WHITE PAPER

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ADDRESSING SCIENTIFIC UNCERTAINTY IN BARR LAKE AND MILTON RESERVOIR

Implementation of the Phased pH/DO Total Maximum Daily Load (TMDL) for Barr Lake (Barr) and Milton Reservoir (Milton) includes reducing the uncertainty between water quality parameter interactions and the loading of phosphorus to each reservoir. Both reservoirs are exceeding the pH and dissolved oxygen (DO) standards for warm water lakes. To achieve pH and DO compliance, there needs to be a better understanding of how chlorophyll-a (Chl-a), total nitrogen (TN), total phosphorus (TP), alkalinity, annual loads, and the fate of nutrients interplay as a whole in the reservoirs.

Uncertainties articulated in the Barr Lake and Milton Reservoir Watershed (BMW) Phased pH/DO TMDL (BMWA, 2013) include:

1. Uncertainty associated with the relationships among pH, TP, and Chl-a;
2. Uncertainty with the calculated magnitude of the existing annual TP load;
3. Uncertainty in the derivation of internal loading of TP; and
4. Uncertainty in the future effect of alkalinity on pH attainment.

Implementation of the TMDL utilizes an adaptive approach – establish goals, implement projects, analyze and evaluate results, and re-adjust goals if needed. Reducing uncertainty is a part of this adaptive management approach. BMW has conducted studies, collected new information, and evaluated the results to help address the uncertainty issues. This memo summarizes these efforts.

TMDL Water Quality Targets

Based on watershed and in-reservoir modelling along with well-established empirical models (Wagner, 2009), it was determined that a summer time maximum TP of 100 µg/L should limit the growth of algae to no more than 25 µg/L of Chl-a. Under these two conditions, pH and DO standards should be met. Because of naturally high pH caused by elevated alkalinity, it was also determined that alkalinity must be reduced to 95 mg/L (Wagner, 2009).

Uncertainty with the Relationships Among pH, Chl-a, and TP

The concept is that TP is the limiting nutrient for fresh water lakes and, if in short enough supply, TP will limit the growth of algae which is measured by Chl-a. If there is a reduction in Chl-a, then more CO_2 will remain in the water keeping the pH below 9.0. Since TP has never been below 200 µg/L until 2015, there was uncertainty in whether the water quality targets would achieve the pH and DO standards. Will a maximum concentration of 100 µg/L TP be low enough to keep Chl-a below 25 µg/L during the summer season and will the DO remain above 5.0 mg/L and pH below 9.0 85% of the time?

To answer this question, BMW spent four years conducting limnocorral studies to observe how pH and Chl-a would respond if TP was reduced below 100 µg/L. Using alum products to strip phosphorus from the water column, TP was reduced in the limnocorrals. Based on linear regression analysis, Chl-a does decrease when TP decreases and pH decreases when Chl-a decreases (Lundt, 2016). The limnocorral results indicate that the TMDL water quality goals should result in measurably lower pH values that meet the standard. The limnocorral studies also showed that a TN:TP ratio of 15:1 or greater would keep the reservoirs phosphorus limited which helps control blue-green algal blooms from dominating the system.

Uncertainty of the Annual TP Loads

BMW developed three different annual loading estimates of phosphorus for both reservoirs (AMEC in 2008 mass balance (Boyer, 2008), Lewis and McCutchan in 2009 mass balance (Lewis, 2009), and AECOM in 2009 modeling (Wagner, 2009)). Ultimately, to establish the annual loads in the TMDL and to rectify the three modeling differences, best professional judgement was used. The SWAT/WASP models used by AECOM were updated in 2013/14 to include a re-calibration and validation using 2003 to 2009 field data. Another round of model updating will occur in 2018/19 to test the models against field data from 2011 to 2017 and to include recent changes in the watershed such as the addition of the Northern Treatment Plant and the temporary cessation of the Burlington Pumps since 2013. Mass balance and empirical models will again be used to develop an updated annual TP loading to both reservoirs.

Uncertainty in the Internal Loading

BMW conducted an In-canal Treatment Study for Barr in 2014/15 and an In-reservoir Treatment Study for both reservoirs in 2016. Both studies considered treatment options for the internal loading of phosphorus. In-canal treatment would intercept incoming phosphorus but would also distribute an alum flocc to Barr Lake to further reduce internal loading (Harper, 2015). The In-reservoir Treatment Study included collecting 20 sediment samples from Barr and 15 sediment samples from Milton to evaluate internal loading potential (Wagner, 2016). The initial internal loading estimate from the TMDL was 4,000 kg/yr in Barr and 2,000 kg/yr in Milton. From the In-Reservoir Treatment Study's results that considered sediment oxygen demand, percent organic matter, available phosphorus concentrations, and iron levels, the new estimate for internal loading for Barr is 680 to 1,360 kg/yr and 650 to 1,300 kg/yr for Milton.

