Tanners Lake CIP Performance Evaluation

Prepared for
Ramsey-Washington Metro Watershed District

August 2003

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Project Summary

A study was performed to evaluate the Tanners Lake Water Quality Improvement Project which was initiated to improve the water quality, clarity, and aesthetic and recreational enjoyment of Tanners Lake. This project consisted of several Capital Improvement Projects (CIPs). The CIPs included a storm water detention basin located on the eastern side of Tanners Lake, a modified pond southeast of the lake, an infiltration basin on the southwest of the Lake, permeable weirs at the outlet of wetlands directly north of the lake, and an alum treatment facility located north of the lake. This current study was conducted to evaluate the benefit that these CIPs have conferred on the water quality of Tanners Lake. This study included the development of a hydrologic model, a phosphorus mass balance model, and an in-lake model for Tanners Lake. Modeling was performed for a calibration year (2002) and for a year that was considered a typical hydrologic year (2001). Major findings of the study are as follows:

- The interim total phosphorus goal of 0.03 $\pm$ 0.005 (i.e., 0.025-0.035) mg/L for Tanners Lake has been achieved as a result of the construction and operation of the CIPs.
- The long-term total phosphorus goal of 0.02 $\pm$ 0.005 (i.e., 0.015-0.025) mg/L is likely achievable, but internal phosphorus loading will make it difficult for this phosphorus level to be consistently attained.
- During a typical hydrologic year (ie., 2001), the Tanners Lake CIPs reduced phosphorus loading to Tanners Lake by 48 percent. The Alum Treatment facility was responsible for approximately 97 percent of this phosphorus loading reduction.
- The Alum Treatment Facility removed 88 percent of the total phosphorus from flows ***into*** the facility in 2001 and 61 percent in 2002. Based upon laboratory jar tests performed to identify appropriate alum doses for the treatment facility, it was expected that the facility would remove 90 percent of the total phosphorus that entered the system.
- 58 percent of the total phosphorus load was removed from the watershed tributary (flows above 5 cfs bypassed the treatment facility, loading from these flows is included in this calculation) to the alum treatment facility in 2001 and 32 percent of the load was removed in 2002.
- Overall, the alum treatment system removed 47 percent (140 kg) of the total phosphorus load from ***all*** watersheds tributary to Tanners Lake in 2001 and 25 percent (95 kg) of the load in 2002. The removal rate in 2001 was commensurate with the expected removal rate of 58 percent identified in the document *Diagnostic/Feasibility Study of Water Quality Problems and Restorative Measures for Tanners Lake* (Barr, 1993)

- The combined annual (May 15 to October 31) cost to remove 1 pound of phosphorus is estimated to be $1700 for the Boat Ramp Pond, the 5th Street Basin, and the infiltration trench.
- The annual (May 15 to October 31) cost to remove 1 pound of phosphorus is estimated to be $290 for the Alum Treatment Facility.
- Phosphorus loading from the watershed tributary to the Tanners Lake alum treatment facility is now more typical of non-urban, forested systems when consideration is given to the phosphorus removal provided by the facility.
- The results of an in-lake model for Tanners Lake showed that phosphorus removal by the alum treatment facility reduced the average summer total phosphorus concentration by 0.014 mg/L in 2001 (typical hydrologic year) and 0.01 mg/L in 2002 (calibration year).
- From 1998 to 2001 the operation of the alum treatment facility resulted in an approximately 1 mg/L ***net*** increase in the concentration of aluminum in stormwater that is treated by the plant. In 2002, the operation of the alum treatment facility resulted in a 2.5 mg/L ***net*** increase in aluminum to stormwater. The addition of alum at current doses has not led to a suppression of the pH to a level that is believed to cause aluminum toxicity to aquatic organisms.
- Most of the alum that is added at the alum treatment facility is removed by the settling pond. A very approximate estimate of 10 to 20 percent of the alum added at the treatment plant is potentially depositing in the downstream wetlands.
- 1.5 acre-feet of alum floc have accumulated in the floc settling pond after 5 years of operation of the alum treatment facility. The pond has a total volume of about 2.5 to 3.0 acre-feet and it appears that alum floc will need to be removed once every 3 to 5 years to ensure that the pond can have enough volume to adequately capture alum floc produced by the alum treatment facility.
- Removal of the accumulated alum sludge in the settling pond will improve treatment efficiency and reduce the concentration of aluminum that passes through the pond. It is expected that when the accumulated floc is removed from the settling pond, the concentration of aluminum at the permitted compliance point at 7th Street will be below permit requirements.
- Disposal of alum sludge by land application is the most cost-effective option of disposal. Three to 4 months of time will be required for planning and permitting.
- A 14 percent increase in the alum dose (i.e., from 6.6 mg/L to around 7.5 mg/L) would likely improve alum floc development and increase the overall removal of alum floc by the settling pond. A large alum dose increase is not recommended because of the potential to suppress

the pH below 6.0 at the outlet of the pond. If the pH drops below 6.0, there is a potential for adverse effects to aquatic organisms downstream of the pond. Increasing the alum dose by around 14 percent is considered a small increase and would not result in increased potential for adverse effects.

- Increasing the alum dose approximately 14 percent is expected to increase the annual cost of alum used at the Tanners alum treatment facility by about $2,600 during a typical climatic year (2001) and $2,700 during a wet year (2002). Hence, a 14 percent increase in alum dose is expected to result in annual alum costs ranging from $20,000 during a typical climatic year to $24,000 during a wet year. Annual alum costs during 2001 and 2002 were $17,380 (16,000 gallons of alum) and $21,283 (19,535 gallons of alum), respectively (Rob Langer, 2003).

- Methods available to remove residual aluminum at the outlet of the alum floc settling pond include filtration and ion exchange. Filtration is expensive (well in excess of a million dollars for the flows experienced at the treatment plant) and requires extensive maintenance. Ion exchange is more appropriately suited for aluminum removal but is also expensive ($100,000 to $220,000 for installation of the Stormwater Management Storm Filter System and up to $72,000/year for ion exchange cartridges). Implementation of both of these systems is limited by available land at the treatment facility.

Recommendations

- Monitor for dissolved and total aluminum at 7th Street in 2004. This is the permit compliance point for the alum treatment facility.

- Remove the accumulated alum sludge from the alum floc settling pond before the start up of the 2004 treatment season. Remove alum sludge from the settling pond every three to five years to ensure that the pond operates properly. Begin planning now to identify the least expensive method to dispose of the sludge material in the future.

- Investigate methods available that can be used to reduce the required frequency of alum sludge removal from the floc settling basin.

- If possible, relocate the pH probe located at the outlet of the settling pond so that it can be serviced more frequently. This will ensure that the pH readings are accurate.

- Occasionally monitor for alkalinity and pH at the inflows to the treatment facility. This data will be used to determine whether the alum dose used at the facility has the potential to suppress the pH at the outlet of the floc settling pond.

- Perform three one-week tests (spring, summer, and fall) at the treatment facility in 2004 to determine the alum dose that will maximize alum floc capture by the floc settling pond but will not cause pH to be suppressed below 6.0.

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1.0 Introduction

A water quality monitoring and modeling study has been completed for the Tanners Lake watershed to evaluate the performance of capital improvement projects (CIPs) that were implemented as part of the Tanners Lake Water Quality Improvement Project. The CIPs include: (1) three detention basins (5th Street Basins) located in a watershed directly east of Tanners Lake, (2) an alum treatment facility located northwest of the lake, (3) improvements to permeable weirs at the outlet of wetlands located just north of the lake, (4) an infiltration basin on the southwest side of Tanners Lake, and (5) an upgraded pond southeast of the Lake. All of these CIPs were designed to reduce the overall loading of phosphorus to Tanners Lake which will improve the water quality, clarity, and the aesthetic and recreational enjoyment of the lake. The detention basins remove phosphorus by settling phosphorus that is associated with sediment particles. The permeable weir holds water in the wetland to increase the detention time of water in the wetland. The infiltration basin reduces phosphorus loading to the lake by infiltrating runoff. The advanced treatment system uses alum to promote enhanced sedimentation and to precipitate phosphorus that is associated with small particles, or what is considered to be dissolved.

