LPL-1014-05

Report

Lake Study Summary

Little St. Germain Lake Protection District

Project I.D.: 05L001

Little St. Germain Lake Protection District

May 2006

Foth & Van Dyke

Lake Study Summary
Little St. Germain Lake Protection District

Contents

1. Sediment Phosphorus Evaluation

Lake studies done by USGS in 2001 and 2005 produced a phosphorus budget for the Little St. Germain Lake. The phosphorus budget included input values for precipitation, stream inflow, groundwater inflow, and septic tanks. USGS identified internal sediment loading as a potential source of phosphorus but had no input values available to use with the phosphorus budget. Internal loading occurs as phosphorus contained in the sediment is released back into the water column. This release takes place under aerobic and anoxic conditions.

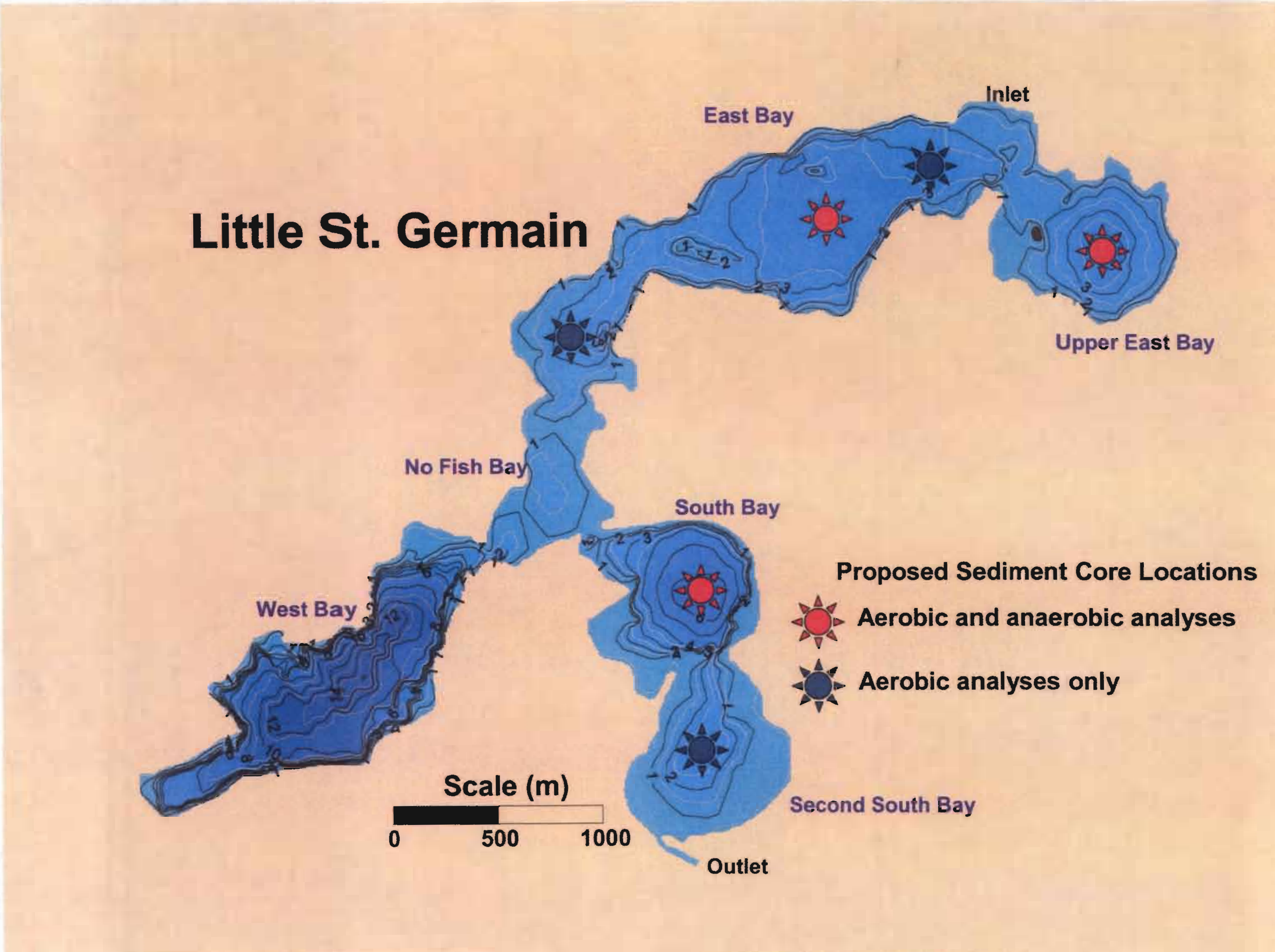
The Little St. Germain Lake Protection District received a WDNR Lake Planning Grant to study internal phosphorus loading to the lake. This work was completed by the United States Geological Survey (USGS) in 2005. The intent of this work was to identify the internal phosphorus loading to the lake and determine if this loading would reduce the effectiveness of chemical treatment to remove phosphorus.

Sediment core samples were collected in the summer of 2005. Figure 1 shows the sample locations. The core samples were sent to the State Lab of Hygiene for analysis. Core samples were incubated under aerobic or anoxic conditions. The water above the sediment cores was sampled for soluble reactive phosphorus on a daily basis. The results were calculated in a phosphorus release rate (mg/m^2/day).

The sediment core test results are shown in Attachment 1. USGS found the maximum phosphorus release rate to be 1 mg/m^2/day and occurred under anoxic conditions. This release rate was applied to the upper East Bay in the area that experiences anoxic conditions (below 10 feet water depth). This area is 44,000 square meters. Over a 60 day period (approximately equal to a winter anoxic period) the phosphorus release from the Upper East Bay is estimated at 5.8 pounds. The measured aerobic release rate was near zero.

The result of the study shows that with a total lake phosphorus input budget of over 1,000 pounds of phosphorus per year, the relative input from sediment release is small. With the Upper East Bay as a model for the other three bays that experience anoxic conditions, the total internal phosphorus release is approximately 25 pounds per year.

Based on this study, the internal phosphorus loading is less than 3% of the overall phosphorus loading. Chemical treatment to remove phosphorus in Muskellunge Creek can be effective and internal phosphorus loading will have little impact on the effectiveness of the chemical treatment.


Little St. Germain
Inlet
East Bay
Upper East Bay
No Fish Bay
South Bay
West Bay
Second South Bay
Outlet
Proposed Sediment Core Locations
Aerobic and anaerobic analyses
Aerobic analyses only
Scale (m)
0
500
1000

Little St. Germain Lake Protection & Rehabilitation District
Phosphorus Removal Study

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1. Introduction

The Little St. Germain Lake Protection and Rehabilitation District (District) completed a Lake Management Plan in January 2001. The report identified Muskellunge Creek as a source of 53% to 61% of the phosphorus input to Little St. Germain Lake on an annual basis. A model was used to evaluate the impact of a reduction in phosphorus from Muskellunge Creek. The model evaluated phosphorus reduction levels in Muskellunge Creek of 50%, 75%, and 100% and the impact on the East Bay of Little St. Germain Lake (the mouth of Muskellunge Creek). The measured total phosphorus concentration in East Bay averages 0.046 mg/l. The model predicted a reduction in total phosphorus of 0.012, 0.019, and 0.021 mg/l respectively in the East Bay. The impact on the lake would be expected to increase the average summer Secchi depth reading by 0.7, 1.0, and 2.0 ft respectively. As a result of the phosphorus reduction, the frequency of blue-green algae blooms was also expected to decrease.

The lake management plan recommended that chemical phosphorus removal from Muskellunge was the best technology but that further evaluation was needed due to the potentially high cost. To accomplish the phosphorus removal evaluation, a lake protection grant was applied for in the spring of 2000. The District was successful in obtaining a Lake Protection Grant from the Wisconsin Department of Natural Resources (WDNR) to do preliminary engineering work related to phosphorus removal.

The preliminary engineering work scope is as follows:

A. Phosphorus Removal Preliminary Design
B. Preliminary Lagoon Design
C. Land Acquisition Assistance
D. Permitting

This report focuses on items A and B. If the preliminary concepts and costs are feasible to the District and upon your authorization, items C and D will be completed.

2. Phosphorus Removal Testing

2.1 Jar Testing for Alum Dosage

Jar testing was done to determine the approximate dosage of alum that could be used to remove phosphorus from Muskellunge Creek water. Jar testing is a chemical simulation of a treatment process. Water samples are placed in jars and chemicals added to provide treatment. Various concentrations are used to determine which concentration would be best. Foth & Van Dyke has facilities in their office to complete the jar testing.

Alum is the common name for aluminum sulfate. This chemical is commonly used in water and wastewater treatment as a coagulant (settling aid) and for phosphorus removal. Many lakes have applied alum to the entire lake for phosphorus removal. Alum separates in water into aluminum ions and sulfate ions. The aluminum reacts with dissolved phosphates to produce a precipitate. This precipitate makes the reacted phosphorus unavailable to plants and algae.

A sample of water from Muskellunge Creek was collected by Foth & Van Dyke. Foth & Van Dyke added varying alum dosages to the test samples. The samples were mixed and allowed to settle. The supernatant (clear liquid above the settled solids) was collected from each jar and analyzed for total phosphorus, dissolved phosphorus and total suspended solids. The results are shown below:

Alum Dose – mg/l	Total P – mg/l	Dissolved P – mg/l	Total Suspended Solids – mg/l
0	0.032	0.022	4
10	0.026	0.014	7
20	0.018	0.008	10
30	ND	0.008	3
40	ND	0.007	6

The results showed that a dose of 20 mg/l had reacted with almost all the dissolved phosphorus and a dose of 30 mg/l had removed almost all the total phosphorus. Note that the raw water sample without the alum dose had a relatively low phosphorus concentration compared to the long term Muskellunge Creek average concentrations of 0.050 mg/l.

The best floc (chemical precipitate) was formed at an alum dose of 30 mg/l or higher. The floc settled to the bottom of the jar with some smaller particles remaining suspended.

2.2 Laboratory Settling Column Testing

A laboratory settling column is a useful tool in determining the speed at which a particle settles and simulates actual conditions more closely than a jar test. The settling column used is 7 feet tall and 8 inches in diameter. The column is clear plastic with sample ports located at one foot increments. Foth & Van Dyke has a settling column at their office and used this apparatus for the test.

Alum was added to the raw water as the water was added to the settling column. This procedure simulated field conditions. Samples were taken after 4 hours, 8 hours, and 24 hours. At each sample collection time, samples were collected at 1 foot intervals for a total of 18 samples per test period.

The first test was conducted at an alum dose of 3 mg/l. The second test was done at a higher concentration of 29 mg/l. The test at 3 mg/l alum dosage was done to see if the larger scale test could demonstrate improved performance at a lower alum dosage.

