Consent Agreement Annual Report
2010

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Summary - 2010

Overview

The goal of the Consent Agreement is to restore and preserve the water quality of Big Platte Lake (Lake). This goal is being advanced by minimizing the flow and phosphorus discharge from the Platte River State Fish Hatchery (Hatchery) and by developing strategies to reduce non-point phosphorus loads from the watershed.

Compliance with Consent Agreement

Figure 1 summarizes the level of compliance with the Consent Agreement. The Consent Agreement mandates that the Hatchery net annual load should be limited to a maximum of 175 lbs. per year. The corresponding maximum load for any consecutive three month period is 55 lbs. The actual net Hatchery annual loading for 2010 was 80.2 lbs. This is significantly less than the Consent Agreement limit. The maximum allowable load for any 3 month period of 55 lbs. was not exceeded during any period during 2010. The average water use at the Hatchery was 6.88 mgd which is 66% less than the Consent Agreement limit of 20 mgd.

The average volume-weighted total phosphorus concentration of Big Platte Lake was 7.98 mg/m^3 in 2010. The water quality goal of 8.0 mg/m^3 was achieved only 49% of the time. This is not consistent with the goal of 95% attainment as stipulated in the Consent Agreement.

A total of 12,796 adult Coho and 179 adult Chinook salmon passed the Lower Weir in 2010. These numbers are in compliance with the Consent Agreement limits of 20,000 adult Coho and 1,000 adult Chinook salmon.

Major Accomplishments for 2010

- The Hatchery treatment pond was dredged in November and December of 2010 after more than 20 years of operation.
- Equipment was installed to deliver ferric chloride to the backwash flow to precipitate phosphorus in the clarifier. Precipitated phosphorus is stored in the sludge tank and trucked away. The addition of FeCl has contributed to lower phosphorus discharges from the Hatchery and subsequent compliance with the Consent Agreement limits.
- A phosphorus loading model for the Hatchery has been developed using mass balance

and the Wisconsin Fish Bioenergetics approach. The components of the model are the net load, fish food, fish production, pond loss, and trucked phosphorus from the sludge storage tank. This model calculates the annual average phosphorus concentration and loads at various locations within the Hatchery based on the above parameters. This capability allows the Hatchery staff to track system performance on a real-time basis.

- The backwash flow pumps were calibrated using a bucket test. This allows accurate calculation of the flow from each backwash pump as a function running time. Running time is based on electrical log data from the individual pumps.

- The Sigma automatic sampling equipment was reprogrammed to collect on a continuous seventy-two hour schedule. This provides for essentially continuous sampling of the phosphorus concentration of various inlet and output Hatchery flows. Recent data collected using this strategy has improved the accuracy of phosphorus mass balance calculations for the Hatchery.

- A long-term phosphorus model has been developed and validated for the water and sediments of Big Platte Lake. The model can be used with confidence to predict the annual average phosphorus concentration of the lake as a function of changes in flow conditions and phosphorus loading from the watershed. Steady state versions of the model can be used to test planning alternatives being examined in the Watershed Protection Plan document currently under preparation.

- The capabilities and functionality of the database are being improved and expanded on an ongoing basis. Phosphorus and hydraulic mass balance reports have been created for the Hatchery, Platte River Watershed, and Big Platte Lake.

Recommendations for 2011

- Efforts should continue to improve the accuracy of the phosphorus mass balance calculations for the Hatchery.

- All SOP documents and equipment maintenance schedules should be reviewed and updated annually. Certification letters regarding the accuracy of the net phosphorus loading, fish production, and weir numbers in the database should be sent to the

Implementation Coordinator for inclusion in the Annual Report.

- The Implementation Coordinator should continue efforts to calibrate and validate the water quality models for the lake.

- The Implementation Coordinator should continue efforts to calibrate and validate the fish bioenergetic and Hatchery process model. This effort is greatly facilitated by the controlled feeding experiment currently underway. It is recommended that this feeding experiment be continued until the spring of 2012 when the adult fish are exported from the system.

- It is recommended that descriptive information and operator observations be recorded to help improve the understanding and efficiency of the disk filters. The goal should be to provide information that will allow timely maintenance of the filters to maintain peak performance.

- It is recommended that plankton sampling be limited to 3 times per year in Big Platte Lake

- It is recommended that sampling of Little Platte Lake be resumed when budget constraints removed. The cycling of various forms of nitrogen is of particular importance. An annual mass balance budget for various forms of nitrogen should be constructed.

