Consent Agreement Annual Report
2014

Report Prepared by:

Dr. Raymond P. Canale
Implementation Coordinator
Emeritus Professor, University of Michigan

Gary Whelan
Research Program Manager
Michigan Department of Natural Resources,

Edward Eisch
Fish Production Manager, Platte River State Fish Hatchery
Michigan Department of Natural Resources

And

Wilfred J. Swiecki
Platte Lake Improvement Association

May 2015

Table of Contents

List of Appendices for 2014

Summary for 2014

Overview

The goal of the Consent Agreement is to restore and preserve the water quality of Big Platte Lake[1] (Lake) and its watershed. This goal is being advanced by minimizing the flow and phosphorus loadings from the Platte River State Fish Hatchery (Hatchery, PRSFH) and by developing strategies to reduce other DEQ permitted and non-point phosphorus loads from the watershed.

Compliance with Consent Agreement for 2104

Figure 1 summarizes the 2014 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. of phosphorus per year. The corresponding maximum load for any consecutive three month period is 55 lbs of phosphorus, as calculated using a running average. The reported net Hatchery annual loading for 2014 was 68.6 lbs of phosphorus and the maximum 3 month loading was 45.8 lbs of phosphorus. These amounts do not exceed either of the maximum allowable phosphorus load specifications. The average water use at the Hatchery was 6.0 million gallons per day (mgd) which is less than the Consent Agreement limit of 20 mgd.

The average volume-weighted total phosphorus concentration of Big Platte Lake was 7.18 mg/m^3 in 2014. The water quality goal of 8.0 mg/m^3 of phosphorus was achieved 75% of the time. This level of attainment is similar to the result for the past several years and is not consistent with the goal of 95% attainment as stipulated in the Consent Agreement.

A total of 9,757 adult coho and 175 adult Chinook salmon passed the Lower Weir in 2014. These numbers are lower than that seen in recent years and are in compliance with the Consent Agreement limits of 20,000 adult coho and 1,000 adult Chinook salmon.

---

[1] Note that Platte Lake is the accredited name listed by the USGS Geographic Names Information System. Big Platte Lake is cited as a variant name that has been used in various reports including the recent Platte River Watershed Protection Plan. Big Platte Lake is used in this annual report to conform to common local usage and to distinguish it from nearby Little Platte Lake.

Major Accomplishments for 2014

1 All requirements of the Settlement Agreement related to PRSFH operations have been met by the parties for 2014.

2 All requirements of the Settlement Agreement related to PRSFH operations have been met for 5 consecutive years.

3 PRSFH laboratory procedures for measurement of total phosphorus have proven reliable and consistent. Iron interference issues have been resolved.

4 Phosphorus mass balance calculations for the hatchery have become more accurate with the inclusion of the Hot Pond data and with the automatic sampling equipment programmed to obtain 72 hour composite samples. This approach is far superior to grab or 24 hour composite sampling. It is concluded that near-continuous sampling of the phosphorus concentration at various inlet and output locations is required to get an accurate representation of phosphorus mass balance calculations for the Hatchery. This mass balance closure ensures that the reported Hatchery loadings are accurate and not inappropriately influenced by non-representative measurements of flow or total phosphorus concentration.

5 Four bioenergetics papers have been peer reviewed and published in the journal of Aquaculture. One paper has been submitted and awaiting peer-review (Canale et al, under review).

6 The Platte River Watershed Protection Plan has been accepted by the Michigan DEQ and the USEPA.

7 A manuscript entitled "An Analysis of Sampling Programs to Evaluate Compliance with Numerical Total Phosphorus Standards for Platte Lake, MI." by Eric P. Smith and Raymond P. Canale has been submitted to the journal of Lake and Reservoir Management for peer-review. The paper uses statistical analyses to determine the minimum number of total phosphorus samples needed to adequately characterize vertical concentration gradients and the number of samples that must be taken during the year to reliably evaluate compliance with the water quality standards. These results are being

used to reduce the cost of sample collection and laboratory analyses.

8 A new database has been developed and is undergoing beta testing for Hatchery operations. The database imports data for daily flow and other operational parameters from a tablet. Several new reports have been developed that are designed to facilitate operation of the Hatchery in a manner consistent with its NPDES permit.