Each sample was analyzed for total phosphorus and total suspended solids. The complete test results are shown in Appendix A. A summary of the test is shown below:

Test 1 – Alum Addition – 3 mg/l

Sample	Total P – mg/l	Total Suspended Solids – mg/l
Raw Water	0.061	10
Average – 4 hours	0.044	13.0
Average – 8 hours	0.032	10.8
Average – 24 hours	0.025	7.7

Test 2 – Alum Addition – 29 mg/l

Sample	Total P – mg/l	Total Suspended Solids – mg/l
Raw Water	0.061	10
Average – 4 hours	0.019	10.7
Average – 8 hours	0.017	5.3
Average – 24 hours	0.017	3.2

The results show that the alum concentration of 29 mg/l was more effective than the lower dose of 3 mg/l. The alum dose of 29 mg/l removed 72% of the phosphorus after 24 hours while the 3 mg/l dose removed 59%. However, the additional cost of the alum at higher dosages should be considered when evaluating chemical cost versus phosphorus removal effectiveness. The above data is shown in graphical form below.

The results also show that the total suspended solids continued to decline from 4 hours to 24 hours. The floc particles apparently move slowly through the water column and quiescent settling of 24 hours or enhanced settling will be needed to provide good particulate removal. Enhanced settling could be accomplished with the aid of a polymer to form larger particles and speed the particulate settling.

