Annual Report for the Year 2004

Consent Agreement Regarding the Operation of the Platte River Hatchery

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June 2005

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Summary for the Year 2004

Overview

The goal of the Consent Agreement is to implement a long-term strategy to restore and preserve the water quality of Big Platte Lake. This goal is being advanced by minimizing the flow and phosphorus discharge from the Hatchery and by developing strategies to reduce non-point phosphorus loads from the watershed. Figure 1 summarizes the compliance with the Consent Agreement and the major accomplishments for 2004.

Compliance with Consent Agreement

The Consent Agreement mandated that the Hatchery net annual load would be limited to a maximum of 250 lbs. during the construction period, 225 lbs. during a 3 year test period, and 175 lbs. thereafter. The corresponding maximum loads for any consecutive three month period are limited to 75 lbs., 70 lbs., and 55 lbs. The year 2004 is the first of three test years where the limits are 225 and 70 lbs. The net Hatchery annual loading for 2004 was 158.1 lbs. This is in compliance with the requirements. The maximum for any 3 month period was 75.6 lbs. This value is above the requirement. The average water use at the Hatchery was 9.8 mgd which is less than the Consent Agreement limit of 20 mgd.

The average volume-weighted total phosphorus concentration of Big Platte Lake was 7.1 mg/m^3 in 2004. The water quality goal of 8.0 mg/m^3 was exceeded 22% of the time. This is not in compliance with the goal of 95% attainment as stipulated in the Consent Agreement.

A total of 16,282 adult Coho passed the Lower Weir in 2004. This is in compliance with the Consent Agreement limit of 20,000. A total of 515 adult Chinook salmon passed the Lower Weir in 2004. This is also in compliance with the Consent Agreement limit of 1,000. Excess salmon that accumulated below the lower weir were harvested, counted, and removed from the watershed. A total of 12,496 adult Coho salmon were harvested for egg collection at the Upper Weir. This is 77% of the number of the Coho that were counted passing through the Lower Weir. A total of 540 adult Chinook salmon were harvested at the Upper Weir. Although this is slightly above the number that were counted passing through the Lower Weir, the discrepancy is considered small given the uncertainty of the measurement procedures.

Major Accomplishments for 2004

- The Hatchery has completed the major renovation program that included the addition of state-of-the-art effluent control systems; new outside raceways with partial reuse capabilities and overhead covers; upgraded headbox; automated feeding systems; and new flow monitoring and measurement equipment.

- The capabilities and functionality of the database have been expanded to facilitate comprehensive data analysis. Extensive and essentially all available historical data have been added for the Hatchery, Big Platte Lake, and several tributaries.

- Storm event flow, phosphorus, and turbidity data were collected at selected Platte River and Brundage Creek locations. Correlations have been developed that relate flow and gauge data at all sampling locations. These data will be used to further calibrate the BASINS watershed model.

- Several additions were made to the sampling program to enhance understanding of ecological processes in Big and Little Platte Lakes. These additions include measurements of filtered nitrate, silica, phosphorus, and alkalinity. New stations were added on Little Platte Lake and Featherstone Creek. The phosphorus, nitrate, and pH of precipitation at the Hatchery location are now being measured.

- An initial annual phosphorus mass balance model has been completed for the Hatchery.

- Special studies were completed to measure the population of zebra mussels in Big and Little Platte Lakes and estimate their impact on water quality.

- Studies of sediment oxygen demand and phosphorus release rates continued in 2004 and are expected to be completed by fall of 2005.

- Mass balances for water flow and phosphorus were developed for the watershed and Big Platte Lake.

- Data from the monitoring program and the baseline calibrated BASINS model were used to help craft local ordinances concerning shoreline buffer strips.

Recommendations and Action Items for 2005

- The phosphorus and turbidity data from the Jug & Needle and Sigma sampler methods are not statistically similar. It is desired by all to resolve the differences and ultimately eliminate the Jug & Needle method if possible. However before this can be recommended we must understand why the two methods differ. It is agreed by all that the Jug & Needle method may fail to obtain an accurate 24-hour composite if a bottle is completely full at the end of a 24 hour period. On the other hand, the Sigma sampler is currently programmed to obtain a sub-sample every 30 minutes. If the flow has highly variable concentrations of phosphorus or turbidity, then it is possible that the Sigma sampler would miss a short spike. Thus each method has advantages and disadvantages. This issue is additionally complicated by the fact that the Jug & Needle and Sigma samplers are not located in the exact same positions except for the pond outlet. It is recommended that we design a test to resolve these issues. It is suggested that we test the performance of both methods at the pond outlet where the concentrations are most stable over a 4 to 8 hour period on dates when normal sampling is not being conducted. The Sigma should obtain as many sub-samples as practical over the test period. This test overcomes obvious differences between the methods and should provide comparable results. Further recommendations will follow the analysis of these test results. Data from this test will be analyzed with recommendations to follow. Normal sampling schedules should be maintained using both methods at all five locations during non-test periods until these issues can be resolved.

- The stored sludge volumes and phosphorus concentrations of the Hatchery storage tank should be measured using the tube method at monthly intervals. Any trucked liquid and sludge should have volumes recorded and phosphorus concentrations measured. The flow (bucket method), total phosphorus, and turbidity of the combined discharge from the sludge tank and clarified should be measured every two weeks.

- Sampling of Brundage Spring at the spring site should be discontinued. Instead it is recommended that both the Sigma and Jug & Needle methods be used at the Hatchery Building site. Samples for phosphorus and turbidity analysis should only be taken when the flow is not zero at any sampling site.

- Flow (Price AA, Pygmy, or Float), phosphorus, and turbidity should be measured monthly at all tributary locations until the end of 2005. Emphasis should be placed on collecting samples during wet weather.

- The flow sampling equipment should be returned to the manufacturer for service on an annual basis.

- The YSI sampling equipment should be returned to the manufacturer for service on an annual basis. A second pH meter should also be purchased, independently calibrated, and used to verify YSI measurements.

- A spreadsheet should be prepared and distributed that contains a maintenance schedule for all sampling and laboratory equipment.

- The event sampling program should be continued until the end of 2005.

- Gauge, total phosphorus, and turbidity measurements should be taken weekly at the Platte River near the stone bridge, at Brundage Creek near the old residence, and at the Platte River automatic sampling locations. This should be added to the automatic sampling equipment maintenance schedule when possible.

- The area, density, and tissue phosphorus of *Chara* should be estimated during late July to allow determination of the amount of phosphorus in this nutrient sink.

- Shoreline debris should be collected at several locations several times during the year by PLIA members to allow the determination of the amount of phosphorus in this nutrient sink. Wet and dry weight, density, and phosphorus content should be measured and entered into the database.

- Current and historical egg mortality data should be organized into a spreadsheet for entry into the database.

- Samples from Big and Little Platte Lake should be tested for microcystin by PLIA using field kits produced by Envirologix. Further evaluations should be conducted if the preliminary testing shows elevated levels of toxin.

- It is recommended that CMU repeat validation of its measurement technique for calcium using purchased standards. In addition CMU should measure hardness of several samples to verify that calcium is less than or equal hardness.

- Studies of the bio-availability of Hatchery and non-Hatchery phosphorus sources should be conducted when the sediment oxygen demand and phosphorus release rates are completed in fall of 2005.

