Annual Report for the Year 2001

CONSENT AGREEMENT

Concerning

Operation of the Platte River Hatchery

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Overview for the Year 2001

The goal of the Consent Agreement (see Appendix 1) is implement a long-term strategy to restore and preserve the water quality of Big Platte Lake (see Figure 1). This goal will be advanced by minimizing the flow and phosphorus discharge from the Hatchery and by implementing strategies to reduce non-point phosphorus loads from the watershed. Table 1 shows the annual total phosphorus load from the Hatchery since 1990 as well as the flow of the Platte River at the USGS gauging station on US-31. This table also shows the volume-weighted total phosphorus of Big Platte Lake and the percent of the time the concentration exceeds the water quality standard of 8.0 mg/m^3.

The net Hatchery total phosphorus load for the year 2001 was 212 lbs. This is not in compliance with the interim standards of 210 lbs. The maximum loading for any three-month period was 81 lbs. This is also not in compliance with the interim standard of 75 lbs. as defined in the Consent Agreement. However, the Hatchery is currently in the final design phases of a major renovation program that is expected to reduce the Hatchery total phosphorus loading. In addition, measurements taken during 2001 show that the final settling ponds are often a source rather than a sink of phosphorus. Studies are underway to help understand the causes of this undesirable situation and to determine corrective measures to improve the removal efficiency.

A total of 18,423 adult Coho and 42 adult Chinook salmon passed the Lower Weir in 2001. Any excess salmon that accumulated at the lower weir were harvested, counted, and removed from the watershed. A total of 14,946 adult Coho salmon were harvested for egg collection at the Upper Weir. This is approximately 81% of the Coho that passed through the Lower Weir. A total of 43 adult Chinook salmon were harvested at the Upper Weir. This is essentially the same as the number that passed through the Lower Weir. The numbers of adult Coho and Chinook salmon that passed the Lower Weir in 2001 are in compliance with the Consent Agreement.

The annual-average volume-weighted total phosphorus concentration of Big Platte Lake was 7.5 mg/m^3 in 2001. The water quality standard of 8.0 mg/m^3 was exceeded on 120 days or approximately 33% of the time. This is not in compliance with the goal of 95% attainment. The violations were primarily the result of unusually high Lake total phosphorus concentrations that occurred during May, June, October, and November of 2001. It is not clear why the water quality of the Lake declined in 2001 compared to recent years. However, high numbers of decaying alewife were seen in 2001 that likely contributed to the elevated total phosphorus concentrations in the spring.

The average 2001 Platte River flow at the USGS station was 113 cfs (See Table 1). This flow is about 10% higher than the last two years but less than the average flow of 123 cfs since 1990. Thus, 2001 can be characterized as a moderately dry year.

The Hatchery staff has taken over the job of sampling the Hatchery, tributary streams, and the lake. Laboratory analyses are now being conducted by CMU, replacing GLEC in an effort to reduce costs. The Hatchery, tributary, and Lake sampling strategy is currently under comprehensive review. The new sampling program must be provide for the requirements of the Consent Agreement and support the development of watershed and lake water quality models, and be consistent with overall cost limitations.

A Microsoft ACCESS database is being designed to maintain the Hatchery, tributary, and Lake data. This database will accommodate all historical and future data. It is important that the data be screened for accuracy and consistency. The database will have improved data retrieval capabilities that will facilitate a much-needed comprehensive analysis of the data.

LimnoTech has completed several initial steps toward the development of the BASINS watershed model. This has resulted in the preparation of a useful watershed map that shows selected sub-drainage areas and the proposed sampling stations for 2002.

A one-layer dynamic mass-balance model for lake total phosphorus has been completed. The model has been used to estimate the magnitude of total phosphorus loads needed to simulate the elevated lake phosphorus concentrations that occurred during the spring and fall of 2001. Some of these loads were not measured as part of the regular sampling program but are needed to obtain agreement between the model and the measured data. These analyses were performed as a first step in understanding complex processes that effect the water quality of the lake.

In addition an empirical model has been developed that relates Secchi Depth to chlorophyll levels and the Saturation Index for 2001. The preliminary results indicate the need to analyze data for other years and conduct the proposed light attenuation special studies. These efforts will expand when the database is completed.

Significant coordination continues with the Benzie Conservation District regarding wet weather sampling and development and application of watershed model. It is expected that the District will have a major role in further funding of the BASINS model effort and will eventually use the model to assist with the implementation of remedial activity.

An excellent spirit of coordination, cooperation and communication has been maintained between the Implementation Coordinator and the parties.

Hatchery Operations

Flow

The Consent Agreement commits the Hatchery to minimize the volume of its flow and to maintain accurate flow measurements. The Hatchery staff currently measures weir height at the outlet location and allocates the total outflow among Brundage Creek, Brundage Spring, or the Platte River. Flow and recycle processes in the Hatchery are currently under comprehensive review as part of the ongoing renovation project.

Total Phosphorus Loads

The Consent Agreement states that the interim Hatchery load will be limited to a maximum of 210 lbs. for the pre-construction period including the year 2001. In addition, the maximum allowable phosphorus load should not exceed 75 lbs for any three consecutive month period. The net Hatchery loading for 2001 was 212 lbs. The maximum load for any three-month period was 81 lbs. These loads do not comply with the Consent Agreement. Appendix 2 contains the data and describes the method used to calculate the loads. Note that linear interpolation was used in the spreadsheet to determine loads for the end or beginning of each month.

Figure 2 and Table 1 show the long-term pattern of decreasing Hatchery total phosphorus loads from 1980 to 2001. Note that the Hatchery total phosphorus load has increased slightly during the past five years. However, the total phosphorus loads during recent years are only about 25% of the loads that occurred during the early 1990's. The water quality model currently planned should be capable of accurately simulating the water quality impacts of this long-term trend of decreasing Hatchery loads.

