- Pump (100 hp +)
- Pipe anchors

Advantages

- More efficient in worst conditions than air
- Direct solution oxygen to anoxic water
- Good results in large deep stratified lakes
- Good results in shallow water
- 80%+ O_2 transfer efficiency
- Oxygen-rich water comes out horizontally over sediment
- Less pipes required than air/TVA systems

B. TVA-Mobley Bubbler



<u>System Requirements</u>

- Diffuser array (soaker hose)
- Oxygen source (liquid or compressed)
- Approx. 5 miles or pipes (@$70/ft)
- Pipe anchors

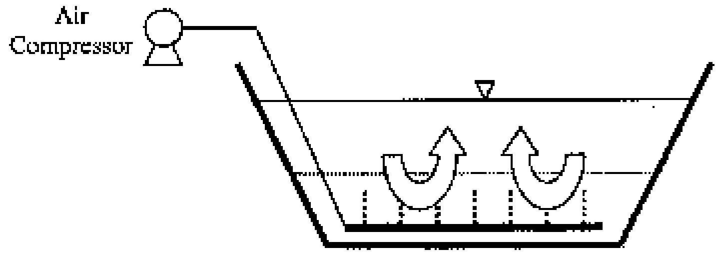
<u>Advantages</u>

- More efficient in worst conditions than air
- Direct solution oxygen to anoxic water
- Good results in large deep stratified lakes
- No pump or compressor required

<u>Disadvantages</u>

- Only 50% O_2 transfer efficiency
- Cost $200,000 per year for oxygen
- Oxygen goes up, not sideways or down
- Incomplete oxidation at anoxic zones between arrays
- Lots of pipes required (diameter smaller than the air system)

C. Compressed Air



System Requirements

- 300-3000 cfm (to be further calculated) air compressors at 9.2 $m^3/min/km^2$
- Approx. 4 miles or pipes
- Pipe anchors

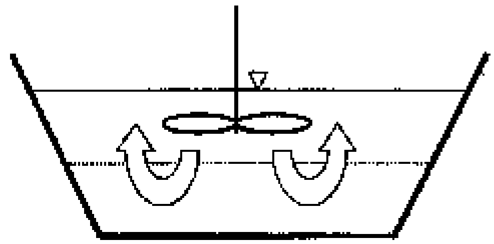
Advantages

- Used widely in lakes
- Oxygen source not required

Disadvantages

- Little quantity data available
- Less than 10% O_2 transfer efficiency
- Inverse correlation of efficiency and need (demand)
- Mixed record of success in other lakes
- Sediment resuspension
- Low potential for entire lake sediments
- Hard to maintain good DO (>6 mg/L)
- Noise abatement needed
- Low flexibility of operation
- Nitrogen Narcosis (140% saturation)
- Large compressors (with redundancy) required
- Lots of large diameter pipes needed

D. **Propeller Mixer**



System Requirements

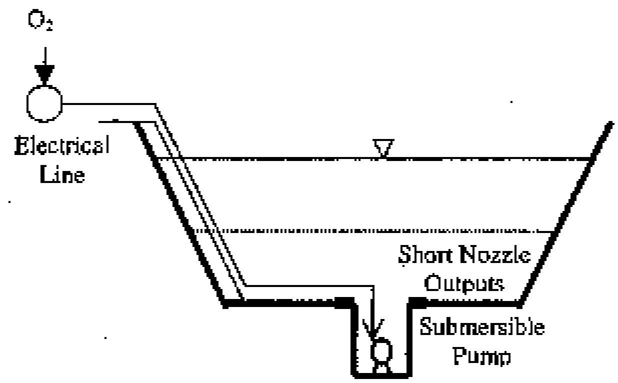
- Propellers (cones off)
- Anchors
- Floating platforms

Disadvantages

- Negative impact on recreation
- System needs to be isolated
- Low feasibility; inverse correlation of efficiency associated with water buoyancy
- Safety concerns
- Can increase algae
- Little data from other lakes