This report evaluates the effect that these CIPs have had on the water quality of Tanners Lake. The subjects that are considered in this report include:

- A brief historical account of the alum treatment facility starting with the *Diagnostic/Feasibility Study of Water Quality Problems and Restorative Measures for Tanners Lake* (Barr, 1993), implementation of the system, and finally operation of the system.
- The results of a water quality monitoring and modeling study that was initiated to evaluate phosphorous loading to the lake after the implementation of the CIPs and the capability of the alum treatment facility to improve the water quality of Tanners Lake.
- The fate of aluminum that is introduced by the alum treatment facility and how this relates to the permitting of the system in the future.
- Evaluation of pH data and its influence on the potential adverse effects of aluminum.
- Results from a survey of alum floc accumulation in the alum treatment facility detention pond and a discussion of appropriate measures that can be used to handle, prepare, and dispose of the floc.

- Recommendations for future alum treatment facility operation.

2.0 Project History

The results of the study entitled "*Diagnostic/Feasibility Study of Water Quality Problems and Restorative Measures for Tanners Lake*" (Barr, 1993) revealed that phosphorus loading to Tanners Lake was responsible for the water quality problems of the lake. Several CIPs were proposed to remove phosphorus from watersheds that were tributary to Tanners Lake. Each CIP was implemented to provide additional treatment of a tributary watershed or improve treatment of an existing treatment device. Since the watershed north of Tanners Lake is considered fully developed (see Table 1) and already has an extensive network of watershed ponds and wetlands that treat stormwater runoff, it was concluded that there was little potential benefit from the construction of additional ponds or wetlands in this watershed (see Figure 1). Since chemical coagulants, such as alum, promote enhanced sedimentation and precipitate phosphorus that is associated with small particles or phosphorus that is considered to be dissolved, an alum treatment facility was constructed to remove phosphorus from lake inflows originating from the northern Tanners Lake watershed (see Figure 1 for the location of the plant).

Table 1 Land use of the Tanners Lake Watershed

Land Use	Area (acres)
Commercial	95
Developed Park	73
Highway	78
High Density Residential	95
Institutional	110
Institutional - High Imperviousness	13
Industrial/Office	40
Low Density Residential	776
Medium Density Residential	23
Natural/Park/Open	198
Open Water	130
Wetland	100
Total	1,731

*Metropolitan Council's 2000 land use GIS data along with 2002 aerial photography were used to develop this land use breakdown.

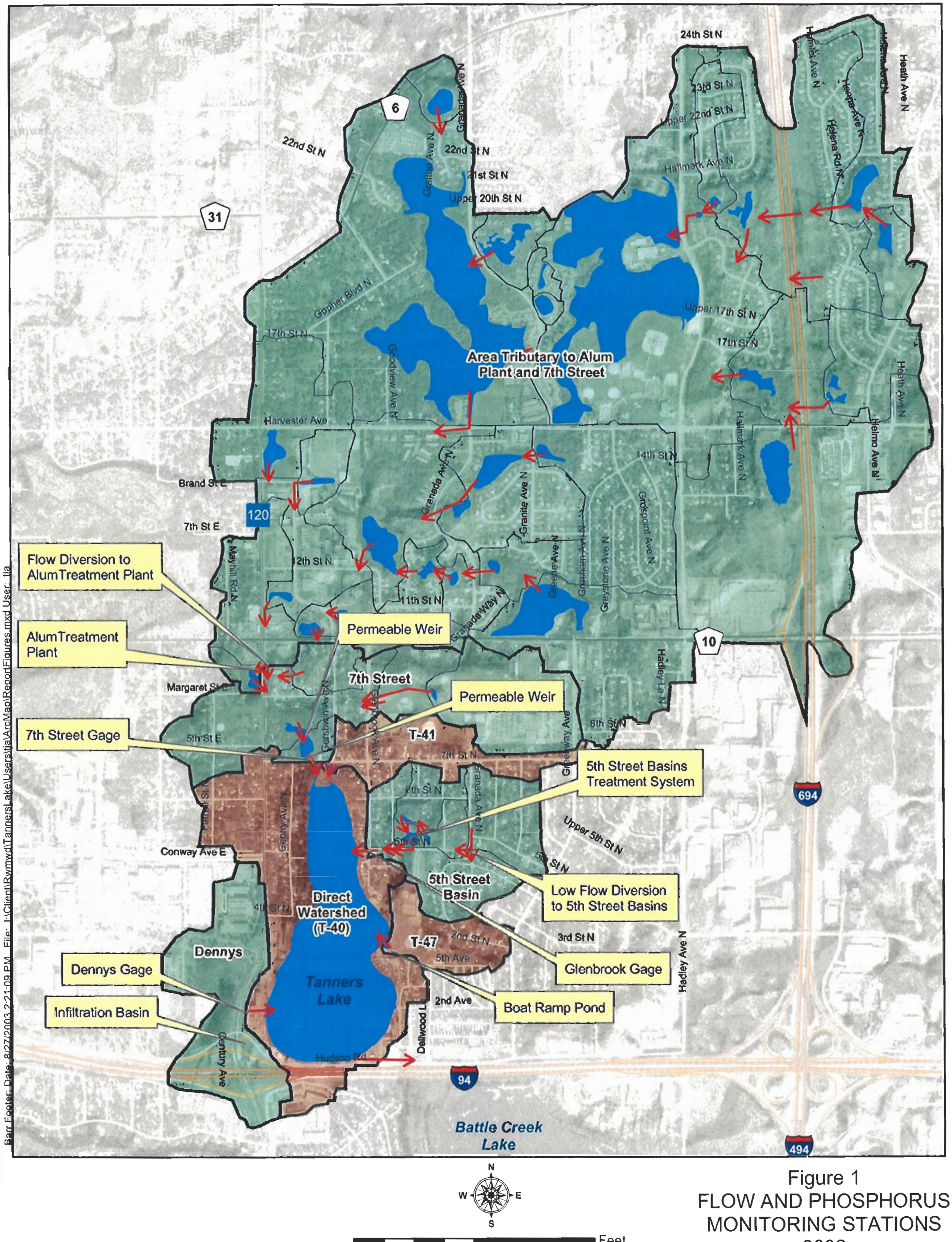


Figure 1
FLOW AND PHOSPHORUS MONITORING STATIONS
2002

Below is a brief timeline of events for the Tanners Lake CIPs.

1987	Construction of wetlands/permeable weirs north of Tanners Lake
1993	Completion of the Tanners Lake Diagnostic Feasibility Study Maintenance of the wetland/permeable weir system
1994	Improvements to the wetland/permeable weir system
1997	Construction of the Tanners Lake alum treatment facility completed in the fall. Construction of the 5th Street Wetland Treatment System Improvements to the Boat Ramp Pond
1998	Operation of the Tanners Lake alum treatment facility begins, various start-up adjustments and testing of a temporary mechanical mixer to enhance alum floc formation
1999	Installation of a permanent mechanical mixer in June
2000	First full year of operation with the permanent mechanical mixer
2001	Alum dose increased by a factor of 2
2002	Extensive monitoring at the Tanners Lake alum treatment facility and at Tanners Lake inflows for water volume and phosphorus concentrations
2003	Evaluation study of the Tanners Lake CIPs completed

3.0 Capital Improvement Projects (CIPs)

Below is a description of the water quality CIPs that have been implemented in the Tanners Lake watershed, the approximate costs for each project, and for some of the CIPs the estimated cost to remove 1 kg of phosphorus assuming that each CIP has a lifespan of 20 years.

3.1 Wetland/Permeable Weirs

In 1987 a wetland treatment facility with two sets of permeable weirs was constructed north of Tanners Lake. This system was designed to treat stormwater runoff from a 1,368 acre watershed by providing a permanent pool of water to settle sediment. Maintenance and improvements to this system were made in 1994. The wetland/permeable weir system also receives water treated by the alum treatment facility.

3.2 Boat Ramp Pond

Improvements to an existing pond located on the southeast corner of Tanners Lake were constructed in 1997. Improvements included an increase in the pond size and grading and storm sewer construction intended to capture additional runoff from the 24 acre watershed that is tributary to the pond.

3.3 5th Street Basins

The 5th Street Basins function as a series of wetlands and dry detention ponds that capture a large fraction of the runoff from the 74 acre watershed that is located on the east side of Tanners Lake.

3.4 Infiltration Trench

A weir and infiltration trench system that is located near the southeast shore of Tanners Lake is designed to treat a portion of the runoff originating from a watershed (includes a portion of the I-94 interchange) on the southwest side of Tanners Lake

3.5 Alum Treatment Facility

The Diagnostic Feasibility Study identified the northern watershed of Tanners Lake as the primary source of phosphorus loading to Tanners Lake. An advanced treatment system was constructed in 1997 and treats runoff from the 1,246 acre northern Tanners Lake watershed. The treatment system uses alum to precipitate phosphorus from storm water inflows.