Figure 3 shows a bar graph of the Hatchery loading for each month for 1998 through 2001. Note that loads are usually higher in the spring and fall when the Hatchery has the highest biomass of actively growing fish. The maximum load occurred during October in 2001. This is also a time of the year when Lake total phosphorus concentrations are often elevated (see discussion below). It is important to have a quantitative understanding of the relationship between higher Hatchery loads during the fall and the elevated fall Lake total phosphorus concentrations. This understanding may be facilitated by the planned water quality model of the Lake.

Weir Operations

The 2001 weir operations have remained similar for the past two years. The Lower Weir was closed from August 15 until November 14, except for brief periods to allow for passage of boats and canoes and to allow salmon to migrate upstream for egg collection activities at the Upper Weir.

Salmon were released upstream by raising the boat gate a small amount and manually counting the salmon as they passed. Two Hatchery employees and one PLIA observer performed independent counts that were in close agreement. A total of 18,423 adult Coho and 42 adult Chinook salmon passed the Lower Weir in 2001. The number of salmon harvested was also estimated by periodically counting the number of salmon in a tote and multiplying the average of these numbers by the number of totes harvested. All harvested salmon were removed from the watershed.

The Upper Weir stops further upstream migration of salmon after August 15. All salmon were collected and individually counted during the harvest and egg collection operations at the Upper Weir. A total of 14,946 adult Coho salmon were harvested at the Upper Weir in 2001. This is approximately 81% of the number of salmon passed through the Lower Weir. A total of 43 adult Chinook salmon were harvested at the Upper Weir or essentially 100% of the number passed at the Lower Weir. Appendix 3 contains a report that describes the operation of the Lower and Upper Weirs in more detail.

Figure 4 illustrates the amount of phosphorus associated with fish that are not captured at the Upper Weir. The phosphorus content of the fish was estimated by multiplying the number of fish by the average weight of an individual fish and converting to phosphorus assuming that the wet tissue contained 0.4465 % phosphorus. In 2001 about 543 lbs. of fish phosphorus was released into the Lake through the Lower Weir. A total of approximately 98 lbs. or 44 kg. of this phosphorus was lost and not harvested at the Upper Weir. This lost phosphorus either remains in the lake and thereby representing a loading to the system, or fishermen could remove it. An accurate creel census may help establish the amount of phosphorus removed from the system by fishermen. The planned water quality model of the Lake should be capable of estimating the impact of phosphorus contributed as decomposing fish tissue on the water quality of the Lake during the fall.

Note from Figure 4 that the largest difference between fish passed into the Lake and fish harvested at the Upper Weir occurred in 1999. However, observe from Table 1 that the some of the highest water quality conditions in the Lake were measured in 1999. This suggests that there may be only a weak link between TP lost in fish and Lake water quality. However, this issue is still open to careful analysis and must await completion of the water quality model.

Plant Renovations

The Platte River State Fish Hatchery will undergo a major renovation during the 2002-2003 period to include the addition of state-of-the-art effluent control systems, new outside raceways with reuse capabilities, headbox upgrades, and new water monitoring equipment. The overall objectives of this program are to minimize water use, improve solids removal, and consolidate the piping for the purpose of expediting measurement of inlet and outlet flows and concentrations.

The effluent system will have disc filters at each raceway pass and no quiet settling zone so the solids will be taken out of the water column as soon as possible. Indoor raceway water will also go through one of the disc filters to remove any residual solids that escape the indoor vacuum system. All filter wastes will go to a new clarifier where the solids will be separated from the water and sent to a new sludge storage tank. There will also be an effluent pond bypass construction to allow for the widest range of options for effluent pond management. Other improvements will be made to the effluent pond to increase its effectiveness.

The new outdoor raceways will be reoriented and have multiple uses of the water instead of the current one pass. This in additional to the ability to reuse water within the outdoor raceway complex will significantly bring down the amount of water use and allow Brundage Creek and Spring to be used as the major water sources. This has many advantages to effluent management, disease control, and temperature control. The outdoor raceways will be completely covered to control avian and mammalian predators and will reduce stress, which should reduce effluents.

A completely new water monitoring system will be installed at the hatchery. This system will allow for the monitoring of all inflow and outflow water. It will also allow for easy collection of water samples for chemical analysis.

Planning for this renovation began in earnest in 2001 and is now complete. The bidding process will commence during the summer of 2002. Construction for the Hatchery renovation will begin in mid to late summer 2002 and will be complete in fall 2003.

Antibiotics and Disinfectants

The Consent Agreement commits the Hatchery to monitor and evaluate its use of antibiotics and disinfectants. Antibiotic use at the Hatchery involves supplying oxytetracyctine (OTC) to Chinook salmon delivered in the fish feed. The total amount of OTC in the feed was 122.2 pounds in 2000 and 89.1 pounds in 2001. Monitoring of the Hatchery discharge for OTC occurred during 2001. Replicate grab samples were collected during the last day the OTC feeding cycle. The samples were collected from the discharge of an inside and outside raceway, the inlet to the settling basin, the two discharges, and from 300 feet below the lower discharge in the Platte River. The samples were analyzed for OTC by the RASL laboratory at the University of Michigan. The procedure has a detection limit of 0.05 mg/L. All samples contained 0.055 mg/L or less OTC. Twenty-four composite and grab samples were collected on the last day of the treatment cycle during 2001. These samples were frozen and stored for possible future analysis. Laboratory analysis of these samples is not deemed necessary at this time. However, the samples are frozen and stored for possible future analysis.

Parasite-S (formalin) is used as a disinfectant to control fungus growth on fish eggs. This product consists of 37% formaldehyde by weight in water. In 2001 a total of 795 gallons of Parasite-S were used to control fungus on salmon eggs during the period October 3 to January 4, 2002. Formaldehyde was monitored in the discharge on three dates in 1999. The results of these tests showed that formaldehyde was below detection levels in all samples. Parasite-S use in 2001 was comparable to the use in 1999. Therefore formaldehyde measurements were not taken in 2001.