9 Eighteen Implementation Coordinator/MDNR/PLIA conference calls were conducted in 2014 (Appendix A). These discussions of hatchery operations and the water quality of Big Platte Lake have proven useful to attaining the goals of the Consent Agreement.

10 All Standard Operating Procedures and Preventative Maintenance requirements have been followed and updated where appropriate in 2014 (See Appendices B, C, and D).

Recommendations for 2015

1. Efforts to improve the accuracy of the phosphorus mass balance calculations for the Hatchery should continue. The current monitoring program as discussed below should be continued and better estimates of the fish tissue phosphorus content should be obtained. The on-going project to improve existing estimates of the fish tissue phosphorus content should be completed as soon as possible and a paper on the results submitted to a peer-reviewed journal for possible publication.

2. It is recommended that the validated bioenergetic model be used to assist to determine feeding rates at the PRSFH to demonstrate its application and utility. If successful, software and an accompanying user manual should be made available to others engaged in aquaculture operations.

3. It is recommended that the watershed plan should be expanded to include the Upper Platte River Watershed upstream of the current monitoring station located above the PRSFH at the Stone Bridge site.

4. It is recommended that a new series of storm event sampling be conducted for comparison with results from 2005. Event sampling should occur at 3 locations: the Platte River upstream of the Hatchery at the Stone Bridge site; Brundage Creek at the

Old Residence site; and the Platte River at the USGS gauge site at M-31 west of Honor. These data can be used to evaluate the effectiveness of efforts to reduce non-point phosphorus loads such as projects to reduce stream bank erosion at the Reynolds Road crossing and other up-river sites.

5. It is recommended that the current BASINS model be re-calibrated for the Lower Platte River Watershed using all available and appropriate data as the current BASINS model only uses data collected through 2005. More reliable data are now available that can be used to improve model calibration. It is recommended that the BASINS model be expanded to include the upper watershed. This will require additional data for the Upper Platte River Watershed to support the development of the BASINS model and models for total phosphorus for Long Lake and Lake Ann.

6. It is recommended that a shoreline *E. coli* and *Cladophora* survey be conducted around Big Platte Lake every 10 years or following distinct visual changes in shoreline periphyton distribution or density. The survey employs two sampling periods:1) An early summer sampling period that measures phosphorus and fecal coliform bacteria and maps the growth of *Cladophora* as an indicator of sources of phosphorus; and 2) . A late summer sampling period to determine if summer residents increase local concentrations of phosphorus or the number of indicator bacteria.

7. It is recommended that the septic tank demonstration project be continued through 2015.

8. Efforts should be made to quantify the effect of the Honor Wastewater Treatment Plant on the water quality of Big Platte Lake. This effort should include water sampling of test well sites near the treatment plant and the resumption of sampling of Collision Creek, the Platte River at Pioneer Road and the Henry Street Bridge, and at an upstream location on the North Branch of the Platte River.

9. It is recommended that bi-weekly sampling of Little Platte Lake be resumed when funding is available. The nitrogen cycling is of particular interest at this location as the available data indicates that nitrogen limits algal growth during the summer in Little Platte Lake. An annual mass balance budget for nitrogen should be constructed for Little Platte Lake.

10. It is recommended that all parties should continue continuous maintenance of the database to insure sustained functionality and reliability of the watershed and hatchery

databases. Additionally, documentation should be updated on an annual basis.

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.

In addition we wish to commend the following individuals from the MDNR Fisheries Division: 1) Edward Eisch for his support of the Consent Agreement requirements and the overall management of the Fish Production system; 2) Aaron Switzer for work on the management of the PRSFH and his broad fisheries and water quality sampling expertise that helps to guide his staff; 3) Paul Stowe for his efforts on sample collection of Hatchery, Lake, and tributaries; and 4) Nikki Sherretz for her work on laboratory measurement of total phosphorus.

We also acknowledge and appreciate the support and assistance of several individuals from the Platte Lake Improvement Association (PLIA): 1) Jim Berridge for his work on the database; 2) Mike Pattison for his regular participation in the coordination meetings and his work on the web site; 3) Steve Peterson for his marketing and public relations efforts; and 4) Maris Ziemelis for taking over the PLIA task of independent measurement of the Secchi depth in Big Platte Lake.