3.6 Project Costs

The following are estimates of the construction and engineering costs for each of the above projects, and if available, the maintenance cost and annual staff time devoted to the operation of a given facility. It should be noted that these costs are based upon the year in which the system was constructed, engineering and design performed, or the maintenance performed. No interest rate was applied to these costs to project what the cost would be for a specified year.

Wetland/Permeable Weir System

The total project cost for this system was $165,000 and maintenance in 1994 was $22,000.

Boat Ramp Pond, 5th Street Basin, and Infiltration Trench

The combined cost to construct these systems was $253,900 and the engineering and design cost was $96,000. Maintenance has not yet been required for these systems. The 1993 Diagnostic Feasibility Study (Barr 1993) estimated annual maintenance costs for each system at approximately $600. Not including potential phosphorus removal by the infiltration trench, the estimated annual (May 15 to October 31) cost to remove 1 pound of phosphorus has been $1,700. The cost to remove 1 pound of phosphorus includes construction and engineering (20 year life span) and annul maintenance costs.

Alum Treatment Facility

The cost to construct the Alum Treatment Facility was $496,000 and the engineering and design cost was $180,000. Average annual operating cost of the plant has been $25,000 and staff time to maintain the system has cost $5,000/year. It is also estimated that the annual cost to remove the accumulated alum sludge in the floc pond is $25,000. The estimated annual (May 15 to October 31) cost to remove 1 pond of phosphorus has been $290. The cost to remove 1 pound of phosphorus includes construction and engineering (20 year life span) and annul maintenance costs.

4.0 Water Quality Monitoring and Modeling Study

The purpose of this study was to evaluate the effect the Tanners Lake CIPs have had on phosphorus loading to the lake, and ultimately, the concentration of phosphorus in the lake. To be able to evaluate the effect of these CIPS on phosphorus levels in Tanners Lake, extensive phosphorus and flow measurements were taken in 2002. The measurements were used to calibrate a hydrologic, a phosphorus mass balance, and a lake model. Once these models were calibrated, loading and lake predictions were made for what is considered to be an average hydrologic year (2001), and for the calibration year (2002), which turned out to be more typical of a wet year.

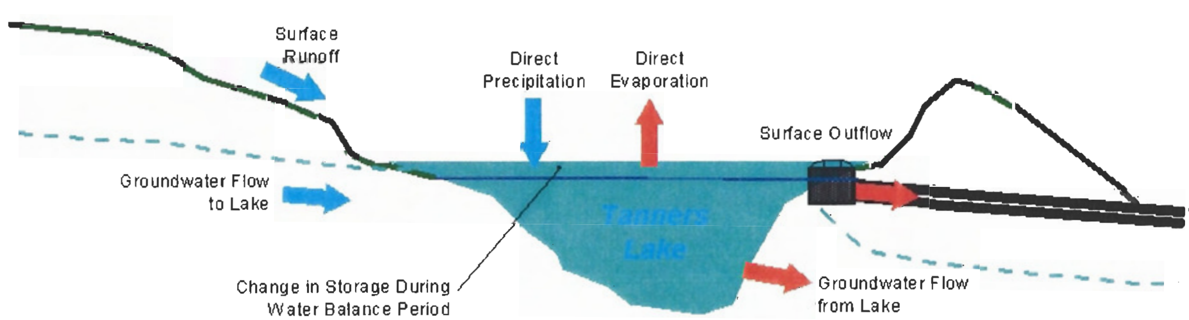
4.1 Methods and Model Calibration

Below is a description of the hydrologic, mass balance, and lake model calibration.

4.1.1 Water Balance for Tanners Lake

The development of an accurate water balance is one of the key data elements necessary to estimate the effect the Tanners Lake CIPs have had on the water quality of Tanners Lake. Water balances were necessary for both the calibration year (2002) and the typical hydrologic year (2001).

Figure 2 shows a schematic of the water balance for Tanners Lake. Each of these components were either estimated and or measured for the periods studied.



Surface Outflow = (Surface Runoff + GW_{in} + Precipitation) – (GW_{out} + Evaporation) - Change in Storage

Figure 2 Water Balance Schematic

The 2002 water balance was calibrated from May 11 through September 30. These dates were selected because detailed rainfall, flow and phosphorus data were collected during this period. It was assumed that a calibrated hydrologic model based upon 2002 monitoring data could be used to estimate flows in watersheds with similar land use to the "calibrated" watersheds and that the calibrated model could be used to predict runoff in other years. The calibrated hydrologic model was used to simulate watershed flows for 2001. The water balances for each of the modeling periods are shown in Table 2. Each of the components of the water balance is discussed below.

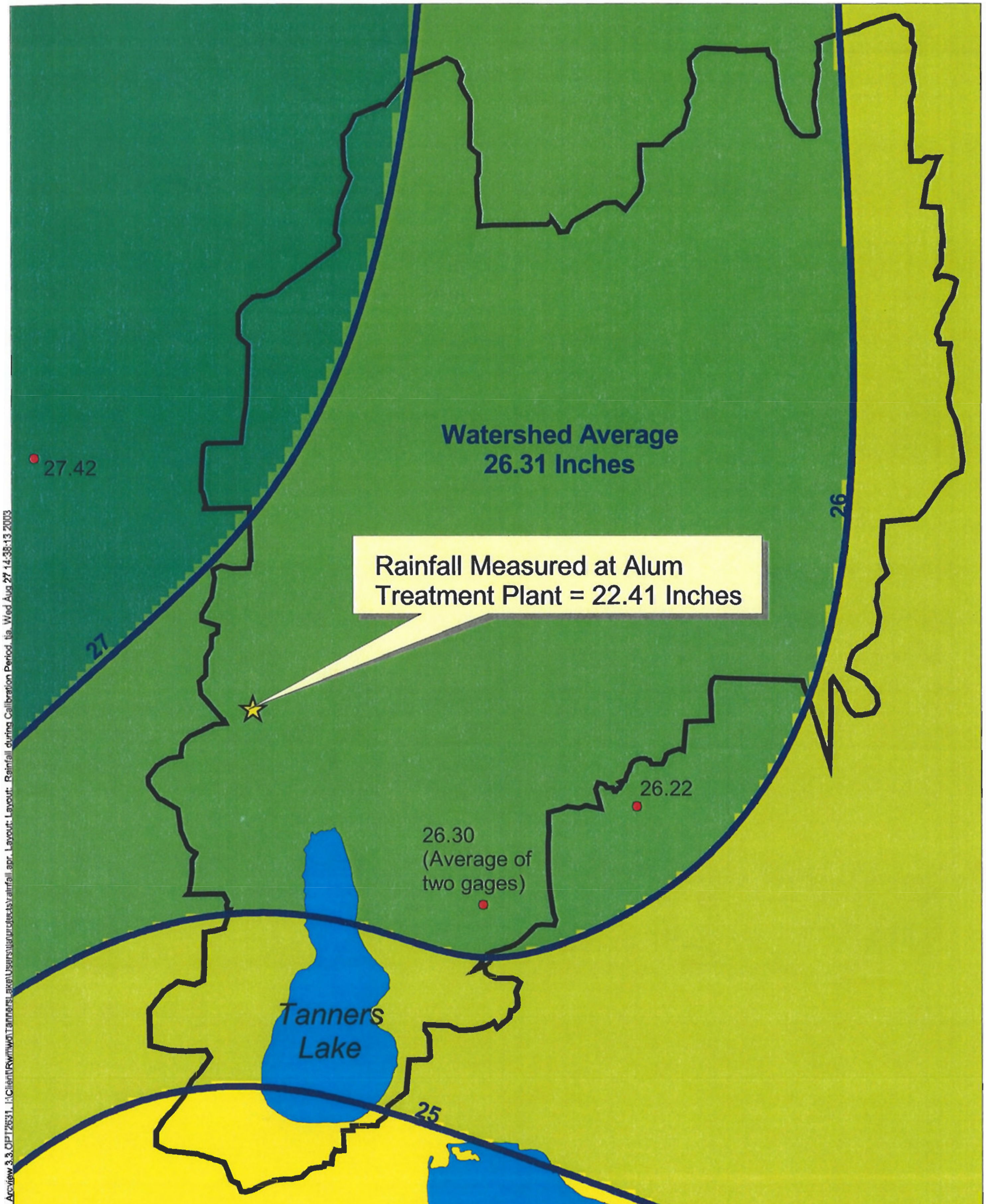
Table 2 Water Balance Components and Volumes for 2001 and 2002.