- The Implementation Coordinator should continue efforts to define the minimum number of samples needed to characterize the annual average phosphorus concentration of Big Platte Lake and to determine compliance with the Consent Agreement water quality standard.

- The Implementation Coordinator should continue efforts to define the minimum number of samples needed to characterize the phosphorus loading into Big Platte Lake from tributaries. This capability will allow quantitative analysis of the extent of improvements attained through future BMP projects in the watershed.

- The Implementation Coordinator should continue efforts to determine the extent of Secchi depth improvements as lake phosphorus concentrations are reduced and attain the numerical phosphorus standard of 8.0 mg/m3. It is expected that improvements in water clarity may be limited by marl formation.

- It is recommended that the flow and phosphorus concentration of the waste pumps be measured. This flow component should be added to the Hatchery mass balance equations. Failure to properly account for this factor may result in overestimating the efficiency of the filters and the amount of phosphorus being directed to the clarifier and sludge tank.

- It is recommended that work continue on the watershed plan and to expand the lake phosphorus model to include the upper watershed.

Acknowledgements

The Implementation Coordinator would like to take this opportunity to again thank Gary Whelan (MDNR Fisheries Division) and Wil Swiecki (PLIA) for their continuing contributions to this project. Gary has extraordinary leadership and management skills and has kept this project focused and moving forward. Wil has been tireless in his efforts to ensure the reliability of the data and has displayed incredible perseverance working toward the PLIA goal of preserving the water quality of the Lake. As a result, excellent coordination and communication has been maintained within our group as well as with many outside organizations and individuals. The minutes of our coordination meetings in 2010 are contained in the Appendix A.

Jim Berridge (PLIA) deserves a gold star medal for outstanding service to Platte Lake. He has contributed his talents and endless hours of his time to create an Access database for the laboratory and field data collected on this project. This daunting task is an ongoing process. All those interested in preserving the water of Big Platte Lake owe him their gratitude.

Aaron Switzer (MDNR Fisheries Division) has the major responsibility of collecting the field data and has done an absolutely outstanding job with this task. The reliability of the data would suffer without his careful and conscientious efforts. He has contributed not only through his perseverance and consistency but also through thoughtful analysis of procedures and data. He prepared appendices that summarize Hatchery production (Appendix B), maintenance (Appendix C), and quality control (Appendix D).

We also acknowledge and appreciate the support and assistance of Edward Eisch (MDNR Fisheries Division) for his overall management of the facility. He has been instrumental in assuring that Hatchery meets its commitments to the Consent Agreement. Ed and Nikki Sherretz helped develop the Hatchery SOPs and were involved in the design and implementation of the

Hatchery flow measurement program.

The authors would also like to thank and acknowledge the valuable contribution of many individuals from CMU. Jenny Estabrook and Scott McNaught have left no stone unturned in their efforts to evaluate and improve their laboratory methods. Scott McNaught has reviewed the historical plankton data, recommended much improved methods for sample collection, added biomass measurements, and contributed Appendix E.

Finally, several additional individuals associated with the PLIA have made significant contributions to this project: Mike Pattison has done a terrific job developing and maintaining the PLIA web site with the latest version of the database. Tom Inman has worked with the Hatchery staff on counting the Fall Salmon Runs, and Sally Casey has been making weekly open water Secchi Depth measurements for over 25 years. Steve Peterson has made significant strides in marketing the efforts of all to the public.

Hatchery Operations

Net Total Phosphorus Load

The water used to culture fish becomes enriched with phosphorus as it passes through the Hatchery from fish excretion, egestion, and from unconsumed feed. The net phosphorus daily loading from the Hatchery is defined as the difference between the daily phosphorus loading that leaves the system (usually from the Upper Discharge or any by-pass) and the daily phosphorus entering the system from the three possible water sources (Brundage Spring, Brundage Creek, and the Platte River). Negative net loads on any day are set equal to zero for calculation purposes as specified in the Consent Agreement. Linear interpolation is used to determine the net load on days when no measurements are taken. This may require the use of the last measurement of the proceeding year and the first measurement of the following year to complete the calculation. The summation of daily net loads for the year gives the annual net phosphorus loading. Figure 2 shows the history of total annual net phosphorus loads from the Hatchery from 1990 through 2010 and demonstrates that the loads since 2000 are about 25% of those in 1990. The net phosphorus load was 80.2 lbs. for 2010. Appendix F is a spreadsheet that shows the loading calculations in detail.