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 and egestion, and from unconsumed feed. A summary of Hatchery and fish production activities is contained in Appendix E. 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) and the daily phosphorus entering the system from three major surface water sources (Brundage Spring, Brundage Creek, and rarely the Platte River) and two minor mostly groundwater sources (Filter Backwash and Hot Pond waste pump).

Negative net loads on any day are set equal to zero for purposes of calculating compliance with the requirements specified in the Consent Agreement and the Hatchery NPDES permit. 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 2005 through 2014. The net phosphorus load from the hatchery to the Platte River was 68.6 lbs. for 2014. Note that the net annual Hatchery load has been less than 100 lbs. for 5 consecutive years.

The concentrations of total phosphorus and turbidity of the Hatchery inlet and outlet flows were measured using 72-hour composite samples during 2014. Figure 3 shows the concentration of total phosphorus in the Upper Discharge during 2014. Note that there are three distinct periods. High concentrations were typical during the first 120 days of 2014, followed by low values during the summer, then a general rise for the remainder of the year. Figure 4 shows the corresponding 3-month net phosphorus loads for 2014. The loads for the first 5months correspond to a period when extremely cold temperatures froze nearby water bodies, including Lake Michigan, for extended periods. During this period the pond was one of the few open water feeding opportunities for waterfowl. These birds disturbed the pond bottom sediments resulting in high net loads. The lower loading during the summer occurs during a period where fish from the pervious year class are no longer present in the system and the size of the current year class coho salmon is still relatively small. Normally, rapid growth and increased feeding of the current year class of coho salmon results in an increase in the loading during late summer and fall. These increases are offset by the addition of ferric chloride in excess of the stoichiometric requirement during 2014 as shown in Figure 5 (also see Appendix E). Also during the last summer and fall, time, aquatic macrophytes in the pond go through their seasonal senescence and decomposition, resulting in further increasing net total phosphorus concentrations.

<u>Phosphorus Mass Balance</u>

Phosphorus mass balance models are essential tools that can be used to help understand and manage the net phosphorus load from the Hatchery as a function of production activities and facilities operation in near real time. 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).

$$\text{Accumulation or Storage of P} = \text{Sum of Inputs} - \text{Sum of Outputs} \qquad (1)$$

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 tanks and raceways. This term is calculated by multiplying the weight of the food fed times the percent 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 (not used during 2014), and the Service and Hot Pond waters (primarily groundwater with a minor amount of surface runoff). The phosphorus input load 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 percent phosphorus in the fry tissue. Note that this approach avoids the need to count or weigh the egg harvest and egg mortalities.

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

1. Shipped, Planted, and Mortality 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 effluents from the Hatchery. Currently, the Upper Discharge is only outlet location. Note that the phosphorus value of this term is calculated by multiplying the discharge flow rate times the phosphorus concentration. The Net Discharge based on mass balance is the difference between the measured phosphorus Gross Discharge and the sum of the measured phosphorus inputs and can be a negative value. Possible negative values are arbitrarily set equal to zero for purposes of Settlement Agreement and NPDES compliance. Therefore, the Net Discharge based on mass balance is usually somewhat lower the reported than Net Discharge for compliance.

3. Trucked P. This term refers to the amount phosphorus that is trucked away from the

Hatchery and removed from the watershed, predominately the result of emptying and cleaning the solids storage tank. The 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 or storage terms are calculated by subtracting the outlets from the inputs. Accumulation can be positive or negative. The three major accumulation terms are:

1. Fish Tissue P. This term refers to the phosphorus present in Hatchery fish. The 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 value 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, this term is negative. 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 value of this term is the average phosphorus concentration of the solids in the tank multiplied by the sludge 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 is stored in the bottom of the pond. Phosphorus that settles to the bottom is prevented from leaving the pond by a clay liner and remains in the bottom sediments until the system is drained and dredged. The phosphorus value of this term cannot be easily measured directly, but can be 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 are needed to accommodate the case where the pond is drained and bottom materials removed.