- The BASINS model should be calibrated using wet weather stream data to allow the full and appropriate utilization of this watershed planning tool. The estimated cost of this effort is approximately $60,000.

- Development and calibration of the water quality model for the lake by the Implementation Coordinator should continue as additional data become available.

Acknowledgements

The Implementation Coordinator would like to take this opportunity to 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 2004 are contained in the Appendix A.

Jim Berridge (PLIA) deserves a special 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 taken over full responsibility of collecting the field data and has done an absolutely outstanding job with this task. He has contributed not only through his perseverance and consistency but also through thoughtful analysis of procedures and data. He always stands ready to get “just a few more samples” to satisfy the needs of Ray, Gary, and Wil. The reliability of the data would suffer without his careful and conscientious efforts. We are also appreciative of the support and assistance of both Edward Eisch and Janice Sapak (MDNR Fisheries Division) in gathering information and assuring Aaron that he has the necessary support to do the critical sampling properly.

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, and added biomass measurements. Michael Holmes and Scott McNaught are working on a project to study phosphorus release dynamics from Big Platte Lake sediments.

Meg Woller from the Leelanau Conservancy did a great job conducting the zebra mussel study.

Mark Mitchell (Contractor) and Jerry Heiman (PLIA) have been measuring the flow rates of several tributaries and collecting samples for measurement of water quality parameters.

Mike Pattison (PLIA) has done a terrific job developing and maintaining the PLIA web site.

Finally, several additional individuals associated with the PLIA have made significant contributions to this project. Tom Inman has coordinated closely with the Hatchery staff on counting the 2004 Fall Salmon Run. Sally Casey has been making weekly Secchi Depth measurements for many years. Joe Francis has been measuring stream flow and pH of the North Branch of the Platte River and the Platte River at US-31and M-22.

Monitoring Program

Objectives

The overall purpose of the monitoring program is to facilitate and support the goals of the Consent Agreement. The sampling program has the following specific objectives.

- To quantify the total phosphorus loading from the Hatchery as required by the NPDES permit for the facility and the Consent Agreement.

- To determine the volume-weighted total phosphorus concentration of Big Platte Lake to insure compliance with water quality standards.

- To support trend analyses of the water quality of Big Platte Lake and its tributary streams so that long-term changes can be identified and quantified.

- To construct mass balances for water and total phosphorus for the Hatchery, lake, and watershed to support the development of water quality models for the system.

- To support the development, calibration, and validation of the BASINS model for watershed total phosphorus loading as a function of land-use, soil type, and weather conditions to allow the full implementation of this watershed planning tool.

- To determine total phosphorus and suspended solids loads from sub-watershed basins during storm events to allow the proper calibration of the BASINS model and to determine potential high priority remediation locations.

- To support the development, calibration, and validation of a water quality model of Big Platte Lake to support the overall watershed planning efforts.

- To document changes in water quality following possible future remedial activities within the watershed.

2005 Sampling Plan

The sampling plan for 2005 involves collecting data from the Hatchery, watershed streams, and Big and Little Platte Lakes (see Figure 2). The sampling stations are shown in Figures 3 and 4. The sampling frequency of each station and the list of measured parameters are given in Figure 5.

The net Hatchery total phosphorus load to the system is evaluated by subtracting the inlet load from the total outlet loading. Measurements of flow, total phosphorus concentration, and turbidity are currently taken at five locations two times per week using both the Jug & Needle and Sigma samplers. It is recommended to maintain this regular schedule in 2005.

The tributary sampling program is designed to calculate the non-point phosphorus loading into Big and Little Platte Lakes. Measurements of flow, phosphorus, and turbidity are taken on a regular basis and during wet weather flow events. These data will allow a detailed evaluation of water quality for various hydrologic conditions, provide sub-watershed loading estimates, assist in defining high priority remediation areas, and support the calibration and validation of the BASINS watershed model.

Big and Little Platte Lakes are sampled every two weeks during the year. A Yellow Springs Instruments (YSI) meter is used to measure dissolved oxygen, temperature, pH, conductivity, and ORP. Discrete depth and tube samples are analyzed for total phosphorus, turbidity, phytoplankton, alkalinity, chlorophyll, total dissolved solids, and calcium. Zooplankton is sampled using a vertical net haul. Light penetration is measured with a Licor Light Meter. Secchi depths are measured with a standard Secchi disk.

In addition to the regular sampling program, the following are recommended.

- Weekly samples for gauge height, total phosphorus, and turbidity should be taken at the four automatic sampling sites shown in Figures 3 and 4. These samples can be taken during routine maintenance trips to the sites. These sites will significantly enhance the accuracy of upstream phosphorus loading estimates and non-point loadings within the watershed critical to calibrating the BASINS model.

- It is proposed to make a preliminary estimate of the area, density, and tissue phosphorus content of the *Chara* population in Big Platte Lake. This will complement the earlier vegetative mapping work of the MDNR and should be done in late July or early August. This measurement will allow better understanding of the impacts of macrophyte die-off on fall phosphorus dynamics in the lake.

- It is proposed to discontinue sampling Brundage Spring at the spring site. Instead it is recommended that both the Sigma and Jug & Needle methods be used at the Hatchery Building site. Samples for phosphorus and turbidity analysis should only be taken when the flow is not zero at any sampling site.

- It is proposed to measure density and tissue phosphorus content of debris on the shoreline of Big Platte Lake. These measurements should be taken at several locations multiple times during the spring, summer, and fall. The information will allow better estimates of the amount of phosphorus that can be diverted from the lake through citizen efforts to remove shoreline debris.

- The phosphorus mass balance for the Hatchery is sensitive to the amount of phosphorus contained in fish in the Hatchery, planted fish, fish stocked outside of the Platte River Basin, and in fish eggs. It is proposed that these quantities be measured and recorded on a regular monthly basis and during major plant and ship periods.

- It is possible that a low-volume high-phosphorus flow enters the pond from the routine clarifier and sludge tank overflow water. This is a possible way to obtain addition control on the phosphorus discharge from the Hatchery. Therefore, it is recommended that this site be sampled for flow, phosphorus, and turbidity every two weeks.

<u>Quality Assurance and Control</u>

Extensive efforts have been made to insure the accuracy of all of the various field and laboratory procedures. The following is a list activities and recommendations for 2005.

- CMU regularly measures the phosphorus concentration of purchased standards that have concentrations of 5 and 10 mg/m^3. The average concentration of about 160 measurements of the 5 mg/m^3 purchased standard solution was 5.001 mg/m^3 with a standard deviation of 0.013 mg/m^3. The average concentration of about 160 measurements of the 10 mg/m^3 purchased standard solution was 10.02 mg/m^3 with a standard deviation of 0.099 mg/m^3. These results are extraordinarily accurate and precise and provide strong confidence regarding the reliability of the CMU phosphorus measurements.

- In addition, CMU measures the 10 mg/m^3 in-house standard solution that is used to develop the correlation curves that relate total phosphorus concentration to absorbance. Figure 6 shows a histogram of these results and those using the purchased standards. It is seen that the re-run samples increase in concentration by about 0.4 mg/m^3 and the standard deviation increases to 0.399 mg/m^3. These increases are caused by the extra handling required to re-run the samples. It is concluded that significant errors can be introduced by increased sample handling and that the careful procedures employed by CMU are necessary to insure accuracy.