The concentrations of total phosphorus and turbidity of the Hatchery inlet and outlet flows were measured on samples collected using two methods during 2010. The Sigma Samplers were programmed to collect 24-hour composite samples during the first two months of 2010 and 72-

hour composites for the remainder of the year. Figure 3 shows the concentration of total phosphorus in the Upper Discharge during 2010. Note that there are three distinct periods. High concentrations were typical during the first 100 days of 2010, followed by a slow general decline for the remainder of the year. Figure 4 shows the corresponding 3-month net phosphorus loads for 2010. Note that the loads for the first 4 months of 2010 were close to the Settlement Agreement limit of 55 pounds. This corresponds to a period when water temperatures at the Hatchery are increasing and the Chinook and coho salmon from the proceeding year classes are reaching maximum size just before being planted. It is also a transition period when many improvements were being incorporated into the operation of the Hatchery effluent management system. The lower loading period between Days 100 and 225 occurs during periods of warm temperatures. During this period, the coho salmon from the proceeding year class and current year class of Chinook salmon have been stocked and the sizes of the current year class coho salmon are still relatively small. Normally, rapid growth and feeding of the growing coho salmon results in a higher loading between Days 250 and 310. However, in 2010 this increase was offset by the addition of ferric chloride at increasing amounts during 2010 as shown in Figure 5. Note that possible impacts of the pond dredging operations in November and December of 2010 were completely offset by the addition of ferric chloride (Figures 3, 4, and 5).

Phosphorus Mass Balance

Mass Balance can be used to help understand and develop a model for changes in the net load from the Hatchery as a function of production activities and facilities operation. The mass balance equation requires that the accumulation of phosphorus in the Hatchery is equal to the difference between the amount of phosphorus that enters the system (Inputs) and the amount leaving the system (Outputs).

Accumulation of P in the Hatchery = Sum on Inputs – Sum of Outputs (1)

The input terms refer to any phosphorus that enters the Hatchery, these terms include:

1. Food P. This term is the amount of phosphorus associated with the food that is fed to the fish in the Hatchery starter building and raceways. The phosphorus value of this term is calculated by multiplying the weight of the food fed times the phosphorus content of the feed.

2. Source Water P. This is the amount of phosphorus contained in all of the Hatchery source water. The sources are Brundage Spring and Creek, the Platte River (only

used rarely), and Service water. The phosphorus value of the input amount is determined by multiplying the flow rate times the phosphorus concentration.

3. Fry Tissue P. This term refers to the phosphorus introduced to the system when fry are added into the fish inventory. It is calculated by multiplying the wet weight biomass of the fry times the measured percent phosphorus in the fry tissue. Note that this approach avoids the need to count or weigh the egg harvest and egg morts.

The output terms refer to phosphorus that leaves the Hatchery, these terms include:

1. Shipped, Planted, and Mort Fish Tissue P. This term refers to all the phosphorus that leaves the Hatchery in the form of fish tissue. It is not relevant to the mass balance equation if the fish are shipped to another watershed, planted in the Platte River, or disposed as mortalities. The phosphorus value of this term is calculated by multiplying the whole wet weight biomass of the fish times the percent phosphorus in the fish tissue.

2. Discharge P. This term refers to the gross loading of phosphorus that leaves the system as flowing water. These flows include the Upper and Lower Discharges and any bypassed flows. Currently, the Upper Discharge is only outlet flow. Note that the phosphorus value of this term is calculated by multiplying the discharge flow rate times the phosphorus concentration. The Net Discharge is the difference between the phosphorus measured Gross Discharge and the sum of the measured phosphorus inputs, and is used for NPDES and Settlement Agreement purposes.

3. Trucked P. This term refers to the amount phosphorus that is trucked away from the Hatchery, predominately the result of emptying and cleaning the solids storage tank. The phosphorus value of this term is calculated by multiplying the measured number of gallons of liquid trucked away times the average measured phosphorus concentration of the liquid.

The accumulation terms are calculated by subtracting the outlets from the inputs. Accumulation can be positive or negative. There are three major accumulation terms.