<u>Hatchery Mass Balance for 2014</u>

Figure 6 shows Hatchery mass balance terms for 2014. The phosphorus associated with the source water and discharge was measured using the Sigma 72 hour sampling method. The best overall mass balance closure was achieved using a fish tissue phosphorus content of 0.374 % of the gross wet weight. This value is lower than expected and lower than data for rainbow trout published by Shearer (1997). It is recommended that efforts be completed to measure the tissue phosphorus content of the PRSFH coho and Chinook salmon. There was a net decrease of 17 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 calculations suggest that the filters removed about 57% of the phosphorus from the water that leaves the Hatchery Building and Raceways. Approximately 98% of the phosphorus removed by the filters is retained in the sludge storage tank with about 9.09 lbs of phosphorus flowing to the pond as clarifier overflow. The sludge storage tank was emptied and cleaned in late December 2014. The measured removal was 507.02 lbs of phosphorus. Linear extrapolation is used to estimate that an additional accumulation of approximately 2.25 lbs of phosphorus would be in the tank at the end of the year. This amount is offset by 98.93 lbs that were present in the tank at the beginning of 2014. Approximately 80.92 lbs (21%) were removed by the pond resulting in a net gross discharge of 36.6 lbs based on mass balance that gives credit for negative discharge days. The net Hatchery loading increases to approximately 68.6 lbs. when no credit is given for negative days.

It is imperative that significant efforts be continued to accurately measure all the inputs and outputs of phosphorus from the system at 2014 locations to ensure 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.

Big Platte Lake Water Quality

Total Phosphorus: The annual variation of the volume-weighted total phosphorus concentration in Big Platte Lake for 2014 is shown in Figure 7. The average value of 15 measurements during the year was 7.18 mg/m^3. There were 90 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. The actual attainment was 75%, significantly lower than the 95% requirement.

Secchi Depth: Secchi disk depth is a visual method used to measure water clarity and is an important indicator of water quality. Regular measurements of Secchi depth have made in Big Platte Lake since 1982. The 2014 seasonal variation of Secchi depth in Big Platte Lake is shown in Figure 8. The minimum measured Secchi depth was about 8 feet. Secchi depth dynamics are a complex function of calcite precipitation, suspended sediments, and the concentrations of plankton and phosphorus in the Lake. 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).

<u>Temperature and Dissolved Oxygen:</u> Figures 9 and 10 show the measured annual variations of temperature and dissolved oxygen concentrations in Big Platte Lake during 2014. Typical patterns of both winter and summer temperature stratification were measured in 2014. However, the average surface and bottom layer temperatures were 63.4 and 45.3 degrees F in 2014 compared to 66.2 and 46.4 degrees F in 2013. Dissolved oxygen depletion in the hypolimnion of Big Platte Lake is closely related to temperature gradients and the onset of spring stratification (Figure 10). The concentration of dissolved oxygen dropped below 2 mg/L in waters deeper than 90 feet for only 67 days in 2014 as a result of relatively cold water temperatures. This is a critical period for phosphorus dynamics in the Lake because dissolved phosphorus will be released from the sediments during this anoxic and chemically reducing 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 10. Another key period of phosphorus release from sediments is during the winter ice cover when there is significant potential for oxygen depletion. Figure 11 shows the total number of days where measured dissolved oxygen concentrations are less than 2 mg/L. The downward trend since 1995 is likely due to the depletion of phosphorus in the sediments and annual changes in temperature. The number of days where the dissolved oxygen concentrations is less than 2 mg/L are used to calculate the estimated phosphorus release from the sediments. The internal loading and cycling of phosphorus can be compared to both non-point and point sources and can be used to estimate an annual phosphorus budget for the lake as shown in Figure 18. Ultimately, the magnitude of the internal cycling of phosphorus determines how quickly the lake will respond to changes in input phosphorus loadings.

Watershed Discharge and Phosphorus Balances

<u>Watershed Discharge and Phosphorus Balance</u>

Figure 12 shows the long-term trend of the 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 160.3 cubic feet per second (cfs) in 2014. This flow is the highest annual average on record and is significantly higher than the long-term average flow of 124.8 cfs since 1990. Thus, 2014 can be characterized as a very wet year compared to an average year.

The watershed above the USGS gauging station has an area of 125 square miles. The long-term average rainfall reported at the Traverse City, Michigan airport is 29.8 inches per year. The product of the watershed area and the annual average rainfall is equivalent to a flow of 274 cfs.