E. **Speece Sump**

(Note: details of this concept has been revised, see report)



System Requirements

- 10-ft deep 10'x10'sump (contact chamber) below lake bottom
- 200 hp submersible pump
- Electrical cable (1 mile)
- Oxygen supply
- 2-inch diameter oxygen supply pipe (1 mile)
- Nozzles (1')
- Pipe anchors

Advantages

- 85% O_2 transfer efficiency (50 ppm)
- No large pipe/manifold required
- No compressor required

Disadvantages

- Submarine construction, open excavation
- Need contact chamber

APPENDIX H

Draft Report

Aeration System for Lake Elsinore

by

City of Lake Elsinore
Lake Operations Division

August, 2000

Draft

AERATION SYSTEM for LAKE ELSINORE
by
Lake Operations Division
(August, 2000)

Overview:

Lake Elsinore's dissolved oxygen level is often depressed below natural levels due to excess algae. Both living and decaying algae can lower the dissolved oxygen level. During daylight hours, living algae produce more oxygen than they need for metabolism and dispel the surplus oxygen to the water. This results in the sunlit surface waters being much higher in oxygen than normal. However, at night oxygen production will cease, but algal respiration still continues to consume oxygen. So at night, when large algae blooms begin to utilize the oxygen dissolved in the surrounding water, they can significantly depress the Lake's overall oxygen level.

In contrast to living algae, decaying algae passively lower the oxygen level in the water. Algae contain less than one-percent phosphorus on a dry weight basis. Therefore, one-pound of phosphorus can create 135-pounds of algae. A Theoretical Oxygen Demand (ThOD) for one-pound of algae shows that 1.7-pounds of oxygen is needed to decompose the algae back to carbon dioxide and nitrate. Consequently, the algae created by just 1-pound of phosphorus requires a total of 230-pounds of oxygen to decompose. Therefore, an accumulation of organic matter on the bottom, in the form of dead algal cells, can exert a tremendous bio-chemical oxygen demand (BOD) on the Lake.

Depressed oxygen levels can negatively affect the aquatic ecosystem in several ways. Low oxygen levels in the hypolimnion slows down the decomposition of dead algae by changing conditions from the rapid "aerobic" to the slower "anoxic" form. This slow down of microbial processing facilitates the accumulation of organic matter on the Lake-bottom. Low oxygen levels in the hypolimnion restricts access for zooplankton to the bottom. Beneficial zooplankton that feed on living and decaying algae often take shelter in the bottom waters. If the bottom waters are not accessible, then the number of beneficial zooplankton will soon fall. The zooplankton become easy prey for small fish when suspended against the sunlit surface waters. What's more, low oxygen levels just exacerbate the problem of sediment release of phosphorus. This leads to a vicious cycle that revolves around low oxygen levels, sediment phosphorus release and algae blooms. Finally, the most visible affect of low oxygen levels are the massive fish kills that periodically occur on Lake Elsinore.

Lake-wide aeration presents a paradox for simultaneously limiting nitrogen and phosphorus. True, phosphorus release from the sediment will be substantially reduced by oxygenation of the bottom waters. This was successfully demonstrated by the "Jar Testing" conducted on Lake Elsinore's sediment by the consulting firm of Montgomery-Watson (1997). On the other hand, nitrate-nitrogen removal requires waters that are almost devoid of oxygen. Under low oxygen conditions (≤0.1 mg/L), bacteria that normally use elemental oxygen during metabolism will switch to pulling oxygen off the nitrate molecule and release nitrogen gas as a byproduct. This process is called denitrification and is the main pathway by which nitrogen is removed from the Lake. So, can the Lake be oxygenated by an aeration system to prevent sediment release of phosphorus, while still carrying-on "anoxic" nitrate-nitrogen removal through the process of denitrification?

