Subject: Pipe Lakes Understanding Updates

Authors: Larry Bresina, Citizens Advisory Committee for Water Quality
Craig Roesler, Wisconsin DNR Water Resources Management Specialist

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Introduction

This memo supplements the previous 2000-1 and 2003 planning grant studies on Pipe and North Pipe Lakes. The purpose of this supplement is to improve general understanding of how the Pipe Lakes work and build confidence in predicting the affect of lake management projects on in-lake phosphorus concentration. Accomplishing this objective required revising estimates of the phosphorus load, estimates of the water load, and mathematical models to predict the in-lake phosphorus concentration. The following subjects were investigated:

1. Ground-water inflow and surface runoff
2. Phosphorus load
3. Phosphorus inflow concentration
4. North Pipe Lake internal phosphorus cycling
5. In-lake phosphorus model.

Conclusions and Recommendations

1. The revised lake phosphorus modeling improves incorporation of existing data and fit to observed data. These revisions should aid in assessing future Pipe Lakes management proposals.
2. Contamination of the lakes by septic effluent is unlikely because the Pipe Lakes probably sit above the water table. The annual Lake Management Program update should include modifications to reflect this finding.
3. The effective growing season phosphorus internal load for North Pipe Lake is estimated to be less than 20% of the external load.
4. Future studies to consider:
    a. Verify that negligible ground water flows into the lakes, e.g., by small-diameter piezometers situated around the lakes and/or examination of existing wells.
    b. Review and correct boundaries for subwatersheds NPI-E3, NPI-NE, PI-E, and PI-GUL.
    c. Calculate sub-watershed phosphorus loads from measured mean stream concentration and estimated runoff depth. Also calculate sub-watershed loads from export coefficients used in this update. Correct any inconsistencies between the 2 load calculation methods.

Ground-water Inflow and Surface Runoff

Based on a 1999 report by the Wisconsin Geological and Natural History Survey, the Pipe Lakes elevations are likely to be (perched) above the ground-water table. This indicates that the amount of ground-water flowing into the lakes is negligible since no hydrostatic head exists to move ground water to the lakes. Further evidence that ground water inflow to the lakes is negligible is the relatively low conductivity of the lake water. Conductivity for Polk County lakes averages 140 umho/cm while the Pipe Lakes conductivity range is 20-40 umho/cm. If significant amounts of ground-water were entering the Pipe Lakes, their conductivities should be higher. A beneficial result should be negligible flow of nutrients that leach from septic systems to the lakes.

The apparent lack of groundwater inflow required adjustments to the previous lake modeling. The average annual "runoff" for the Pipe Lakes locality is 9.5 inches. This value includes both surface runoff and groundwater discharge. Since the Pipe Lakes are perched and do not appear to receive groundwater inflow, this runoff value needed to be reduced. Kirby Lake is a perched lake in Barron County where the USGS did a hydrologic study. The USGS study showed that the surface water inflow from the watershed to Kirby Lake was equivalent to about 2.6 inches of runoff. The Kirby Lake watershed has similar land use to the Pipe Lakes watershed. However, it has somewhat more permeable soils and more water retention areas. To account for the differences an annual runoff of 4.5 inches was estimated for the Pipe Lakes.

Phosphorus Loading Estimates

The table below shows the total phosphorus external load estimates from the 2 previous planning grants and our new estimates. The most significant change is more than doubling of the load to Pipe Lake relative to the 2003 planning grant analysis. This increase results largely from using a different modeling approach from that used for the 2003 grant work. Our approach utilized the LTPP module of the Wisconsin Lake Modeling Suite (WILMS) while the 2003 study utilized the LEAP module in WILMS. The LTPP module permits estimates of the effect of various land use types while the LEAP module incorporates a generic land use approximation. In addition, with the LTPP module we specifically addressed North Pipe's ability to settle out phosphorus before its water flows to Pipe Lake. The updated load calculations also reconciled the calculated stream phosphorus concentrations (See Phosphorus Inflow Estimates below) with the available measured stream concentrations. The 1st planning grant also used the LTPP module to estimate phosphorus loads.

Total External Phosphorus Load Estimates

	Planning Grant 1 (Data to 2001)	Planning Grant 2 (Data to 2003)	2006 Update (Data to 2005)
North Pipe	94 kg/yr	58 kg/yr	60 kg/yr
Pipe	156 kg/yr	59 kg/yr	124 kg/yr

Phosphorus Inflow Estimates

The previous planning grant (2003) lake modeling did not approximate the measured flow-weighted mean stream phosphorus concentrations, especially for Pipe Lake. This inadequacy makes predictions based on the model unreliable. The table below shows measured and calculated stream phosphorus concentrations. For Pipe Lake, the LEAP model used in the 2003 study predicted a 20 ug/l phosphorus stream concentration. Actual intermittent sampling in 2003 produced a 104 ug/l flow-weighted mean concentration, excluding the flow from North Pipe Lake.