Water Balance Component	Water Volume (Acre feet)	
	Typical Hydrologic Year 2001	Calibration Year 2002
Direct Precipitation (Tanners Lake)	103	165
Surface Runoff (Inflow)	613	1,233
Surface Outflow (residual)	613	1,233
Groundwater Inflow and Groundwater Outflow	0	0
Direct Evaporation (Tanners Lake)	103	165
Change in Lake Storage	0	0

4.1.1.1 Direct Precipitation (Tanners Lake)

Fifteen-minute interval rainfall data were collected at a RWMWD gage located at the alum treatment facility. These data were reduced to a 1-hour time increment required by the P8 model. The total rainfall measured at the alum treatment facility for the calibration period (May 11 through September 30, 2002) was found to be 22.41 inches. This total was compared with rainfall data available from the Minnesota State Climatologist Office and appeared to be significantly less than any of the totals of nearby stations.

To adjust for this discrepancy, data from the State Climatologist Office for the 2002 calibration period were interpolated to determine the basin-wide average rainfall. This average was estimated to be 26.31 inches. For use in the model calibration, the hourly rainfall values from the alum treatment facility were multiplied by the ratio of the basin-wide rainfall to the measured rainfall at the treatment facility (26.31 inches/ 22.41 inches) so that the period total matched the average precipitation of the entire watershed. The distribution of the rainfall data in and near the Tanners Lake watershed is shown in Figure 3. A similar relationship was developed for the 2001 modeling period.



Rainfall Isolines

Tanners Lake Watershed

Approximate Gage Location of State Climatologist Data

N W E S

750 0 750 1500 Feet

Figure 3
Distribution of Rainfall in and near the Tanners Lake Watershed (inches)
May 11 - September 30, 2002

A comparison between total rainfall for 2002 and typical rainfall for the same period (May 11 through September 30) shows that rainfall for 2002 was significantly greater than normal. Because of the abnormally high amount of rainfall during the period, water and total phosphorus balances were also developed for a typical hydrologic year (2001) to evaluate the effectiveness of the alum treatment facility and the 5th Street Basins for more typical rainfall conditions. Table 3 below shows the rainfall totals and typical rainfall for the period modeled.

Table 3 Rainfall for 2001 and 2002 and for Average Years

Year	May 11 through September 30 Rainfall Total (inches)	Comment
2001 (Typical Hydrologic Year)	16.38	Collected by RWMWD, adjusted using State Climatologist data
2002 (Calibration Year)	26.31	Collected by RWMWD, adjusted using State Climatologist data
Average at St. Paul Airport	19.49	Average of 1971-2000 data
Average at Minneapolis-St. Paul Airport	17.31	Average of 1971-2000 data

4.1.1.2 Surface Runoff (Inflow)

Surface runoff (inflow) was measured using continuous flow monitoring equipment for the period from May 11 through September 30, 2002 at the outlet of watersheds identified as:

- Alum treatment facility inflows.
- 7th Street (most northern point of lake).
- Dennys (Southwest corner of lake).
- 5th Street Basins (east side of lake).

These locations are shown on Figure 1. The data collected at these sites were used to calibrate the hydrologic output of the P8 model. As an example of how the calibration was evaluated, Figure 4 shows the results of the calibrated model for the 7th Street monitoring station. This figure shows that the volume and distribution of flow generated by the model closely matches the volume and distribution of flow that was measured at this location. The majority of the Tanners Lake watershed discharges to Tanners Lake through the 7th Street station. The watershed area to 7th Street is 1,368 acres (79 percent of the total watershed area to Tanners Lake). Most of the runoff from this watershed is treated by the Tanners Lake alum treatment facility.

The results of the calibrated model were used to generate flows for non-monitored watersheds for 2002 and for all watersheds in 2001.

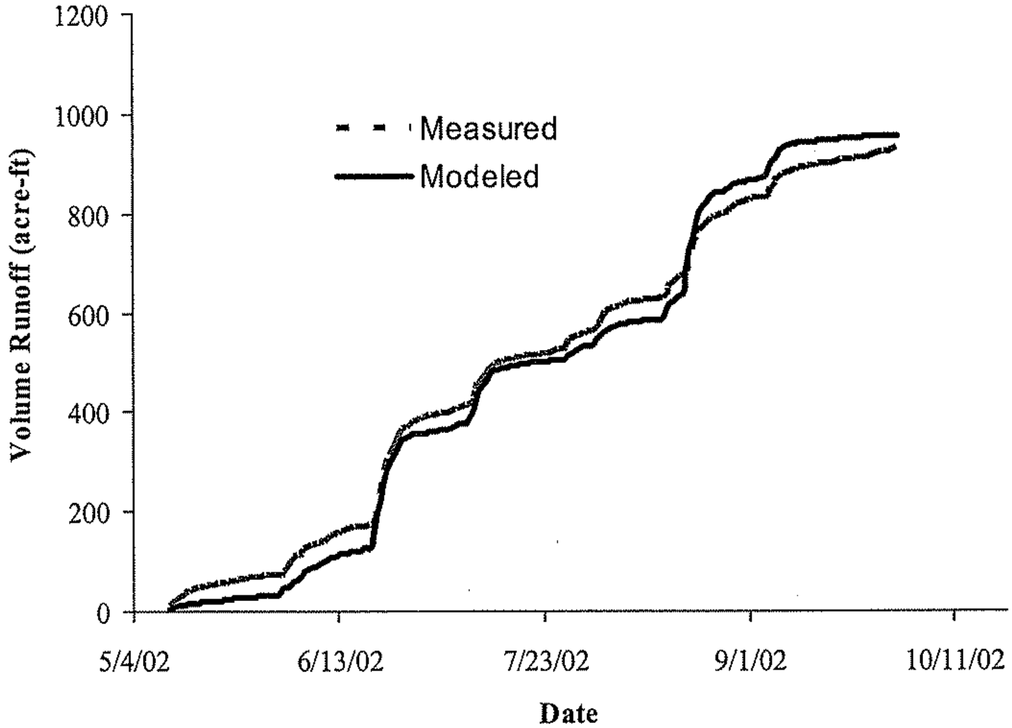
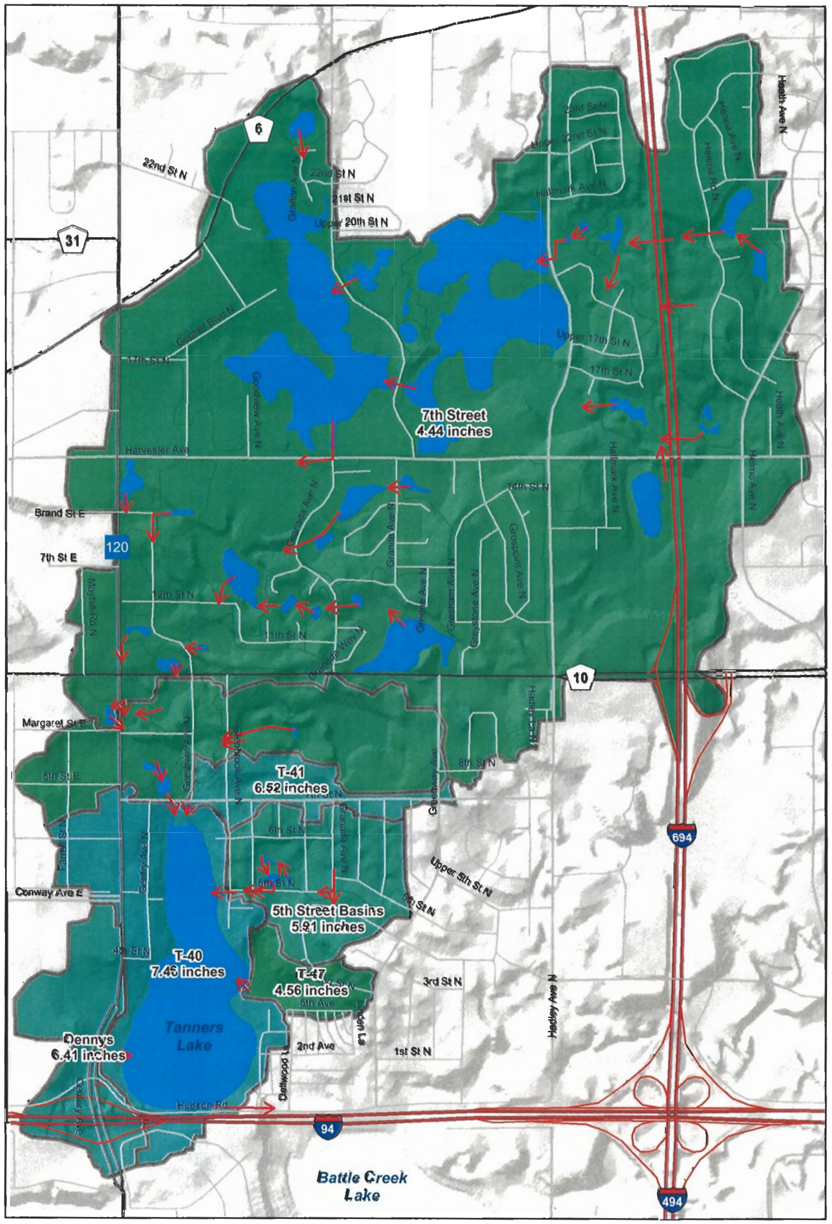