The answer to the above question is a conditional... YES! It is possible to carry-on both aerobic and anaerobic respiration in the same system. This is now quite common place in the Wastewater Treatment field through the use of facultative ponds and basins. Specific design and operation criteria have been established for these engineered facultative systems. The Wastewater Treatment Industry now has a cookie-cutter approach in building and operating this type of system, which is very different from the unique systems of natural lakes.

Each lake is different and the parameters that affect the quantity & distribution of oxygen, as well as nutrients are always influx. This makes it impossible for anyone to design a set-system that will always produce the desired results. Therefore, operational flexibility will need to be designed into Lake Elsinore's aeration system to cope with the frequent changes. Furthermore, on-going monitoring and analysis, with the intent to develop a set of operational criteria will need to occur. Operational adjustments to the system would be fairly simple, just a matter of turning air-blowers or valves either "on or off".

Three zones are needed in the Lake to support the fishery, to control sediment phosphorus release and to promote nitrate-nitrogen removal. The aerobic zone will be a large and highly oxygenated area needed to support a warmwater fishery. This aerobic zone will extend from about 3-feet off the bottom to the surface, as well as the in-shore areas that are less than 3-feet deep. Warmwater fish require a minimum average oxygen level of 3-4 ppm, but many fish can enter water lower in oxygen for brief periods of time. The oxygen levels will gradually increase while moving closer to the surface, with the mid-depth to the surface being 100% oxygen saturated. A transitional zone, in which oxygen ranges from 0.2 to 3.0 ppm, will sporadically occur in the bottom 3-feet of the Lake. From the bottom to about 1-foot off the bottom will be an anoxic zone ($\leq$0.1 ppm O_2) that will also occur scattered throughout the Lake. The "transitional" and "anoxic" zones will frequently overlap.

These anoxic micro-zones are needed for the removal of nitrate-nitrogen, although there is some concern about phosphorus release from the sediment in these anoxic areas. To quell this concern there is a multiple approach in controlling phosphorus release from the sediment. Much of the liable phosphorus will be bound to aluminum through a metal salt addition. The aluminum-phosphorus bond does not break under anoxic conditions, like the iron-P bond. Escaped phosphorus will be bound continuously by deposition of calcite through the enhancement of high calcium waters. Reducing conditions that cause sediment phosphorus release will be limited through artificial circulation. Competition for phosphorus between algae and bacteria will increase as the steady-state bacterial population is elevated through suspension of bacteria by artificial circulation, similar to the activated sludge process of a POTW. Additional competition for phosphorus will come from the planting of aquatic vegetation. Finally, the presents of nitrate alone is known to prevent the reducing conditions that cause sediment phosphorus release.

Lake Elsinore experiences low oxygen levels for about 120-days per year, between mid-June to mid-October. Therefore the artificial circulation system would only need to be run from 3 to 6 months per year. When to turn on the system and how much of the system to activate at one time would be based on several factors. Some of the factors that would need to be considered are the need for nitrogen removal by denitrification, the need to maintain a beneficial thermal stratification and the need to prevent Lake-wide low dissolved oxygen levels. For instance, in 1998 there was a major inflow of cold water and nutrients, followed by the slow onset of summer. When hot summer temperatures did finally arrive, they rapidly heated the surface waters of the Lake. This rapid warming resulted in a thermal stratification of 13°F between the surface and bottom waters. Water testing results during this time period showed that the bottom waters contained 3-times the Ortho-P and 17-times the inorganic nitrogen levels than the surface waters. Low nutrients in the surface waters, especially nitrogen, resulted in a low algae population throughout the summer and no summer fish kills. Apparently, the large temperature difference acted as a barrier for the migration of nutrients from the bottom to surface. Under this unusual circumstance, it may not be wise to turn on an artificial circulation system that would bring-up nitrogen from the bottom to the algae at the sunlit surface.