Figure 2-1 Settling Column Phosphorus - 3 mg/l Alum

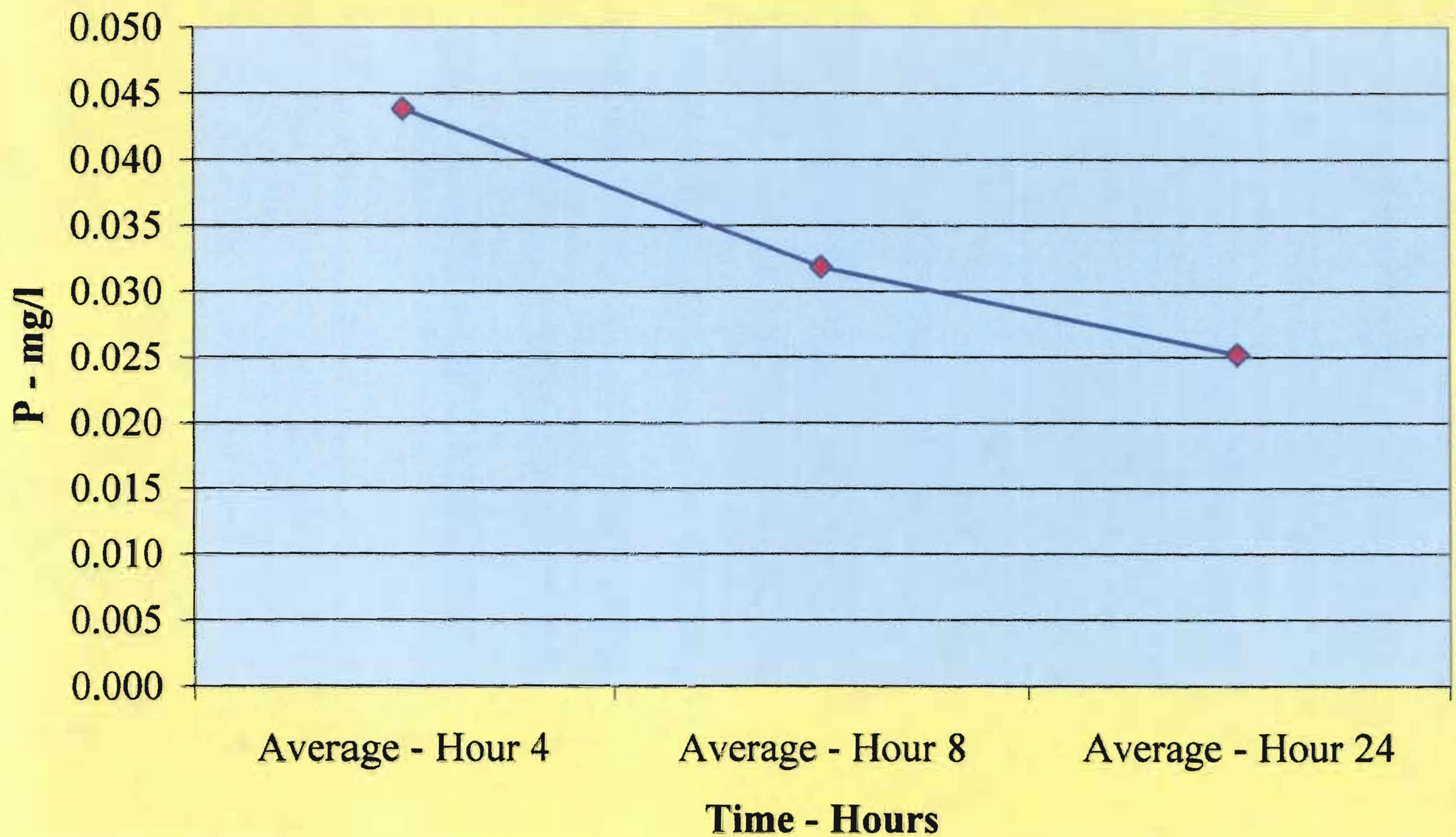


Figure 2-2 Settling Column TSS - 3 mg/l Alum

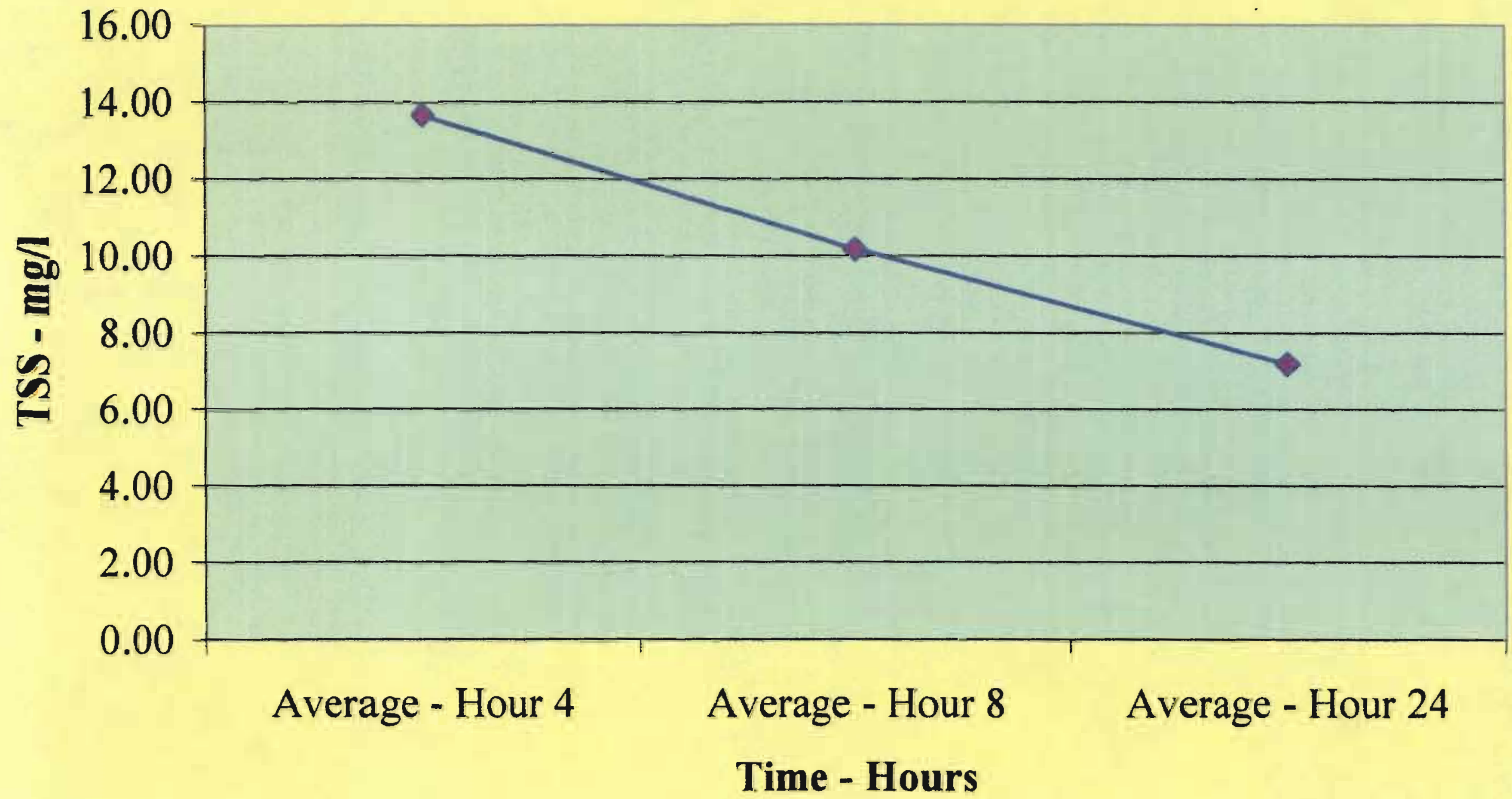


Figure 2-3 Settling Column Phosphorus - 29 mg/l Alum

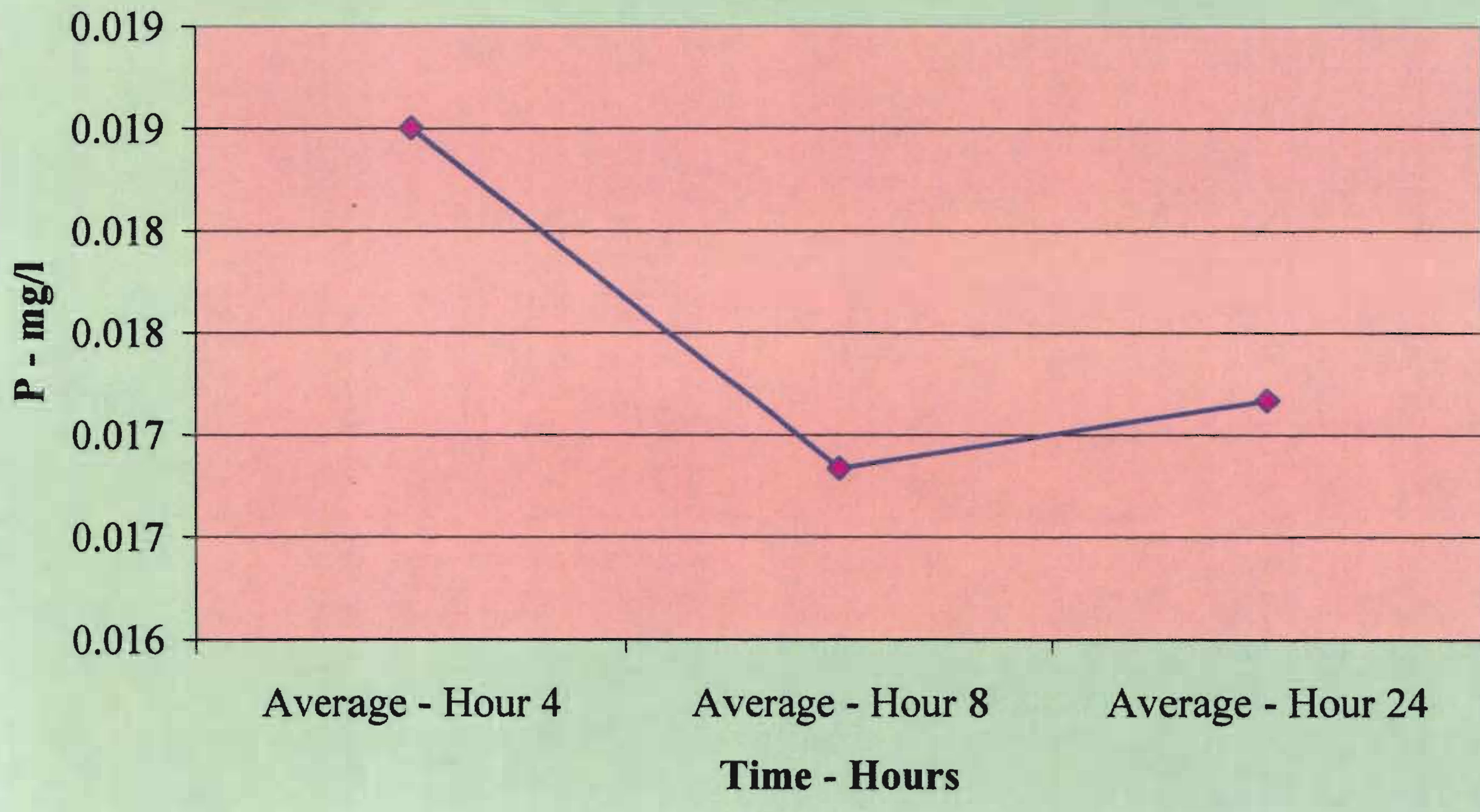
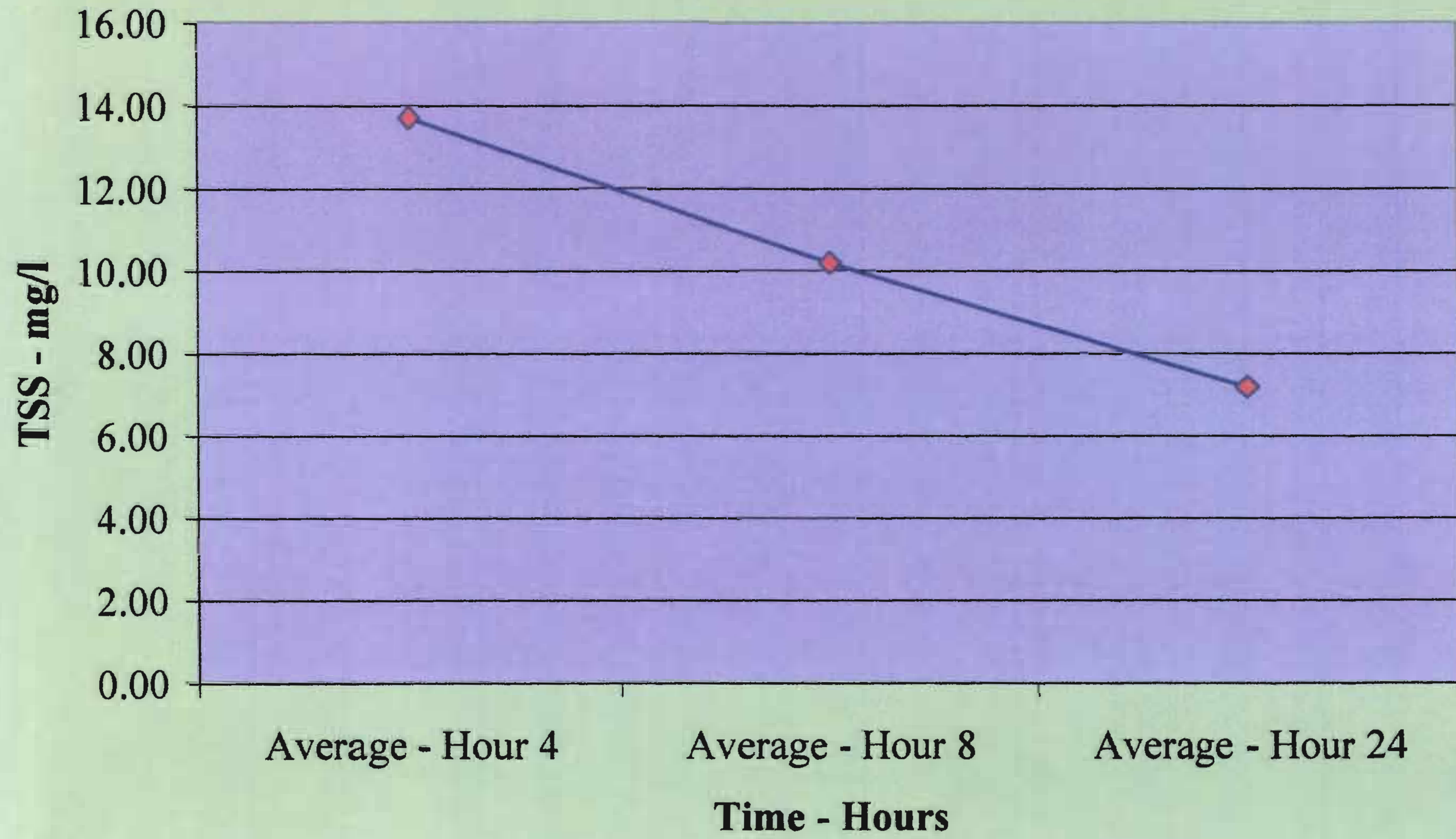


Figure 2-4 Settling Column TSS - 29 mg/l Alum



3. Phosphorus Removal Alternatives

The Lake Management Plan evaluated biological and chemical phosphorus removal alternatives. In the Plan, the biological phosphorus removal alternative was eliminated due to cost, unproven performance, and seasonal operation. Chemical phosphorus removal using alum was considered to be technically feasible. Three options were identified; chemical addition directly to the creek, stream diversion with side stream treatment, and partial lake treatment.

3.1 Direct Chemical Addition to Muskellunge Creek

3.1.1 Process Description

Alum can be applied as a liquid and directly fed to Muskellunge Creek. The alum will react with the phosphorus in the stream to form a precipitate. The precipitate will bind the phosphorus making it unavailable to algae and plants in the lake. Phosphorus precipitate will settle to the bottom of the creek and lake. Figure 3-1 shows sites A and B that are potential sites for adding chemical for phosphorus removal.

3.1.2 Capital Cost

The facilities for this process are relatively simple. A chemical feed system to pump liquid alum into the creek is all that is required. The chemical feed system includes a chemical storage tank and chemical feed pumps. A building will be required to maintain the chemical storage tank above freezing and to protect equipment from the weather and vandalism.

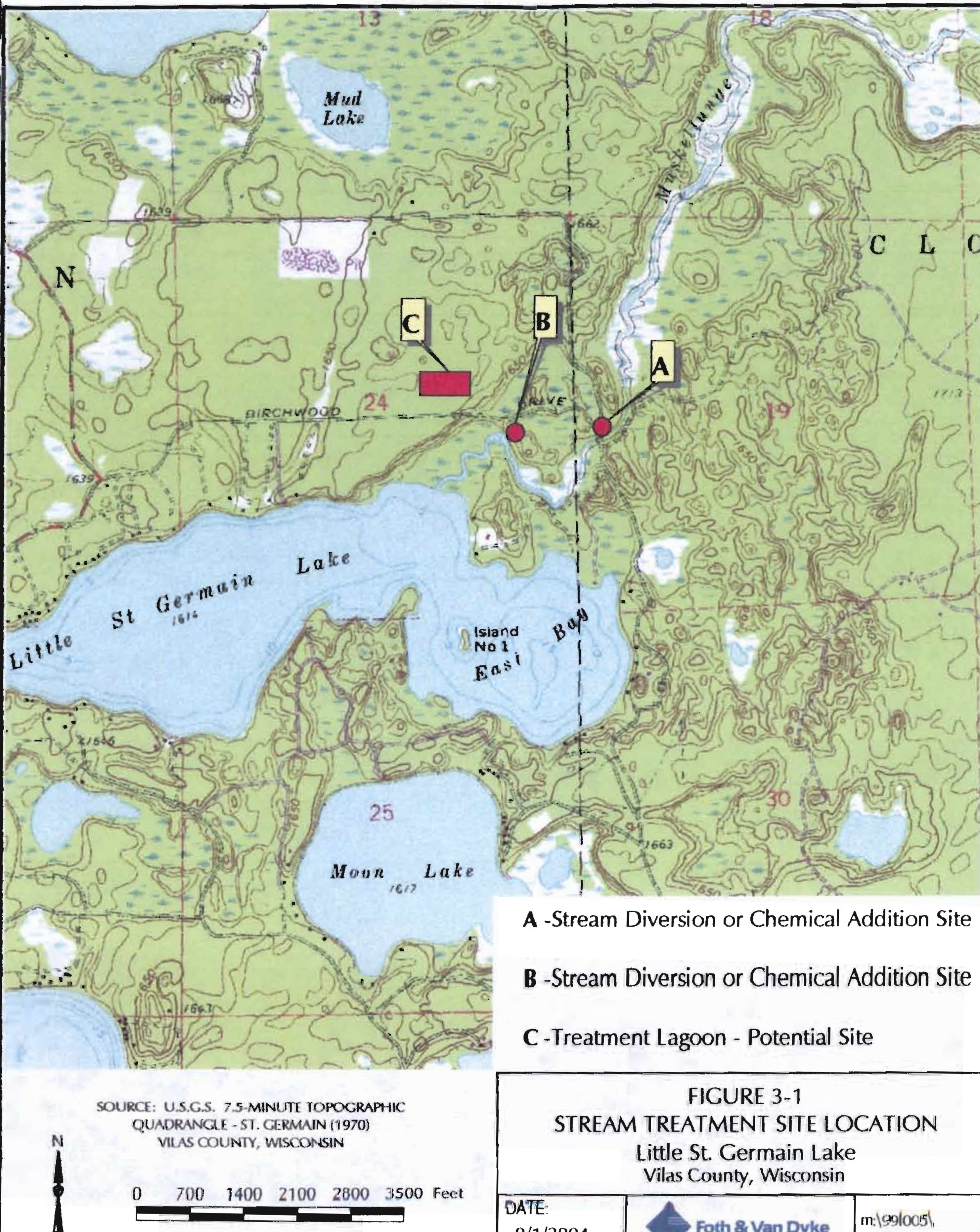
The chemical can be added to the stream through a small diameter pipe (1 inch size). The pipe can be placed on the stream bed and the alum distributed through evenly spaced orifices to get a well mixed process.

3.1.3 Operation Cost

The main operation costs are chemical addition and sludge removal. To determine the cost of these items, an analysis of the processes must be made. The items below describe the potential costs and impacts for each item.

3.1.3.1 Chemical Usage

The settling column test showed 72% of the phosphorus was removed after 24 hours with an alum dose of 29 mg/l. When the alum dose was reduced to 3 mg/l, the test showed 59% of the phosphorus. The USGS report estimated a 50% phosphorus reduction in the stream would decrease the East Bay phosphorus concentration by 0.012 mg/l. A 75% phosphorus reduction would decrease the East Bay phosphorus concentration by 0.019 mg/l. The test results from the settling column were between the two model predictions. Through interpolation, it is estimated that if 59% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.015 mg/l. If 72% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.018 mg/l.



