Report on Evaluation of Potential of Calcium Treatment to Enhance Water Quality in Lake Elsinore

Prepared For
Lake Elsinore & San Jancito Watershed Authority

Prepared By
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October 28, 2002

Introduction

Lake Elsinore has water which is alkaline (10.5 meq L^{-1} alkalinity), phosphorus rich (total phosphorus in excess of 100 ug L^{-1}) and a declining water level. The latter condition is necessitating the addition of recycled water. In the absence of recycled water, the water quality of Lake Elsinore is poor with algal blooms and low dissolved oxygen conditions at certain places and times. The recycled water will undoubtedly exacerbate existing water quality problems as it is apparently extremely phosphorus rich (total phosphorus concentration of 2.6 mg L^{-1} or some 25 times the in-lake concentration). Further, the phosphorus in the recycled water is all likely available for immediate consumption by aquatic organisms such as algae or green scum (for example in the report prepared by Anderson 26 June 2002, 101% of total phosphorus was soluble reactive phosphorus).

Alternatives for treating the lake water and the recycled water have been evaluated quite intensively for Lake Elsinore (although the lake's water quality problems originate with phosphorus from the watershed, internal recycling from the phosphorus-rich sediments which have accumulated over time, are a critical phosphorus source). Over the years and with no treatment, water quality will undoubtedly continue to deteriorate in the lake. As the lake is a dynamic creature, predictions about the quality of water must take into account the within lake variability as well as the changes over time (Anderson 2001). Maintenance of the *status quo* or improvements in water quality will require a combination of treatments to the lake itself as well as the watershed. The treatment scenarios considered for the lake include: biological (fish removal), chemical (alum, calcium), physical (sediment removal, aeration) (Black & Vetch 1994; Anderson 2000; HDR Inc. 2001). The proposed alternatives come with some inherent limitations. Alum (potassium aluminum sulfate dodecahydrate; Cooke 2001, 2002; Anderson 2002) although effective at phosphorus removal, is likely due to the alkaline water to produce unacceptably high concentrations of aluminum in Lake Elsinore. Total removal of carp will be required for any detectable improvement in water quality and this likely requires either rotenone or an *act of god*. Sediment removal would be cost prohibitive for the dynamic Lake Elsinore. Aeration has been evaluated elsewhere and would likely produce only limited results on its own. This report will focus on the used of calcium as a treatment option.

Context for lake treatment

Prior to the discussion of calcium as a potential treatment option for Lake Elsinore, this or any other treatment option, needs to be put in perspective. The vast Lake Elsinore watershed is the ultimate source of most phosphorus deposits in the Lake, and watershed inputs must be controlled for long term (ie. decadal or more) improvements in water quality. Thus my first recommendation is for a comprehensive watershed management plan to accompany any proposed lake treatment. This recommendation follows from my report of April 2002 for comprehensive watershed management.

> **Recommendation 1**
> **Improvements in water quality in Lake Elsinore will require a comprehensive watershed management plan to complement any *in situ* work.**

Secondly, target phosphorus concentrations need to be established for the lake although targets of :

> "reducing sediment phosphorus release by two-thirds for a period of 3 to 5 years", and
>
> generating "a residual calcium concentration in the water column of 75-100 mg L^{-1} as a mechanism to perpetuate algal self-regulation and as an alternative means to facilitate re-application of a calcite treatment to the sediments"

were proposed by Kilroy (2002). In this way, a program can be developed and evaluated relative to a set of goal posts. Ultimately the issue is lakewater phosphorus. Without these goal posts there is no way to evaluate progress in lakewater quality.