- CMU has also participated in a program conducted by the National Water Research Institute Environment Canada to test the accuracy of their total phosphorus measurements. This test required CMU to measure the total phosphorus concentration of 10 unknown samples with concentrations ranging between 2.0 and 378.0 mg/m^3. The results of this independent test (See Figure 7) demonstrate that the accuracy of CMU procedure is outstanding. Furthermore, the standard deviation for the 8.2 mg/m^3 standard for all laboratories was 1.8 mg/m^3 and 1.2 mg/m^3 for the 16.3 mg/m^3 standard. These results show that variation among laboratories is greater than the variation among the CMU repetitions.

- The YSI pH meter is calibrated with pH = 7.0 buffer solution just prior to each lake sampling. Possible drift of the instruments is measured after every use. Despite these efforts, the lake pH data for 2004 are suspect and are inconsistent with similar measurements obtained by PLIA taken at the outlet (M-22 site). One problem may be the need for regular service of the equipment. Therefore, the YSI meter should be sent to the manufacturer for annual during periods when ice conditions do not permit regular sampling. In addition, it is recommended that pH measurements of lake surface water and Platte River water be taken with the YSI, PLIA, and the new hand-held pH meters. These tests should be taken to insure all three instruments are consistent within 0.1 pH unit.

- Procedures were developed to calibrate the YSI meter dissolved oxygen meter before every use. This is accomplished using air saturated refrigerated and room temperature distilled water to simulate conditions on the bottom and surface of the lake. The dissolved oxygen concentration of these waters is measured with the air-calibrated YSI meter. The measured concentrations are compared to known values to verify the accuracy of the meter readings. This procedure has worked well and should be continued.

- The average concentration of calcium in the top 30 feet of Big Platte Lake was about 68 mg/L in 2004 as measured by CMU. This value is almost double GLEC historical measurements that average about 40 mg/L. It is recommended that CMU repeat validation of its measurement technique for calcium using purchased standards. In addition CMU should measure hardness of several samples to verify that calcium is less than or equal to total hardness.

Data Management

An ACCESS database has been developed that accommodates the current sampling at the Hatchery, in tributary streams, at lake stations, and the Hatchery weather station, and USGS. The new database contains all the 2004 data and is current with data being collected in 2005.

The Platte Lake Watershed Sampling Database consists of three components: Field, Data Manager, and Data Viewer as shown in Figure 8.

The field component is used to enter various measurements taken in the field or conducted in the Hatchery laboratory on the computer keyboard. Typical field measurements are the YSI probe data, turbidity, flow rates, weather conditions, and light attenuation with depth. The field component also records bottle numbers associated with samples and measurement instructions. The field measurements, bottle numbers, and measurement instructions are sent to the Data Manager component as small text files through email. The bottle numbers and the measurements instructions are sent to CMU. This information is sent to CMU in the form of text files using email and as hard copy sheets packed in the shipping coolers.

Laboratory results for various bottle numbers are sent to the Data Manager in the form of EXCEL spreadsheets using email. The Data Manager program imports the laboratory results and matches this information with the bottle numbers obtained from the Field component. At this point conflicts such as inconsistent bottle numbers and missing data must be resolved. Following the resolution of all conflicts the Data Manager updates and distributes the data files to the Data Viewer through email.

The main function of the Data Viewer component is to produce and analyze various reports that summarize the data in convenient forms. The Data Viewer component cannot change data entries in the database. However, the Viewer can suspend use of suspicious data temporarily or make other adjustments to facilitate interpretation of the data. The reports examined through the Data Viewer are also used to produce graph and tables for the Annual Report.

Note that despite the computer programs developed to accommodate these tasks, significant communication and coordination is required among the four components to insure that all data are correctly entered and displayed. The following section describes recent major enhancements to the database.

Major Database Enhancements

- Historical data have been added to the database for alkalinity, calcium, chlorophyll, flow, oxygen, pH, phosphorus, phytoplankton, Secchi depth, and zooplankton at Big Platte Lake, Hatchery, and stream sites. In addition, historical data have been added for the upper and lower weir for 1988 through 2005.

- The capability to compare various measurements for multiple years has been added to the database.

- The capability to perform correlation analysis for various measurements has been added to the database.

- All daily average USGS flow data for the Platte River at US 31 have been added to the database.

- Daily rainfall measurements at the Hatchery weather site have been added to the database. Periodically, rainfall is measured for phosphorus and nitrate content, and pH.

- Historical fish production and other operational data have been added to the database back to 1990.

Hatchery Operations

Renovations

The renovation of the Platte River State Fish Hatchery is now complete. The following items have been installed: headbox; covered outdoor raceways with automatic feeders and low head oxygen units; effluent management system including disc filters, clarifier and sludge storage; a partial recirculation system; a new water sampling and measurement system; and a liquid oxygen system (LOX). Nearly all of new equipment and facilities have been through 1 year of production and all are working within design parameters. The new automatic feeders will be fully operational in 2005. The new significant automatic feeders will be up and fully running in 2005. The only adjustment that had to be made was changing the disc filters from 20-30 micron filters to 40 micron filters at the end of each raceway as the smaller filters were constantly clogging and backwashing. The system is now operating properly. Other than minor adjustments to the facility, additional renovations are not expected at this time.

Hatchery Coho Loss Report

Sometime between 4 PM on March 7 and 8 AM on March 8, the main pump between Outdoor Raceways A and B stopped operating. The loss of water to Raceway B caused the loss of 458,000 yearling Coho salmon which weighed approximately 24,000 lbs. Staff discovered the loss at approximately 8 AM during a routine inspection of the raceways. These fish have an estimated replacement or production value of $330,000 at $0.70 per fish. The estimated recreational value of these fish is a minimum of $ 2 million dollars. These fish were buried on hatchery property along Brundage Creek on March 10 after consultation with DEQ and PLIA.

While investigations on the loss are still ongoing at this time, the preliminary determination on the cause of the loss indicated that the Variable Frequency Drive Controller Board failed. Additionally, programming problems caused the failure of the alarm system to detect pump failure. If the alarm system would have been activated, on-call staff would have been called in and backup pumps would have been turned on.

All of the preliminary causes of the pump failure were corrected by early April 2004. The Variable Frequency Drive Controller Board was replaced under warranty and programmed properly. The alarm system has been fully analyzed and additional alarm points have been added to the system to ensure the proper operation of the alarm system.

The loss of 458,000 yearling Coho salmon resulted in only two locations being stocked with Coho salmon. The Platte River was stocked at the hatchery on April 6th with 608,000 fish and the Anna River near Munising received 25,000 fish in mid-April. In early October 2003, the Paw Paw River near St. Joseph received 500,000 fall fingerling Coho salmon to reduce densities at the Platte River State Fish Hatchery to alleviate concerns with construction activities.

Antibiotic and Disinfectant Use

Antibiotic use at the Platte River State Fish Hatchery involved feeding oxytetracycline (OTC) to Chinook salmon to produce a readable mark on the vertebra of hatchery produced fish. The antibiotic was delivered to the fish in the form of medicated feed which was produced by Bio Oregon of Warrenton, Oregon. The OTC (TM100) was mixed in the feed at a rate of 25.11 pounds per ton of feed in 2004. A total of 6,336 pounds of medicated food was delivered and used during the marking process that occurred during the period May 5, 2004 to May 22, 2004. This compares to a total of 7,568 pounds fed during 2003. The total amount of OTC in the feed in 2004 was 79.5 pounds which compares to 95.0 pounds in 2003. The marking protocol for 2004 called for the fish to be fed the OTC food for 4 days with one day off followed by 4 additional days of the OTC feed.