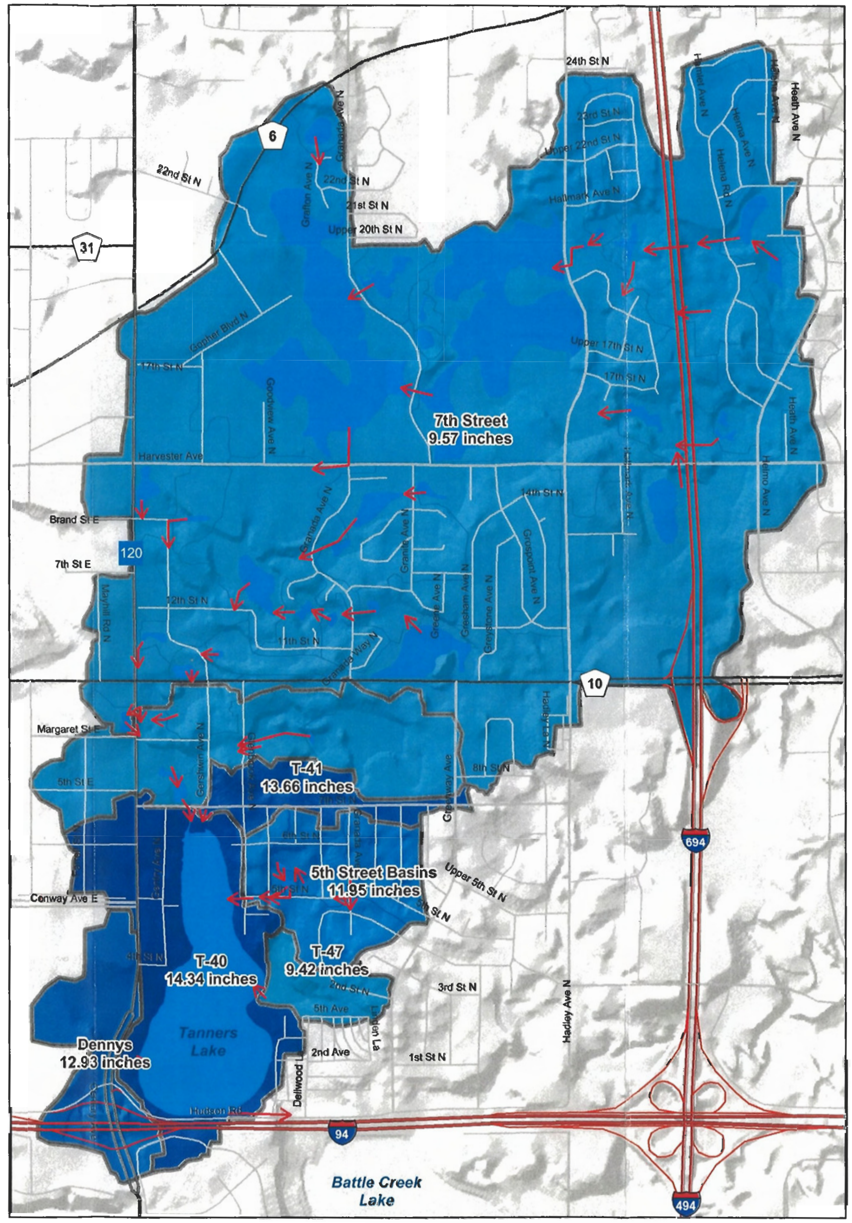
Figure 4 Measured and modeled flow volume at the 7th Street Monitoring Station.

Figure 5 summarizes the results of the surface water flow modeling for the 2001 and 2002 modeling periods. Figure 5 shows the "inches" of runoff from each of the lake's major inflow points. The figure indicates that the direct watersheds to Tanners Lake generate more runoff per acre than the watershed discharging via the 7th Street monitoring station. This is due to the higher imperviousness and the low percentage of open water and wetlands in these watersheds as compared to the much larger 7th Street watershed. Wetlands and open water tend to reduce the flow from a watershed during long periods of time due to evaporative loses.

Figure 5 also shows that the 2002 calibration period had approximately double the volume of flow compared to 2001. This was the result of the much higher than average rainfall during the spring and summer of 2002.



2001 (17.98 Inches Precipitation)



2002 (30.77 Inches Precipitation)

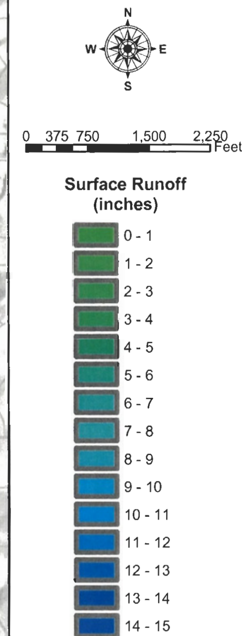


Figure 5
SURFACE RUNOFF FOR MAJOR INFLOW POINTS
May 15 - October 31
2001 and 2002

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4.1.1.2.1. Flows into the Alum Treatment Plant

Inflows to the alum treatment facility are controlled by a diversion structure immediately northeast of the plant (see Figure 6). This structure was designed to divert to the plant all flows up to 5 cfs. The P8 model incorporated this diversion to estimate how much flow is diverted to the plant under varying climatic conditions. In 2002 (calibration year) it was found that approximately 61 percent of the water volume that was generated in the northern watershed and routed to the diversion structure was treated by the alum treatment facility. In 2001 (typical hydrologic year), 76 percent of the runoff volume was treated.

4.1.1.3 Surface Outflow (Residual)

Because of problems with accurate measurements at the Tanners Lake outlet structure, it was assumed that the surface outflow was equal to the inflows. This assumption was used because it would not have a measurable effect on the lake modeling results.

4.1.1.4 Groundwater Inflow and Groundwater Outflow

It was assumed that groundwater inflow and outflow were equal in the water balances developed.

4.1.1.5 Change in Lake Storage

Because of problems with accurate measurements at the outlet structure, it was assumed that lake storage did not change.

4.1.1.6 Director Evaporation (Tanners Lake)

Because it was assumed that lake storage did not change, evaporation was assumed to equal precipitation. The assumption was necessary for surface outflow to equal the inflows (see discussion in previous paragraph).

4.1.2 Watershed Total Phosphorus Loading

Flow-based composite samples were collected at the outlet of watersheds identified as Dennys, the 5th Street Basins, 7th Street, and at the outlet of the alum floc settling pond in 2002 from May 11 through September 30 to calibrate a phosphorus loading model (see Figure 1 for the location of the sampling stations).

4.1.2.1 7th Street Monitoring Station 2002

Total phosphorus data collected at 7th Street were used to develop a relationship between storm event volume (in acre feet) and total phosphorus mass (in kilograms). It should be noted that some samples were taken under base flow conditions.

Water that enters Tanners Lake at 7th Street includes water that was treated by the alum treatment facility, water that by-passed the facility, and water from areas directly tributary to Tanners Lake. Adjustments were made to the 7th Street data so that a separate account could be developed for loading from water that bypassed the treatment facility and also originated from areas directly tributary to Tanners Lake. The adjustment consisted of subtracting the flow volume and total phosphorus mass for water that passes through the alum treatment facility from the flow volume and total phosphorus mass data collected at 7th Street (see Figure 6 below).