Chloramine-T was used on May 9 and 10, 2001 to control bacterial gill disease (BGD) that affects Chinook salmon. The treatment consisted of supplying approximately 13.2 kilograms Chloramine-T to the raceways during a period when the Hatchery flows were about 9.5 mgd. Grab samples were collected at various locations to determine resultant concentrations of Chloramine-T. However, it has been that determined that Chloramine-T degrades rapidly in water, and that samples must be analyzed within 2 hours of collection to obtain valid results. The 2001 samples were not processed within this time interval and were therefore not analyzed. It is planned to test for free-chlorine in future sampling efforts. This is a residual of Chloramine-T that can be easily measured using a Hach free-chlorine test kit. A Hach free-chlorine test kit has been ordered and will be used during the next testing period.

Appendix 4 contains the complete Fisheries Division report and a more detailed discussion of antibiotic and disinfectant use at Platte River Hatchery during 2001.

New NPDES Requirements for Suspend Solids Monitoring

The number of measurements of suspended solids required by the NPDES permit has been substantially reduced. This is because traditional suspended solids measurements have provided little useful information. These techniques involve weighing solids collected on a filter. The technique is inaccurate because the concentrations are very low (near detection). Therefore, it is not surprising that the concentration of suspended solids does not correlate well with total phosphorus or flow. An investigation is underway to determine the application of turbidity measurements as replacement. These measurements can be done in the field using a new Turbidity meter recently purchased by the DNR.

Pond Efficiency Studies

Data taken during 2001 show that the final settling ponds often act to increase the Hatchery phosphorus load rather than decrease it. This negative efficiency of the Hatchery pond may be associated with either increases in either soluble or particulate phosphorus. Increases in the concentration of soluble phosphorus may be related to increases in soluble phosphorus loading to the pond or increases in the rate of hydrolysis of particulate phosphorus. In addition, decreases in the rate of algal or macrophyte uptake or increases in the rate of algal or macrophyte excretion will alter the balance between soluble and particulate forms. Finally, soluble phosphorus may be released from the pond sediments. Increases in the concentration of particulate phosphorus may be related to increases in particulate phosphorus loading to the pond or to increases in the rate of macrophyte sloughing or die-off. High winds can decrease the rate of settling of particulate phosphorus to the sediments and increase the rate of sediment scour or re-suspension. The interactions among the processes that effect removal efficiency in the pond are illustrated in Figure 5.

Obviously the task of quantifying each of these mechanisms is not trivial and will require significant additional data and perhaps a model of regarding pond operations and efficiency. An initial analysis of the data indicates that the effluent pond stores more phosphorus than it releases at higher pond loading but releases more than it stores at low pond loading (see Appendix 5). Efforts are underway to measure the turbidity of the pond influent and effluent on a daily basis. These data will supplement twice-per-week measurement of total phosphorus. The goal will be to determine if there is a correlation between total phosphorus in the effluent and turbidity. A positive correlation would suggest that decreases in pond efficiency are linked to processes such as macrophyte sloughing or sediment re-suspension during periods of high wind.

Standard Operating Procedures

It is important to formalize and document sample collection and handling procedures. The Hatchery staff has prepared preliminary Standard Operating Procedures (SOP) that will be reviewed and modified as experience is gained during 2002.

Big Platte Lake Water Quality

Total Phosphorus

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.

Table 1 lists the Hatchery total phosphorus loads for 1990 to 2001 and the annual average flows of the Platte River at the USGS station at US-31. Also listed are the measured average volume-weighted total phosphorus concentrations and the percent of the time that the concentrations exceed the 8 mg/m^3 standard.

The average annual volume-weighted total phosphorus concentration of Big Platte Lake declined from about 9.1 mg/m^3 in 1990 to minimum of about 6.3 mg/m^3 in 1998 and 1999 and then increased to about 7.5 mg/m^3 in 2001. There were 120 days in 2001 when the total phosphorus concentration exceeded the 8.0 mg/m^3 standard. This corresponds to about 67% compliance as compared to the 95% requirement (Figure 6). Appendix 6 contains an Excel spreadsheet that contains the appropriate data and demonstrates the calculation of the Big Platte Lake volume-weighted total phosphorus concentrations for 2001. Note from Table 1 that both Hatchery loading and USGS flow are higher in 2001 compared to 2000. These increases are consistent with higher TP levels and more violations of the 8 mg/m^3 goal in the Lake in 2001 compared to 2000.

Figure 7 shows the seasonal variation of the volume-weighted total phosphorus concentration in Big Platte Lake for 1998 to 2001. Note that the concentrations are usually low during the summer and at or near maximum levels in the spring and fall. The average value drops to about 4 to 6 mg/m^3 between mid-July and mid-September and then increases sharply until the end of the year. In recent years spring concentrations generally vary between about 5 and 8 mg/m^3. However in 2001 concentrations began dramatically increasing around day 100 and reached a maximum of almost 10 mg/m^3. Figure 8 shows the 2001 data summarized into 3 layers. The top layer is represented by the surface to the 30-foot depth, the middle layer extends from 30 to 75 feet, and the bottom is below 75 feet. Note that the increase starting around day 100 is largely associated with the top layer. Although the cause for the increase is not known for certain, observed alewife decay during 2001 could account for the elevated concentrations. It is critically important to understand these dynamic patterns to facilitate efforts to comply with the water quality standards for the Lake. The BASINS watershed and the lake water quality models should be helpful in resolving some of these issues and uncertainties.

Dissolved Oxygen

Figure 9 shows the changes of bottom water dissolved oxygen concentrations for 1998 to 2001. Note that the concentration of dissolved oxygen drops below 2 mg/L for about 110 days. It is expected that dissolved phosphorus will be released from the sediments during these periods of low dissolved oxygen. Big Platte Lake has a relatively high level of sediment phosphorus because it has received excess phosphorus loading for a period for many years. The total phosphorus content of Big Platte Lake cores has been measured by Saloni, 2001. The top layers of sediment from the deepest part of the Lake are estimated to contain between 600 and 800 mgTP/kgDW. This value is higher than other area lakes.