No monitoring was planned during the Chinook marking of 2004 because of the results of previous years. The maximum amount fed on a given day during the treatment period was 299.2 lbs (3.7 lbs of TM100). Flow through the hatchery during the treatment period was 11.07 mgd. In 2003, the flow during the treatment period was 10.42 mgd.

Parasite-S (formalin) is used to control fungus on fish eggs. Parasite-S is a trade name for formalin that consists of 37% formaldehyde by weight in water. The standard treatment used is a 15-minute flow through with formalin at a concentration of 1 to 600 (1,667 ppm). In 2004, eight hundred seventeen gallons of Parasite-S were used to control fungus on salmon eggs during the period October 1, 2004, to January 11, 2005. This compares to 688 gallons used during the 2003 incubation season. Maximum daily treatments were 11.1 gallons per day (per 15 minutes). Hatchery flows during the period ranged from 8.69 mgd to 11.45 mgd as compared to a range of 11.83 mgd to 14.80 mgd during the 2003 incubation season.

No monitoring for formaldehyde in the discharge was done in 2003 because of monitoring results that were obtained in 1999.

During the month of August of 2004, the Hinchenbrooke strain Coho salmon in the outdoor raceways were diagnosed with an external Columnaris infection. On August 14 and 15, 2004, 1.362kg of Chloramine-T was used in a flow through treatment to clear up the Columnaris. The flow on those days was 10.04 mgd.

Weir Operations

Platte River weir operations in 2004 were similar to 2003. The Consent Agreement with the Platte Lake Improvement Association allows 20,000 adult Coho to be passed upstream of the lower Platte River weir during the fall salmon run. This number ensures that sufficient eggs and milt can be obtained in order to maintain the MDNR Coho stocking program. The agreement also allows for passage of up to 1,000 adult Chinook salmon. As in 2003, American Canadian Fisheries, Inc. of Bear Lake, Michigan, held the contract to harvest the surplus salmon. Harvested fish were trucked by Canadian American Fisheries back to their processing plant in Bear Lake.

The biological data taken from Clevenger (2004) have been entered into the database. Biological data were collected from harvested salmon by MDNR staff at the Bear Lake facility. Biological data were collected from approximately 7.5% of all harvested Coho and 15% of all harvested Chinook. Estimated numbers of fish per tote were provided to the survey crew by weir staff to allow for the proper number of fish to be examined and processed. Data collected from the sub-sample of examined fish include sex, weight, fin clips and lamprey wounds.

The lower weir installation was completed prior to August 15, 2003. Weir operations began on August 15, 2003, when the boat gate was lowered. At the request of the Platte Lake Improvement Association, the lower weir was left in place until December 15, 2003, to block passage of any late running salmon. In past years, the standard practice was to remove the weir on November 15. During the extended period of weir operation in 2003, there was only one Coho harvested, thus the run was over by November 15.

The weir was manned 8-10 hours a day during the early part of the run to pass canoes and count any salmon or trout that passed when the gate was open. The weir was manned on a 24 hour a day basis only after larger numbers of salmon began to accumulate below the weir. The weir was only manned on harvest days once the run was obviously diminished.

Salmon were passed upstream for egg-take by raising the boat gate a small amount and manually counting the salmon as they swam through. A white plate spanning the width of the boat gate was placed on the bottom just upstream of the weir to help count the salmon as they moved upstream. Two Fisheries employees did the counting, one counting adult salmon and the other counting jack salmon, steelhead, browns and other trout. A PLIA (Platte Lake Improvement Association) observer was also present and counted all fish moving upstream for comparative purposes. A total of 16,282 adult Coho, 814 jack Coho, 515 adult Chinooks and 44 jack Chinooks were also passed upstream. Adult Coho and Chinook numbers passed were very similar to 2003 (16,255 Coho and 422 adult Chinook), but the number of jack Coho passed was up by fifty-five percent. This may be an indicator of a larger run of Coho expected in fall 2005.

All surplus salmon were harvested. The number of salmon harvested was estimated by periodically counting the number of salmon in a tote and multiplying the average of these numbers by the number of totes harvested during the day. All trout encountered during the harvest were passed upstream. A total of only 1,979 adult Coho and 813 jack Coho were harvested at the lower weir along with 6,438 adult Chinook and 199 jack Chinook. The overall Coho run was reduced from that which was seen in 2003. In 2003 there were 9,013 adults harvested compared to only 1,979 harvested this year. The mean weight of adult Coho was down when compared to 2003. The adults harvested in 2003 had a mean weight of 5.72 pounds. The adults that returned in 2004 had a mean weight of 4.79 pounds.

The upper weir was installed and effectively stopped all upstream migrations of salmon by August 15, 2003. Salmon moved into the maturation ponds of their own accord and no counts of salmon moving into the ponds were made. All salmon are individually counted during egg-take and harvest operations at the upper weir. The weir is left in place over the winter and will stay in place until July (after lamprey run is over) when all boards in 2 bays are removed. A total of 12,496 adult Coho and 654 jack Coho, as well as 540 adult Chinook and 11 jack Chinook were removed at the upper weir. Note that more jack Coho were harvested than passed. This is likely due to jack Coho being hidden in among the adults when the fish were being passed in their largest numbers. The number of jack Chinook harvested is markedly smaller than the number passed. In part this is likely due to adult Coho being misidentified as jack Chinook at passage. The small percentage of passed adult Chinook harvested is a phenomenon seen virtually every year. Chinook spawn a few weeks earlier than Coho and many of those may have spawned in the river below the upper weir. This would also be true of some of the jack Chinook salmon.

Net Total Phosphorus Load and Water Use

The water used to culture the fish becomes enriched with phosphorus from fish fecal pellets and unconsumed feed as it passes through the Hatchery. The net phosphorus loading from the

Hatchery on a given day is defined as the difference between the phosphorus loading the leaves the system and the phosphorus entering the system from the three possible water sources (Brundage Spring, Brundage Creek, and the Platte River). Negative net loads are set equal to zero for calculation purposes as specified in the Consent Agreement. Linear interpolation is used to determine loads on days where no measurements were taken. The summation of daily net loads for the year gives the annual net phosphorus loading. All samples are daily composites collected using the Jug & Needle method.

Figure 9 shows the long-term changes in the annual average Hatchery effluent flow between 1990 and 2004. The long-term average flow is about 11.0 mgd. The minimum and maximum flows over this period are 7.5 and 13.0 mgd. The average flow or water use for 2004 is 9.8 mgd. This is less than the long-term average. The Hatchery's water use is about 11.3% of the total flow of the Platte River at the USGS gauge station for 2004 and about 45% of the flow from the North Branch of the Platte River for 2004.

Figure 10 shows the long-term trend in annual net phosphorus loading measured using the Jug & Needle method. Note that the 2004 loading of 158 lbs. lower than the 175 lb limit that will be in effect starting in the year 2007. Figure 11 shows a bar graph of the Hatchery net loading for each month. Higher net loads occurred in the late fall when the Hatchery accommodated the highest biomass of actively growing fish. Net loads are likely a product of high biomasses at higher water temperatures when fish are consuming the most food. Note that the net load slightly exceeded the 75 lb limit for the month of November.