Limnologists that have studied Lake Elsinore generally agree that an aeration system needs to be installed. However, the type of aeration system is currently under evaluation. This paper is intended to refine the discussion for the best type of aeration system for Lake Elsinore and to provide some preliminary engineering details for a Diffused Aeration/Artificial Circulation System.

Lake Aeration Operating Criteria:

1. Safe operation for the general public.
2. Compatible with the recreational uses of the Lake.
3. Prevention of significant fish kills due to low dissolved oxygen levels.
4. Function under variable water levels (MSL 1,240' to 1,255').
5. Cost-effective delivery of oxygen to the bottom waters (\$/lbs of 0_2 transferred).
6. Function under intermittent use.
7. Ability to turn on/off aeration zones for anoxic removal of nitrate through denitrification.
8. Low Maintenance Costs (labor & parts).
9. Low Operating Costs (electric &/or pure oxygen purchase).
10. No disturbance of sediment.
11. Low noise level.
12. (?) Maintain thermal stratification under rare occurrence (?)

General Analysis of "Stratmix" Lake Aeration/Artificial Circulation System:

Lake Elsinore's surface water is supersaturated with oxygen during the day, where as the bottom waters are often devoid of oxygen. This dichotomy is due to the production of oxygen near the sunlit surface by photosynthesizing algae and the use of oxygen on the bottom of the Lake by bacteria that process the dead algae. If the high oxygen in the surface water were regularly re-distributed to the bottom, then oxygen demanding organic matter would not accumulate on the bottom and all the benefits of an well oxygenated Lake would be attained.

The mechanical addition of oxygen to water is termed "Aeration" and is commonly used in the Wastewater Treatment Industry. But a Lake is much different from a Wastewater Aeration Basin. Again, the main problem on Lake Elsinore is re-distribution of oxygen, not necessarily addition of oxygen. This re-distribution can be accomplished by transforming a diffused aeration system into highly efficient water pump. By so doing, it is possible to vertically mix the low oxygen bottom waters with the high oxygen surface waters in a cost-effective manner. A diffused aeration system uses land-based air blowers to send compressed air through pipe and tubing distributed on the bottom of the Lake. A diffuser at the end of the tubing allows the release of tiny bubbles. As the air-bubbles rise they entrain water in an upward current, thereby vertically mixing the bottom and surface waters. This process is termed "Artificial Circulation" and it has proven to be very economical in bring oxygen to the bottom waters of shallow, eutrophic lakes.

According to the scientific literature, airflow of 1.3-SCFM (Standard Cubic Feet per Minute) per surface acre is required to maintain oxygen levels in lakes (Lorenzen & Fast, 1977). Therefore, Lake Elsinore would require about 4,000-SCFM of air to aerate the main Lake-basin of approximately 3,000 surface acres. Given the fluctuating water levels (MSL 1,240-1,255), this would require air blower(s) in the range of 300-horsepower at 80% efficiency that produces about 15-20 scfm per hp. According to the Vendor's literature, a diffused aeration/artificial circulation system can move about 5,000 gpm per horsepower. Therefore a properly sized system would completely turnover Lake Elsinore in about a week.

The Stratmix Diffused Aeration System fits well into the concept of aeration and artificial circulation by combining both high oxygen transfer rates and moderate vertical mixing rates. In addition, the "Dura-Disc" diffuser uses flexible membrane technology that allows the diffuser to be self-cleaning. The Dura-Disc diffuser is also ideal for intermittent use without clogging of the diffuser, because the slits in the membrane are normally closed when no air-pressure is applied. This is very different from the typical ceramic dome diffusers used in Wastewater Aeration Basins. When air is shut-off to a ceramic dome diffuser both water and small particles flood into the diffuser and ultimately cause clogging.

Dr. Claude Boyd of Auburn University has verified the performance of the Stratamix System for Aquaculture and has produced the following data.