The phosphorus release rate from sediments can be estimated using an equation developed by Nurnberg (1986). This equation relates anoxic release rates to sediment total phosphorus as given below:

$$R = 6.3\,(TP)^{0.76} \qquad (1)$$

where R is the release rate (mg P/m^2/day) and TP is expressed as gmTP/gDW. The estimated release rate for Big Platte Lake is about 4.8 mgTP/m^2/day. Laboratory studies using sediments from Big Platte Lake are recommended to verify the applicability of Equation 1.

Secchi Depth

Figure 10 shows the average and minimum Secchi Depth for 1998 to 2001 as measured by PLIA. Note that the highest average and minimum Secchi Depth occurred in 1999. The data shown in Table 1 show that 1999 was also a year of relatively low Hatchery loading and USGS flow and overall high water quality in the Lake.

Volume-Weighted Lake TP Calculation

The current method used to calculate the volume-weighted Lake TP concentration does not use the TP measurement taken at the surface. This is because in 1991 there were a few very high TP measurements taken under the ice that were contaminated by debris. This occurred again for a few samples in 1996. Otherwise the surface measurements (1990-2000) are generally consistent with the samples taken at the 7.5-foot depth.

The surface measurements should either be used or dropped from the monitoring program. It is recommended that a new approach be employed that uses all 8 TP measurements -- surface, 7.5, 15, 30, 45, 60, 75, and 90 feet. In addition it is recommended that median of the three measurements be used rather than the average. This eliminates the need to arbitrarily disregard any valid measurement.

The recommended algorithm averages the surface and 7.5 foot TP median values and multiplies this by the volume of water between the surface and 7.5 feet. Next the average of the 7.5 and 15 foot median values is multiplied by the volume between 7.5 and 15 feet, and so forth. The volume of water below 90 feet is multiplied by the 90-foot median value. The product of concentration and volume for each layer gives the total mg of TP in each layer. The total mg of TP in the Lake is the sum of the mg of TP for each layer. The total mg of TP in the Lake divided by the total lake volume gives the volume-weighted concentration. Note that this method uses the surface value once and the middle values twice during the calculation. The recommended procedure is consistent with formal and rigorous numerical algorithms such as the Trapezoidal Rule (Chapra and Canale, 1998).

The surface concentration is considered contaminated if it is more than double the 7.5-foot concentration. In this case the surface concentration is automatically discarded, and the total mg in the surface layer is simply the product of the volume of the surface layer and the 7.5-foot concentration.

The significance of this preferred method of calculation will be examined using all the measurements when the ACCESS database is completed.

Tributary Flows and Water Quality

USGS Station at US 31

Figure 11 and Table 1 show the 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 113 cfs in 2001. This flow is about 10% higher than the last two years but less than the average flow of 123 cfs since 1990. Thus, 2001 can be characterized as a moderately dry year. Figure 12 shows daily and monthly hydrographs for the Platte River at the USGS gauging station for 1998 to 2001. Note that the monthly hydrograph is quite uniform with up to 25 % higher flows in the spring and fall. The actual sampling dates are shown on the daily hydrograph for 2001. Note that the sampling dates miss most of the wet weather spikes. However the averages of the measured flows and the average of the daily flows were almost identical. The measured non-point load may underestimate the actual non-point load because many spikes are missed. The proposed wet weather sampling and the BASINS model will permit a more accurate assessment of non-point TP loads.

Figure 13 shows total phosphorus concentrations in the Platte River at the USGS station for 1998 to 2001. Note that high flows and concentrations generally occur during the spring. Fall TP concentrations are generally about half spring values. However note that isolated high concentrations have been observed in 1998 and 2000 and are associated with high runoff events.

Figure 14 show the correlation between flow and TP at the USGS station for 1998 to 2001. Note that generally good and consistent results were obtained for all years except 2001. Note that the linear approach uses instantaneous values of flow and TP and does not account for the history of flow during proceeding days. The proposed wet weather sampling and the BASINS model will permit a more accurate assessment the relationships between flow and TP concentration.

North Branch of the Platte River

Flows for 1998 to 2001 for the North Branch of the Platte River (also known as Deadstream) are shown in Figure 15. Note that values are about 20 to 25 % of the USGS flow at US 31. In addition flows are generally higher in spring and fall with intermittent spikes during wet weather. This pattern is generally consistent with the seasonal variations of the Platte River. Figure 16 shows measured TP concentrations in the North Branch of the Platte River for 1998 to 2001. The concentrations are in the same range as USGS values but are occasionally higher especially during the spring of 2001.

Figure 17 shows a reasonably good correlation between the North Branch of the Platte River flow and USGS flow at US 31. The correlation between the North Branch of the Platte River flow and TP is poor. The proposed wet weather sampling and the BASINS model will permit a more accurate assessment the relationships between flow and TP concentration.

Sampling Program

<u>Objectives</u>

Several water quality sampling studies have been conducted in the past to define the magnitude of various sources of total phosphorus within the watershed and the Hatchery loading and to estimate their impact on the water quality of Big Platte Lake. The most significant of these studies were those performed by Grant in 1979 and by Kenega and Evans in 1982. In addition, the MDNR and PLIA have conducted an extensive sampling program in the watershed since about 1990.

It is proposed to undertake a major effort during the next two years to repeat the K&E study and to obtain tributary data during wet weather events. Figures 18 and 19 and Table 2 describe historical, current, and proposed sampling locations for the system. The Kenega and Evans study sampled nine tributary and one lake location on a monthly basis in 1980. The data were used to perform hydrologic and total phosphorus balances for the system. The data provide a good historical baseline and can be used to evaluate changes in water quality in the tributaries and lake over time. The current sampling plan proposes to conduct regular weekly sampling at these same stations in 2002. This will allow a detailed evaluation of water quality for various hydraulic conditions. These data will be supplemented by wet weather event sampling. Note that only two of the nine K&E tributary stations are currently being sampled.

The net Hatchery total phosphorus load to the system is evaluated by subtracting the inlet load from the total outlet loading. Measurements of flow and concentration are currently taken at five locations two times per week. It is proposed to maintain this regular schedule in 2002.