This assumes that no water is lost by evaporation or percolation into the soil. The actual measured long-term average flow at the USGS site is 124.8 cfs. These results indicate that 54.5% of the water that enters the watershed as rainfall percolates into the soil or is lost by evaporated and that 45.5% contributes to the actual flow. Similar calculations for 2012, 2013, and 2014 indicate that the potential flow from rainfall without losses would be 308 cfs, compared to the measured average of 139.7 cfs. For these years, 45.4% of the rain flow is measured as river flow compared to the long-term average of 45.5%. These results suggest, that although flows during recent years were extraordinary high, the measurements are consistent with long-term trends. Figure 13a shows monthly variations in the expected flow at USGS site assuming no loses. Figure 13b shows a similar trend for the actual measured flow for the same time period. Note that peaks in rainfall often give rise to peaks in measured flow rates. However this correlation was not seen during June 2012 and September 2014.

Figure 14 shows the daily hydrograph of the Platte River as well as the days sampled for water quality. Note that no samples were taken during high flow events, therefore all 2014 samples characterize baseline flow conditions. An analysis of the hydrograph as indicated by the green triangles suggests that there were about 27 storm events when higher than baseline flow total phosphorus concentrations are expected but were not measured. Figures 15 and 16 show measurements of total phosphorus and turbidity at the USGS site on the Platte River and at the North Branch of the Platte River at Deadstream Road during 2014 that characterize 2014 baseline conditions.

Figures 17 and 18 show the annual average discharge and total phosphorus concentrations at various sites in the Lower Platte River Watershed. Figure 19 shows the phosphorus load balances for the lower watershed starting at Fewins Road and extending to the outlet of Big Platte Lake. The discharge 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 linear relationships with the USGS measured flows at US-31 (USGS Gauge 04126740 – Platte River at Honor, MI). These linear relationships were developed over a three-year period using flow measurements at intermediate locations in the watershed. The 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. Figures 12 and 17 show about 27 storm events in 2014 where flows rapidly increased and then receded over a one or two day period. The storm flows during peak events accounted for about 10% of the total flow during 2014. Baseline flows are generally associated groundwater inputs and accounted for 90% of the hydrologic inputs.

The development of an accurate annual phosphorus balance for the watershed is not a simple task because the Platte River and tributary loadings are significantly affected by high flows that occur during several storm events throughout the year. The measured total phosphorus concentrations during 2014 only reflect baseline conditions. Thus, estimates of the total phosphorus loading into Big Platte Lake based on these flow measurements are not expected to accurately estimate the loading because of the 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 71.7, 50.8, and 42.6 mg/m^3, respectively. 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 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 2014, were used to determine the total phosphorus loads into Big Platte Lake as shown in Figure 19.

The annual phosphorus load at the USGS Gaging Station site was 6,104.8 pounds in 2014. This value is about 91% higher than the average loading for the past several years with the 2014 phosphorus loads were exceptionally high in 2014 compared to other years. Storm events contributed 14.1% of total phosphorus load compared to 10% of the flows. The total phosphorus concentration at the USGS Gaging Station at Honor, MI site was measured 17 times during 2014. The average total phosphorus concentration was 17.6 mg/m^3 and the annual average flow was 160.3 cfs. This is equivalent to an annual phosphorus load of 5,556 lbs., an amount that is about 9% 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 disproportionately greater than corresponding phosphorus loads from dry weather or baseflow conditions.

The left hand side of Figure 19 shows numerical values of direct and internal phosphorus loads. The direct drainage phosphorus load was 551.7 lbs. This value is based on the direct drainage area between the USGS site and the lake outlet. This area is multiplied by a unit area phosphorus load determined from the calibrated USEPA BASINS model and varies as a linear function of the annual average flow at the USGS site. Sediment release of 43.7 lbs. was determined by multiplying the number of days the dissolved oxygen was below 2 mg/L in four zones (see Figure 10) by the area of each zone and the sediment release rate. The atmospheric phosphorus loading was estimated to be 201.1 lbs. in 2014. This value was calculated by multiplying the total annual rainfall (44.2 inches), the lake surface area, and an atmospheric total phosphorus concentration of 7.95 mg/m^3. The lost fish phosphorus loading was estimated to be 41.9 lbs. in 2014. This value is calculated by multiplying the difference between the fish biomass that passes the lower weir and the fish biomass collected at the upper weir by the fish tissue phosphorus concentration. This value is a very conservative upper bound and does not account for possible removal by anglers or avian predators. The outlet loading of 2822.9 lbs. for 2014 is calculated by multiplying the outlet flow times the lake median total phosphorus concentration. The difference between the sum of all the external and internal loads and the outlet load is retained in the lake bottom sediments. The retention was 64.2 % of the inlet load in 2014. The apparent settling velocity was 30.4 m/yr. This value is about 2.3 times values seen in the past several years. It is noteworthy that the effect on the Lake of the high tributary loads in 2014 was entirely offset by this high apparent settling velocity and retention. The annual average volume-weighted phosphorus concentration in 2014 was about 9% lower than concentrations measured during the past several years.