Figure 12 shows the calculated cumulative net Hatchery phosphorus loading for 2003 and 2004 (J/N). Note that spring and early summer loads in 2004 were low because of the low biomass of fish in the Hatchery due to the March loss. In addition, 2004 lacked elevated summer loads due to construction activities. The low loading in 2004 is the result of the facilities renovation program and efficient management.

Figure 13 shows the flow, turbidity, and phosphorus of various Hatchery sources and discharges. Note that most of the water used by the Hatchery came from the Brundage Creek in 2004 and very little came from the Platte River, as was anticipated and planned for during the Hatchery renovation. Brundage Spring had the highest phosphorus concentration, and the Platte River had the lowest average value. Brundage Creek had the highest turbidity and Brundage Spring the lowest.

Evaluation of Automated Sampling Equipment

The concentrations of total phosphorus and turbidity of the inlet and outlet flows from the Hatchery are currently sampled using two methods. For several years a composite sample has been taken using a jug equipped with a fine gage needle that slowly allows water to enter the jug. Sigma Samplers were recently installed in association with the renovation program. These samplers obtain a 24 hour composite sample by pumping sub-samples at regular intervals.

Figures 14 and 15 show the measured values of phosphorus and turbidity of the Brundage Creek input water using the Jug & Needle and Sigma methods. Note that high spikes in phosphorus concentration are almost always associated with spikes in turbidity for both methods. Figures 16 and 17 compare the phosphorus concentrations and turbidity of the Brundage Creek intake water sampled with the Jug & Needle and Sigma methods. Note that although long-term average values of the two methods are similar, the phosphorus and turbidity spikes do not always occur on the same days for the two methods. This suggests that on a given day different water samples are being taken. It is also noted that the location of the influent stream samplers are not exactly the same. Note that similar analyses can be conveniently performed on the other water sources. Figures for these cases are not presented here for the sake of brevity, but can be viewed using the Data Viewer.

Figures 18 through 22 are correlations between phosphorus concentration and turbidity for all Hatchery locations. Note that the correlations are quite poor except for Brundage Creek despite the fact that many of the dynamic plots in Figures 14 through 17 suggest that the two sampling methods often give similar results. Figure 23 show results of the 2-tail Student t test for phosphorus and turbidity for 5 Hatchery sampling locations for both J & N and Sigma sampling methods. This test shows that the turbidity at the five locations measured with the J & N method is different than the Sigma measurements. The mean phosphorus concentrations at the three inlet locations are somewhat similar, but the two outlet concentrations are statistically different. The overall results are inconsistent and it is difficult to reach any general conclusion regarding the two sampling techniques at this time.

Figure 24 summarizes the concentrations and loading calculated using each method. Note that Sigma phosphorus indicates that pond is contributing phosphorus, whereas J & N shows removal, although both methods show removal of turbidity. Because the differences are significant and the explanation elusive, it is recommended that samples be taken using both methods and analyzed for phosphorus and turbidity. The Sigma Sampler inlet tubes should be cleaned regularly. The official Hatchery loading should be calculated from Jug & Needle total phosphorus measurements until sample values from both techniques are found to not be significantly different or all parties agree that the Sigma sampler is providing superior data.

Hatchery Fish Production and Phosphorus Mass Balance

The purpose of this section is to examine the annual total and monthly variations of food use and fish production at the Hatchery. In addition data are presented that show the ultimate fate of the fish being produced. All of the major sources and sinks of phosphorus that enter or leave the Hatchery are estimated and compared for the purpose of gaining a better understanding of how these processes affect the net total phosphorus loading and ultimately the water quality of the Lake. This analysis also provides a quality control check on all of the hatchery related phosphorus and flow data being collected.

Monthly fish production data for 2004 are shown in Figure 25. Annual summaries are illustrated in Figure 26. The Hatchery produced 81,471 lbs. of fish in 2004 using 66,138 lbs. of feed. The total mortality losses in 2004 were about 15% of the total production. The remaining 46% of the production were either shipped outside of the watershed or planted in the Platte River. Note that the ratio of food fed to annual production is less than 1.0. This is part of an industry trend as reported by Hardy (2002) and shown in Figure 27. In the 1970s, 1 to 2 pounds of food were used to produce a pound of new fish biomass. This ratio has decreased such that only about 0.8 pounds of food are required to produce a pound of fish. The long-term decreasing trend is apparent and reflects greatly improved food mixtures and feeding practices.

Figure 28 shows monthly data for fish production and net growth rates for 2004. The percent net growth of fish over any month period is calculated according to Equation 1.

% Net Growth = 100*(Net Growth for the Month) / (Average Fish in system during the Month) (1)

where:

Net Growth = Fish present in system at end of month + mortalities + fish planted + fish shipped – fish present in system at beginning of month (2)

These calculations are illustrated for August 2004 in Figure 28. The maximum growth rate is usually occurs in May or June attains a maximum value of approximately 80% per month. Winter values decrease to about 10% per month.

Figure 29 shows the growth rate of the fish and the feeding rate as functions of time for several years. Note that the magnitude and annual variation of the feeding rate and growth rate are similar. This indicates that close to 100% of the food fed is being converted into new growth during these periods.

The following are the major sources of phosphorus to the Hatchery:

- Brundage Spring
- Brundage Creek
- Platte River
- Fish food
- Fish eggs
- Fish present in Hatchery at beginning of the year

The following are the sinks or losses from the system:

- Waste sludge
- Upper discharge
- Losses to the pond sediments
- Fish planted into the Platte River
- Fish shipped from the Hatchery
- Fish mortality (morts)
- Fish remaining in the Hatchery at end of the year

Note that fish present in the system at the start of the year is a source of phosphorus, and that fish remaining in the system at the end of the year is a sink of phosphorus.

Figure 30 shows the overall phosphorus mass balance for the Hatchery in 2004. All terms are expressed as the phosphorus equivalent to facilitate comparison. These calculations assume that fish biomass is 0.4465 % phosphorus by wet weight and that fish eggs are 1.3 % phosphorus by wet weight. Note that 74.6 pounds of phosphorus was trucked away from the solids tank in July 2004. It is estimated that the total loss of trucked phosphorus for 2004 is 91.9 pounds based on splitting the total trucked in July 2004 between 2003 and 2004 and the number of days in operation in each year. Also an amount was extrapolated to the end of the year. This estimate will be adjusted after the next time the tank emptying.

Figures 31 and 32 provide additional detail on this point. The phosphorus from three organic sources (feed, start of the year, and eggs) totals 1,324 pounds. Approximately 945 pounds are converted to four organic sinks (morts, plants, shipped, and end of the year). The remaining organic phosphorus of 379 pounds and the tributary phosphorus from the three input streams is the excess phosphorus in the system. This phosphorus leaves the system through three possible pathways (transport from the solids thickening tank, lost to the bottom of the pond, or discharged through the outlet). Note that about 105 more pounds of phosphorus are calculated to enter the system than is discharged. This is only about 6% of the overall amount of phosphorus that is processed annually by the Hatchery. This close agreement suggests that the overall process is well understood and that accurate measurement techniques are being employed. Better estimates of the storage tank phosphorus volumes and phosphorus concentrations as well as the phosphorus content of the eggs and fish might allow even more accurate estimations in 2005. It is therefore recommended that the phosphorus in eggs and fish tissue be measured monthly when possible.