> **Recommendation 2**
> **Target phosphorus concentrations and dates must be established for Lake Elsinore.**

Calcium therapy for Lake Elsinore

Over the past, at least, five years calcium has been considered as one of the alternatives for lake restoration. Although I have an incomplete knowledge of the evaluations done, I am in possession of reports written in: 1997 (Viencek), 2001 (Anderson), and 26 June 2002 and 3 July 2002 (Anderson). The initial Viencek report documents that biologically available phosphorus concentrations would be reduced if calcium concentrations were increased in Lake Elsinore water. The subsequent report indicated that with sediment cores collected from the deepest part of the lake, an addition of 50 g Ca m^{-2} caused a 65% reduction in phosphorus release from the bottom sediments. In the 2002 Anderson draft report, calcium addition at 215 g Ca m^{-2} resulted in a reduction of phosphorus release from the bottom sediments of 50%. Further biologically available phosphorus (SRP) was reduced to less than 10% of pretreatment conditions in the recycled water following addition of agricultural gypsum. However similar treatments resulted in a drop of only 27% in total phosphorus and 40% in chlorophyll *a* concentrations in calcium addition tests with jars filled with Lake Elsinore water. Anderson hypothesized that the calcium treatments would be most effective on biologically available phosphorus such as found in the recycled water (26 June 2002 Anderson).

Dr. Anderson's reports are well organized and well written. They provide important insights into the opportunities for chemical treatment of Lake Elsinore water. Further Dr. Kilroy's memo of 29 April 2002 puts calcium treatments in a context. At this point I would like to divide my comments into two categories: (1) A discussion of the potential for calcium to be effective on phosphorus content of the lake water, and (2) a discussion of the potential for calcium treatments to reduce phosphorus content of recycled water additions to Lake Elsinore.

In my letter to D. Ruhl on 22 April 2002 I recommended a set of laboratory tests to review the relative and absolute impacts of calcium treatment on Lake Elsinore water. Those tests established that gypsum ($CaSO_4 \cdot 2H_2O$) was likely the most appropriate form of calcium treatment for Lake Elsinore water, as it reduced phosphorus concentration while enhancing residual calcium concentration. However, my reservation about Dr. Anderson's June 2002 report is that it extrapolated beyond what a small set of jar tests can do. As the conditions in a lake are much more dynamic, so are the results (eg. Burley, Prepas & Chambers 2001). Precipitation of phosphorus by calcium treatments involves both physical removal of phytoplankton (e.g. Zhang and Prepas 1996) and reduction of phosphorus release from bottom sediments (Prepas et al. 2001) as well as a yet unquantified portion of direct phosphorus precipitation with the calcite. The laboratory experiments only capture a portion of the essence of a whole lake treatment and likely underestimate whole lake effects. Thus Dr. Anderson's cost estimates provided 5 July

2002 may overestimate cost per unit phosphorus removed with *in situ* calcium additions. That is to say there is evidence that a single strong calcium treatment may have both measurable impacts

<u>Recommendation</u>
A single high dosage of calcium (> 200 g Ca m^{-2}) as gypsum has good potential to reduce short- and long-term concentrations of lakewater phosphorus.

on a short- (days) and longer-term (years) phosphorus content of water in Lake Elsinore.

The impact of calcium treatments on the recycled water in Lake Elsinore was none less than spectacular (more than 90% removal). Given the gruesome statistics on the Lake Elsinore water, it is imperative that the accumulated phosphorus in the lake sediments not be increased. Lake sediments have long memories that are hard to erase. Thus the recycled water should be treated with calcium as it enters the lake. An evaluation of this process would provide an excellent opportunity to understand the dynamics of calcium additions in Lake Elsinore. That evaluation should consider routine monitoring of essential water quality parameters (see Prepas *et al.* 2001) as an integral part of the program.

<u>Recommendation</u>
An immediate program be undertaken to treat the recycled water with agricultural gypsum (200 mg L^{-1})

Lake Elsinore water requires a long-term program to stabilize and reduce total phosphorus concentrations. Given the complex nature of the watershed and lake dynamics this program will undoubtedly be multi-faceted. Should new technologies such as hydrogen peroxide become available for lake restoration, they may have possibilities for Lake Elsinore.

References

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Appendix 1

Review of water quality data on Lake Elsinore, California April 2002

By: Dr. Ellie Prepas, Ph.D

Part A

The material sent for review includes:

1) Lake Elsinore Water Quality Management Plan – April 1994. Prepared by Black and Veatch

The 1994 study gives background on Lake Elsinore as well as a detailed hydrologic study. Although this study also dealt with water quality, the data analysis is rather superficial (e.g. listing of algal/cyanobacterial genera (Table IV-3)). No detailed nutrient budget is constructed for the lake, although prime sources (e.g. Railroad Canyon Reservoir, reclaimed water) are identified. The watershed (21 mi^2) is described as: "primarily residential, commercial, industrial, and natural or agricultural". "Approximately 90% of the watershed is agricultural area" (pg. 5-1). Sedimentation or in-lake processes are dealt with as a phosphorus sink (Figure V-1), although in-lake recycling of phosphorus is identified. Treatment options (primarily in situ) are explored.

