CHERRY CREEK RESERVOIR DESTRATIFICATION SYSTEM

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Memorandum

To: Chuck Reid, Manager, CCBWQA

Cc: Rick Goncalves, Chairman TAC

From: William P. Ruzzo, P.E.

Date: June 10, 2008

Re: Cherry Creek Reservoir Destratification Project – Project Summary

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Presented in this memorandum is a summary of the Cherry Creek Reservoir Destratification Project requested by the Board at their May 15, 2008 meeting.

BACKGROUND AND PURPOSE

The Cherry Creek Basin Water Quality Authority (Authority) has been implementing watershed-based, best management practices (BMP) and constructing pollution reduction facilities (PRF) for many years to protect the beneficial uses of Cherry Creek Reservoir. However, the chlorophyll *a* standard (15-µg/l) was not being met from 1996 through 2005, but was met in 2006 and 2007. In addition, there is a trend in water quality improvement since 2002 (see Figure 17 below from the annual monitoring report). Note that the horizontal dashed line represents average value and not the standard). In addition, the phosphorus goal (40-µg/l) has only been met once in 1989 and has been on an upward trend for a number of years (see Figure 15 below).

The 2004 special study[1] of in-lake nutrient enrichment indicated that nitrogen is the limiting nutrient for algae growth. Dr. Lewis also noted that "*reduction in phosphorus concentrations sufficient to induce phosphorus deficiency in the phytoplankton of year 2003 would involve decreases in upper water column concentrations of at least 50%, or about 30 µg/L*". What this means is that controlling algal growth by reducing nutrients in the Cherry Creek watershed alone is very difficult and that algae must also be controlled "*…based on non-nutrient factors*", according to Dr. Lewis

Even though the Authority and others have implemented watershed controls with some success, watershed controls alone are not sufficient nor are the phosphorus reductions timely enough to control algae growth in the near future. Therefore, the need for supplemental strategies to control algae growth, such as in-lake management, became more apparent.

Dr. Lewis found that during periods when the reservoir was not being naturally mixed by wind activity, then algal growth activity was at its highest. He determined that the most practical approach

[1] Lewis, Willam M. Saunders, James F III, and McCutchan, James H. Jr. January 22, 2004. *Studies of Phytoplankton Response to Nutrient Enrichment in Cherry Creek Reservoir, Colorado.*

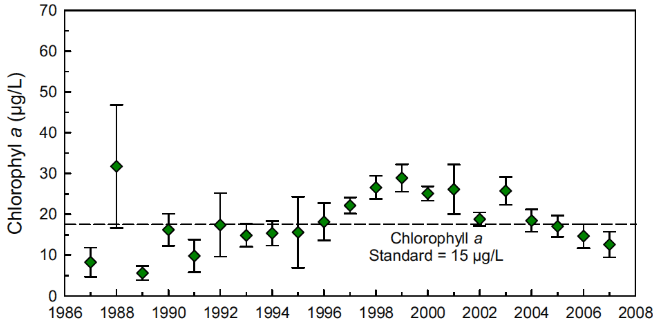

Figure 17: Seasonal mean (July to September) chlorophyll *a* concentrations measured in Cherry Creek Reservoir, 1987 to 2007. Error bars represent 95% confidence interval around each mean.

to controlling this growth would be to artificially mix the reservoir. Since the reservoir is relatively shallow, it can usually be mixed by normal wind activity. Several times throughout the year, however, extended periods of hot, dry and windless weather cause the lake to stop mixing and to stratify. This stratification not only causes anoxic (lack of oxygen) conditions at the bottom of the reservoir, but also allows blue-green algae to bask in the sunlight on the surface of the reservoir, fixing all the nitrogen they need from the air. And, with plenty of phosphorus in the water, they can reproduce explosively. Thus, an algae bloom is created.

