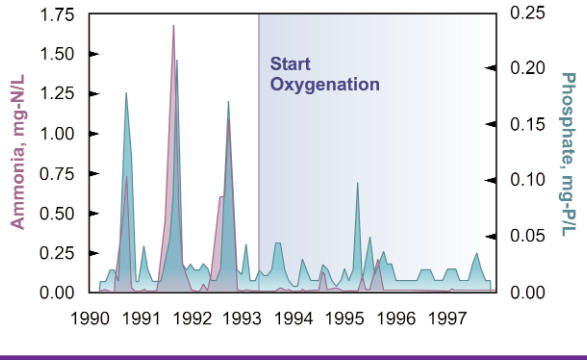
Improving Water Quality Using Lake Oxygenation

Brown and Caldwell helped the East Bay Municipal Utility District implement an innovative oxygenation system to improve water quality in Camanche Reservoir, California.

BROWN AND CALDWELL



After operation of a hypolimnetic oxygenation system in Camanche Reservoir, levels on ammonia and phosphate in bottom water dropped dramatically. This decrease in internal nutrient loading led to lower levels of algae and improved water clarity in surface waters.

BACKGROUND

East Bay Municipal Utility District serves 1.3 million people in the greater Oakland metropolitan area with water obtained from the 585-square-mile Mokelumne River Watershed Basin in the Sierra Nevada. The district operates two reservoirs on the river, including Pardee (210,000 acre-feet), which serves as a domestic water source, and Camanche (420,000 acre-feet), which supplies water for recreation, hydropower generation, downstream irrigation, stream flow regulation, flood control and fishery needs.

During the drought of the late 1980s, poor water quality from Camanche Reservoir negatively affected fish at the Mokelumne River Fish Hatchery. The hatchery raises salmon and steelhead trout to mitigate for the loss of spawning habitat resulting from reservoir operations. Studies carried out by Brown and Caldwell identified seasonal hypoxia and the subsequent formation of hydrogen sulfide in the bottom water of the reservoir as the cause of the hatchery problems.

SOLUTIONS

Once the cause was identified, the district retained Brown and Caldwell to rapidly implement a solution. Time was of the essence and design constraints were complex—a system had to be installed that would

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oxygenate bottom water in the reservoir while maintaining thermal stratification and avoiding resuspension of fine sediment on the reservoir bottom. Not only did the hatchery require well-oxygenated water, but also cold water free of fine suspended matter.

Brown and Caldwell developed the pre-design for an innovative aeration system using pure oxygen, and implemented and managed an accelerated design-build contract to ensure the timely installation of the oxygenation system. The system consists of a submerged cone-shaped contact chamber mounted on the lake bottom. A submersible pump draws water into the top of the cone. Oxygen gas supplied from an on-shore facility is injected at the top of the cone. As water flows down the cone it suspends rising oxygen bubbles and allows for nearly complete dissolution of the oxygen into the water. The oxygenated water is then discharged through a horizontal outfall diffuser. By injecting pure oxygen under high hydrostatic pressure, oxygen can be dissolved into lake water at more than 10 times the concentration normally found in water.

Brown and Caldwell also managed intensive water quality monitoring after start-up and confirmed that the system met or exceeded all project objectives. To date, the hatchery has not reported any problems related to water quality, and water quality in the entire reservoir has improved substantially.

Details of Oxygenation System

On-Shore Facilities
13,000-gallon liquid oxygen storage tank
Evaporator units

In-Lake Facilities
12-ft-diameter, 23-ft-high submerged cone
170-hp submersible pump with capacity of 35 cfs
150-ft outfall diffuser with 100 2-inch ports

System Capacity
8,000 kg of oxygen per day

Capital Costs
$1.5 million

Operating Costs
$ 1,000 per day over 4-5 months

METHODS AND RESULTS

- Identified environmental causes of fish hatchery problems
- Developed pre-design of innovative lake aeration system using pure oxygen
- Implemented and managed accelerated design-build contract to ensure the rapid installation of the oxygenation system
- Managed extensive water quality monitoring after system start-up to quantify impacts of operation on water quality
- No water quality related problems at hatchery since start-up of the system
- Well-oxygenated plume of water migrated 10,000 feet up the reservoir
- Maintenance of more than 5 mg/L of dissolved oxygen in bottom water discharged to hatchery and to the Mokelumne River
- Maintenance of thermal stratification in the reservoir resulting in delivery of required cold bottom water to the hatchery and to the Mokelumne River
- No resuspension of bottom sediments near outfall diffuser
- Increase in power generation revenue since bottom water could now be sent through power turbines that discharge directly to the Mokelumne River (previously, low-oxygen bottom water had to be re-aerated using valves that sprayed the water out the side of the dam)
- Elimination or decrease in bottom water accumulation of problem-causing reduced substances, including sulfide, ammonia, and phosphate
- Decrease in algae content and increase in water transparency as a result of decreased internal recycling of nutrients

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