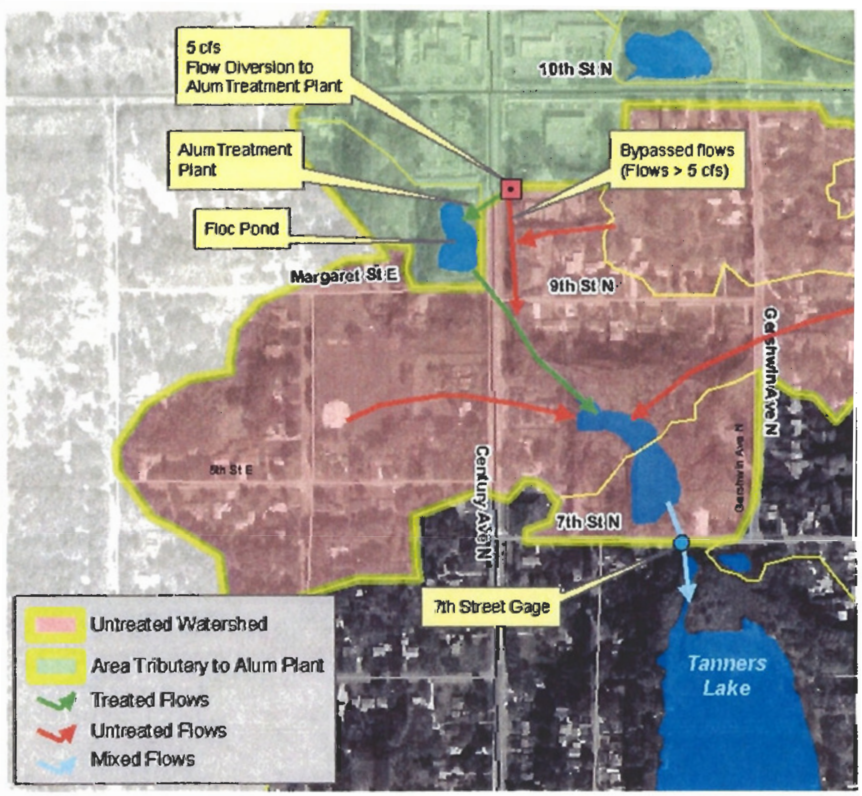


Figure 6 Origin of Flows and Total Phosphorus Monitored at the 7th Street Monitoring Station

The total phosphorus mass leaving the alum treatment facility was estimated in 2002 by multiplying the average total phosphorus concentration (flow-weighted) leaving the facility by the measured flow. The flow-weighted concentration leaving the facility was 0.079 mg/L. The flow-weighted concentration entering the treatment facility was approximately 0.200 mg/L.

Using the methodology described above, the flow-weighted total phosphorus concentration of the untreated portion of flows at 7th Street was 0.240 mg/L. To determine daily phosphorus loading at 7th Street, flow volumes not treated by the alum treatment facility were multiplied by a total phosphorus concentration of 0.240 mg/L. The flow volumes from the alum treatment facility were multiplied by a total phosphorus concentration of 0.079 mg/L.

4.1.2.2 7th Street Monitoring Station 2001

Flow and total phosphorus data were not collected at the 7th Street Monitoring Station in 2001. There were two options for estimating total phosphorus loading at 7th Street:

Option 1. Use the relationships and concentrations developed from the 2002 data; or

Option 2 Use the flow-weighted total phosphorus concentration calculated from 2001 monitoring data collected at the inlet and the outlet of the alum treatment facility.

We chose to use the flow-weighted total phosphorus concentration calculated from the 2001 monitoring data (Option 2). Table 4 below summarizes the average flow-weighted phosphorus concentration for water entering and exiting the alum treatment plant and for water entering Tanners Lake at 7th Street. The unadjusted value is the actual average monitoring concentration and includes phosphorus exiting the alum treatment facility and phosphorus from direct tributary inflows. The adjusted value is an estimate of what the total phosphorus concentration would have been if the treated flows were not mixed with the direct tributary inflows.

Table 4 Flow-Weighted Total Phosphorus Concentration Entering and Exiting the Alum Treatment Facility and Entering Tanners Lake at 7th Street

	Flow-Weighted Total Phosphorus Concentration (mg/l)			
Year	Alum Plant Inflow	Alum Plant Outflow	7th Street Unadjusted	7th Street Adjusted
2001	0.389	0.064	Not Available	Not Available
2002	0.202	0.079	0.174	0.242

The data show that the concentration of total phosphorus entering the alum treatment facility diversion structure in 2001 was nearly double that of 2002. The dryer climatic conditions in 2001 may have been responsible for the higher total phosphorus concentration. Therefore, the 2002 flow-weighted total phosphorus concentration was not a valid estimate of the 2001 flow-weighted total phosphorus concentration at 7th Street. It should be noted that the 7th Street adjusted values for 2002 (the concentration of phosphorus from the direct tributary north of Tanners Lake) with the alum plant inflow concentration shows that the values were similar (0.240 mg/L vs. 0.200 mg/L). Therefore, it was concluded that the average concentration of total phosphorus entering the alum treatment facility in 2001 could be used to estimate the concentration of total phosphorus for the untreated portion of the 7th Street flows.

4.1.2.3 Tanners Lake Direct Watersheds

Composite samples were collected for multiple flow events at the 5th Street Basins and Dennys monitoring stations from May through September 2002. The average total phosphorus concentration from these watersheds was calculated as a flow-weighted average. It should be noted that only about half of the water originating in the 5th Street Basins watershed is routed through the wetlands and ponds located in this watershed.

The water quality calibration parameters of the P8 model (using the previously calibrated hydrologic parameters) were developed for the 5th Street Basin and Dennys watersheds. It was assumed that the calibration parameters which were developed from the Dennys monitoring data could be used to estimate total phosphorus loading from watersheds T-47, T-41, and T-40 (see Figure 1 for watershed locations) because of similar land use. A separate calibration was performed for the 5th Street Basin watershed because it contained stormwater detention ponds. The calibrated P8 model for 2002 was used to calculate total phosphorus loading estimates for the 2001 modeling period (using the adjusted 2001 climatic data).

4.1.3 Lake Modeling

Lake modeling consists of an account of the water and phosphorus inputs into a lake, water and phosphorus losses from a lake, and the residual mass of phosphorus left in the lake divided by the lake volume. In the form of an equation, the lake model used in this study can be described as follows:

$$\frac{\Delta C}{\Delta t} = \frac{Q_{in} * C_{in} - Q_{out} * C_{lake} - C_{lake} * A * Vs}{V}$$

where:

C = concentration of total phosphorus in the lake,

t = time,

Q_{in} = water flow into lake

Q_{out} = water flow out of lake,

A = lake area,

Vs = net total phosphorus settling "removal" rate, and

V = lake volume.

It should be noted that this model assumes that the lake is completely mixed, and that after each storm event, phosphorus is distributed evenly throughout the lake. All model calculations were performed in a spreadsheet.

4.1.3.1 Calibration Methodology

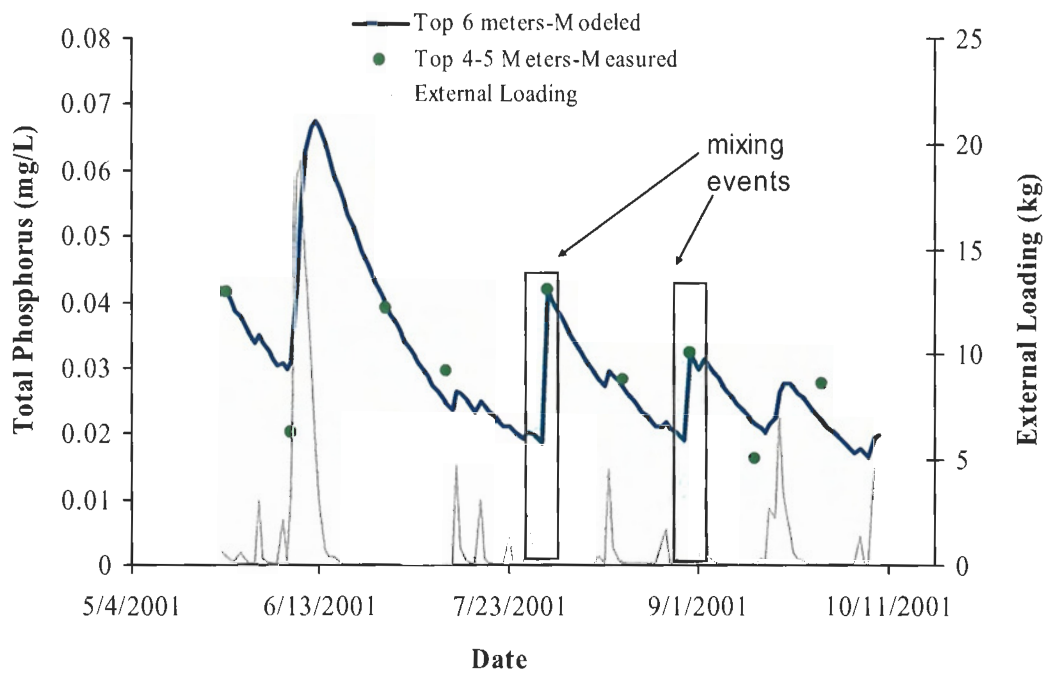
Water flows and phosphorus concentrations entering Tanners Lake in 2001 and 2002 were estimated from the calibrated P8 model. To simplify the lake model, the area and volume of the lake was fixed. The lake volume was split into the volume that could be attributed to the epilimnion (the top layer of the lake) and the hypolimnion (the bottom layer of the lake). The depth to which the epilimnion extended in Tanners Lake was determined from 2001 and 2002 temperature profiles of the lake and it was assumed that all runoff (i.e. phosphorus inputs) only mixed with the epilimnion because the runoff would have a temperature similar to the temperature of the epilimnion. Water that is discharged to a lake has a tendency to insert into the lake lawyer that has the same temperature. Hence, the volume of the epilimnion rather than the whole lake was used for the "V" term above. It was assumed that water inflows were equal to water outflows.