SOURCE: U.S.G.S. 7.5-MINUTE TOPOGRAPHIC QUADRANGLE - ST. GERMAIN (1970) VILAS COUNTY, WISCONSIN

FIGURE 3-1
STREAM TREATMENT SITE LOCATION
Little St. Germain Lake
Vilas County, Wisconsin

DATE: 9/1/2004	Foth & Van Dyke	m:\99\005\ apr\little_sg_1.apr

The above analysis shows that a 10-fold increase in chemical addition resulted in a reduction in lake phosphorus concentration of only 17%. The addition of higher amounts of chemical will result in greater phosphorus removal but the additional cost and solids production may outweigh the benefits.

The average stream flow for Muskellunge Creek at the Birchwood Drive road crossing is 7.3 cubic feet per second. This is equivalent to about 4.7 million gallons of water per day. The amount of alum needed to produce 29 mg/l for this amount of water is approximately 227 gallons per day at a concentration of 5 lbs alum/gallon. At a cost of $1.5 per gallon, the daily cost for alum addition is $340 or $124,300 annually.

If the chemical dosage is reduced to 3 mg/l, the amount of liquid alum required is 23.5 gallons per day. The daily cost for this dosage is $34 or $12,900 annually.

3.1.3.2 Solids Production

The use of alum will form a precipitate when it reacts with phosphorus and other compounds in the water. Some of these solids will eventually settle to the bottom of the river but most will settle in the lake. The area where solids will settle will depend on the settling rate of the solids. From the settling column testing, solids settled consistently over a 24 hour period. This leads to a conclusion that the area where solids will settle will be relatively large. Wind, currents, and boating traffic near the mouth of Muskellunge Creek could disperse the light solids formed from alum addition to the creek water. It is estimated that an area of 70 acres (the upper portion of the 336 acre East Bay) may be impacted from solids deposition. Over time the solids that settle will compress and become part of the sediment. The initial solids concentration may be 2% but over time the concentration may increase to 5% to 10%.

The solids production can be estimated from the settling tube testing. When the higher dose of 29 mg/l was added, some solids quickly settled to the bottom of the settling column. The remainder settled slowly over the 24 hour period until a low level of suspended solids remained. It is estimated that 30 mg/l of suspended solids were precipitated in this test. At a concentration of 2% solids, this volume would be 343,000 cubic feet. Over a 70 acre area, the annual increase in sediment would be 0.11 feet (1.3 inches).

The lower dose of alum produced lighter solids that settled slowly. The solids increased to 13.67 mg/l after 4 hours but dropped to 7.17 mg/l by the end of the test. After 24 hours, it is estimated that 6.5 mg/l of suspended solids were precipitated. At a concentration of 2% solids, this volume would be 75,000 cubic feet. Over a 70 acre area, the annual increase in sediment would be 0.025 feet (0.3 inches).

3.1.3.3 Solids Removal

Solids can accumulate in a lake to an extent that causes navigational problems or becomes a nuisance. Dredging is the method used to remove sediment from a lake. The technique for a large body of water is to use a barge and a pump. The pump suction is connected to an auger that removes sediment from the lake bottom. The solids are pumped to shore through a flexible pipe.

Solids disposal can be done in a variety of ways. Liquid sediment can be trucked to a disposal area. Solids can also be dewatered near the dredging site and hauled as a cake to a disposal area.

3.1.4 Risk Issues

While alum has been used extensively in lake rehabilitation and water treatment, there are several unknowns related to continuous use to precipitate phosphorus from a stream. The rate of solids deposition is difficult to predict and could impact the potential of future sediment removal. The area of the lake impacted by the solids deposition is also unknown and will vary depending on the amount of chemical added, the rate at which the chemical settles, and the water movement near the mouth of Muskellunge Creek.

The addition of alum (aluminum sulfate) has no known toxicity issues but the long term affect from aluminum or sulfate is not known. Sulfate has been linked to an increase in mercury concentration by means of chemical reactions in the sediment releasing mercury into the water column. If Little St. Germain Lake has adequate sulfate concentration naturally, then additional sulfate will not cause more mercury release.

3.1.5 Seasonal Operation

A consideration should be made to operating a chemical feed system on a seasonal basis. If an objective of the chemical phosphorus removal is to reduce the weed growth and algae blooms in the East Bay, then reducing the phosphorus concentration in East Bay during the summer growing season may be all that is required.

East Bay is the largest bay in the lake and covers 336 acres. The maximum depth is 16 feet but over half the bay is less than 10 feet deep. It is estimated that the upper half of East Bay is most affected by Muskellunge Creek. If ½ of East Bay is targeted and is calculated to be 170 acres at 10 feet of depth, the volume of this water is 74 million cubic feet. With an average flow rate of 8 cfs, Muskellunge Creek would replace that amount of water in 107 days. If chemical treatment of Muskellunge Creek began at the beginning of March, by early June, much of the upper ½ of East Bay would have been displaced and the phosphorus concentration would be significantly lower. Treatment could continue until late August for a seven month treatment period.

Seasonal treatment may accomplish most goals at a lower operational cost and reduced risk.

3.2 Sidestream Chemical Phosphorus Removal

3.2.1 Process Description

This alternative diverts a portion of Muskellunge Creek to a treatment lagoon where alum is added and the solids settle in the lagoon. The treated water is then returned to Muskellunge Creek before it discharges into Little St. Germain Lake. This process is complex and includes a diversion structure in the creek, a pumping system capable of about 5,000 gpm, a treatment lagoon, and a return flow structure to discharge water back into Muskellunge Creek. Figure 3-1 shows sites A and B as potential for stream diversion locations. Site C is identified as a potential lagoon site for treatment and settling of the solids.

3.2.2 Capital Cost

The facilities for this process are much more extensive than the in-stream chemical addition alternative. A water diversion structure will be required to intercept water from Muskellunge Creek. This structure is proposed to be concrete and be located in the stream channel. Water from Muskellunge Creek will be diverted to a pump station. The pump station will transfer water to the treatment lagoon. The pump station will be sized for about 5,000 gpm and will have controls to allow about 75% of the creek water to be pumped to the lagoon. At high flows, the amount of water bypassing the pumps will be greater.

At the lagoon, alum will be added to the pumped water and discharged into the lagoon. The lagoon will be sized for a minimum retention time of 24 hours. The required volume is 7.2 million gallons with an additional million gallons reserved for sediment storage. The dimensions of the lagoon will be approximately 280 feet by 520 feet with a water depth of about 10 feet. Solids will settle in the lagoon and clear water discharged back to Muskellunge Creek.

A chemical feed system to pump liquid alum into the treatment lagoon will be required. The chemical feed system includes a chemical storage tank and chemical feed pumps. A building will be required to maintain the chemical storage tank above freezing and to protect equipment from the weather and vandalism.

3.2.3 Operation Cost

The main operation costs are chemical addition and solids removal. To determine the cost of these items, an analysis of the processes must be made. The items below describe the potential costs and impacts for each item.

3.2.3.1 Chemical Usage

The settling column test showed 72% of the phosphorus was removed after 24 hours with an alum dose of 29 mg/l. When the alum dose was reduced to 3 mg/l, the test showed 59% of the phosphorus. The USGS report estimated a 50% phosphorus reduction in the stream would decrease the East Bay phosphorus concentration by 0.012 mg/l. A 75% phosphorus reduction would decrease the East Bay phosphorus concentration by 0.019 mg/l. The test results from the settling column were between the two model predictions. Through interpolation, it is estimated that if 59% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.015 mg/l. If 72% of the phosphorus were removed from the stream, the impact on East Bay would be a phosphorus reduction of 0.018 mg/l.

The above analysis shows that a 10-fold increase in chemical addition resulted in a reduction in lake phosphorus concentration of only 17%. The addition of higher amounts of chemical will result in greater phosphorus removal but the additional cost and solids production may outweigh the benefits.

The average stream flow for Muskellunge Creek at the Birchwood Drive road crossing is 7.3 cubic feet per second. This is equivalent to about 4.7 million gallons of water per day. The pump station will pump about 75% of the stream flow (3.5 million gallons per day). The amount of alum needed to produce 29 mg/l for this amount of water is approximately 169 gallons per day at a concentration of 5 lbs alum/gallon. At a cost of $1.5 per gallon, the daily cost for alum addition is $253 or $92,300 annually.

If the chemical dosage is reduced to 3 mg/l, the amount of liquid alum required is 17.5 gallons per day. The daily cost for this dosage is $26 or $9,500 annually.

3.2.3.2 Solids Production

The use of alum will form a precipitate when it reacts with phosphorus and other compounds in the water. These solids will eventually settle to the bottom of the treatment lagoon. From the settling column testing, solids settled consistently over a 24 hour period.

The solids production can be estimated from the settling tube testing. When the higher dose of 29 mg/l was added, some solids quickly settled to the bottom of the settling column. The remainder settled slowly over the 24 hour period until a low level of suspended solids remained. It is estimated that 30 mg/l of suspended solids were precipitated in this test. At a concentration of 2% solids, this volume would be 256,000 cubic feet per year. Over a 3 acre area, the annual increase in lagoon solids would be 2.0 feet.

The lower dose of alum produced lighter solids that settled slowly. The solids increased to 13.67 mg/l after 4 hours but dropped to 7.17 mg/l by the end of the test. After 24 hours, it is estimated that 6.5 mg/l of suspended solids were precipitated. At a concentration of 2% solids, this volume would be 55,000 cubic feet per year. Over a 3 acre area, the annual increase in lagoon solids would be 0.42 feet.

3.2.3.3 Solids Removal

Solids that accumulate in the lagoon will need to be removed on a regular basis. Excessive solids in the bottom of the lagoon can reduce detention time and treatment capacity. Dredging is the method used to remove solids from a lagoon. The technique for a large body of water is to use a barge and a pump. The pump suction is connected to an auger that removes solids from the lagoon bottom. The solids are pumped to shore through a flexible pipe. An alternative to dredging is to drain the lagoon and allow the solids to dry. The solids could then be removed as a dry product. To facilitate operation and removal, the treatment lagoon could be divided into two cells and one cell remains in operation while one cell is drained and the solids removed.

Solids disposal can be done in a variety of ways. Liquid sediment can be trucked to a disposal area. Solids can also be dewatered near the dredging site and hauled as a cake to a disposal area. Solids removed as a cake have a lower disposal cost due to lower transportation costs.

Because dredging or dry solids removal is an expensive process with a large portion of the cost tied up in mobilization, solids removal should be delayed until a large enough amount of solids is in the lagoon

3.2.4 Risk Issues

This alternative reduces the risk issues associated with phosphorus precipitation in the lake. Implementation is a large risk with this alternative for the following reasons:

- WDNR strives to maintain natural streams and navigable waterways. A large diversion structure in the stream bed, while technically feasible, may be difficult to get permitted for construction.

- Land will need to be acquired near Muskellunge Creek and Birchwood Drive. Because the land requirements are quite specific, if the land is not available, is located in an environmentally sensitive area, or is too expensive, there are no other alternatives available to locate a lagoon and treatment system.

- The cost of the system including operation may be prohibitive.

3.3 Partial Lake Chemical Phosphorus Removal

3.3.1 Process Description

This alternative chemically treats the majority of Little St. Germain Lake. This process applies alum to the lake where the water depth is greater than five feet. The phosphorus in the water column is removed and settles to the bottom. In addition, the alum precipitate reacts with phosphorus released from the sediment preventing it from entering the water column.