As a result, the Authority considered in-lake management techniques that could be beneficial to reducing chlorophyll a, as well as nutrients and dissolved oxygen (DO) concentrations in the near term. Dr. Lewis suggested destratification (mixing) as a method to address internal loading and other factors that increase algal growth and therefore, chlorophyll a and phosphorus and nitrogen concentrations. It was noted that watershed management is a necessary component of the Watershed Plan 2003[2] and both BMPs and PRFs should continue to be implemented. The continuation of these programs was also a condition for the approval of the Department of Natural Resources for the installation of the aeration system.

INVESTIGATION PHASE

The Authority then had prepared a conceptual investigation[3] to identify other lake mixing projects, the pros and cons of aeration for mixing, and the order of magnitude of cost. The investigation concluded that aeration is used in local lakes (e.g., Bear Creek Lake, McClellan Reservoir, Coors lakes and Quincy Reservoir) with varying degrees of success and complexity of the systems, with the simplest systems performing with greater reliability than more complex systems. The projected capital, design, and administration costs were around $700,000.

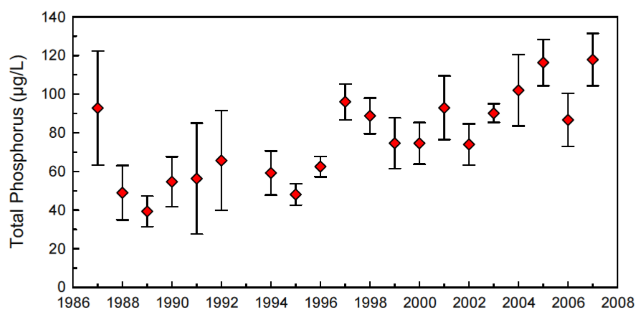

Figure 15: Seasonal mean (July to September) total phosphorus concentrations (µg/L) measured in Cherry Creek Reservoir, 1987 to 2007. Error bars represent a 95% confidence interval for each mean.

TECHNICAL FEASIBILITY

The Authority then authorized by contract with AMEC Earth and Environmental (AMEC) dated August 3, 2005 a more detailed investigation[4] to further identify technical feasibility and costs. After

[2] Cherry Creek Basin Water Quality Authority 2003. *Cherry Creek Reservoir Watershed Plan 2003.*
[3] Brown and Caldwell, May 4, 2004. *Conceptual Investigation of Reservoir Destratification for Cherry Creek Reservoir*
[4] AMEC Earth and Environmental May 5, 2005. *Feasibility Report for Cherry Creek Reservoir Destratification.*

a eight month investigation and evaluation that included representatives of Cherry Creek State Park, the Army Corps of Engineers, the Colorado Division of Wildlife and representatives of the fishing and boating community, the AMEC team recommended the installation of a submerged mixing system in the 330 acre portion of the reservoir which is greater than 16 feet deep. The primary objectives for the mixing system were to:

- Destratify and strongly mix the deepest portions of the reservoir,
- Vertically mix algae to compromise their habitat and reduce production of blue-green algae, and
- Oxidize of the deep bottom sediments to reduce the release of nutrients from the sediments into the water column.

The estimated capital costs were projected to be up to $700,000.

FINAL DESIGN AND CONSTRUCTION

The Authority then authorized final design and construction of the AMEC recommended focused mixing system by contract amendment approved by the Board on February 16, 2006. The final design was completed in September 2006 and estimated the construction costs were $810,400. The project was awarded in separate contracts to supply the compressor and aeration line, underwater installation, above water installation and other miscellaneous items, which is summarized in the table below.