2) Lake Elsinore In-Lake Water Quality Treatment Program. April 2001. Prepared by HDR Inc.

This study reviews three broad treatment options for the lake: carp removal or biomanipulation, nutrient reduction with chemical treatment (aluminum sulfate, calcium chloride), and aeration. Water quality is identified as being nutrient polluted and the goal of the proposed alternatives is reduced phosphorus and chlorophyll concentrations for Lake Elsinore. The study places these treatments in an operational setting, exploring concerns as well as some alternative approaches (for example, transportation of the chemical to the lake).

3) Internal loading and nutrient cycling in Lake Elsinore. August 2001. Submitted by Michael Anderson.

In this report internal phosphorus cycling is identified as an important input of phosphorus to water in Lake Elsinore, on an annual basis. Further the portions of the lake bottom with the most nutrient rich sediments are identified. As expected, nutrient rich sediments are concentrated in the deeper parts of this shallow lake/reservoir. The report includes openwater chemistry and provides a solid background for considering water quality concerns in the lake.

4) Laboratory and limnocosm-scale evaluations of restoration alternatives for Lake Elsinore. Undated. Submitted by Michael A. Anderson.

Dr. Anderson reviews the phosphorus reduction abilities of alum, and alum plus calcium, treatments of Lake Elsinore water. As best as I can reconstruct the calcium treatments involve calcium chloride. Alum treatment had potential.

5) Alum application to Lake Elsinore, California: Responses to Questionnaire and Questionnaire update. August 2001 and January 2002. Prepared by G. Dennis Cooke.

Although initially positive about the potential for alum treatment to reduce phosphorus and algal concentrations, new information on alkalinity (500 mg/L $CaCO_3$) along with the high pH of the lakewater could result in toxic aluminum ions being released. Based on the material presented, Dr. Cooke (who along with Dr. Welch) is an acknowledged world expert on alum treatment, recommended against alum treatment.

Part B

Based on the material presented and my experience with eutrophic and sometimes alkaline, lake water I recommend the following approach to the water quality problems identified in Lake Elsinore.

1) **Phosphorus and nitrogen budgets should be prepared for the watershed**. There appears to be extensive external loading to the system from anthropogenic sources. This loading is contributing to the high phosphorus

concentrations in the lake, as well as the internal loading of this nutrient. Lake sediments, in shallow eutrophic lakes, act as a long-term memory for past excesses in external phosphorus loading. The more phosphorus added, the greater the internal loading problem. Lake sediments have memories which can last for decades or more. Thus with each passing storm, the cleanup problem for Lake Elsinore water increases.

Nitrogen and phosphorus ratios are important for tracing the development of cyanobacteria. Although Anderson (undated report) identified phosphorus as the nutrient most responsible for stimulating algal biomass in the lake, nitrogen data would enhance the development of a comprehensive watershed-based plan for nutrient control. Thus a nitrogen along with a phosphorus budget would assist a lake recovery plan.

2) **As external inputs are controlled, a plan can be developed for <u>in situ</u> treatments to reduce sediment memory of past phosphorus/nutrient loading**. Although alum is likely out of the question, calcium has some potential. The material reviewed appears to focus on calcium chloride. My experience is with calcium carbonate and calcium hydroxide. The latter was most effective (see attached reference list and summary of published results Fig 1). Bioassays need be conducted with water from Lake Elsinore to check dosage. I would recommend a treatment of between 100 and 200 mg/L. We sought to insure that pH did not rise above 10. Given the alkalinity of water from Lake Elsinore, this should not be a problem. Then there is the question of whether other chemicals could/should be added with the lime. See for example the paper of Burley et al (2001), in the attached list.

3) **Other opportunities should be pursued at the same time to enhance the recovery plan**. Biomanipulation has been successful elsewhere, although I have no personal experience with this technique. Education and community cooperation are obvious components as well.