Tributary Flows and Water Quality

Flow Rates

Figure 33 shows the long-term trend of annual average flow of the Platte River measured at the USGS station at US 31. The average Platte River flow at the USGS station was 134.3 cfs in 2004. This flow is slightly higher than the long-term average flow of 126.5 cfs since 1990. Thus, 2004 can be characterized as a slightly wetter than average year. Figure 34 shows the daily hydrograph for the Platte River at the USGS gage station and the Hatchery rainfall for 2004. Note that the hydrograph is relatively uniform with the peak spring flows being about 75% greater than the summer low flows. Several spikes in flow correspond to significant rainfall events. Note in Figure 35 that the sampling dates for 2004 correspond closely to some of these wet weather spikes. The average of the flows on the actual sampling days was 5% higher than the average of all the daily flows.

Figure 36 show the results of measurement of flow and gauge height at the Stanley Creek and the North Branch of the Platte River sites. Note that good correlation between flow and gauge height at a site allows easy estimation of flow without actual in-stream measurement. These correlations will be particularly useful to estimate flow during storm events using recorded gauge height. Historical estimates of flow at minor tributary sites can be attained using correlations between flows at any site compared to the measurements on the same day at the USGS US-31 location. This capability will be useful for the development of the lake water quality models.

Figure 37 summarizes the results for all tributary sampling locations. Note that the correlations between flow at a site and the gauge height at that site are excellent except for Stanley Creek. Furthermore, the correlation between the measured instantaneous flows at various sites correlates very well with the daily average flow at the USGS station on the Platte River except for the North Branch site.

Phosphorus Concentrations

Figure 38 shows measured total phosphorus concentrations in the Platte River at the USGS station at US-31in Honor for 2004. Note that baseline concentrations in the spring are around 16 mg/m^3 and about 10 mg/m^3 in the summer. The average phosphorus concentration increases to about 40 mg/m^3 during periods of high flow in the spring and during storm events in the fall.

Figure 39 summarizes measured phosphorus concentrations during 2004 for all sites using both Dip and Auto methods. Note that the total phosphorus concentration measured during high flow periods is typically two to three times higher than during dry baseline flows. Note that the average concentrations of the Platte River at Pioneer Road and at Collison Creek are unusually high. It is recommended that 2005 sampling efforts focus on these locations. Mathematical correlations between flow and phosphorus concentration await collection of additional data.

Storm Event Sampling

Figure 40 shows an example of data collected at Brundage Creek with automatic sampling equipment. Note that order of magnitude increases of phosphorus and turbidity are associated with relatively small increases in flow gauge levels. The duration of such events is several hours. Note that gauge levels have been converted into flow rates using correlations developed from the 2003 and 2004 measurements. Thus, non-point loads based on routine measurements alone may underestimate the actual non-point load because many spikes are missed. Furthermore, the magnitude of the phosphorus loads associated with just these events may exceed the annual phosphorus load from the Hatchery. Thus, it is important that the tributary monitoring program and the BASINS modeling effort accurately evaluate the non-point total phosphorus loads in the system. Eventually it is planned to estimate of the transport of phosphorus during storm events. This will be used to determine the percentage of the overall phosphorus budget contributed by storms.

Big Platte Lake Water Quality

Total Phosphorus

Trend Analysis. Figure 41 shows long-term trend data for a number of parameters that may affect the total phosphorus concentration of Big Platte Lake. Note that the median concentration of total phosphorus of Big Platte Lake was exceptionally low for the years 1997 through 2000. The concentration during this period was about 1.5 to 2.0 mg/m^3 lower than might be expected based on trend analysis. It is important to determine if the period of low measured concentrations is associated with decreased Hatchery loads, unusual weather conditions, or unique ecological factors, or perhaps an artifact of the sampling and laboratory procedures.

Figure 42 shows a plot of total phosphorus concentrations for several locations starting with Brundage Spring and progressing downstream to Big Platte Lake. Note that the concentrations at all six locations are low during 1997 through 2000. Furthermore, all six concentration plots generally increase between 2001 through 2004. It is not expected that total phosphorus concentrations in the Hatchery input streams such as Brundage Spring should increase by 50% because the watershed is stable. Furthermore, it is not expected that the total phosphorus concentrations of these streams could be as low as 7.4 mg/m^3. In addition, it has been demonstrated (Figure 43) that GLEC total phosphorus concentrations are systematically lower than CMU measurements, especially for concentrations below about 10 mg/m^3. It is concluded that the low total phosphorus concentrations observed in Big Platte Lake between 1997 and 2000 are likely the results of inconsistent laboratory procedures rather than the result of lower Hatchery or non-point loads to the lake. Finally note in Figure 44 that changes in the total phosphorus concentration in Big Platte Lake are not well correlated with Secchi depth or the annual average flow of the Platte River into the Lake.

2004 Data Analysis. The annual variation of volume weighted total phosphorus in Big Platte Lake in 2004 is shown in Figure 45. 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 average annual volume-weighted total phosphorus concentration was 7.1 mg/m^3. There were 80 days in 2004 when the total phosphorus concentration exceeded the 8.0 mg/m^3 goal. This corresponds to about 78% attainment as compared to the 95% requirement.

Dissolved Oxygen Depletion

Figures 46 and 47 show that the annual variation of temperature and dissolved oxygen at eight lake depths. As expected, dissolved oxygen depletion in the hypolimnion of Big Platte Lake is closely related to temperature stratification. Figure 47 shows spring overturn on day 95, some stratification for about 30 days, and complete mixing again on day 125. Fall turnover is complete on day 290. Thus, the lake was stratified for about 165 days during 2004. Figure 47 illustrates that the bottom water dissolved oxygen concentration decreases rapidly with the onset of spring stratification. The concentration of dissolved oxygen drops below 2 mg/L in waters deeper than 90 feet for 103 days in 2004. This is an important period because this is when it is expected that dissolved phosphorus will be released from the sediments. Shallower water experience shorter periods low dissolved oxygen conditions as shown. These data are used to calculate the phosphorus release from the sediments in another section of this report as shown in Figure 72. The calculations account for the area of sediment exposed to low oxygen conditions for varying periods of time. This internal loading of phosphorus will be compared to both non-point and point sources and used by the lake water quality model to simulate the annual dynamics of phosphorus in the lake. Ultimately, the magnitude of the internal source of phosphorus will be used to determine how quickly the lake will respond to changes in input phosphorus loadings.

Light Attenuation

Secchi depth is a common and simple method used to measure water clarity and light attenuation. Figure 48 shows the maximum, average, and minimum Secchi Depth for 1990 to 2004. Note the recent upward trend of the average Secchi depth, particularly in 2004. This increase may be the result of clearing of phytoplankton by the recently established zebra mussel population. Relatively low Secchi depths occur around day 220 (August 8). Water clarity, as characterized by measurements of Secchi Depth is an important indicator of water quality conditions in Big Platte Lake. However, this measurement of water transparency is often inconsistent and inaccurate. Therefore, LICOR light measurements are made function of depth and are used to calculate the extinction coefficient. Note that the maximum Secchi depth (Figure 49) occurs around day 180 and corresponds to the minimum extinction coefficient.