The alum is applied to the lake through a special barge designed to apply liquid alum to the lake surface or injected below the surface. The barge can carry several thousand gallons of liquid alum at a time.

3.3.2 Capital Cost

There is no capital cost for this alternative. All costs are incurred by contracting with a company for phosphorus treatment.

3.3.3 Operation Cost

The operation cost is the cost for contracting a company to do the phosphorus removal. Preliminary estimates of a cost for treating approximately 650 acres (excluding West Bay and Upper East Bay) are about $60,000. If the West Bay and Upper East Bay are included, the cost would be greater. The question relating to operating cost is the frequency that total lake treatment is needed.

The volume of water in the 650 acres impacted by Muskellunge Creek (between mouth of the creek and the outlet stream) is about 250 million cubic feet. The annual input from Muskellunge Creek and groundwater is about 350 million cubic feet as determined by the USGS hydrology report from October 2000. These numbers show that there is a water exchange of about 260 days. If chemical treatment is applied in June each year, by March of the following year, the water from the creek and groundwater would have replaced the treated lake water. With phosphorus concentrations in the creek and groundwater at levels higher than normal lake water, the chemical treatment will have little impact on lake phosphorus concentrations for more than 12 months. To maintain low levels of phosphorus in the lake, chemical treatment will be required each year.

3.3.3.1 Solids Production

The amount of alum used for partial lake treatment is similar to the option of adding 30 mg/l to Muskellunge Creek. The amount of precipitate will be spread out over 650 acres and will accumulate at a rate of 0.13 inches per year assuming in settles to 2% solids concentration.

3.3.3.2 Solids Removal

Solids can accumulate in a lake to an extent that causes navigational problems or becomes a nuisance. Dredging is the method used to remove sediment from a lake. The technique for a large body of water is to use a barge and a pump. The pump suction is connected to an auger that removes sediment from the lake bottom. The solids are pumped to shore through a flexible pipe.

Solids disposal can be done in a variety of ways. Liquid sediment can be trucked to a disposal area. Solids can also be dewatered near the dredging site and hauled as a cake to a disposal area.

3.3.4 Risk Issues

This alternative includes risk issues associated with phosphorus precipitation in the lake. These issues were discussed in Section 3.1.4. The cost of annually treating the lake for phosphorus may be prohibitive.

3.4 Lake Aeration Impact

Lake aerators are used in winter to provide oxygen to areas of the lake that typically become anoxic. There are three aerator locations in Little St. Germain Lake; South Bay, Upper East Bay and near the mouth of Muskellunge Creek. The aerators are operated for approximately 3 months in winter beginning in January and ending in late March.

Phosphorus precipitation from addition to the stream or lake will settle near the aerators located at the bottom of the lake in South Bay and near the mouth of Muskellunge Creek. Areas near the aerators may have velocities great enough (approximately 1 foot per second) to re-suspend settled particles. This is true of phosphorus precipitates as well as other lighter sediments. These light particles will settle in other areas of the lake that have less turbulence.

The lake aerators are not operated when the seasonal phosphorus treatment system is operated. This is true for the in-stream treatment alternative and the partial lake treatment alternative. The phosphorus precipitate will settle under natural lake conditions before the lake aerators are started up in winter. The only impact the aerators will have on phosphorus precipitates is in areas adjacent to the aerators where velocities are high enough to suspend light sediment. The total area impacted by the aerators will be less than 1 acre.

4. Phosphorus Removal Cost Analysis

4.1 General

A cost-effectiveness analysis will be performed on the three phosphorus removal alternatives. The cost-effectiveness analysis is based on a 20 year project life. Each phosphorus removal alternative uses the present worth analysis method to compare total costs over a 20-year period. The interest rate used in this evaluation is 6%. The analysis includes capital costs and operation and maintenance costs.

4.2 Direct Chemical Addition to Muskellunge Creek

The capital cost for this alternative includes:

- Chemical feed building
- Chemical feed equipment
- Piping
- Site work
- Electrical
- Land
- Technical, administrative
- Contingency

The estimated project cost is $279,000. Appendix B contains detailed information on the project cost.

The operation cost was calculated for a 12 month operational period and a 6 month operational period. The cost for operation over a 6 month period is $13,700 while the cost of operation over a 12 month period is $24,800. These costs assume an alum feed rate of about 3 mg/l.

4.3 Sidestream Chemical Phosphorus Removal

The capital cost for this alternative includes:

- Stream diversion structure
- Pump Station
- Treatment Lagoon
- Chemical feed building
- Chemical feed equipment
- Piping
- Site work
- Electrical
- Land
- Technical, administrative
- Contingency

The estimated project cost is $1,632,000. Appendix B contains detailed information on the project cost.

The operation cost was calculated for a 12 month operational period and a 6 month operational period. The cost for operation over a 6 month period is $49,100 while the cost of operation over a 12 month period is $98,100. These costs assume an alum feed rate of 3 mg/l.

4.4 Partial Lake Chemical Phosphorus Removal

There are no capital costs for this alternative. The annual operation and maintenance cost is estimated at $60,000 for a chemical application to the main lake channel.

4.5 Present Worth Summary

The following table summarizes the cost-effective analysis for the phosphorus removal alternatives:

Alternative	Capital Cost	Annual O&M Cost	Total Present Worth
In-stream Treatment	$279,200	$13,700	$436,300
Treatment Lagoon	$1,632,000	$49,100	$2,195,000
Partial Lake Treatment	$0	$60,000	$688,200

The above table shows the in-stream treatment alternative to be the most cost-effective. This analysis assumed that seasonal phosphorus removal would be implemented to reduce the annual operation cost.

5. Internal Phosphorus Loading

The USGS report dated October 2000 included a phosphorus budget for Little St. Germain Lake. Sources of phosphorus identified in the report included precipitation, stream inflow, groundwater, and septic tanks.

An additional phosphorus source not previously identified is internal loading. This occurs as phosphorus contained in the sediment is released back into the water column. This release takes place under aerobic and anaerobic conditions.

At this time it is unknown what impact the internal loading has on the overall phosphorus budget in Little St. Germain Lake. Before the District evaluates phosphorus removal alternatives, the impact of internal phosphorus loading should be considered. If the internal loading is a relatively large portion of the phosphorus budget, then chemical treatment of the stream may be less effective in lowering the phosphorus concentration in the lake. Therefore, an analysis of internal phosphorus loading should be done before a decision is made on chemical phosphorus treatment.

6. Conclusions and Recommendations

6.1 Conclusions

- Muskellunge Creek contributes 53% to 61% of the total phosphorus to Little St. Germain Lake.
- Removing phosphorus from Muskellunge Creek will improve water clarity and reduce phosphorus concentrations up to 46%.
- Little St. Germain Lake will remain a eutrophic lake if all the phosphorus is removed from Muskellunge Creek.
- Laboratory tests showed alum can remove phosphorus from Muskellunge Creek.
- A laboratory settling column test showed that significant phosphorus removal (59% removal) occurred with an alum dose of 3 mg/l provided that 24 hours of settling occurred.
- An alum dose of 29 mg/l provided more rapid settling and greater phosphorus removal (72% removal).
- Direct chemical addition to Muskellunge Creek is a feasible alternative with risk issues regarding solids settling in the lake.
- Sidestream chemical addition and treatment will eliminate most solids settling in the lake but has a higher cost and may not be permitted due to impacts on the stream habitat.
- Seasonal chemical treatment should be considered to reduce operational cost and minimize solids build-up.
- Partial lake treatment is a feasible alternative to reducing phosphorus concentrations in the lake. To keep phosphorus concentrations low, partial lake treatment will need to be repeated each year. The water entering the lake from the inlet stream and groundwater has an average residence time of less than one year.
- Internal phosphorus loading has an unknown impact on the lake.
- Lake aeration will have a negligible impact on phosphorus precipitation.

6.2 Recommendations

- Determine the impact of internal phosphorus loading in the summer of 2005. Contact USGS to prepare a work plan and apply for a lake planning grant to conduct the work.
- Evaluate the feasibility of implementing the direct chemical treatment in Muskellunge Creek alternative by doing the following:

A. Determine location of treatment facilities and the possibility of obtaining land and easements.
B. Review permitting issues with WDNR.
C. Consider model of lake phosphorus based on seasonal operation.
D. Prepare financing plan including WDNR Lake Protection Grant.
E. Obtain property owner comments with educational flyer and survey.

Executive Summary

Foth & Van Dyke was retained by the Little St. Germain Lake Protection District (District) to evaluate management alternatives based on water quality studies completed over the last several years. The District received a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) which provided funding up to $10,000 for this project.

This evaluation and report focused on the existing water budget and water quality, lake management alternatives available to improve the water quality of Little St. Germain Lake, and the cost to implement these alternatives.

Water Quality

Much of Little St. Germain Lake is classified as eutrophic. Algae blooms and excessive weed growth occur in summer and anoxic (lack of oxygen) conditions occur in winter in much of the lake. These water quality problems are due to high levels of phosphorus in the lake. Studies identified the main tributary, Muskellunge Cr., as the primary contributor to the high levels of phosphorus in the lake.

Water and Phosphorus Budget

The study of the water and phosphorus budget for Little St. Germain Lake shows Muskellunge Cr. to be the largest input of water and phosphorus. Groundwater is the second largest source of both water and phosphorus. Little St. Germain Cr. is the largest source of water outflow. Surface runoff and septic systems were minor sources of phosphorus and contribute little to the water quality status.

Water Quality Improvement Alternatives

Effective phosphorus reduction can best be accomplished by removing phosphorus from Muskellunge Cr. Other sources of phosphorus were either minor or could no be treated at one location. Chemical phosphorus removal using alum was evaluated and determined to be the recommended approach. Alum can be added to the creek and settled in the lake or water from the creek can be diverted and treated separately before discharge back into the creek. Alum added directly to the creek will have sludge settle in the lake that may need to be removed at a future time.

Oxygen can be added to the Upper East Bay and the South Bay to minimize the anoxic conditions that occur there in winter. The lake water can be aerated with an in-lake aeration device, utilizing compressed air or by pumping lake water to a cascade device on the shore and discharging back into the lake.

Cost and Impact Analysis

The cost for direct alum addition to Muskellunge Cr. for phosphorus removal is the lowest capital cost estimated at $188,000. The future cost for dredging the lake of accumulated sludge could be high and the annual operation cost assumed accumulating funds for a future dredging project. The present worth of this alternative is $1,967,000. A second alternative evaluated pumping approximately 75% of the creek water to a pond where the chemically treated water would settle the phosphorus sludge before returning to the creek. The capital cost is higher for this alternative but the lake would not need to be dredged in the future. The sludge could be removed from the pond at a much lower cost than dredging the lake. The capital cost is estimated at $817,000. The present worth cost for this alternative is $1,626,000. The chemical treatment alternatives are nearly equal in present worth costs and should be selected based on other factors. The alternative that is most protective of the lake is the use of the treatment pond.

The cost for pumping lake water to a cascade device is estimated at $170,000. The cost for a compressed air system with air diffusers at the lake bottom will be about $44,000. Based on these costs, the compressed air system is the most cost-effective system and is recommended.