Appendix 2

April 22, 2002

David P. Ruhl, P.E.
LESJWA Project Manager
Santa Ana Watershed Project Authority
11615 Sterling Avenue
Riverside, CA 92503

Dear Dave,

Further to my meeting with the TAC last Thursday and the tour of Lake Elsinore, I have the following information for your consideration.

Lime Treatment

pH of the water column:

Based on studies with calcium hydroxide or hydrated lime, "lime" was most effective at removing phosphorus from the lake epilimnion when the pH of the water was kept above 8 (Reedyk, Prepas and Chambers 2001). Our treatment of four (hardwater) lakes on the Boreal Plain in the province of Alberta, Canada resulted in no detectable impact on either invertebrate nor vertebrate populations where epilimnetic pH was below 10 (see issue Freshwater Biology 2001). Thus based on both a literature review and our studies, the optimum pH for treatment is between 8 and 10. Lime treatments, so defined, removed phosphorus as well as algal cells from the water column. Although some water treatment scenarios which enhance water clarity have resulted in greater macrophyte biomass, such was not the case in either the lake or small pond ("dugout") experiments on the Boreal Plain. Macrophyte biomass, if anything, was reduced following lime application.

Dosage:

In general we found that higher dosages are most effective. Alternatively multiple dosages worked well in our two lakes, Halfmoon and Figure Eight, treated more than once with a moderate dosage. (Prepas et al. Freshwater Biology. 2001 46:1089-1103). High dosages are defined as 200 to 250 mg/L $Ca(OH)_2$, assuming even mixing of the added lime in the lake water. Similarly moderate dosages were 50 to 100 mg/L $Ca(OH)_2$. Based on numerous "jar" tests, we used a general rule-of-thumb of 1mg/L $Ca(OH)_2$ for each mg/L alkalinity in the receiving water, as an upper bound.

In the case of Lake Elsinore, all factors point to high or moderate dosages being appropriate. The alkalinity is sufficiently high that 250 mg/L $Ca(OH)_2$ could be applied with a large margin of error. Further multiple treatments could suit your treatment circumstances. Whatever the approach, the size of the lake ensures a time span for application in the order of weeks. With a time frame of weeks, it virtually ensures no dramatic increases in water column pH, given the alkalinity of the water.

Form and dosage of lime:

In our studies, as a final check before proceeding, we did some "jar" tests. In the case of Lake Elsinore, there is the added complexity of which form of "lime" is appropriate given sources. I recommend a set of "jar" studies where lime is added to epilimnetic water and epilimnetic water plus bottom sediments. Minimally two forms should be assessed: $Ca(OH)_2$ and calcium chloride. If a third form is applied it could be calcium carbonate. The tests should be run for a short time (say 8-48 hours) and measurements on the "jar" water should include: pH and total phosphorus with fewer alkalinity and calcium measurements as water permits. Dosages could run from 50 or 100 to 250 mg/L "lime" as long as the water pH does not stray from reasonable bounds.

Sufficient replicates are required to weed out noise and aberrant jars. The precise experimental protocol should be worked out by scientists involved. I will incorporate the results in my recommendations for lake treatment.

<u>Longevity</u>:

Although there are many fewer published studies on lime than alum, the literature and my experience is consistent with longevity of lime and alum being similar. Obviously watershed control/reduction of nutrient inputs is a key factor in longevity of the results. Similarly unusual weather (e.g. floods) can reduce the longevity of the results.

<u>Environmental concerns associated with lime application</u>:

As long as the pH of epilimnetic water is kept below 10, and appropriate application gear is used, there are no environmental concerns associated with lime application that I am aware of. Lime treatment mimics a natural process called, "whitings" or calcium carbonate precipitation found in calcium-rich waters such as Lake Michigan.

<u>Timing of next visit</u>:

Although the initial proposal was for me to return to Lake Elsinore, California in May 2002 for the Board meeting, it would be more appropriate to await the "jar" test results prior to focusing on the specifics of the recommended treatment(s). With the new information a report will be prepared which combines my notes prepared last week, this week's notes and the outcome of the jar tests. I anticipate a visit in July (preferred) 2002.

I look forward to working with you on this lake restoration initiative.

Yours sincerely,

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