Uncertainty in the Effect of Alkalinity on pH Attainment

Alkalinity is the buffering capacity of the water. Alkalinity helps determine equilibrium pH and the magnitude of pH changes but does not cause pH swings. For Barr and Milton, alkalinity is high, averaging 143 to 178 mg of $CaCO_3$/L. Based on the alkalinity, the equilibrium pH for both reservoirs is 8.78 (Lorenzen, 2009). Lower alkalinity will support a lower eqilibrium pH, but it may also create a more sensitive system subject to larger pH swings with lower alkalinity (less ability to buffer the pH changes).

The use of alum during the limnocorral studies reduced alkalinity along with TP. Data indicated that lower alkalinity correlated with lower pH. What is still uncertain is if an alkalinity of 95 mg as $CACO_3$/L will help maintain the pH standard by buffering the reduction of CO_2 when there is algal growth during the growing season. In other words, a lower alkalinity will lower the equilibrium pH but the system will have less capability to buffer changes in pH during an algal bloom. This is why TP and alkalinity both need to be reduced. TP reductions will lower algal bloom intensities and a lower alkalinity will result in a lower equilibrium pH.

Summary of Uncertainty

BMW has implemented several studies to gather more information about the specific limnological interactions within both reservoirs. It is clear with recent declines in growing season TP concentrations and both reservoirs meeting the pH standard three out of the past five years that the water quality targets are within reason. These efforts have made it more certain that TP can control algae and help reduce pH. Uncertainty about the amount of internal loading of phosphorus has been reduced with better estimates but the need to reduce annual loading from this source remains important when it comes to implementation of the TMDL.

Areas of Remaining Uncertainty

One area of uncertainty is in the limiting factor that controls algal growth in both reservoirs. With TP still relatively high, neither system is limited by phosphorus. The relationships between Chl-a, TP, and pH under shifting ratios of nitrogen to phosphorus is still not well understood. Based on limnocorral study results, a ratio of TN:TP of 15:1 or above, causes phosphorus to become the limiting nutrient.

Separate from the uncertainty specified in the TMDL, but a subject of uncertainty related to future TMDL implementation success, is the application of Regulation No. 31 nutrient criteria scheduled for 2027. As currently proposed, the TN standard for warm-water reservoirs will be 0.91 mg/L and the TP standard will be 0.083 mg/L. This represents a TN:TP ratio of 11:1 (0.91 mg of TN to 0.083 mg of TP = 10.9) which would indicate nitrogen limitations based on the Redfield ratio (Redfield, 1958). In other words, the nutrient criteria values that will go into effect in 2027 may not support the correct ratio of nitrogen to phosphorus for meeting other in-lake standards like chlorophyll-a, pH, and DO.

A third area of uncertainty is with the question of how alkalinity will impact the magnitude of pH change, background pH levels, and duration of pH fluctuations caused by algal growth. Higher alkalinity causes higher background pH levels and resistance to pH change. Lower alkalinity causes lower background pH but leaves less buffering capacity that results in larger pH fluctations of shorter duration.

Next Steps

Implementation of the phased pH/DO TMDL is based on an adaptive management approach. Implementation of priority controls to meet TMDL and upcoming nutrient criteria standards is underway through point source reductions. BMW will continue to coordinate reservoir monitoring, modeling, and data assessment to support future phases of control measures. This cyclical implementation process allows for scientific inquiry and evaluation to inform the implementation process in a stepwise fashion, both for determining final and appropriate water quality goals and applying control measures that meet TMDL endpoints.

Next steps that have been identified to date include:

- Update current models and annual loads and allocations to quantify progress made to date.
- Evaluate limiting factors to determine which nutrient is controlling algal growth at various TN:TP ratios).
- Further evaluate the effect of alkalinity on pH to as it relates to maintaining lower background pH levels.
- Evaluate the effect of ongoing wastewater treatment upgrades in reducing phosphorus loading in each reservoir.
- Evaluate the effects of watershed-wide stormwater improvements by collecting and analyzing stormwater at the Burlington Canal headgate.
- Evaluate progress made overall by point source load reductions to help inform and verify the future needs for nonpoint source control measures such as in-canal treatment to reduce external loads or in-reservoir treatment to address internal loading.

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