Marl lakes such as Big Platte Lake may precipitate calcium carbonate causing high turbidity and low Secchi depth. Such events are usually associated with high pH conditions that occur during periods of intense algal activity. The Saturation Index is used to evaluate the potential for calcium precipitation. It is a function of temperature, pH, alkalinity, calcium, and total dissolved solids. Positive values of the Saturation Index characterize conditions that favor the precipitation of calcium carbonate, whereas negative values indicate dissolution of calcium carbonate. The calculated Saturation Index is compared with various measures of water clarity for 2004 in Figure 50. Note that periods of low water transparency do not correspond to periods when the Saturation Index is a positive number. This suggests water transparency in Big Platte Lake is not affected by calcium carbonate precipitation. However, the Saturation Index is a strong function of pH. Data for 2003 and 2004 pH are shown in Figure 51. Note that surface water pH values in 2004 are extremely low (below 7.0) and are inconsistent with 2003. This situation is highly unusual for a marl lake and suggests that the YSI pH measurements are erroneous. It is recommended that the YSI pH meter be sent to the manufacturer for maintenance. It is also recommended that a second pH meter be purchased and independently calibrated and used to verify YSI pH measurements.

Plankton Abundance

The abundance and diversity of zooplankton and phytoplankton can provide insight and a more thorough understanding of nutrient and water clarity dynamics and long-term changes in the productivity of Big Platte Lake. The easiest way to estimate the quantity of phytoplankton in the lake is through measurements of chlorophyll a. Figure 52 shows the seasonal variation of chlorophyll in the top 30 feet of water in Big Platte Lake. High chlorophyll values were documented near day 120 and 225. Also observe that samples filtered at the Hatchery are about 50% higher than those filtered at the CMU laboratory. This is result of the deterioration of the samples between the time they are collected from the lake and the time the samples are filtered at the CMU laboratory.

A better way to measure plankton abundance is through direct measurements of numbers and biomass. Currently, phytoplankton is sampled every two weeks with a 2-cm diameter rubber/silicone tube dropped vertically through the epilimnion (where algae are most abundant). Three tube samples should be collected from separate locations off the boat. These composite tube samples are also used to measure chlorophyll and other water quality parameters. Algal numbers are determined by direct counts using a microscope. Algal biomass is determined by multiplying algal counts by the size of an individual and the appropriate weight for the individual species at that size. Additional details are provided in Appendix B.

Zooplankton is collected every two weeks with a 30-cm diameter 64 micron mesh net. Rotifers are accurately sampled with this net. Zooplankton numbers are determined by direct counts using a microscope. Biomass is determined by multiplying zooplankton counts by the size of an individual. Additional details are provided in Appendix B.

Figure 53 shows that phytoplankton biomass closely mirrors chlorophyll a concentrations and roughly similar to turbidity. Figure 54 shows phytoplankton numbers and biomass. Golden and green are the most abundant in terms of number throughout much of the year. On the other hand, diatoms are dominant in terms of biomass because of their relatively large size. There are two major diatom and green peaks in the spring and summer, and a blue green peak in late summer. Additional details are provided in Appendix B.

Figure 55 shows zooplankton numbers and biomass. Rotifers are most common in number and while cladocerans and copepods contribute the major biomass. There are two cladoceran peaks and one copepod peak. Additional details are provided in Appendix B.

Figure 56 shows a food web for Big Platte Lake. Figure 57 shows the biomass of edible phytoplankton (all type except blue-greens), herbivores (cladocerans, rotifers, and Nauplii), and carnivores (copepods). It is seen that spring diatom bloom is followed by an increase in zooplankton. Low zooplankton biomasses are associated with the bloom in the summer. Note that the phytoplankton is also filtered by zebra mussels acting in competition with zooplankton. Finally, that the composition of the zooplankton community is affected by the presence of fish that crop off the larger zooplankton. The interactions between phytoplankton and zooplankton species is discussed in more detail in Appendix B.

Special Studies

Overview

The development, calibration, and final validation of the BASINS watershed loading model and the water quality model for Big Platte Lake will be based on the Hatchery, tributary, and lake monitoring data described above. However, it is also important to enhance the model reliability by conducting special studies that will provide direct estimates of some of the model coefficients that are independent of the regular monitoring data. These special studies are described below.

Macrophyte Abundance

Hass (2003) mapped the distribution of biomass and density of common macrophytes in Big Platte Lake. However, the study did not include measurements of *Chara.* It is recommended that a survey be conducted in July or August 2005 to estimate the area, density, and tissue phosphorus of *Chara* in Big Platte Lake. These measurements will help make estimates of the impact of this species on phosphorus mass balance and dynamics.

Sediment Studies

Michael Holmes and Scott McNaught from CMU are working on a project to study sediment oxygen demand and phosphorus release dynamics of Big Platte Lake (see Appendix D). The overall objective is to measure and characterize phosphorus release and oxygen uptake in the sediment from different locations and times of the year and determine the influence of different sediment types. Sediment cores are taken at several sites (Figure 58) and stored on ice prior to conducting phosphorus release and oxygen uptake experiments. All sediment cores were incubated (Figure 59) in the dark at temperatures similar to the current hypolimnion. Measured parameters include chemical oxygen demand (COD), total organic carbon (TOC), volatile solids (VS), grain size (GS), and total sediment phosphorus (total phosphorus).

The oxygen uptake experiments will be conducted using procedures suggested by Gardiner (1984). Water overlying the sediment is saturated with dissolved oxygen and the decrease in concentration recorded over time. Figure 60 shows preliminary results for SOD in Big Platte Lake. The SOD typically ranges between 1.0 and 1.5 $gmO_2/m^2/day$. These are values consistent with data from other lakes similar to Big Platte Lake. Note however that the SOD varies with location and with the time of year.

The phosphorus release experiments are handled similarly to studies done by Kamp-Nielson (1974) and Penn et al. (2000) in which phosphorus release was monitored under both oxic and anoxic conditions. Preliminary phosphorus release rates measured in Platte Lake show that they vary with location in the lake and time of year (see Figure 61). Maximum values occur in the late summer and fall and typically range from about 0.2 to 1.5 mg P $/m^2/day$. These values are somewhat lower than values for similar lakes. The low release rates may be affected by the high marl content of the sediment although such interactions have not been documented in the scientific literature.

The sediment studies are expected to be completed by the end of 2005. At this time it will be possible to refine the estimates of the significance of sediment release on the overall phosphorus budget for the lake as shown in Figures 70 and 72.

Zebra Mussel Study

Zebra mussels (*Dreissena polymorpha*) are known to have widespread ecological impacts in freshwater systems. Such impacts include increases in underwater light penetration, macrophyte growth, benthic productivity, mortality of native clam species, and the frequency and intensity of cyanobacterial blooms. The respiration of zebra mussels can also be a significant oxygen demand (Canale and Chapra, 2002).

Zebra mussels are efficient filter feeders. Each adult mussel can filter greater than one liter of water per day, consuming primarily detritus and phytoplankton (Stegemann 1992). Recently, an increase in cyanobacterial blooms, particularly the species *Microcystis aeruginosa*, has been observed in southwest Platte Lake. Such blooms are believed to be promoted by zebra mussel activities (Raikow 2004); in fact, the density of *M. aeruginosa* can be linked to zebra mussel population filtering capacities (Keilty and Woller, 2004). Zebra mussels reject *M. aeruginosa* as unpalatable while consuming their competitors (Vanderploeg et. al 2001). The purpose of this study was to assess the zebra mussel population at specific locations in Big and Little Platte Lakes and estimate their impact on phytoplankton assemblages (see Appendix E).