The report concludes with a recommendation to obtain a lake planning grant for installing two aeration devices and completing preliminary engineering to develop a design for phosphorus removal. This engineering work would perform chemical addition and settling tests to confirm the correct chemical dosage and sludge settling rate.

Lake Management Plan

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Appendices

1 Introduction

1.1 Purpose

The purpose of this lake management plan is to identify the problems relating to Little St. Germain Lake and develop a plan to address these problems. The planning process evaluates alternatives to address the problems. The intent of this process is to determine the most cost-effective and environmentally sound approach to address the water quality problems in Little St. Germain Lake.

1.2 Scope

The work contained in the lake management plan includes the following major items:

- Summarize water quality issues.
- Determine existing water budget.
- Determine existing phosphorus budget.
- Identify alternatives for water quality improvements in Little St. Germain Lake.
- Evaluate alternatives on cost and environmental impact.
- Recommend alternatives for implementation.
- Provide an implementation schedule and financial approach.

1.3 Project Planning Area

The project planning area is the physical watershed around Little St. Germain Lake. Appendix A contains a recent report published by USGS regarding water quality studies done on Little St. Germain Lake. Figure 1 in Appendix A shows the project planning area and the land use in the planning area.

2 Existing Conditions

Little St. Germain Lake has been the subject of significant research in the past decade. This research has helped lake district members and the scientific community understand the existing conditions. This lake management plan will not provide detailed information on past work but will summarize the research to document the water quality problems in the lake and provide a basis for identifying water quality improvement alternatives.

2.1 Fishery

The Wisconsin Department of Natural Resources completed a creel survey report on Little St. Germain Lake in 1997. The survey showed that Little St. Germain Lake has the highest fishing pressure of any lake in north east Wisconsin. Fishermen spent about 106 hours of effort for each acre in the lake. This is a rate over three times the county average.

From this data we can conclude that fishing is an important recreational activity. To maintain a quality fishery, water quality must be maintained.

2.2 Water Quality

Little St. Germain Lake is unique in that water quality varies considerably from one area of the lake to another. A common tool in evaluating water quality is trophic status index. This index considers concentrations of phosphorus and chlorophyll a as well as Secchi depth to determine the trophic state of the lake. The three lake categories based on trophic state are :

Oligotrophic: Young lakes with low productivity which are generally clear, cold, deep, and free of weeds or large algae blooms. Oligotrophic lakes are low in nutrients and therefore do not support plant growth or large fish populations, however are capable of sustaining a desirable fishery of large game fish.

Mesotrophic: These lakes are in an intermediate stage between the oligotrophic and eutrophic stages. They are moderately productive, supporting a diverse community of native aquatic plants. The bottoms of mesotrophic lakes lack oxygen in late summer months or winter periods which limits cold water fish and causes phosphorus cycling from sediments. Overall however, mesotrophic lakes support good fisheries.

Eutrophic: Lakes which are high in nutrients and support a large biomass are categorized as eutrophic. These old age lakes are usually weedy and/or experience large algae blooms. Most often they support large fish populations, however are also susceptible to oxygen depletion which limits fishery diversity. Rough fish are common in eutrophic lakes.

The trophic state of a lake can be determined by observing three lake characteristics including total phosphorus concentration (Total-P) which indicates the amount of nutrients present which are necessary for algae growth, Chlorophyll *a* concentration which is a measure of the amount of algae actually present, and Secchi disc readings which is an indicator of water clarity. As expected, low levels of Total P are related to low levels of Chlorophyll *a*, which are related to high Secchi disc readings.

To determine the trophic state of the lake, the Wisconsin Trophic State Index (WTSI) can be applied to each of the above noted factors. The WTSI converts the actual measurement into a value which is representative of one of the trophic states. Values less than or equal to 39 indicate oligotrophic conditions, values from 40-49 indicate mesotrophic conditions, and values equal to or greater than 50 represent eutrophic conditions.

The Northeast Basin had trophic status index values that were consistently in the eutrophic range. The South Basin had trophic status index values that were both eutrophic and mesotrophic. The West Basin had trophic status index values consistently in the mesotrophic range.

2.2.1 Phosphorus

The lower water quality in the East and South Basins is predominantly caused by high phosphorus concentrations from Muskellunge Cr. Muskellunge Cr. enters Little St. Germain Lake in the East Basin. This creek influences flow patterns in the lake and water flows south and west through the South Basin to exit at St. Germain Cr. The West Bay is isolated from the impacts of the creek and has consistently better water quality.

Phosphorus concentrations in Muskellunge Cr. averaged 71 ug/l in 1997 and 55 ug/l in 1999. Phosphorus in Little St. Germain Lake was affected by the creek. The East Bay had P concentrations of approximately 50 ug/l, the South Bay had concentrations of approximately 35 ug/l, and the West Bay had concentrations of approximately 15 ug/l. The water quality in the East Bay and the South Bay are affected by Muskellunge Cr. The high phosphorus concentrations in the East Bay and South Bay have led to algae blooms and reduced water clarity.

2.2.2 Dissolved Oxygen

Dissolved oxygen is an important water quality parameter in regard to fisheries. The Upper East Bay, East Bay, and South Bay in Little St. Germain Lake have experienced oxygen depletion in winter. Studies showed dissolved oxygen greater than 2 mg/l (the minimum concentration for fish survival) within 5 feet of the surface in East Bay and almost no dissolved oxygen (anoxic) in Upper East Bay and South Bay and West Bay had adequate dissolved oxygen at depths of over 20 feet.

The anoxic conditions in Upper East Bay, East Bay and South Bay have a negative impact on fisheries. These areas are not habitable by fish during anoxic conditions. Fish either leave these areas or die. Late in winter, fish are congregated in West Bay which is good for fisherman but may not be good for fish. Anoxic conditions also impact other biological organisms that live in the sediments. These organisms are food for fish but most cannot survive extended periods of anoxic conditions.

Anoxic conditions also affect the lake chemistry. When oxygen is present in the water, phosphorus is less soluble and will remain in the sediment. Organic material decomposing under anoxic conditions can release odorous compounds and may cause a nuisance at some times of the year.

2.2.3 Water Level Fluctuation

Water levels in Little St. Germain Lake are controlled by the Wisconsin River Authority. Each winter the lake level is drawn down by about 1.5 feet. This draw down removes a supply of oxygen from the lake and contributes to the anoxic conditions in South Bay and East Bay. Unfortunately, this condition will continue since the Wisconsin River Authority uses the draw down and refilling for power and flood control.

2.3 Water Budget

A water budget was prepared to aid in analyzing inputs to Little St. Germain Lake. Figure shows the water budget. Muskellunge Creek is the largest input to the lake. The flow from Muskellunge Cr. varied considerably from 1997 to 1999. The flow in 1999 was about 40% lower than the flow in 1997. This was due to a decrease in rainfall and water table in the drainage basin. The lake also shows a net groundwater inflow to the lake. The outlet, St. Germain Cr. is the largest outflow from the lake.

2.4 Phosphorus Budget

Muskellunge Cr. is the largest input to phosphorus in Little St. Germain Lake. Groundwater is another significant component. The phosphorus input from Muskellunge Cr. is apparently flow sensitive. In 1997, the phosphorus load from Muskellunge was 1,500 pounds. The phosphorus load dropped to 700 pounds in 1999. Most of the decrease was due to lower flows in Muskellunge Cr., although the phosphorus concentration in the creek also decreased from 1997 to 1999. This analysis shows that 50% to 60% of the phosphorus entering the lake came in from Muskellunge Cr.

Groundwater is the second largest source of phosphorus added to Little St. Germain Lake. The actual concentration of phosphorus in the groundwater and the volume of groundwater was not measured but estimated based on the overall water and phosphorus budget. The estimated phosphorus load from groundwater was 835 pounds in 1997 and 512 pounds in 1999. This represents 35% to 39% of the total phosphorus budget.

The phosphorus budget also shows that precipitation related phosphorus addition is a minor amount compared to additions from Muskellunge Cr. and groundwater. The land use tributary to Little St. Germain Lake has little or no agriculture and as a result, precipitation has little impact on the lake water quality. Approximately 2% of the total phosphorus budget is contributed by precipitation.

Septic systems were also shown to be a minor source of phosphorus. The typical on-site wastewater system does remove particulate forms of phosphorus in the septic tank. A properly sited and operating soil absorption system will also remove phosphorus. The result is little impact from septic systems when compared to the significant impact of Muskellunge Cr. Approximately 2% of the total phosphorus budget is contributed by septic tanks.

It should be noted that soil has a finite capacity for phosphorus removal. When soil capacity has been reached, phosphorus will leach into the groundwater. The potential contribution by septic systems is significant.

2.5 Summary

Little St. Germain Lake is a popular recreational lake and productive fishing lake. Water quality is eutrophic in many areas of the lake and could lead to impairment of the recreational uses. Eutrophic conditions are evident from algae blooms, excessive weed growth and anoxic conditions in winter. The eutrophic conditions are primarily caused by high phosphorus loading from Muskellunge Cr. Dissolved oxygen becomes depleted in some areas of the lake in winter which can have a negative impact on fish and their food supply.

3 Watershed and Land Use

The watershed around Little St. Germain Lake is almost entirely natural woodland and wetland. Residential and commercial development is mainly along the shores of the three large lakes in the watershed; Little St. Germain Lake, Muskellunge Lake, and Snipe Lake. The land use is shown on Figure 1 in Appendix A. The analysis done on the phosphorus budget indicated a low percentage of phosphorus came from septic systems or precipitation.

Initial studies show a significant quantity of phosphorus enters Muskellunge Cr. between Muskellunge Lake and Little St. Germain Lake. The source of the phosphorus was concluded to be groundwater. This conclusion was based on the native woodland and wetland environment between the two lakes, therefore, the phosphorus addition is a natural occurrence predominantly coming from groundwater.

Muskellunge Cr. is prime habitat for beavers. The high phosphorus loading in 1997 was during a period of significant beaver activity. Beaver dams cause the creek to flood areas of wetland which can release phosphorus from sediments and vegetation. The removal of beaver dams in 1999 may have had a positive impact on the phosphorus concentration in Muskellunge Cr.

4 Need and Problem Assessment

Residents of the Little St. Germain Lake Protection District have been involved with the water quality study over the past several years. The lake district commissioners have held public meetings to discuss issues regarding the lake. The concerns expressed by most residents are:

- algae blooms
- weed growth
- anoxic conditions in winter

These problems have been documented through water quality research. The problems indicate a eutrophic condition in the lake and the high concentration of phosphorus in the lake is the cause for this condition.

Many residents expressed a desire to move forward with steps to improve the lake water quality rather than continue to study the lake. The eutrophic conditions that have caused algae blooms and excess weed growth in the lake will likely continue and increase in intensity without taking positive steps to change those conditions.

5 Water Quality Improvement Alternatives

5.1 No Action

This alternative allows conditions to remain as they are without expending money or effort on lake improvements. The existing problems will continue and likely will increase without actions to improve the water quality. This alternative is not recommended.

5.2 Weed Control

Chemical and physical weed control have been used at many lakes as part of an overall lake management plan. Weed growth has been a concern to residents and may require management at some time. At the present time, residents have stated that a greater emphasis should be placed on improving the algae problems.