Summary of Destratification Project Capital Costs

Item	Cost
Investigation, Design & Administration	
Technical Feasibility Report	$70,000
Final Design and Construction Management	$93,000
Administration	$9,000
Sub-Total Investigation, Design, Admin	*$172,000*
Construction	
Compressor Purchase	$58,500
Hydraulic Hose and Fittings	$243,100
Underwater Construction	$142,500
Above Water construction	$478,600
Power Installation	$12,000
Aerator System Inspection and Adjustment	$11,400
Sub-total	*$946,100*
Less enlarged trail costs in the amount[5]	$150,000
Net Construction	**$796,100**
TOTAL CAPITAL COSTS	***$968,100***

To supply the air to the diffusers, a distribution line was placed partially across the face of the dam and covered with a berm large enough for maintenance access. The berm was enlarged during construction to become a portion of a formal trail across the entire face of the dam at the request of Colorado Division of Parks. The extra cost of $150,000 to enlarge the berm was reimbursed to the Authority by the Department of Natural Resources.

The destratification system was substantially completed by December 14, 2007 and the official start up of the system took place on April 4, 2008. Subsequent to the official start up modifications were made to the compressor building, consisting of duct work to improve the heat ventilation and compressor cooling, installing the extra aerator assemblies, and additional inspection and adjustment of existing aerator assemblies. This work, which is part of the annual operations and maintenance budget, was approximately $15,000.

HOW DOES THE SYSTEM WORK?

The destratification system works by pumping air into the bottom of the Reservoir at a rate of 200 to 250 standard cubic feet per minute (SCFM) at a pressure of 51 pounds per square inch gage (psig). The 125 Hp compressor used to deliver this air is housed in a 19 by 17 foot block building with a metal roof near the Marina and has a rated maximum capacity of 455 SCFM. The reserve capacity of the compressor is available for enlargement of the in-lake portion of the system in the future if that proves to be desirable. The air passes through over 40,000 feet of 1-1/4 inch hydraulic hose leading to 102 air diffusers placed at the bottom of the deepest part of the reservoir, which is greater than 16-feet and covers 350-acres of the 850-acre total surface area. These diffusers are expected to move about 1,000,000 gallons of water per minute (approximately 4,400 acre feet per day) which will “turn-over” the mixing zone about once per day.

HOW WILL IT BE DETERMINED IF THE SYSTEM WORKS?

The aeration and mixing system was designed to meet the following program objectives:

1) Reduce the release of phosphorus and nitrogen nutrients from the bottom sediments into the water column of the reservoir in a typical year by 810 lbs/yr and 1,140 lbs/yr, respectively,
2) Decrease the seasonal mean (July-September) chlorophyll a concentrations by approximately 8 ug/L under typical year conditions,
3) Decrease annual peak chlorophyll a concentrations by up to 30 ug/l,
4) Increase dissolved oxygen concentrations in the deepest and most vulnerable zones of the reservoir into the range of 5 mg/L, and
5) Reduce the production of blue-green algae by making the habitat of the reservoir less suitable for the production of blue-green algae via vertical mixing.

The ultimate test of whether destratification and mixing works will be the reduction of algae biomass and density as measured by chlorophyll a and species identification and enumeration, particularly the blue-green species cyanobacteria. The more immediate test will be to determine if the reservoir stays mixed throughout the algae growing season from May through October, as measured by the vertical temperature and dissolved oxygen profile of the water column.

During the regular growing season, the authority contracts with GEI\Chadwick Division to conduct bi-monthly sampling in the reservoir at three locations. During each sampling episode on the reservoir, three main tasks were conducted, including: 1) determining water clarity; 2) collecting depth profile measurements for temperature, dissolved oxygen, and pH conductivity; and 3) collecting water samples for chemical and biological analyses. In anticipation of construction of the destratification system, the Authority had GEI install three temperature arrays consisting of Onset HOBO® Water Temp Pro data loggers in the deepest part of the reservoir. These data loggers recorded temperature measurements on 15-minute intervals for each 1 meter water layer. This monitoring program was continued in 2008 to determine how well the reservoir stays mixed and may be extended beyond 2008.

In addition to the temperature loggers at the three monitoring sites, GEI will also perform monthly Oxidation Reduction Potential (ORP) profiles along a transect through the deep water zone, including measurements near the water/sediment surface during the July to September period. The sample locations and transect will be consistent with locations previously established by AMEC during their destratification feasibility study.