As can be seen from the equation above, the model is designed to predict how the in-lake total phosphorus concentration changes with a given change in phosphorus loading. However, there needs to be a starting point from which to initiate the model. For 2002, the Tanners Lake total phosphorus data collected on May 21 was used as the starting point. This value is an average of the total phosphorus concentration for water samples taken at the surface and above the thermocline; it is in effect an estimate of the average total phosphorus concentration in the epilimnion. The model then uses watershed total phosphorus loading and water volume inputs to calculate a change in the lake total phosphorus concentration. In an iterative process, the model-estimated total phosphorus concentration for the lake is then compared to actual monitoring data. The net total phosphorus settling term (Vs) is then adjusted to minimize the difference between the model-predicted and monitored total phosphorus concentration for Tanners Lake. This procedure was followed for 2002 and 2001. The 2002 and 2001 calibrations resulted in a Vs value (i.e., net total phosphorus settling "removal" rate) of 0.16 m/day.

4.1.3.2 Calibration Results

It can be seen in Figure 7 that each large phosphorus loading event to Tanners Lake (right axis) in 2002 lead to a corresponding increase in the modeled as well as the monitored concentration of phosphorus in Tanners Lake. It is clear that changes in external loading, followed by a constant rate of phosphorus settling and variable outflows from Tanners Lake, is the primary cause of a change in the concentration of total phosphorus in the lake's water column throughout the year. Overall, the use of a constant net phosphorus settling rate, Vs, led to good agreement between predicted and actual total phosphorus concentration in the lake.

The same net phosphorus settling rate was used for modeling efforts using 2001 water and phosphorus loading data. There was initially poor agreement between model predictions and actual monitoring data for July 31 and August 30, 2001. It is clear from the total phosphorus monitoring data for Tanners Lake on these dates that the lake experienced small mixing events that led to the mixing of water from the hypolimnion with the epilimnion. This required that the model be "reset" to the monitored phosphorus concentration. At these points the model was reset and then allowed to continue on from that point. This methodology of dealing with unexpected loading from the sediments led to good agreement between the modeled and monitored total phosphorus concentrations. Because there was accurate and detailed data on external phosphorus loading, these mixing events and the effect of internal loading were revealed in this modeling effort.



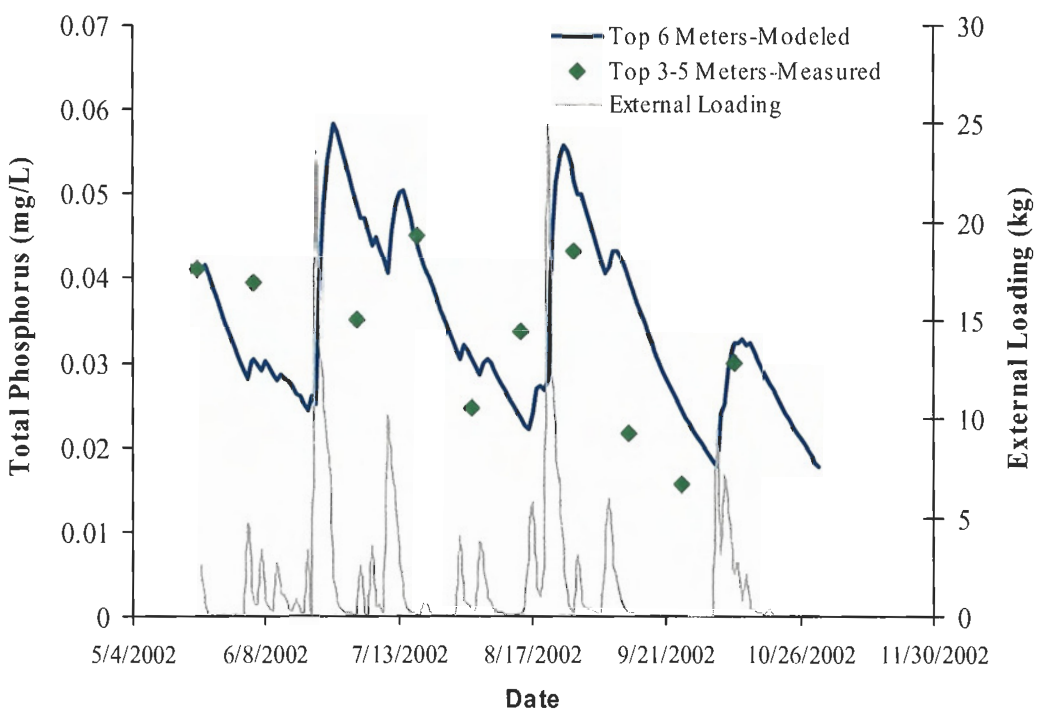


Figure 7 Result of the Tanners Lake Model Calibration

4.2 Results of the Water Quality Modeling Study

4.2.1 Phosphorus Loading

Phosphorus loading to Tanners Lake in 2001 (from May 15 to October 31) was 161 kg and in 2002 (from May 15 to October 31) it was 286 kg. Without the implementation of the Boat Ramp Pond improvements and the construction of the 5th Street Basins and the Alum Treatment Facility, it is estimated that the loading in 2001 would have been 306 kg and in 2002 the loading would have been 386 kg. Overall, these CIPs reduced phosphorus loading to Tanners Lake by 48 percent in 2001 and 26 percent in 2002. The Alum Treatment Facility was responsible for 96 to 97 percent of the phosphorus load reduction during these years.

The load reductions from the CIPs are presented graphically (Figure 8), and as maps (Figures 9, and 10). Overall phosphorus removal by the Alum Treatment Facility from the watershed tributary to the Alum Treatment Facility in 2001 was commensurate with the expected phosphorus removal of 58 percent predicted in the *Diagnostic/Feasibility Study of Water Quality Problems and Restorative Measures for Tanners Lake* (Barr, 1993). For the area tributary to the Alum Treatment Facility, loading is now more typical of non-urban, forested systems when consideration is given to the phosphorus removal provided by the facility (see Figures 9 and 10).