1. Fish Tissue P. This term refers to the phosphorus present in fish in the Hatchery Building and raceways. The phosphorus value of this term is calculated by multiplying the whole wet weight biomass of the fish times the percent phosphorus in the fish tissue. If the fish

tissue phosphorus is greater at the end of the year than the start of the year the accumulation term is positive. If the fish tissue phosphorus is less at the end of the year than the start of the year then this term is negative. Note that additions, transfers, or removals of fish from the system are not considered in the calculation because such factors are accommodated by other terms in the mass balance equation.

2. Tank P. This term refers to the amount of phosphorus in the solids storage tank. The phosphorus value of term is the average phosphorus concentration of the solids in the tank multiplied by the tank volume. This term can also have a positive or negative value depending on the amount of phosphorus in the tank at the start and end of the year. Phosphorus removed by truck is included in separate terms in the mass balance equation.

3. Pond P. This term refers to the amount phosphorus that settles and is permanently stored in the bottom of the pond. Phosphorus that settles to the bottom is prevented from leaving by a clay liner. The phosphorus value of this term cannot be easily measured directly, but is usually calculated by subtracting all the inputs of phosphorus to the pond from the outlets. Normally, the inputs are greater than the outlets. Other terms in the mass balance would need to be added to cover the case where the pond is drained and bottom materials removed.

The steady state form of the Mass Balance equation can be applied to the Hatchery on an annual basis and expressed in terms of regulatory, fish production, and facilities operation as Equation 2.

$$\text{Net P Load} = \text{Food} - \text{Production} - \text{Tank Retention} - \text{Pond Retention} \qquad (2)$$

The “Net P Load” is the difference between the measured Gross Discharge Loading and the summation of the loadings from the various source waters. All the input terms are routinely measured. “Food In” represents the phosphorus in the food fed to the fish. The “Production” term is the annual amount of phosphorus associated the net growth of new fish biomass. The net annual production of fish is defined as the phosphorus equivalent of the fish that leaves the Hatchery as Morts, Shipped or Planted or contributes to an increase in the fish inventory in the raceways. Increases or decreases in inventory and the transferred fish are offset by the amount of fry that annually enter the system. The remaining terms are losses or retentions of phosphorus due to cleaning and trucking tank phosphorus, phosphorus settling to the bottom of the pond, or storage of phosphorus in the sludge tank.

Hatchery Mass Balance for 2010

Figure 6 shows Hatchery mass balance terms for 2010. The phosphorus associated with the source water and discharge was measured using the Sigma-72 sampling method for most of the year. The fish production terms were calculated using a fish tissue phosphorus content of 0.42% of the gross wet weight, a value that is consistent with recent measurements. There was a net increase of 9.3 lbs. of phosphorus associated with fish resident in the system at the end of the year when compared to values at the start of the year. The measurements show that the filters removed about 56% of the phosphorus that leaves the Hatchery Building and Raceways. Approximately 95% of the phosphorus removed by the filters is retained in the sludge storage tank with about 21 lbs of phosphorus flowing to the pond as clarifier overflow. Approximately 40 lbs are removed by the pond resulting in a net discharge of 36 lbs based on mass balance. This calculation gives credit for negative discharge days. The net Hatchery loading increases to approximately 80 lbs. when no credit is given for negative days. The sludge storage tank was emptied and cleaned at the end of August 2010. The measured removal was 204.5 lbs. Linear extrapolation to the end of 2010 gives an additional accumulation of approximately 57 lbs. Mass balance calculations suggest that 384 lbs of phosphorus was accumulated in 2010. The difference between the mass balance value and the measured value is equivalent to an error of about 8% of the total input of phosphorus through the system. Overall, the measured input of phosphorus to the Hatchery was 1,612.5 lbs. in 2010 compared to 1,489 lbs. that can be accounted for from known or measured losses.

These results suggest the following possible explanations:

1. The source water phosphorus loading is lower than is being measured.
2. The discharge loading is actually larger than that being reported.
3. The actual pond losses are greater than those being measured.
4. The phosphorus in the food is actually lower than that reported by the supplier.
5. The biomass of the fish leaving the system is larger than that reported.
6. The phosphorus associated with fish tissue is greater than 0.42%.
7. The actual tank losses are greater than those being measured.

It is imperative that significant efforts be continued to accurately measure all the inputs and outputs of phosphorus from the system so that mass balance calculations can be verified each year. Understanding of the operation of the Hatchery and the ability to track movement of various phosphorus pathways comes under significant question without such mass balance closure.