Stratamix Aeration Data

Parameter	Value
Standard Aeration Efficiency (SAE) @ 14-ft depth & 4.0-SCFM/diffuser.	10.4-lbs 0_2/hp-hr
Standard Oxygen Transfer Efficiency (SOTE)	28.7% of the oxygen contained in the air transferred into the water.
Correction Factor for SAE under actual operating conditions for Lake D.O. & temperature.	0.4
Actual Aeration Efficiency under Lake conditions @ 5-ppm 0_2 & 83°F.	4.2-lbs 0_2/hp-hr

By combining Dr. Boyd's Stratamix data of 4-cfm per diffuser with Lorenzen & Fast's rule of thumb for adequate lake mixing of 1.3 cfm per surface acre, then Lake Elsinore would require about 1,000-Stratamix units laid-out in a grid over the 3,000 surface-acre main Lake-basin.

Pounds of Oxygen added to the Lake by direct Stratamix Aeration

- Estimated Pounds of Oxygen Transferred per Day:

(4.2-lbs 0_2/hp-hr)(300-hp)(24-hrs/day) = 30,240 pounds oxygen per day

- Estimated Electrical Cost per Day:

(300-Hp)(0.746-Kw/Hp)($0.075/Kw-hr)(24-hrs) = $403 per day

- Estimated Electrical Cost per Month:

($403/day)(30.4-days/month) = $12,251 per month

- Estimated Electrical Cost per 6-Months:

($12,251/month)(6-months) = $73,506 per 6-months

- Estimated Cost per Pound of Oxygen Transferred to the Water:

($403/day) ÷ (30,240 pounds oxygen/day) = $0.0133 per pound of oxygen

Pounds of Oxygen transferred to the bottom-waters by Stratamix Circulation

Given:

- Mid-depth to surface-water average D.O./24-hrs = 8 ppm
- Bottom-water to mid-depth average D.O./24-hrs = 4 ppm
- Average Lake Depth = 14-feet
- Approximate Lake Volume = 40,000 acre-feet
- Approximate Lake turnover time by Stratamix Circulation = 7-days

Estimated Pounds of Oxygen in Surface-water (7-14 feet):

(8 ppm)(20,000 acre-feet)(2.72 pounds/ppm/acft) = 435,200 pounds of oxygen

Estimated Pounds of Oxygen in Bottom-water (0-7 feet):

(4 ppm)(20,000 acre-feet)(2.72 pounds/ppm/acft) = 217,600 pounds of oxygen

Estimated Total Pounds of Oxygen in the Lake (0-14 feet):

435,200 + 217,600 = 652,800 pounds of oxygen

Estimated Pounds of Oxygen added to the bottom-waters per day:

(652,800 pounds of oxygen)÷(2) ÷(7-days) = 46,629 pounds of oxygen per day

APPENDIX I

Summaries of Environmental Commitments and Mitigation Requirements for EVMWD's Existing Wetlands

Table 1
Environmental Commitments

404 Permit Environmental Special Conditions

b. Mitigation Monitoring Plan
   - Reliable Water Supply
   - Detailed Planting Scheme
   - Isolate Wetlands with buffer
   - Shallow Fish Habitat
   - Aeration (see 1601 Permit #12)
   - 5 year maintenance and monitoring plan

c. Mitigation complete prior to Notice of Completion
d. Deed Wetlands and Low flow Channel Conservation Easement
e. Watering markers placement

1601 Permit Environmental Special Conditions

6. Mitigation Plan
   a. Detailed implementation plan and schedule to accomplish 404 Special condition "b."
   b. Detailed hardscape and softscape for low flow channel and connection to main lake
7. Document water will be available when necessary for low flow. channel, wetlands & lake
9. Conduct an agricultural suitability test & measures to assure vegetation viability
11. Controlled access to wetlands & low flow channel be constructed by 6/2/90
12. Maintain Reg. Board Basin Plan D.O. in the lake. Report monthly D.O. readings to the Dept.
14. Monitor revegetation and provide quarterly reports with follow-up mtgs for 5 years
15. Establish 3 & 5 year plant height standards
16. Revegetation: 80% survival 1st year; 80% cover 3rd year; 100% cover 5th year
18. Revegetation of stripped or exposed areas
19. Bridge or culvert bottoms not to impair water flow
38. Pump intakes will be screened with 1/8" or 1/4" screen, depending on the season