Mean Stream Phosphorus Concentration Estimates

	2003 Measured	Planning Grant 2 Calculation (Data to 2003)	2006 Update Calculation
North Pipe	119 ug/l	87 ug/l	98 ug/l
Pipe with N. Pipe inflow	70 ug/l	NA	78 ug/l
Pipe without N. Pipe inflow	104 ug/l	20 ug/l	122 ug/l

Calculations of the stream flow-weighted mean using 4.5 inches of runoff produces results closer to the measured values as shown in the table above. For Pipe Lake, the agricultural export coefficients were also reduced to account for the large wetland system that intercepts runoff from the agricultural land, thereby helping to reduce the calculated stream concentration.

North Pipe Lake Internal Phosphorus Cycling

Internal phosphorus cycling due to sediment phosphorus release during anoxic (no oxygen) conditions can contribute to poorer summer water quality in some lakes. In North Pipe Lake phosphorus cycling of sediment-released phosphorus appears to be restricted largely to spring and fall turnover. North Pipe Lake loses oxygen long enough during the summer and winter stratification periods to produce phosphorus concentrations which can exceed 300 ug/l near the sediments. Concentrations at this level can add to the external load discussed above and increase the total phosphorus load to the lake.

Surface phosphorus concentrations in North Pipe Lake typically show a substantial increase in October due to this internal phosphorus cycling at fall turnover. Another increase occurs during spring turnover following ice-out, although the spring increase is harder to separate from phosphorus increases resulting from spring runoff. The added phosphorus from internal phosphorus cycling at spring turnover can contribute to algae growth during the summer period.

The potential magnitude of internal phosphorus cycling was estimated using calculations from depth profile measurements of the phosphorus concentrations. Data from fall, 2005 and spring, 2006 were used. Internal phosphorus cycling can potentially contribute up to 15.7 kg of phosphorus in the spring and 34.4 kg in the fall. Since fall cycling does not occur until October, it does not affect the lake phosphorus model which is based on May – September lake conditions. Spring cycling can affect the model. Spring phosphorus cycling occurs only in April and much of the released phosphorus is likely to re-precipitate and settle to the lake bottom fairly quickly. A contribution considerably lower than 15.7 kg is likely. As shown in the table below, adding a 5 kg load attributed to spring cycling allows the model to match the observed 29 ug/l growing season mean concentration. Although there is no proven way to estimate the effective internal load from existing data, an estimate of 5-10 kg is consistent with the existing data.

In-lake Phosphorus Model

Using the updated estimate of phosphorus and hydraulic loads, we searched for 1 lake model that would predict the mean phosphorus concentration for both lakes. We evaluated spring overturn, growing season, and annual mean models. Our main interest was to predict the growing season mean since that should correlate best with summer clarity. Among the models available in WILMS, the Rechow 1977 (water load < 50m/yr) growing season model fit the measured in-lake phosphorus concentration the best. The table below shows this model's results along with the observed concentrations.

Growing Season Total Phosphorus Concentration – Observed & Predicted

	Model Name	Internal Load Added	Observed	Model Prediction
North Pipe	Rechow 1977	0 kg	29 ug/l	27 ug/l
North Pipe	Rechow 1977	5 kg	29 ug/l	29 ug/l
Pipe	Rechow 1977	0 kg	11 ug/l	11 ug/l

The updated loads and models can estimate the effect of management projects to reduce the phosphorus concentration in either lake. For example, a proposed control structure to reduce delivery of phosphorus to a lake can be assessed. The models selected above predict the following effects of a 10 kg/yr phosphorus load reduction on the phosphorus concentration.

Estimated Effect of 10kg/yr Phosphorus Load Decrease on Growing Season Total Phosphorus Concentration

	Model Name	Current Average	10 kg Load Decrease
North Pipe	Rechow 1977	29 ug/l	25 ug/l
Pipe	Rechow 1977	11 ug/l	10 ug/l

Reference and Definition Information

1. The term load refers to the amount of phosphorus or water delivered to a lake.
2. All references to phosphorus in this memo refer to the total phosphorus. This includes the soluble reactive phosphorus which is often measured separately.
3. Planning Grant 1 refers to work mostly completed during the 2000-2001 period. The grant report is dated 2002 by the Polk County Land and Water Resources Department.
4. Planning Grant 2 refers to work mostly completed during 2003. The grant report is dated 2004 by Blue Water Science of St. Paul, MN.