It is proposed to sample twelve tributary locations in the system during three wet weather storm events. Six samples are taken to define transient conditions during each event at each location. The flow as well as the concentration of total phosphorus and suspended solids will be measured for each sample. This program is difficult to conduct and depends on suitable weather conditions. Therefore completion of this part of the program may require 2 or more years. It is also proposed to experiment with the use of automatic sampling equipment to conduct this task as a cooperative project with the Benzie County Conservation District.

It is proposed to sample the lake at 8 depths every week during both non-stratified and stratified periods of the year. The lake samples should be analyzed for total phosphorus, suspended solids, phytoplankton, zooplankton, chlorophyll, pH, total dissolved solids, calcium, and alkalinity. Secchi Depth, dissolved oxygen, temperature, pH, and ORP should be measured with field instruments and the results validated using laboratory analyses. It is recommended that the chlorophyll analysis be performed in triplicate and that tube samplers be used instead of discrete bottle samples. This is a convenient way to obtain a surface layer composite sample.

The sampling program has the following specific objectives for 2002.

- To quantify the total phosphorus loading from the Hatchery as required by the NPDES permit for the facility.
- To collect data to support the development of a phosphorus model for the Platte River State Fish Hatchery.
- To determine the volume-weighted total phosphorus concentration of Big Platte Lake to insure compliance with water quality standards.
- To collect data to support trend analyses over time of the water quality of Big Platte Lake and it's tributary streams.
- To collect data to construct mass balances for water and total phosphorus for the system.
- To collect data 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 collect data to support the development, calibration, and validation of a water quality model of Big Platte Lake.
- To determine total phosphorus and suspended solids loads from sub-watershed basins during storm events.
- To document changes in water quality following remedial activities within the watershed.
- To provide a GIS-based assessment tool for local planning and zoning officials.

When these extensive data collection efforts are near completion, available resources will be shifted toward the Special Studies. These combined efforts will facilitate the development, calibration, and final validation of the BASINS loading model and the water quality model for Big Platte Lake.

When these models are completed, it may be possible to divert sampling resources to other uses. For example, additional lake nutrient models should be developed for upper watershed lakes (Ann Lake and Bronson Lake), and the existing model for Long Lake model (Canale, 2000) should be validated. This work will help to improve water resource management in these rapidly developing lake watersheds, support the efforts of local lake associations, and promote more complete understanding of the nature of nutrient and sediment delivery processes in the Platte River system.

Field and Laboratory Activities

In 2001, it was jointly decided by all parties to completely review and evaluate the sampling and water chemistry testing process for the Platte River State Fish Hatchery. After reviewing the existing process, it was decided to have DNR staff conduct the field sampling with the oversight of the Implementation Coordinator, and obtain additional bids to perform the laboratory chemical analysis. Both of these steps would provide cost savings to be used for other implementation items such as watershed phosphorus modeling and could allow for some additional new laboratory experiments that would help the implementation process.

In October 2001, four labs were contacted requesting bids on the laboratory analysis. The lowest cost bid that had the appropriate accuracy was Central Michigan University's Water Research Center and their bid included opportunities to conduct additional laboratory experiments. They were awarded the work in March 2002 and started water chemistry analysis in the first week of April. Great Lakes Ecological Center (GLEC) continued water chemistry analysis until April 19^{th} to allow for side by side comparisons of the data.

In October 2001, the DNR moved forward to hire a new water quality technician to handle the water sampling aspects of the Consent Agreement. Robert Kerry took the position in early December and started at Platte River State Fish Hatchery in late December. Robert Kerry and Bob Eggleston (Platte River State Fish Hatchery Technician) will handle all aspects of water sampling using approved Standard Operating Procedures (SOPs) and DNR water quality sampling was started in early March 2002. Side by side sampling with GLEC was conducted from April 1 to 19 to allow for training and comparison of sampling. The parties are appreciative of the efforts of GLEC and hope that they will bid on future work that we will have at this facility.

To support this effort, the DNR has purchased a number of pieces of equipment including a flow meter, a turbidity meter, a YSI multi-function sampler for lake sampling, a LICOR meter for measurement of light attenuation, and other laboratory equipment. All of the necessary equipment has been purchased or obtained from other facilities to conduct the required sampling.

Additional efforts by the parties and the new DNR staff have resulted in the acquisition of the necessary equipment to bring the existing weather station at Platte River State Fish Hatchery up to operational standards. We are also obtaining mobile automatic samplers in conjunction with the Benzie County Conservation District to allow for storm event sampling in the Platte River Watershed which will fill a data gap in our understanding of phosphorus processing in the watershed.

Special Sampling

The development, calibration, and final validation of the BASINS watershed loading model and the water quality model for Big Platte Lake will depend primarily on the Hatchery, tributary, and lake monitoring data described above. However, it is also desirable to enhance the model reliability by conducting a few special studies that have more of a research nature. These studies will provide direct estimates of some of the model mechanisms that are independent of the regular monitoring data. Several special studies are described below. These research studies will be designed and coordinated jointly by CMU and the Implementation Coordinator. Although these studies may require the occasional help and assistance of the Hatchery staff, they will not require routine commitments.

The magnitude of the internal sources of phosphorus from the sediments of Big Platte Lake is directly related to the area of the bottom that experiences anoxic conditions. Therefore, it is important to measure the area of bottom sediments that are in contact with overlying water that has low dissolved oxygen concentrations (< 2 mg/L). Surveys should be conducted in additional deep-water basins with the YSI meter to search for such areas. In addition sediment samples should be taken at approximately 8 locations at various depths in the Lake. The sediment should be analyzed for total phosphorus, solids density, water content, TOC, and Chemical Oxygen Demand (COD). Laboratory experiments should be conducted to determine phosphorus release rates and Sediment Oxygen Demand (SOD). These measurements will be used to develop correlation relationships between sediment total phosphorus concentration and anoxic release rates. The resulting relationship can be compared with the Nurnberg Equation. The COD measurements will be used as a correlation parameter with SOD.