Environmental Assessment Conditions

1.a.4 Large pumps lower wetlands water after floods; small ones lower level continuously
1.a.6 Water enters wetlands and moves through a series of ponds, then to pumps and into lake
1.a.7 Wetlands would be protected from vehicle access by a 20' wide channel
1.b.1 Aquatic plants such as cattails and bulrushes planted near ponds
1.b.2 50 Ac of large native trees and shrubs and 50 Ac of small native shrubs/grasses planted
1.b.3 Plant size would be at least 1 gallon with 10% 5 gallon or larger
1.b.4 Large plants not to be planted greater than 50 feet apart
1.b.5 Small plants could be started by seeds, cuttings or container plants
1.b.6 Seed mixes should take into account soil character
1.b.7 EVMWD/SAWPA to sponsor recovery program by relocating plants from other wetlands
1.c.1 Designate an operating agency for long term maintenance of the wetlands
1.c.2 Operating agency to coordinate with F&G and F&W
1.c.3 Maintenance to include debris removal & replanting
1.c.4 One time stocking of small fishes 2 to 3 months after plantings
1.c.5 Operating agency would sponsor a Monitoring Program to ensure proper maintenance

E. Wetlands And Riparian Habitat

WETLANDS

A wetlands was constructed in the back basin consisting of over 200 acres of water and three islands with total area of over 100 acres. While the primary purpose was to provide habitat for migratory fowl, under appropriate water level conditions it can also function as shallow fish habitat linked to the main body of the lake by a 48" diameter conduit through the levee.

Environmental commitments related to the Wetlands:

A constructed wetland - (404 cond. a., b.; 1601 cond. 6a.). Over 300 acres of wetlands were constructed.

Reliable Water Supply - (404 cond. b.; 1601 cond. 7; EA cond. 1.a.4) Water level in the wetlands will be maintained between elevation 1240 and 1243, providing a water depth of up to 10 feet. In 1996, CDFG modified the requirement for providing "flow-through" water to the wetlands from the riparian habitat so that water flowing in the river bed need only to reach the downstream end of the riverbed. When lake water or naturally occurring runoff is insufficient to maintain the water surface in this operational range, makeup water from the the lake, EVMWD system, wells, or reclaimed water may be used. Pursuant to the request of the resource and regulatory agencies, the District provided a wetlands water surface elevation marker in the wetlands that can be read from the levee. The District also installed automatic water surface elevation sensors for the wetlands and the lake to eliminate the need for manual elevation readings.

Shallow Water Habitat Replacement - (404 cond. b.; EA cond. 2.) Subsequent to the 404 permit, CDFG agreed that the type, quantity, and location of fish structures for habitat will be as recommended by the CDFG, not as specified in the EA. Subsequent to that change, CDFG dropped the requirement for fish structures.

RIPARIAN HABITAT

The riparian habitat area, also known as the low flow channel, was established in the existing San Jacinto riverbed downstream of the levee. This portion of the mitigation area was originally envisioned as a flow-through system whereby 3 cfs of water would make its way through a narrow low flow channel in the riverbed into the wetlands, thereby maintaining the wetlands water level.