5.3 Phosphorus Reduction

The eutrophic conditions in portions of Little St. Germain Lake have high phosphorus concentrations as the primary cause. The phosphorus budget showed Muskellunge Cr. to be the primary source of phosphorus in Little St. Germain Lake. Reducing phosphorus concentrations in Muskellunge Cr. will have a direct impact on the quantity of phosphorus entering Little St. Germain Lake.

Models done by USGS show that phosphorus concentrations in the East Bay could be reduced by 25% to 46% depending on the amount of phosphorus removed from Muskellunge Cr. Even with this reduction, the water would still be classified as eutrophic. However, water clarity would improve and the blue-green algae nuisance blooms would be expected to decrease in frequency and intensity.

5.3.1 Biological Phosphorus Reduction

Phosphorus is an essential plant nutrient and is readily taken up by many plants. Constructed wetland systems have been designed to enhance the natural phosphorus uptake by plants. Removal of the plants (and the phosphorus they contain) from the system is a key element of this approach. Wetland plants include emergent types like rushes and cattails or floating types like hyacinth and duckweed. Duckweed (Lemna spp.) has a high phosphorus uptake rate and is a native plant species to Muskellunge Cr. Engineered systems are available which contain the floating duckweed plants in a plastic grid. The plants can be harvested by a special harvesting machine without removing the grid or draining the pond.

A large scale pilot system using duckweed was installed on Plum Creek near Denver, Colorado in 1994. The results were mixed caused by the low concentrations of nitrogen and phosphorus in the water. Influent concentrations of phosphorus in Plum Creek were about 100 ug/l. Effluent concentrations were about 50 ug/l. Operation was difficult due to the slow growth rate of the duckweed. Nitrogen and phosphorus fertilizers were used to enhance the duckweed growth. In the first year of operation, no duckweed was harvested and the appropriate plant density was not obtained in spite of several duckweed additions. The detention time used was 10 days.

A full scale system on Muskellunge Cr. would require a treatment pond of 80 to 100 million gallons to achieve a detention time of 10 days. A pond with a depth of 6 feet would require over 50 acres of land area for a volume of 100 million gallons. The estimated cost for this system would be prohibitive (greater than $1,000,000). Other disadvantages are the seasonal operation of the system. Duckweed would be active from mid May through September in north Wisconsin. No phosphorus removal would take place when the duckweed plants were not actively growing. This would allow phosphorus removal to take place in about one-third of the year. Maintenance may be significant to keep the duckweed growing well. For these reasons biological phosphorus removal is not recommended for further evaluation.

5.3.2 Chemical Phosphorus Removal

Phosphorus can be removed from water solutions by the use of metal salts. Aluminum and iron are the most common chemicals used for phosphorus removal. Aluminum is the preferred chemical for natural waters for several reasons. Iron is an effective chemical for phosphorus removal when maintained in an aerobic environment. When iron phosphates are subjected to an anaerobic environment, the phosphorus can be released back into solution. Aluminum phosphates do not re-dissolve which makes aluminum a better chemical choice for this application. Aluminum is also less hazardous to work with. For these reasons, only aluminum will be evaluated for use at Little St. Germain Lake.

Aluminum reacts with phosphorus to convert soluble phosphorus to an insoluble precipitate. Aluminum also reacts with other compounds in the water to form other precipitates. The most common aluminum salt is aluminum sulfate or alum. This chemical is commonly used in wastewater treatment facilities for phosphorus removal. It is also used for clarifying surface waters in potable water treatment plants. In natural waters the alum will form hydroxides and will coagulate small particles and colloidal compounds. The result will be the removal of bacteria, algae, and other small particles. The water will be clearer and a sludge will be formed.

Foth & Van Dyke conducted jar tests on water samples collected in Muskellunge Cr. Alum was added at concentrations of 20 mg/l and greater. Tests showed that nearly all soluble phosphorus was removed with that chemical dosage. It is estimated that effective phosphorus removal can be achieved with dosages of 10 mg/l. The initial phosphorus concentration in Muskellunge Cr. on 9-3-99 was 47 ug/l. The conclusion is that chemical phosphorus removal can be an effective process when applied to Muskellunge Cr. Appendix B contains the phosphorus test information.

Implementing chemical phosphorus removal can be done in several ways. A simple method would be chemical addition to the creek. The advantages of this alternative is minimal construction cost and effective treatment of the entire stream volume. The disadvantages include chemical sludge that will settle out in the lake. The continuous chemical addition will result in an accumulation of sludge in the lake. The sludge would settle similar to a river delta with most sludge around the creek mouth and smaller amounts in the rest of the lake. This sludge may cause a nuisance and will require dredging at some future time. Dredging in a lake is relatively expensive.

A second treatment method is to provide a pond for settling the sludge before the water is discharged to the lake. Water from the creek would need to be diverted to the treatment pond. A pump station would pump the water to the treatment pond where alum would be added. The resulting sludge would settle in the pond. Treated water would be discharged back to the creek and flow to the lake. This alternative would treat water on a continuous basis but would be able to treat only about 75% of the water. The advantage of this alternative is that sludge would settle in the treatment pond rather than in the lake itself. When it became necessary to remove sludge from the pond, the pond could be taken out of service and the sludge removed. The cost for sludge removal from the pond would be much less than sludge removal from the lake.

A third treatment method is to provide a mechanical treatment system for phosphorus removal. Typical unit processes include chemical addition, flocculation, clarification, and sludge removal/storage. All processes will require a building to protect the units from the weather. These processes will be expensive compared to the first two alternatives and will require labor intensive operation. For these reasons, a mechanical phosphorus removal treatment will not be used.

5.4 Supplemental Oxygen

Large portions of Little St. Germain Lake experience anoxic conditions in winter. Adding oxygen at one or more sites in the lake will increase oxygen levels in the lake. Several alternatives exist for oxygen addition.

5.4.1 On-Shore Oxygen Addition

Water can be pumped from a lake or stream up to a cascade structure on the lake shore. The water falls over the cascade structure, adding oxygen as it splashes. The oxygenated water is then discharged back into the water.

There are two potential locations for this type of aeration system. The first is on Muskellunge Cr. before it enters Little St. Germain Lake. Oxygen addition at that point will have an impact on the East Bay since the creek flow moves through the bay. Data collected from Muskellunge Cr. shows relatively high oxygen levels on March 18, 1997 (7.8 mg/l). The dissolved oxygen in the creek would need to be raised to 11 to 12 mg/l to have a significant impact on the lake. As the oxygen concentration increases in water, it requires significantly more energy to transfer oxygen to the water. The size and cost of a cascade aeration system would be prohibitive to raise the dissolved oxygen concentration in water from 7.8 mg/l to 12 mg/l. On-shore oxygen addition on Muskellunge Cr. will not be considered further.

A more efficient location for on-shore aeration is in South Bay or Upper East Bay where the dissolved oxygen concentration is zero in winter. Water would be pumped from the lake bottom to a cascade structure on shore. After the water cascades over the structure and dissolved oxygen is added, the water would be discharged to the lake bottom. This system will be more efficient because the anoxic water drawn from the lake bottom easily receives oxygen from the air. An advantage of this system is that the water can be drawn from a deeper portion of the lake and discharged to a deep portion of the lake. This will minimize surface turbulence and may allow the lake to freeze over these points. Winter recreational activities may be allowed to continue without a problem. Disadvantages are the large structure and pumping system on the lake shore and the large diameter pipes needed to transfer water from the lake to the cascade aeration system.

5.4.2 In-Lake Oxygen Addition

Most lakes with anoxic conditions provide an in-lake oxygen addition system. This typically consists of a blower or air compressor on the lake shore and an air diffuser system installed in the lake. The aeration system adds oxygen to the water and the current caused by the rising air bubbles creates and open area in the lake. This open area also adds oxygen from the atmosphere.

The advantage of this system is the minimal amount of equipment required. The disadvantage is the potential hazard open water creates for winter recreation. The open area must be well marked and blocked from access by snowmobilers and fisherman.

5.5 Evaluate and Improve Septic Systems

Septic systems can be a source of pollutant discharge to lakes. This is true where septic systems are improperly installed, maintained or designed. Pollutants can enter the lake through surface waters when septic systems fail above ground. Pollutants can also enter the lake through groundwater where there is inadequate soil for treatment before the wastewater enters the groundwater.

A sanitary survey is a study that identifies the potential for pollution to enter the lake from septic systems. Various study techniques can be used including on-site inspections, soil borings, and in-lake chemical studies. The findings can be used to upgrade septic systems and reduce the amount of pollutants entering the lake.

The phosphorus balance showed septic systems to be a minor source when compared to Muskellunge Cr. and natural groundwater. Eliminating all septic systems would have a neglible impact on the lake water quality. For this reason, evaluating septic systems is not a high priority and is not recommended for further evaluation at this time.

5.6 Reduce Runoff from Agricultural and Construction Site Sources

The phosphorus budget showed precipitation related phosphorus sources to be minor when compared to Muskellunge Cr. and natural groundwater. With a vast majority of the existing watershed in natural forest and wetland, runoff from agricultural and construction site sources is a small source of phosphorus addition to Little St. Germain Lake.

Erosion control from construction or residential land use should be emphasized by the lake district. This could be done by education and supporting state and local erosion control ordinances. Many publications have been produced regarding residential landscaping and pollution control. These publications should be made available to the district residents and promoted in newsletters. Beyond this effort, runoff related phosphorus control is not a high priority and is not recommended for further evaluation at this time.

6 Cost and Impact Analysis

6.1 Supplemental Oxygen

Supplemental oxygen will be evaluated for locations in Upper East Bay and South Bay. These areas consistently become anoxic in winter and receive no oxygen from Muskellunge Cr. These bays also have areas with a depth of 15 feet or greater. This depth is necessary for aeration devices to be effective. Figure 6-1 shows the proposed aeration locations.

6.1.1 On-Shore Oxygen Addition

This aeration system will require an electrically powered pump on the lake shore to draw water from the lake bottom to the pump. The pump would be located in a wet well with the suction pipe connected to the lake. Lake water would be pumped to a cascade structure with a series of steps where the splashing of the water would add oxygen. Aerated water would discharge from the bottom of the cascade through a pipe to the lake bottom.

The cascade size was assumed to be large enough to add 200 pounds of oxygen per day. To add this amount of oxygen, the oxygen concentration must be raised from 1 mg/l to 5 mg/l and the flow rate must be 4,000 gallons per minute. This flow rate requires a large pump with suction and discharge piping of 20 inch size. The cascade would also be a large structure approximately 10 feet by 20 feet to spread out the water over the steps.