A macrophyte survey should be conducted to determine type, density, area, and phosphorus content. These data can be used to make first-cut approximations of the amount of phosphorus utilized during the growing season and the amount of phosphorus released during the fall die-off period. This information can be used to determine the significance of macrophyte activity on phosphorus dynamics in Big Platte Lake. Measurements should be conducted to determine the fate and transport of decaying macrophytes both in the Lake and in the major tributaries.

Laboratory tests should be performed to determine the bio-availability of various sources of phosphorus. These tests use measurements of algal growth rates to determine the algal growth potential of phosphorus from different point and non-point sources. Results should be compared for watershed and Hatchery sources.

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 light attenuation is often inconsistent and inaccurate. Therefore light attenuation as a function of depth should also be obtained in the Lake using the new LICOR meter. Laboratory and field studies should be conducted to enhance our understanding of the relationship among Secchi Depth, LICOR measurements, chlorophyll concentrations (or phytoplankton and zooplankton counts), calcium carbonate precipitation, pH, and color. The pH is a function of the Lake chemistry, algal activities, and perhaps input of acid rain. It is important to determine if there are relationships between Lake clearing events and rainfall.

The filter-feeding activities of zebra mussels can reduce phytoplankton concentrations and consequently increase Secchi Depth (Canale and Chapra, 2002). The respiration of zebra mussels may be a significant oxygen demand. Lake residents have observed numerous small zebra mussels during the summer of 2002. A survey should be conducted as soon as possible to estimate the area, density, and size-distribution of resident mussels. The changes in the population should be

The major loss mechanism of phosphorus in Big Platte Lake is the settling of particulate matter to the sediments. The settling velocity of these particles is also an important model coefficient. The value of the settling coefficient can be estimated through model calibration by fitting the model output to measured data. However, it is preferable to measure the settling velocity directly. This is accomplished by placing collection chambers in the lake and measuring the accumulated solids as a function of time. The settling velocity can be then calculated from these data.

Finally, it would be appropriate to confirm earlier MDNR findings that the growth of phytoplankton in Big Platte Lake is limited by phosphorus. This can be accomplished by measuring the concentration of TKN, TKN-F, and nitrate in the Lake. It is recommended that these parameters be measured in the surface water and at 7.5 and 15 feet on two occasions in both July and August.

Data Management

Data Storage

Mr. Wil Swiecki and Dr. Michael Pattison have performed the huge task of constructing and maintaining Excel spreadsheets that contains the Hatchery loading, lake and tributary data and calculations. This arrangement has worked very well and it is recommended that they continue this effort.

Data Retrieval and Reporting

The current Excel spreadsheets are primarily intended to provide for storage of the measured data. As a result it is often awkward to use them to retrieve data and to produce plots, tables, and, reports. Furthermore, the structure of the EXCEL spreadsheets makes it very difficult to perform mass balance calculations for the Lake, watershed, or the Hatchery.

The development of a Microsoft ACCESS database is underway, and when completed will facilitate difficult tasks of data retrieval and reporting like the above. It was decided to develop a new relational database that will capture all of the existing data, allow easy linking to a Geographic Information System (GIS) database under development, and provide new data entry forms to allow easy data input. The Department of Natural Resources – Fisheries Division undertook this task in 2001. The new database is expected to be operational in summer 2002 and the old data will be transferred to the new database once it is ready.

Modeling

Watershed Phosphorus Loading Model

The overall goal of the modeling program is to develop a watershed loading model (BASINS) and a lake water quality model. These models can be used as predictive tools to guide and optimize the planning process and as teaching aids to facilitate our understanding of the important physical, chemical, and biological processes that impact the water quality of Big Platte lake.

The BASINS model predicts the magnitude of non-point total phosphorus and suspended solids loads as a function of land-use, soil type, and rainfall conditions in the watershed. The BASINS model is being developed in phases by LTI. This model is well known and is supported by USEPA. This model will provide loading input information to a water quality model for the lake that can be used to predict the impact of non-point total phosphorus loads from the watershed and the Hatchery total phosphorus loads. 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.

The goal of phase 1 of this effort is to develop the BASINS model for the Big Platte Lake watershed using existing data. This task will involve not only obtaining data necessary to drive the model, but also data analysis and formatting for application within the model. The Big Platte Lake watershed has been subdivided into several sub-watersheds with outlets that coincide with existing monitoring stations and the outlet of Long Lake (see Figure 20.). The model will be applied using daily climate data and available land-use data. The model will then be calibrated using the available flow and water quality data. Model coefficients from literature will be used as necessary. All of the activities completed during phase 1 are associated with a step-by-step plan to develop and validate the BASINS model to determine watershed phosphorus loads. Land-use is important in determining runoff, groundwater recharge, and watershed loads of pollutants. It is important, when applying a watershed model, to have a land-use classification system that is consistent across the entire study area. This may require additional. It is planned that the District will provide future funding for the development and validation of the BASINS model.

The goal of phase 2 of the project is two-fold. The first part is to refine the model calibration using new climatic and tributary data to be collected during several storm events at several locations within the watershed. These data will be used to further refine the model calibration, focusing on storm events and several additional locations within the watershed that drain predominantly one land-use.

The second part is to test the effectiveness of several management scenarios using the model. This phase of the project will involve the definition of several management scenarios jointly with the Benzie Conservation District. Because of limitations in BASINS, it may be necessary to simulate the impacts of some scenarios (e.g. buffer strips) outside of the BASINS framework.

Estimated costs for completing the tasks associated with Phase 1 (initial development) are $50,000 and approximately $30,000 for Phase 2 (final calibration and management applications).

Lake Water Quality Model

A comprehensive water quality model for the lake will eventually be needed that can predict the impact 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 also important that the model accurately simulate light attenuation (extinction coefficient or Secchi Depth) and the internal loading of phosphorus from the sediments associated with low bottom water dissolved oxygen concentrations. 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.