Environmental commitments related to the Riparian Habitat:

Reliable Water Supply - (404 cond. b.; 1601 cond. 7; EA cond. 1.a.4.) A reliable water supply is essential to maintain a healthy plant palette. Lake water or naturally occurring runoff will be used when lake levels are high to maintain the habitat. To maintain the habitat when these sources are not available, a pipeline was constructed to supply makeup water to the riparian habitat from the Cereal Street wells on the northern edge of the wetlands. In 1996, CDFG agreed to amend the requirement for providing "flow-through" water into the wetlands through the riparian habitat since the District made additional improvements by constructing water-ponding check structures allowing inundation of the entire width of the riverbed. The CDFG agreed that the water flowing through the riparian habitat need only to reach and maintain a standing pool of water below the last downstream check structure located adjacent to the wetlands and not be required to flow into the wetlands.

WETLANDS AND RIPARIAN HABITAT

Environmental commitments related to both the Wetlands and the Riparian Habitat:

A detailed mitigation plan - (404 cond. b., c.; 1601 cond. 6a., 6b.) The Final Mitigation Plan was completed and distributed to all involved agencies on July 31, 1989. The plan addressed ACOE, CDFG, and FWS comments and requirements for design and operations and maintenance of the wetlands.

A detailed planting scheme - (404 cond. b.; 1601 cond. 6a., 6b.; EA cond. 1.b.) The planting palette was established in the Final Mitigation Plan. Bulrushes from ponds at another EVMWD facility were transplanted into the wetlands. Although other plantings were planned, a successful pallete of "volunteer" plants developed in the area. As a result, the resource agencies were satisfied with the existing vegetation pallette and coverage, and no additional plantings were required.

Revegetation standards and monitoring - (404 cond. b.; 1601 cond. 6a., 6b., 14., 15., 16.) The performance criteria and reports were defined in the permits and agreements. The resource agencies are satisfied with the success of indigenous species in the wetlands. The resource agencies also recognize that this is largely due to EVMWD's tamarisk control program, a multi-year effort of selective manual cutting and basal bark injection, now in its third yeart.

Agricultural Suitability Tests - (1601 cond. 9.) SAWPA conducted suitability tests in July, 1990. More suitability tests will be performed by EVMWD where requested by the resource agencies prior to additional plantings.

Public Access Control - (404 cond. b.; 1601 cond. 11; EA cond. 1.a.7.) Public access by OHV's and motorcycles to the wetlands was restricted by constructing a perimeter berm with 2:1 side slopes around the wetlands. Public access to the north side of the riparian corridor was restricted by keeping the riverbed inundated with water. Public access to the south side of the corridor is not restricted.

Unimpaired Water Flow - (1601 cond. 19.) Installation of structures in water areas were constructed such that water flow was not impaired and assures upstream or down stream passage of fish at all times except in times of drought, or high watert when the lake level and the wetlands water level are too disparate to operate hyraulically.

Pump Intakes - (1601 cond. 38.) Pump intakes placed in stream/lake water will be fitted with 1/8 inch or smaller mesh screens from March 1 through July 30, and 1/4 inch or smaller mesh screens thereafter.

Conservation Easement - (404 cond. d.) A conservation easement was granted to CDFG over the wetlands and riparian habitat.

Water Circulation - (EA cond. 1.a.4; 1.a.6.) The riparian corridor and the wetlands were originally designed as a flow-through system, but was allowed to be changed with the approval of CDFG. A small pump may be used to remove water from the wetlands if water levels rise. Large pumps will lower flood water levels to normal levels after flooding periods. Instead of a series of ponds in the wetlands, the concept was changed to be several interconnected water open areas operating at the same wtater surface elevation.

Management Program - (EA cond. 1.c.) EVMWD entered into an agreement with the City of Lake Elsinore to maintain the wetlands. The maintenance includes periodic debris removal, replantings and inspection. A monitoring program will be sponsored to ensure proper maintenance of the wetlands and riparian corridor. CDFG will be allowed to plant fish or other aquatic species at any time after notifying EVMWD. Except that no endangered or threatened species will be deliberately transplanted to the lake or wetlands without written permission from the District.

Monitoring Program - (EA cond. 1.d.) EVMWD has a multi-year contract with a firm to monitor the wetlands for controlling exotics such as tamarisk in the site.