Lake Water Quality of Big Platte Lake

Total Phosphorus: The annual variation of volume-weighted total phosphorus concentration in Big Platte Lake for 2010 was 7.98 mg/m^3 as shown in Figure 7. There were 186 days when the total phosphorus concentration exceeded the 8.0 mg/m^3 goal. The Consent Agreement mandates that the volume-weighted total phosphorus concentration of Big Platte Lake be maintained below 8.0 mg/m^3 95% of the time. This corresponds to about 51% attainment as compared to the 95% requirement.

Secchi Depth: Secchi depth is used to measure water clarity and is an important indicator of water quality. Consistent measurements of Secchi depth have made in Big Platte Lake since 1990. The 2010 seasonal variation of Secchi depth in Big Platte Lake is shown in Figure 8. This variation is typical with an early summer clearing event followed by a significant algal bloom with Secchi depths dropping to around 7 feet. This variation is a complex function of calcite precipitation and the concentrations of plankton and phosphorus in the Lake. These relationships have been recently described by mathematical models developed by Homa and Chapra (2011) for nearby Torch Lake. Such models can be used to calculate increases in water clarity as a function of decreases in Hatchery and watershed phosphorus loading. Readers should note that as phosphorus concentrations in the Lake decrease, corresponding increases in water clarity may be less than expected due to the precipitation of calcite (marl). It is recommended that a model similar to the Torch Lake model be developed for Big Platte Lake.

Dissolved Oxygen: The 2010 annual variations of the dissolved oxygen concentrations in Big Platte Lake are displayed in Figure 9. The dissolved oxygen depletion in the hypolimnion of Big Platte Lake is closely related to temperature gradients and the onset of spring stratification. The concentration of dissolved oxygen dropped below 2 mg/L in waters deeper than 90 feet for 109 days in 2010. This is a critical period for phosphorus dynamics in the Lake as dissolved phosphorus will be released from the sediments during this anoxic period. Shallower water depths at 75, 60, and 45 feet experience shorter periods of low dissolved oxygen conditions as shown at the top of Figure 9. Another key period of phosphorus release from sediments is during the winter ice cover when there is significant oxygen depletion. These data are used to calculate the phosphorus release from the sediments. This internal loading and cycling of phosphorus can be compared to both non-point and point sources and can be used to calculate the annual dynamics of phosphorus in the lake. Ultimately, the magnitude of the internal cycling of phosphorus determines how quickly the lake will respond to changes in input phosphorus loadings.

Watershed Flow and Phosphorus Balances

Watershed Flow Balance

Figure 10 shows the long-term trend of mean annual flow of the Platte River as measured by the U.S. Geological Survey (USGS) (Station ID 04126740). The mean annual Platte River flow was 108.3 cfs in 2010. This flow is lower than the long-term average flow of 124.0 cfs since 1990. Thus, 2010 can be characterized as a drier than the average year.

Figure 11 shows the daily hydrograph as well as the days sampled for water quality. Note that only one sample was taken during the peak of a high flow event, while the remaining samples characterize baseline flow conditions. Inspection of the hydrograph suggests that there were actually about 13 high flow events when higher than baseline flow and total phosphorus concentrations are expected, but were not sampled in 2010.

Figure 12 shows an annual average flow and phosphorus balance for the lower watershed starting at Fewins Road and extending to the outlet of Big Platte Lake. The flow balance includes the tributary flows into the Platte River and discharge by the Hatchery. Tributary and non-point flows and flows at intermediate locations on the Platte River are based on correlations with the USGS measured flows at US-31. These correlations were developed over a three-year period using flow measurements at intermediate locations in the watershed. Flow at the USGS location is about 2.2 times the flow at Fewins Road, and the Lake outlet is about 2.7 times that of the flow at Fewins Road. Figure 12 includes 13 storm events in 2010 where flows rapidly increased and then receded over a one or two day period. The peak event storm flows occurred only about 4.8% of the time during 2010. Baseflows are generally associated groundwater inputs and accounted for the remainder of the flow or 95.2% of the hydrologic inputs.

Watershed Phosphorus Balance

The development of an accurate annual phosphorus balance for the watershed is not a simple task because the Platte River and tributary loadings are highly affected by high flow events that occur during several storm events throughout the year. The Platte River was sampled for total phosphorus concentration during only one of these storm events in 2010 from a total of about 13 (see Figure 11). Thus, estimates of the total phosphorus loading into Big Platte Lake based on the 24 routine measurements are not expected to accurately estimate the loading because of the inaccurate and under representation of storm events. Unfortunately, it is impractical to measure flow and phosphorus concentration during every storm event at all key locations in the watershed every year.