The development of a new water quality model for the lake will proceed in stages. It will start with a simple approach and draw upon the results and findings of other modeling efforts. This initial modeling effort will produce a useful tool that can be used to analyze and understand water quality measurements in the lake. It will also be used to refine the design of the lake and tributary sampling program. The complexity of the model will increase as more data and the results of the special sampling become available. Figure 21 shows the annual variation of several parameters measured in the Lake in 2001. The complex mechanisms and interactions associated with these variations foretell the difficulty of developing an accurate water quality with detailed spatial and temporal resolution.

One interesting and important aspect of the lake phosphorus variation is the large increases in the concentration during both the spring and fall and then the rapid and dramatic decline during mid-summer. Understanding these variations can facilitated through modeling analyses. Figure 22 shows the mechanisms for one layer dynamic total phosphorus model for Big Platte Lake. These include tributary flow and loading, overflow, settling, sediment release, and any extra loads not measured. A mathematical model that expresses mass balance for the Lake can be expressed as

$$V\,(dc/dt) = W_{\mathbf{T}} - Q\,c - v\,A\,c + W_{\mathbf{ex}} \qquad (2)$$

V is the volume of the lake, c is the volume-weighted concentration of total phosphorus, t is time, $W_{\mathbf{T}}$ is the sum of USGS and the North Branch of the Platte River total phosphorus loading, Q is the sum of USGS and the North Branch of the Platte River flows, v is the net settling velocity, and A is the bottom area. $W_{\mathbf{ex}}$ is sum of other loads to the system such as sediment release, lost fish, decaying alewives, decaying macrophytes, missed wet-weather events, pollen accumulation, and re-suspension of bottom sediments. The components of Equation 2 are illustrated in Table 3. The model is a linear first-order differential equation that can be solved numerically using Euler's method (Chapra and Canale, 1998).

The left panels of Figure 23 show daily variations of total tributary flows and loads. The total load for the year was 1097 kg for the USGS station and 270 kg for the North Branch. These results were obtained using 2001 measurements and linear interpolation. Note that the total loads are higher in the spring compared to the fall because lower concentrations in the fall more than offset higher fall flows. The top right panel of Figure 23 shows simulated lake concentrations that include only tributary flow and loading terms. The model simulations for the lake total phosphorus in the case are higher than the measured data. The lower right panel shows the effect of adding a constant settling velocity with a typical value of 15 m/yr (Chapra, 1997). Note that the model and the measurements agree quite well for the first 100 days of the year with this addition. However, there is significant deviation between the model and the data thereafter.

The difference between the measurements and the model in the spring as shown in Figure 23 can be compensated for by adding an extra constant loading of 5 kg/day for 68 days. This is equivalent to a total of 340 kg. Note that this load has the same magnitude as the tributary loads shown in left panel of Figure 23. The extra loading and the model simulations are shown in the top panel of Figure 24. The model and the measurements now agree for the first 190 days. After this time the concentration drops dramatically. The settling velocity is increased around day 190 to 60 m/yr to account for this measured decline. This value, although 4 times higher than typical annual average net settling velocities, is similar to summer settling velocities measured in lakes where suspended particles are captured in collection chambers. The model and the data now agree for about the first 240 days of the year.

Figure 25 shows an extra fall load of 11 kg/day for 49 days or 539 kg. Note that this load also has the same magnitude as the tributary loads shown in left panel of Figure 22. The model simulations that include this extra fall load are shown in the bottom right panel. In this case good agreement is attained between the model and the data throughout the entire year. Note that this fall load is more than double estimates for 2000 derived by Canale e al. (2001) because the current analysis considers settling and the measured lake concentration gradient is larger in 2001.

Note that a total of 340 kg or 750 lbs. of phosphorus is needed in the spring to account for the measured changes in lake total phosphorus concentration. Durbin et al. 1979 has reported that wet alewife have a water content about 75% and that dry tissue is about 1.5% phosphorus. This is equivalent to about 750/0.00375 = 200,000 lbs of wet alewife tissue. If there are about 20 wet alewife per pound, then the phosphorus from 4,000,000 decaying alewife is needed to account for the missing spring loading. The surface area of the lake is 2526 acres or 110 million square feet. Thus, an alewife density of about 3.6 fish for every 100 square feet of lake surface area would contribute enough phosphorus to account for the extra spring loading that resulted in the elevated measured lake total phosphorus in 2001. Although this density is not inconsistent with qualitative observations of lake residents, the above analysis should be considered a reality check on a hypothesis rather than an establishment of fact.

Canale et al. 2001 estimated that the phosphorus released from the bottom sediments in 2000 was about 77 kg. Figure 4 gives maximum of about 98 lbs or 44 kg of phosphorus potentially contributed by lost migrating fish. Table 4 gives estimates of 45 kg from macrophytes and 155 kg for atmospheric. This leaves about 539 – 77 – 44 – 45 - 155 = 218 kg of phosphorus yet to be identified. Possible candidates for the missing 218 kg missing loading are sediment re-suspension, skipped wet-weather tributary event loading, and elevated groundwater phosphorus. The components of the total phosphorus loads for 2001 are shown in Figure 26.

Although equation (2) has proven useful for the analysis of the measured data and provided useful insights, it cannot yet be used directly for management applications because it is not linked to the BASINS watershed loading model under development. In addition, the model does not predict algal levels, Secchi Depth, or dissolved oxygen. These refinements would be facilitated by completion of the bioavailability special studies described above. It would also be useful to add multiple layers to the model and include a sediment component. This would allow simulation of the history of the water quality of the lake and permit predictions of long-term recovery and response to remedial activities. Finally, it may be appropriate at a future time to include macrophytes and zebra mussels to the model.