The above calculations are considered adequate representations of the hydrologic and phosphorus watershed balances despite the 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, extremely expensive, and outside of the program scope. Given these difficulties and limitations, the above approach is considered a good alternative and a reliable screening tool that can be used for planning applications. However, it is recommended that the full dry and wet weather monitoring program be resumed and the BASINS model be re-calibrated if watershed planning issues arise in the future that involve large expenditures or significantly influence watershed land use.

Monitoring Program Recommendations

Hatchery

The net Hatchery total phosphorus load is evaluated by subtracting the inlet load from the gross discharge load. It is recommended that measurements of flow, total phosphorus concentration, and turbidity be taken at the current six locations using automated water samplers. The equipment should be set to collect 72 hour composite total phosphorus samples twice each week.

The flow rates should be recorded daily based on the capacity and the running times of the pumps within the Hatchery. The flow rates of the backwash and Hot Pond waste pumps should continue to be added to the flows from Brundage Creek and Brundage Spring to calculate the total flow of the Upper Discharge. In addition, all flow rates should continue to be calibrated annually. It is recommended that the monitoring program support phosphorus mass balance calculations for the Hatchery. This can be accomplished by continuing the recording of food use and composition, fish produced, and fish removed through mortality or transport from the system each month. It is particularly important to continue efforts to carefully measure the volume and total phosphorus concentration of sludge removed from the storage tank.

Streams

The tributary sampling program should allow for the reliable estimates of the phosphorus loading into Big Platte Lake. Measurements of phosphorus should be taken on a regular basis independent of flow conditions. It is desirable to measure turbidity and flow especially during unusually high flow conditions. These data can be used to strengthen existing relationships between the flow at the USGS site and the flow of various tributaries, and improve existing correlations for turbidity as a function of flow. Turbidity can be measured in the laboratory using existing equipment and standard methods. 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 minimum monitoring program for 2015 should include two sites on the Platte River (one just upstream of the Hatchery and the USGS Station on US31). One sample should be taken in the North Branch of the Platte River at Deadstream Road.

Big Platte Lake

It is recommended that Big Platte Lake be sampled for total phosphorus at a single location every two weeks during 2015, whenever it is safe to do so. Turbidity should be measured for quality control. A calibrated Yellow Springs Instruments (YSI) or HydroLab meter should to be used to measure vertical variations of dissolved oxygen, temperature, pH, conductivity, and oxidation-reduction potential. The volume weighted total phosphorus concentration should be based on measurements in three layers; surface, middle, and bottom. The surface sample should be a single sample collected from just under the water surface. The middle layer should be an equal volume composite of the water from collected 7.5, 15, 30, 45, and 60 feet. The bottom layer should be a composite of equal volume samples from 75 and 90 feet. Phytoplankton and zooplankton should be sampled during the spring, summer, and fall and preserved for possible analysis in the future in the event major shifts are observed in the plankton community distribution. Secchi depths should be measured with a standard Secchi disk and collected during each lake sampling using the same methods as have been implemented to date. These standard Secchi disk depth data should be supplemented by additional Secchi depth measurements during periods when lake phosphorus samples are not being collected and whenever possible.

References

Canale, R. P., G. E. Whelan, A. Switzer, and E. Eisch. (under review). "A Bioenergetic Approach to Manage Production and Control Phosphorus Discharges from a Salmonid Hatchery", Aquaculture.

Shearer, K. D. (1995). The use of factorial modeling to determine the dietary requirements for essential elements in fishes. Aquaculture. 133, 57-72.

Smith, E. P. and R. P. Canale. (under review). "An Analysis of Sampling Programs to Evaluate Compliance with Numerical Total Phosphorus Standards for Platte Lake, MI". Lake and Reservoir Management.