Lauren Steely / ENSP 340

TO: California Regional Water Quality Control Board, Lahontan Region
Nevada Dept. of Environmental Protection

RE: Mitigating the impact of climate change on water quality Lake Tahoe

The mean annual temperature in the Lake Tahoe basin is predicted to rise 5 ^{o}C by the end of the century, and this rise is expected to harm the clarity and water quality of the lake (Gabrielsen 2013). Rising temperatures will result in reduced Sierra Nevada snowpack, which has already been shrinking in recent years, and more precipitation as rain. More rain will mean greater erosion and sediment loads to the lake (CRWQCB 2010).

A warmer and more stratified lake

Rising temperatures have been warming the water of the lake by 0.015 ^{o}C/yr (ibid.), disrupting the seasonal mixing process that keeps the lake healthy. Lake Tahoe becomes stratified in the summer, with a warm layer of water near the surface and a cold layer at depth. In a normal winter, the cooling of the lake's surface results in a turnover event in which the upper waters sink and mix with bottom waters, bringing dissolved oxygen to depth. Because of rising air temperatures, the long-term trend shows that the waters are remaining stratified for 20 days longer than in 1970 (Borre 2012).

Phosphorus loading and eutrophication

There are two ways in which increased stratification will negatively impact the clarity and famous blue color of Lake Tahoe. First, it will result in longer sediment residence times and reduced clarity in the upper part of the lake (CRWQCB 2010). Second, if the lake warms to a point where inversion and mixing happen less frequently, it will trigger a process called *internal loading*. Without oxygen, the bottom waters will become suboxic, which allows microbes to break down P-containing Fe oxyhydroxides in benthic sediments (Pettersson 1998). The large amount of P liberated by this anaerobic process then enters the lake water, where it can cause runaway eutrophication of the lake. Studies have found that one particular diatom, *Cyclotella*, has been increasing in the lake, clouding the water in the summer (TERC 2012). Primary productivity in the lake has already increased over 500% beyond the 1959 baseline (CRWQCB 2010).

Recommendations

There is little that can be done at the local level to combat a changing climate, warmer lake water and increased lake stratification. Instead, we recommend that RWQCB and NVDEP focus on controlling nutrient and fine sediment inputs to Lake Tahoe to limit the growth of visibility-impairing organisms. We recommend three strategies for controlling nutrients and sediments at the source:

1) **Greater stormwater control in urbanized parts of the basin**. The cities of South Lake Tahoe and Stateline should identify sites for the construction of detention ponds and bioswales to capture fine sediment, remove nutrients, and promote groundwater recharge. Wherever possible, the cities should replace impervious surfaces (parking lots, playgrounds) with permeable surfaces. These measures are expensive and may themselves create sediment issues during construction.
2) **A voluntary nutrient/sediment reduction program in the Lake Tahoe watershed**. South Lake Tahoe eliminated its point source problem in the 1960s by pumping 100% of its sewage out of the basin. However, non-point sources from lawns, golf courses and ski resorts are still a problem. An estimated 46 metric tons/yr of P enter the lake, of which the largest proportion comes from urban and resort areas (CRWQCB 2010). Ski

resorts, which are susceptible to erosion because of their clearcut runs on steep slopes, should be encouraged to implement erosion control programs. Because tourism is a valuable part of the Lake Tahoe economy, we believe a voluntary and incentive-based program would be preferable to increased regulations. But such a program could be ineffective if it is too difficult to monitor and enforce.

3) **Incorporate climate change effects into a new, more stringent TMDL for phosphorus.** The 2010 Lake Tahoe TMDL Report provides a water clarity goal for Lake Tahoe and targeted reductions of phosphate and nitrate loads to meet that goal. However, the new water clarity TMDL does not account for the effects of climate change and internal loading, which will necessitate additional reductions to meet the water quality goals. RWQCB should develop a model of lake eutrophication and nutrient cycling as a function of water temperature. This model could help to predict the amount of P reductions that would be necessary to counteract the effects of benthic internal loading. Once again, monitoring the entire lake for nutrient and sediment inputs is a challenge that could make enforcement difficult.

Sources

Borre, Lisa. “Warming Lakes: Effects of Climate Change Seen on Lake Tahoe”. National Geographic Water Currents blog, October 17, 2012.

CA Regional Water Quality Control Board (CRWQCB) and NV Division of Environmental Protection. *Final Lake Tahoe Total Maximum Daily Load Report.* November 2010.

Gabrielsen, Paul, “Climate change threatens Tahoe’s snow levels, lake clarity,” *Silicon Valley Mercury News*, January 4, 2003.

Pettersson, Kurt. “Mechanisms for internal loading of phosphorus in lakes.” *Hydrobiologia* 373-374, no. 0 (1998): 21-25.

Tahoe Environmental Research Center (TERC). “Tahoe: State of the Lake Report 2012.” University of California Davis, 2012.