Extensive storm event measurements were taken from 2004 to 2006 at the Old Residence location on Brundage Creek and at the Stone Bridge and USGS Gauging Station at Honor, MI sites on the Platte River using continuous water sampling equipment. The average event total phosphorus concentrations at these locations were 68.0, 45.4, and 51.1 mg/m^3, respectfully. The storm event concentrations at the Fewins site and North Branch sites were assumed to be identical to those measured at the Stone Bridge site. The measured storm event total phosphorus concentrations measured at the Old Residence site on Brundage Creek were also used to characterize storm events for the Stanley, Carter, and Collision Creek sites. The total phosphorus concentrations during baseflow conditions were averaged for all years for Stanley, Carter, and Collision Creeks because limited measurements are available for these sites and they are no longer included in the regular monitoring program. These data, along with the regular monitoring data for 2010, were used to determine the total phosphorus loads into Big Platte Lake as shown in Figure 12.

The annual phosphorus load at the USGS Gauging Station site was 2,905.5 pounds in 2010. Storm events contributed 9.2% of total phosphorus load compared to only 4.8% of the flows. The total phosphorus concentration at the USGS Gauging Station at Honor, MI site was measured 24 times during 2010. The average total phosphorus concentration was 12.6 mg/m^3 and the annual average flow was 108.3 cfs. This is equivalent to an annual phosphorus load of 2,690 lbs., an amount that is about 8% lower than the annual load that accounts for increases during storm events. The difference is the result of storm event flows with their higher total phosphorus concentrations being disproportionate greater than corresponding phosphorus loads from dry weather or baseflow conditions.

The above calculations are considered adequate representations of the hydrologic and phosphorus watershed balances despite the assumptions and approximations used in the analyses. Practical alternatives to this approach are problematic. The monitoring program needed to compile a more accurate phosphorus balance for the total watershed is monumental and outside of the current budget for this program. Given these difficulties and limitations, the above approach is considered a good alternative and a reliable screening tool that can be reliably used for planning applications. However, it is recommended that the full dry and wet weather monitoring program be resumed if watershed planning issues arise in the future that involve large expenditures or significantly influence watershed land use.

Monitoring Program

Hatchery

The net Hatchery total phosphorus load is evaluated by subtracting the inlet load from the total outlet load. It is recommended that measurements of flow, total phosphorus concentration, and turbidity be taken at six locations using the Sigma samplers. The Sigma equipment should collect 72 hour composite samples twice each week. In addition, all flow rates should be calibrated annually. The flow rate of the clarifier and waste pumps should be based on pump capacity and the measured running times of the pumps.

Watershed

The sampling plan for 2011 involves collecting data from watershed streams and Big Platte Lake. The proposed lake and watershed sampling program for 2011 includes no sampling of Little Platte Lake; no nitrogen or total dissolved phosphorus samples; and only three samples for phytoplankton and zooplankton.

The tributary sampling program is designed to calculate the non-point phosphorus loading into Big Platte Lake. Measurements of flow, phosphorus, and turbidity are taken on a regular basis independent of flow conditions. These data allow evaluation of water quality for various hydrologic conditions; provide sub-watershed loading estimates; and assist in defining high priority remediation areas. The recommended monitoring program for 2011 contain three sites on the Platte River – one just upstream of the Hatchery, another at the USGS Station on US31, and the last below Big Platte Lake on M-22. One sample should be taken of the North Branch of the Platte River at Deadstream Road.

It is recommended that Big Platte Lake be sampled at two locations every two weeks during the year, whenever it is safe to do so. A calibrated Yellow Springs Instruments (YSI) meter should continue to be used to measure dissolved oxygen, temperature, pH, conductivity, and ORP. Discrete depth and tube samples should be analyzed for total phosphorus, turbidity, and chlorophyll. Vertical net hauls should be taken for zooplankton one time during the spring, summer, and fall. A surface composite (tube sampler) and grab bottom sample should be taken during these same periods for phytoplankton. Secchi depths should be measured with a standard Secchi disk and collected during each lake sampling. It is recommended that four more upstream tributary sites be added and samples be taken for nitrate and TN when current budget restraints are lifted.

References

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