Another interesting aspect of the variations shown in Figure 21 is the large decrease in Secchi Depth observed around day 200. Note that this occurs at a time when a large settling velocity is needed to promote a large decrease in total phosphorus. The requirements of high settling and small Secchi Depth are consistent with an increase of the particulate fraction verses the dissolved fraction of total phosphorus. Thus it is important to understand the relationships between Secchi Depth, particulate fractions, and other limnological parameters. Figure 27 shows the correlation among several measurements. In all cases, although some relationship appears to exist, simple correlation analysis does not appear adequate for accurate predictions. Therefore, it is appropriate to explore alternative ways to examine the data. For example, a simple model for Secchi Depth can obtained by assuming (Chapra, 1997):

$$\text{Secchi Depth} = C1 / Ke \qquad (3)$$

where Ke is an extinction coefficient that describes light attenuation with depth according to Beer's Law and C1 is a constant. The units of Ke are feet^{-1}. Also assume that Ke is linearly related to the chlorophyll concentration and the average Saturation Index (SI) of the top 15 feet of the Lake. Thus,

$$Ke = C2 + C3 * \text{Chlorophyll} + C4 * SI \qquad (4)$$

where C2, C3, and C4 are empirical constants. These constants are approximated by comparing model predictions and measured data as shown in Figure 28.

Note that the model is reasonably consistent with the data for the last 100 days of the year. However, between days 120 and 170 the model calculations are too low, and between days 170 and 225 the model results are too high. It does not appear possible to improve the model further by adjusting coefficients. However, note from Figure 21 that zooplankton numbers vary considerably and are expected to create clearing events and large Secchi Depths because of the decline of algal numbers that result from filter feeding activity. Thus adding more components to equation (4) may improve the predictive capability of the model. However, the zooplankton data seem scattered, irregular, and inconsistent with expectations. It is important to carefully examine these data and determine their reliability. Furthermore, it is appropriate to examine data from additional years to elucidate possible relationships. The development of a Microsoft ACCESS database is underway and this will facilitate these tasks of data retrieval and reporting.

The above analyses show that it is important refine our understanding of plankton cycles in the Lake. Therefore it is recommended that chlorophyll concentrations be measured in triplicate and that a tube sampler be used for phytoplankton and zooplankton sampling. In addition, the results demonstrate the need to execute the special studies for the sediments, bio-availability, and light attenuation as described above.

In the meanwhile, focus will be placed on the development of a watershed-loading model. Eventually (perhaps two years) it will be appropriate to proceed more aggressively with the development of a more comprehensive water quality model for Big Platte Lake.

Coordination

Internal

An excellent spirit of coordination, cooperation and communication has been maintained between the Implementation Coordinator and the parties. Telephone conference calls are held on a regular basis. Appendix 7 documents the minutes of 22 coordination meetings conducted during 2001.

PLIA representatives have participated in the effort to count and record the salmon that pass the Lower Weir. A good working relationship exists between the Hatchery staff and the PLIA.

External

Significant coordination continues with the Benzie Conservation District regarding wet weather sampling and development and application of watershed model. It is expected that the District will have a major role in the funding of the BASINS model and will eventually use the model to assist with the implementation of remedial activity.

The District has developed a Partnership Agreement with the MDNR and the PLIA. This Partnership will facilitate the efforts of the District to secure additional funds to support the objective of preserving the water quality of Big Platte Lake. The National Park Service has also been asked to join the Partnership. Their participation is encouraged because it would strengthen the Partnership and adds momentum to efforts to protect the water quality of Big Platte Lake. In addition, lines of communication have been established with nearby lake-protection associations from Crystal and Long Lakes and other conservation agencies.

The District plans to continue efforts to share in the funding of the BASINS watershed model. For example, the District has provided $5,000 to LimnoTech (LTI) to support the development of the watershed map that delineates sub-watersheds and the sampling stations proposed for 2002. In addition, the District has prepared funding applications that include cost sharing for the continuing development of the BASINS model. They will contribute $20,000 per year for 3 years for this effort provided expected funding materializes as anticipated.

The District is working cooperatively with the Hatchery staff to procure and install automatic sampling equipment to facilitate data collection during wet weather.

References

Canale, R. P. (2000). *Long Lake Water Quality Model.* Report prepared for GLEC, 4 pages.

Canale R. P., Whelan, G., and Swiecki W. (2001). *Annual Report for the Year 2000.* Report prepared for MDNR and PLIA.

Canale, R. P. and Chapra S. C. (2002). “Modeling Zebra Mussel Impacts on Water Quality of the Seneca River, NY”. To appear in the *Journal of the Environmental Engineering Division*, ASEC.

Canale, R. P., Swiecki, W. J. and Chapra, S. C. (1991). *Fish Hatchery Impacts on High Water Quality Lakes*. Report Prepared for PLIA, 25 pages.

Chapra, S. C. (1997). *Surface Water-Quality Modeling*. McGraw-Hill, New York.

Chapra, S. C., (1996). *Data Analysis and Preliminary Modeling of Platte Lake, Michigan*. Report prepared for MDNR and PLIA.

Chapra, S.C. and Canale, R. P. (1998). *Numerical Methods for Engineers*. 3rd Edition. McGraw-Hill, New York

Clerk, Saloni. (2001). *Fossil Chironomids as Indicators of Water Quality: Impacts from Aquaculture Activities*. Master’s Thesis, Queen’s University, Kingston, Ontario Canada.

Durbin, A. G., Nixon, S. W. and Oviatt, C. A. (1979). “Effects of the Spawning Migration of the Alewife, *Alosa Pseudoharengus*, on Freshwater Ecosystems”. Ecology, Vol. 60, No. 1, 8-17.

LinmoTech, Inc. (2001). Report Prepared for Benzie Conservation District

Lung, W., (2000). *Modeling Total Phosphorus and Dissolved Oxygen in Platte Lake.* Report prepared for 30th Circuit Court, state of Michigan.

Nurnberg, G.K., (1986). *Prediction of Phosphorus Release Rates from Total and Reductant-Soluble Phosphorus in Anoxic Lake Sediments*, Can. J. Fish. Aquat. Sci., Vol 45, pages 453-462.

Walker, W. W., (1998). *Analysis of Monitoring Data from Platte Lake, Michigan.* Report prepared for Michigan Department of Natural Resources.

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