Zebra mussels were sampled at 13 sites in Big Platte Lake (Figures 62 and 63). No zebra mussels were found at several locations in Little Platte Lake. Zebra mussel densities were determined by dividing the counts at individual sites by the area of the collection device used at each site. Means zebra mussel shell lengths ranged from 4.3 to 14.0mm. Regression analyses showed that zebra mussel shell length related to water depth (Figure 64), with larger zebra mussels associated with deeper water. This suggests that older zebra mussels tend to populate deeper waters, although such a conclusion is tentative given the limited nature of this study.

Several studies have estimated zebra mussel filtering rates, such as Reeders et. al (1993), Stegemann (1992), and Canale and Chapra (2002). These estimates of filtering rates can be used to estimate the filtering capacity of the zebra mussel population (FC), based on the size of the population (Z), the filtering rate of the individuals (f_z) and the volume of water being filtered (V).

$$FC = V / (f_z Z) \quad (3)$$

FC is equivalent to the time necessary to filter V and was calculated here using the measured zebra mussel density assuming a filtering rate of 1.0 L/ind/day. The calculated filtering capacity of Big Platte Lake is 7.9 days. The maximum *M. aeruginosa* density in Big Platte Lake was 2,562 cells/mL on July 28, 2004. These values are shown in Figure 65 along with results for several lakes in Leelanau County. These results indicate that the filtering activities of the zebra mussels are likely to reduce the populations of diatoms and green algae and enhance the population of blue green species such as *M. aeruginosa.*

The population of zebra mussels in Platte Lake is likely changing as a function of time and is unevenly distributed; therefore the results of this study should be treated as approximations and the best estimate available at this time. Greater accuracy could be attained by repeating the study with additional sites in future years. The cyanobacterial blooms promoted by large populations of zebra mussels may produce the hepatotoxin, microcystin. Samples from Big and Little Platte Lake should be tested for microcystin using field kits produced by Envirologix. If such testing shows elevated levels of toxin, further evaluations should be conducted.

Bio-Availability

Laboratory tests should be performed to determine the bio-availability of different point and non-point sources of phosphorus. These include the hatchery effluent, the upper Platte River, major tributaries within the watershed, Platte River water at the inflow to Big Platte Lake, and small local drainage that discharge directly to the lake. The tests should measure the growth rate of a test algal species to determine the growth potential of various sources of phosphorus.

Watershed Modeling

Non-point phosphorus loads from Platte River watershed are being analyzed using the Better Assessment Science Integrating Point and Non-point Sources (BASINS) approach. This is an integrated multipurpose environmental analysis tool was developed by the U.S. Environmental Protection Agency's (EPA's) Office of Water. It comprises of a suite of interrelated components that perform various watershed analyses (USEPA, 2001). A powerful element of BASINS is the Hydrological Simulation Program – FORTRAN (HSPF). HSPF is a lumped parameter watershed and stream model that is well suited for modeling non-point phosphorus loads from the Platte River drainage basin.

BASINS can be used to simulate non-point pollutants coming off the land. It can also predict the consequences of future land use management scenarios by simulating the generation and movement of pollutants such as sediment and phosphorus from multiple sources in the watershed. These results can be used as inputs to a water quality model for the Big Platte Lake. In this way the BASINS and lake models can be used to help assess the impacts of both point sources from the Hatchery and non-point sources such as agricultural operations, forests, and land developments. Figure 66 illustrates the overall approach.

The BASINS model has been calibrated for baseline conditions by LimnoTech. The calibration must be extended to include recent storm event and tributary measurements as well as detailed local weather data to fully implement this valuable watershed planning tool.

Lake Water Quality Model

Overview

A comprehensive water quality model for the lake is necessary to provide the capability to predict the effects of the non-point total phosphorus loads from the watershed (as determined by BASINS) and the hatchery total phosphorus loads on the water quality of Big Platte Lake. It is important that the model accurately simulate light attenuation (extinction coefficient or Secchi Depth), algal production, dissolved oxygen concentrations, and the internal loading of phosphorus from the sediments. This model will be used to estimate the effectiveness of various remedial control measures designed to promote compliance with the water quality goals of the lake.

Water quality models for Big Platte Lake have been developed by in the past by Canale et al. (1991), Chapra (1996), Lung (2000), and Walker (1998). Unfortunately, these models do not adequately address exchange processes between the water and the sediments and do not include dissolved oxygen or Secchi Depth as model variables. Thus, these models must be improved before they can be used to accurately forecast changes in the water quality of Big Platte Lake.

Watershed and Lake Phosphorus Mass Balances

The first step in the developing a water quality management tool to calculate annual average balances for water and phosphorus for the lake and watershed.

Figure 67 and 68 show a preliminary water balance for 2004 in terms of average flow rate from various sources in units of cfs. The non-point and tributary flows are based on 1997 BASINS calculations. This was used because 1997 is a typical water year and BASINS model runs for 2004 have not been made. Other values such as the flows to and from the Hatchery are based on 2004 direct measurements. Historical data from the Kenaga and Evans (1982) and a few tributary measurements are included for comparison. The data collected by various investigators are relatively consistent except for Collison Creek. Special emphasis will be place on obtaining accurate measurements for this tributary in coming months.

Figures 69 and 70 illustrate a preliminary watershed mass balance for phosphorus in terms of lbs/yr for 2004. Sediment retention is based on subtracting the lake outlet phosphorus from the total inputs. The retention of 61% is consistent with other oligotrophic lakes (Chapra, 1997). An estimated settling velocity of 56 m/yr is based on a settling area below 30 feet in depth and the average lake phosphorus concentration. The calculated settling velocity is consistent with other values determined in similar modeling studies (Chapra, 1997).

The non-point loads are based on the 1997 BASINS model as described above. Hatchery loads are based on 2004 measurements. Figure 71 shows calculations for estimating the phosphorus associated with fish lost between the lower and upper weirs. The phosphorus lost is the difference between the fish passing the lower weir and those that are collected at the upper weir times the percent phosphorus in the fish flesh (0.4465%). This is likely an overestimate as some fish are taken by anglers. Figure 72 shows calculations for planted fish the using measured mass of planted fish and assuming 10% are lost in the lake. Figure 72 also shows the estimated atmospheric phosphorus loading calculated by multiplying the annual rainfall for 2004 times the surface area of the lake times the average of measured rainfall phosphorus concentrations. The macrophyte load consists of fall senesce plus continuous sloughing and excretion. Senesce is calculated as the product of the macrophyte biomass times the measured percent phosphorus of 1.3%. A first-cut approximation of the sloughing and excretion component is the measured biomass divided by two, times a 90 day growing period, times an excretion rate of 0.05 per day as obtained from the literature. Figure 72 shows calculations of phosphorus release from the sediments. The release rate is taken directly from the Holmes measurements and the duration of the period when the dissolved oxygen is less than 2 mg/L as observed from direct measurements for various lake depths.

The estimates of various sources and sinks of phosphorus shown in Figure 72 are components of the phosphorus budget for Big Platte Lake as shown in Figure 70. This model will be refined following Figure 73 that shows various model kinetic components. These model mechanism are chosen to allow accurate modeling of phosphorus, water clarity, and dissolved with minimum model complexity.

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Appendices