Review

Barr Lake: Reservoir Water-Quality Assessment

Barr – Milton Watershed Association

Author: J. M. Boyer

The purpose of this assessment was to use multi-year databases covering hydrology and water quality, with an emphasis on nutrients and algal biomass, to quantify the status of Barr Reservoir, diagnose temporal trends in the water quality of the reservoir, and put the water quality of the reservoir into context with that of other similar water bodies along the Front Range. The author offers cause and effect interpretations of water-quality information and makes recommendations for collection of additional information.

Dr. Boyer, who is a staff member with the AMEC corporation, prepared this report by use of data provided through Metro District personnel or consultants who had been employed by the Barr Lake Watershed Association or others to collect information on the reservoir. The review given here does not include an examination of the primary documents from which the AMEC report was prepared. The internal consistency of the data as presented in the AMEC report suggests that the underlying data collection in all cases was of acceptable quality for the purposes of this assessment.

I. Specific comments.

1) The author concludes that there are no significant differences among the three sampling stations with regard to nutrients or other water-quality constituents that were part of the analysis, with the exception of ammonia. This finding is consistent with general experience on reservoirs of this size. Because of wind generated mixing, horizontal heterogeneity in the water

column is suppressed.

2) The author concludes that the lake is not stratified stably for the entire growing season. The data support this conclusion. Like Cherry Creek Reservoir, Barr Lake is discontinuous polymictic, i.e., it stratifies for periods of days or weeks during the growing season, but loses stratification during windy weather or in association with cool fronts that reduce stability of layering. The author is also correct in concluding that withdrawal of water from the bottom of the reservoir prevents maintenance of the substantial vertical temperature difference that would be more characteristic of a natural lake, which would lose water through the surface layer.

3) High pH is of special interest because the lake exceeds 9.0, Colorado's standard for maintenance of aquatic life. It is not clear whether a 24-hour data series would show pH above 9.0, which could be a point to consider for the future. In the latter part of the report, the author correctly interprets this high pH as a byproduct of photosynthesis. Waters that have abundant plant biomass, including algae, produce high pH as a result of the use of bicarbonate as a direct inorganic carbon source by algae or vascular plants. This phenomenon can be found in situations where fertility is naturally high as well as in situations where fertility has been augmented by addition of nutrients or other factors.

4) The author reports a significant upward trend in Secchi depth (more transparent water) through time. Figure 17 shows that a correct interpretation of this trend would be difficult, given the enormous amount of inter-annual fluctuation in Secchi depth, and the relatively small number of years available for analysis.

5) Phosphorus concentrations are uniformly high. Even the lowest concentrations are 10 times as high as the upper concentration threshold for eutrophic status. The author detected a statistically significant downward trend in phosphorus concentrations. Despite intra-annual

variability, the trend seems real, but may be explained by hydrologic factors rather than source water concentration, and may not be sustained through future years.

6) Nitrogen concentrations are also high. The most available forms of nitrogen, however, are completely depleted during the growing season. An apparent downward trend seems real, but may not be sustained because it may be explained by hydrology.

7) The author characterizes the lake as hypereutrophic, based on chlorophyll concentration and other indicators. This seems a reasonable classification. Chlorophyll is more variable in Barr Lake than it is in some eutrophic lakes, probably because the lake is deep enough at times to induce light stress through deep mixing. Peak chlorophylls are very high, but peaks are brief rather than extended. Transparency is strongly affected by chlorophyll.

8) The author does not give an entirely complete explanation of changes in algal abundance from season to season. The dominance of diatoms in the cool months reflects low stability of the water column during the cool season. Diatoms are favored by such conditions, as they have high sinking rates that work against them when the water column is stable, and because they are adapted well to intermittent light exposure, which is characteristic of a moving water column. The bluegreens, which grow more slowly and require more light, are suppressed until the water column becomes more stable, during the warm months. Both *Microcystis* and *Aphanozomenon* have gas pseudo-vacuoles that allow them to control buoyancy and remain near the surface when the water is calm, thus enhancing extended solar exposure. In addition, as pointed out by the author, *Aphanozomenon* is favored when inorganic nitrogen is depleted, which occurs in summer.

9) *Microcystis* and *Aphanozomenon* are characteristic of hypereutrophic or eutrophic lakes.

10) The author attributes loss of nitrogen primarily to algal uptake. This may be true, but would require that primary production be in the vicinity of 1000 $gC/m^2/year$. Denitrification may play a role as well, although there is no convincing evidence for or against this possibility.

11) The author presents water-balance calculations indicating that the vast majority of water in the reservoir originates from the Burlington Canal. The analysis seems reasonable.

12) The internal loading calculations are fairly speculative, given that no actual measurements are available, but provide a reasonable approximation. Note that the estimated internal loading of phosphorus (about 7.2 $mg/m^2/day$) corresponds to about 5.5 $\mu g/m^3/day$, which would total approximately 700 μg/L over a 150-day growing season. Thus, the internal loading may be of the same order of magnitude as the external loading, which is not surprising for a very fertile lake.

13) The author makes a reference on page 39 to the work of Vollenweider (1968). The idea of "permissible" loading as used by Vollenweider was for application to mostly montane European lakes. It is doubtful that these criteria could be applied to Front Range reservoirs, even with extensive elimination of nutrient pollution.

14) The author offers a phosphorus-loading breakdown that seems reasonable. The same sort of information is presented for nitrogen.

15) Phosphorus retention by Barr Lake is in the expected range, but nitrogen retention is suspiciously high, possibly because of denitrification.

16) The author makes comparisons with other Front Range water storage reservoirs and notes the lack of relationship between secchi depth transparency and total phosphorus concentration. She correctly surmises that nitrogen is the controlling factor in these reservoirs, which means that all of the reservoirs are supersaturated with phosphorus and presently not

sensitive to changes in phosphorus concentration.

17) The author presents a partitioning of water sources and phosphorus sources and nitrogen sources including the Metro District effluent. The estimates appear reasonable.

18) The author presents recommendations for further study. Most of these refinements will not matter very much unless costs of some type are allocated pound for pound in relation to nitrogen and phosphorus supply. Even then, the main mass balance is obvious. It is not clear what objective would be attained by use of a complex water-quality model at this point.

II. Main conclusions.

This report is well prepared and generally accurate and well documented. Interpretations are reasonable, although a few might need some revision. Provided that the underlying data are correct, which seems likely, the following points seem to be more or less irrefutable: a) the reservoir is supplied with concentrations of phosphorus and nitrogen that are one to two orders of magnitude above what one might expect from a water supply derived from unpolluted foothills sources, b) despite the high supply of nitrogen, the algae are capable of depleting all of the available (inorganic) nitrogen in the course of the growing season, and suffer nitrogen shortage, which places a cap on biomass production, c) chlorophyll concentration (algal biomass) is high on average, but the most extreme concentrations occur only for short durations. The algae are suppressed by low light availability when the water column is moving and nutrient depletion (nitrogen) when the water column is stable, d) the Metro District is the largest single source of phosphorus and nitrogen for Barr Lake, e) Barr Lake has a significant internal fertilization capability that probably would persist following suppression of nutrient supply from the Metro District or other sources.

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