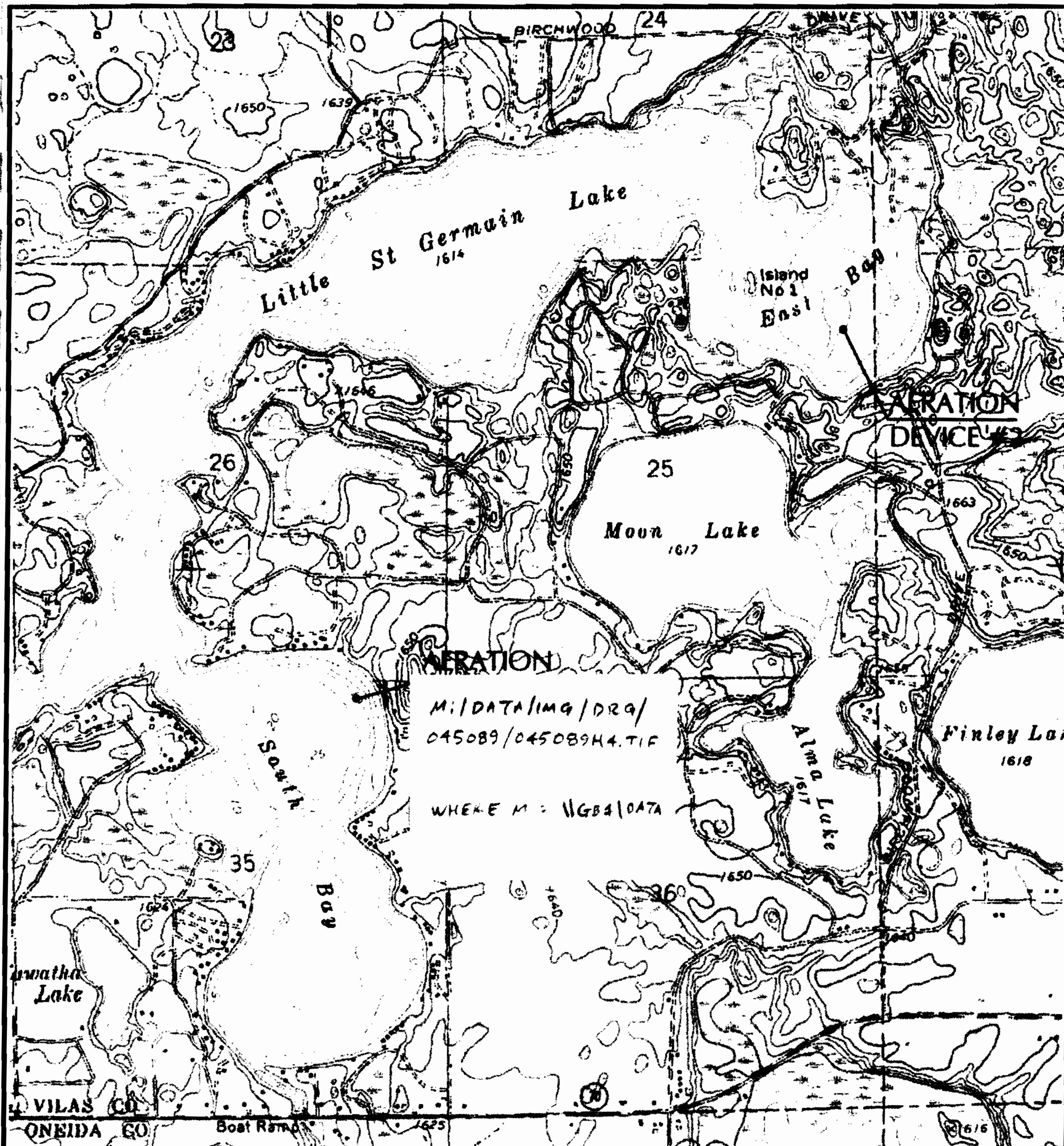
The cost for each on-shore aeration system is estimated at $170,000. Operation costs including power costs for a typical three month aeration season would be approximately $5,000. The large motor size (30 - 40 hp) will require three phase electrical power which may need to be brought in from a long distance or a phase converter required to meet the electrical requirements.

6.1.2 In-Lake Oxygen Addition

This aeration system will require an air blower located on shore with aeration piping extending into the lake. The piping would have air diffusers installed at the end of the pipe and the diffusers would be installed on the lake bottom at about a 15 foot depth. The blowers would need to be housed in a structure on shore for sound control and weather protection.

The operation of the aeration system will keep the ice from forming above the diffusers. This will require the lake district to provide fencing and signs to warn winter sports enthusiasts to avoid the area.

The cost for each in-lake aeration system is estimated at $44,000. Operation costs including power costs for a typical three month aeration season would be approximately $3,000 per year.



SOURCE: U.S.G.S. 7.5-MINUTE TOPOGRAPHIC QUADRANGLE - ST. GERMAIN (1970) VILAS COUNTY, WISCONSIN

N

0 700 1400 2100 2800 3500 Feet

FIGURE 6-1
LAKE AERATION DEVICE SITE LOCATION
Little Saint Germain Lake
Vilas County, Wisconsin

DATE: 1/15/2001

Foth & Van Dyke

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Lake maps show water depths of 15 feet or greater in Upper East Bay and South Bay. The lake district would need to find property owners willing to have the blowers installed on their property.

6.1.3 Oxygen Addition Alternative Comparison

The in-lake aeration system has a capital cost much lower than the on-shore aeration system. The physical structure is smaller and the operation costs are also less than the on-shore aeration system. Developing safety precautions will be an important part of this alternative.

Based on this analysis, in-lake aeration is recommended for implementation.

6.2 Phosphorus Reduction

6.2.1 Direct Chemical Addition to Muskellunge Cr.

Adding alum directly to Muskellunge Cr. will remove soluble phosphorus and coagulate other particles in the water. These particles would primarily settle in the lake. The equipment necessary for this alternative would include a chemical storage tank and chemical feed system. A building would need to be constructed to house the equipment and prevent the equipment from freezing. The most likely location for would be near the Birchwood Drive crossing of Muskellunge Cr. Good road access will be required for chemical delivery trucks. The lake district will need to purchase some land to construct the building but would only need about one acre.

The capital cost for the direct chemical addition alternative is about $188,000. This cost includes equipment, structures, piping, electrical, land, and technical work.

The annual operation cost is estimated at $167,000. Much of this cost is related to sludge disposal. Sludge disposal costs were calculated assuming that dredging would be required in 20 years. Since the sludge would be dispersed in the lake, only 50% of the sludge was assumed to be removed by the dredging process. The dredging process would require a sludge retention pond located on shore to hold the sludge and allow it to settle. Final disposal would remove sludge from the retention pond to apply on land. The estimated cost for the sludge dredging process is $2,600,000. To budget for this future expense, a sum of $131,000 per year was included in the operation and maintenance cost to fund this future expense at year 20.

6.2.2 Chemical Addition to a Sidestream of Muskellunge Cr.

This process would pump water from Muskellunge Cr. to a treatment pond. Alum would be added to the water before it reaches the treatment pond. The phosphorus and other sludge would settle out in the treatment pond. The clean water would be discharged back into Muskellunge Cr. before it enters Little St. Germain Lake.

The treatment pond would be sized based on chemical treatability tests to determine the detention time needed for sludge settling. The cost estimate assumed a pond of about 6 million gallons which allows a detention time of 24 hours or longer. The pond would have an influent and effluent piping header to provide good hydraulics and avoid short circuiting. The land requirement for the treatment pond will be about 10 acres with the pond size of 4.4 acres. The pond is designed without a liner to prevent leakage. The pond will be treating river water that is relatively clean. The water that may leak into the soil would likely discharge back into the river or the lake depending on the pond location and groundwater flow. This design will reduce project cost without impacting the treatment process or groundwater quality.

Advantages of this alternative are that the sludge will be removed in the treatment pond rather settling out in the lake. The sludge can be removed from the treatment pond much easier than from the lake and the cost of removal will be less. It would be possible to take the treatment pond off-line for a time period to drain the pond and remove sludge.

Disadvantages of this alternative are that only a portion of the total stream flow would be treated. The preliminary design assumed about 6 million gallons per day would be pumped from the stream to the treatment pond. Typical stream flow is 8 to 10 million gallons per day. The reason for the partial treatment is to keep the stream open for navigability. Any flow over 6 millions gallons per day would not be treated. This level of treatment will still have a significant impact on the phosphorus concentration in Muskellunge Cr. and will reduce the phosphorus loading to Little St. Germain Lake.

The capital cost for the direct chemical addition alternative is about $817,000. This cost includes equipment, structures, piping, electrical, land, and technical work.

The annual operation cost is estimated at $80,000. Much of this cost is related to sludge disposal. Sludge will need to be removed from the lagoon every 2 to 3 years. The cost of sludge removal is much less from the lagoon than from the lake. The sludge can be removed hydraulically and pumped into a truck or the lagoon can be drained and the sludge allowed to dry before removal. No settling pond will be required. To budget for this expense, a sum of $44,000 per year was included in the annual operation and maintenance cost.

6.2.3 Chemical Phosphorus Removal Alternative Comparison

A present worth analysis was used to compare capital and operating costs for the two chemical addition alternatives. The present worth analysis assumed a 20 year project life and an interest rate of 7% during that time. The results of the present worth analysis show that direct chemical addition to Muskellunge Cr. has a present worth of $1,967,000. The sidestream treatment alternative has a present worth of $1,626,000. The sidestream treatment alternative is favored at this time. More engineering work is needed to develop the appropriate chemical dose and lagoon size. Detailed costs are shown in Appendix C.

7 Recommendations and Implementation

7.1 Install In-Lake Aeration

Previous studies identified anoxic conditions in Upper East Bay, East Bay and South Bay during winter. Eliminating the anoxic conditions will improve fish habitat and survival in winter. In-lake aerators should be installed in Upper East Bay and South Bay since these are the first to become anoxic and have the deepest water allowing efficient aeration. This work should be done to begin aerator operation in the winter of 2001-2002

7.2 Evaluate Phosphorus Removal from Muskellunge Cr.

Little St. Germain Lake is unique in that phosphorus removal from Muskellunge Cr. can have a positive impact on water quality in the lake. The challenge is the relatively large flow and low concentration of phosphorus in the creek. Chemical treatment was determined to be the best technology for removing phosphorus. Two options were identified for phosphorus removal; direct chemical addition to the creek and diverting a majority of flow to a settling lagoon where chemicals are added and solids are removed before flowing into the lake. Due to the potentially high cost of these options, further evaluation and preliminary engineering is recommended. The preliminary engineering work should evaluate the following items:

- Optimum chemical addition rate.
- Sludge production.
- Sludge settling rate.
- Optimum lagoon size and shape
- Settling lagoon location - pump to nearby site; gravity flow to site adjacent to creek.
- Regulatory conditions/obstacles to implementing treatment of creek water.

7.3 Obtain Lake Protection Grant for Implementing the Aeration and Phosphorus Removal Work

The lake district has applied for protection grant funding to implement the recommended action items. The grant was awarded in the fall of 2000.

7.4 Implementation

The funding should be directed to two areas, installation of aeration equipment and further refinement of the recommended phosphorus removal option.

The funds from the grant should be used to purchase and install the aeration systems. It is anticipated that the aeration systems will be in place for the winter of 2001-2002. The lake district will need to include the operation and maintenance cost for the aerators in their annual budget. They will also need to identify one or more people to be responsible for operating the aeration system. This will include maintaining equipment, operating the system, and providing and maintaining fencing around open water.

The grant funds should also be used for evaluating the phosphorus removal options. Revised costs and preliminary layouts should be developed based on laboratory scale chemical and settling tests. Cost reduction alternatives should be evaluated such as constructing a settling lagoon adjacent to the creek to avoid pumping. Alternatives should be discussed with the Department of Natural Resources to identify regulatory issues dealing with chemically treating the stream or removing water from the stream for treatment and the resulting instream structures required. This work should take place in 2001.