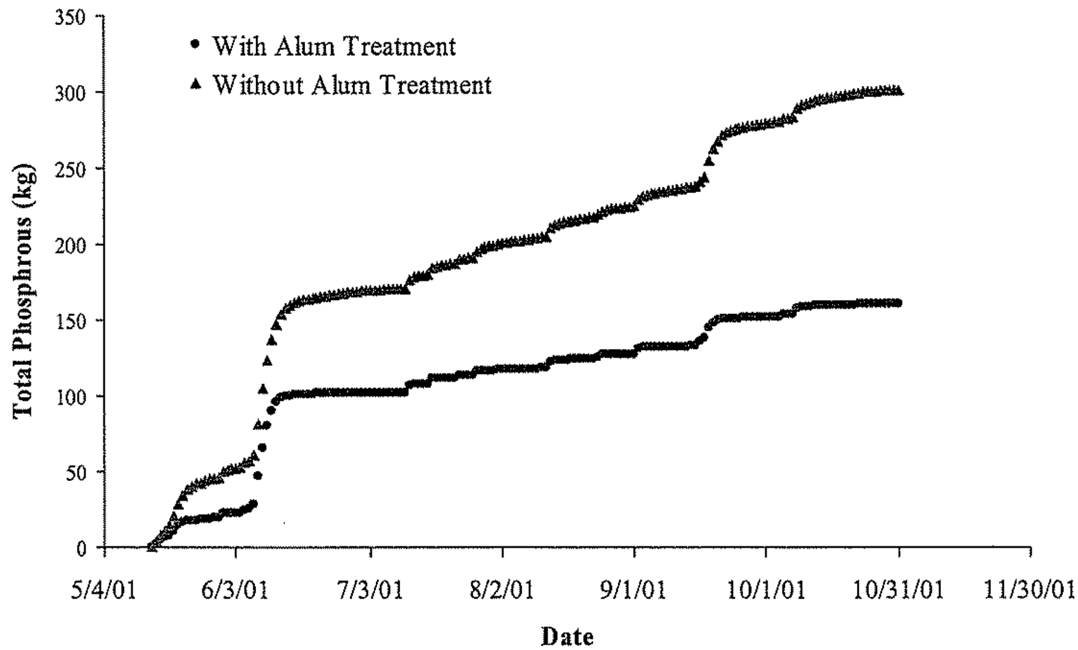
It can be seen that the Alum Treatment Facility removed more phosphorus in 2001 (an average precipitation year) compared to 2002 (a very wet year). In 2002, flows through the alum treatment plant were much greater than 2001. The average alum plant inflow concentration of phosphorus was lower in 2002. In effect, the water was more diluted in 2002, and likely had fewer suspended solids. There are four potential reasons for less efficient phosphorus removal in 2002:

1. The inflow water had fewer suspended solids and that made it more difficult for the alum to cause the solids to precipitate

2. Mixing of alum and water was less complete because high flows through the mixing chamber led to a reduced mixing time.

3. The alum dose was not optimal (likely too low) during storm events that had high flow rates.

4. Flows through the plant were higher and, hence, less time was provided in the alum floc settling pond for the settling of the alum floc particles.



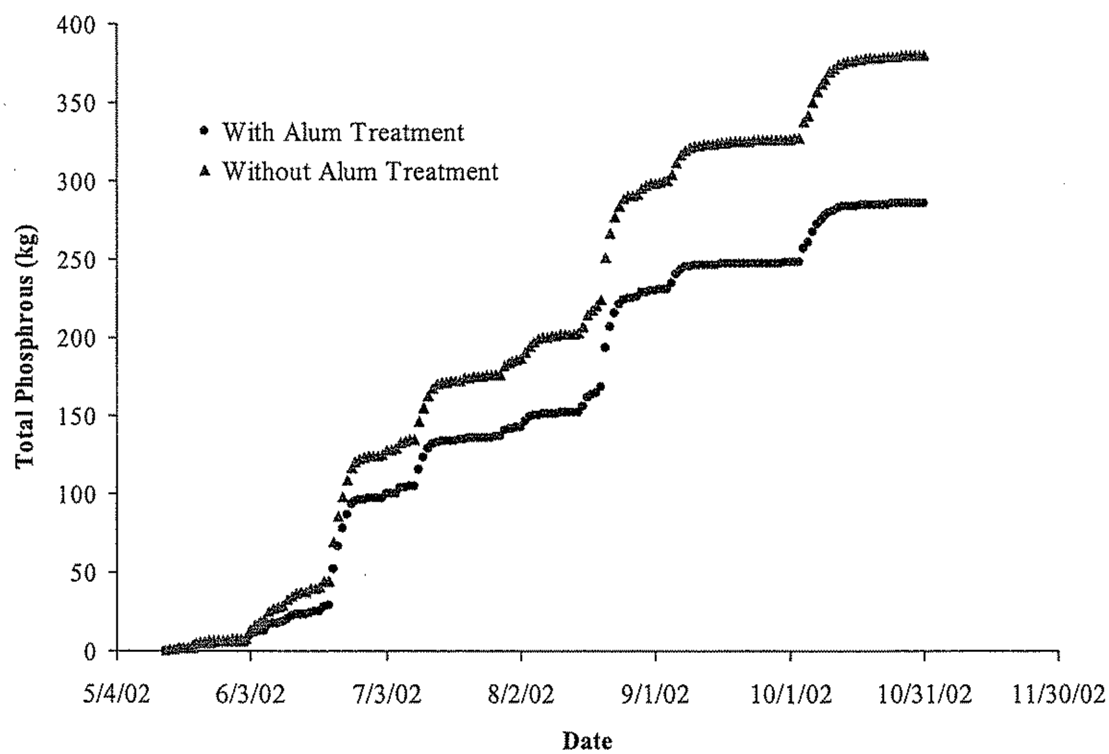
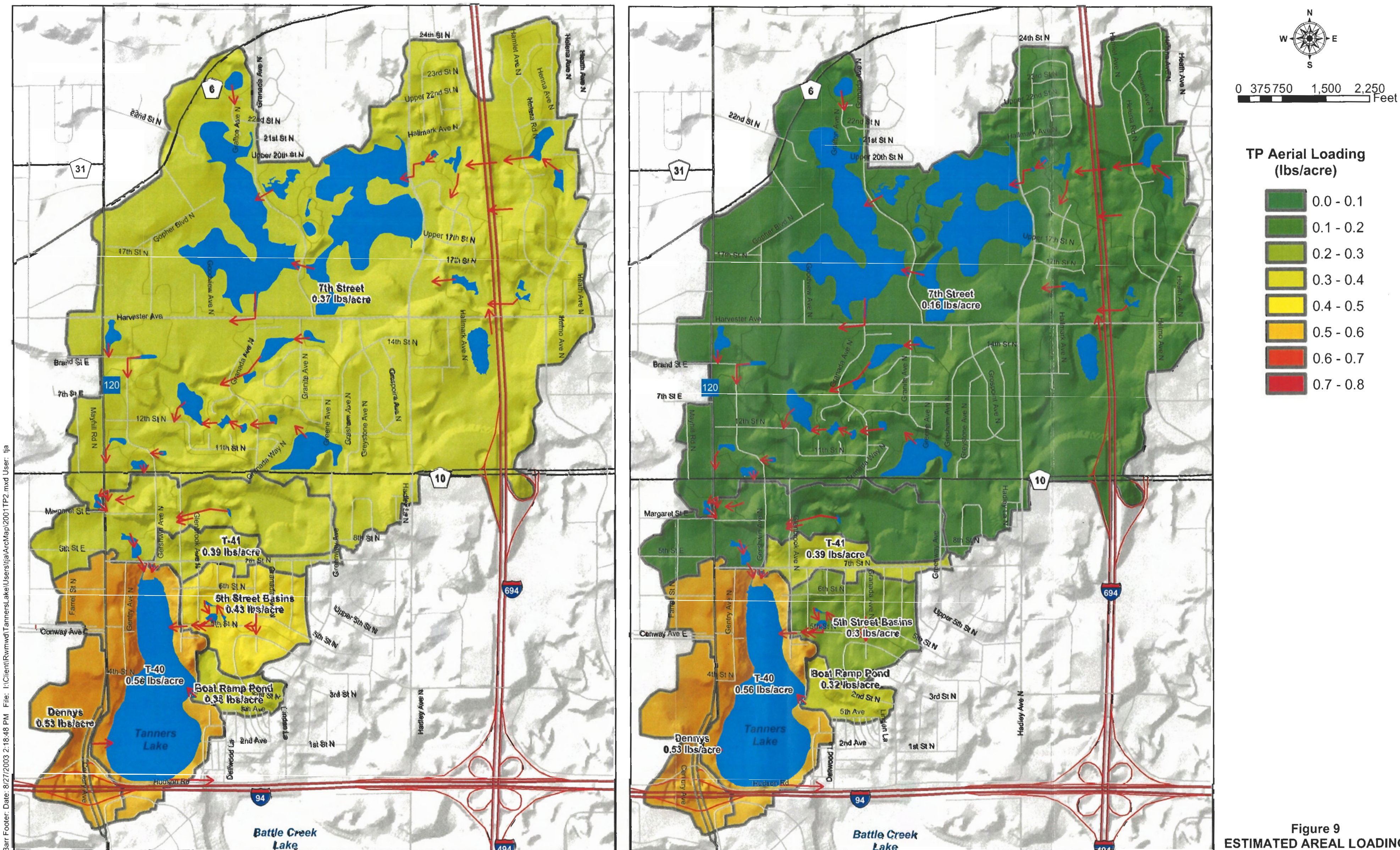


Figure 8 External Phosphorus Loading to Tanners Lake With and Without Alum Treatment



2001 Without Capital Improvements

2001 With Capital Improvements

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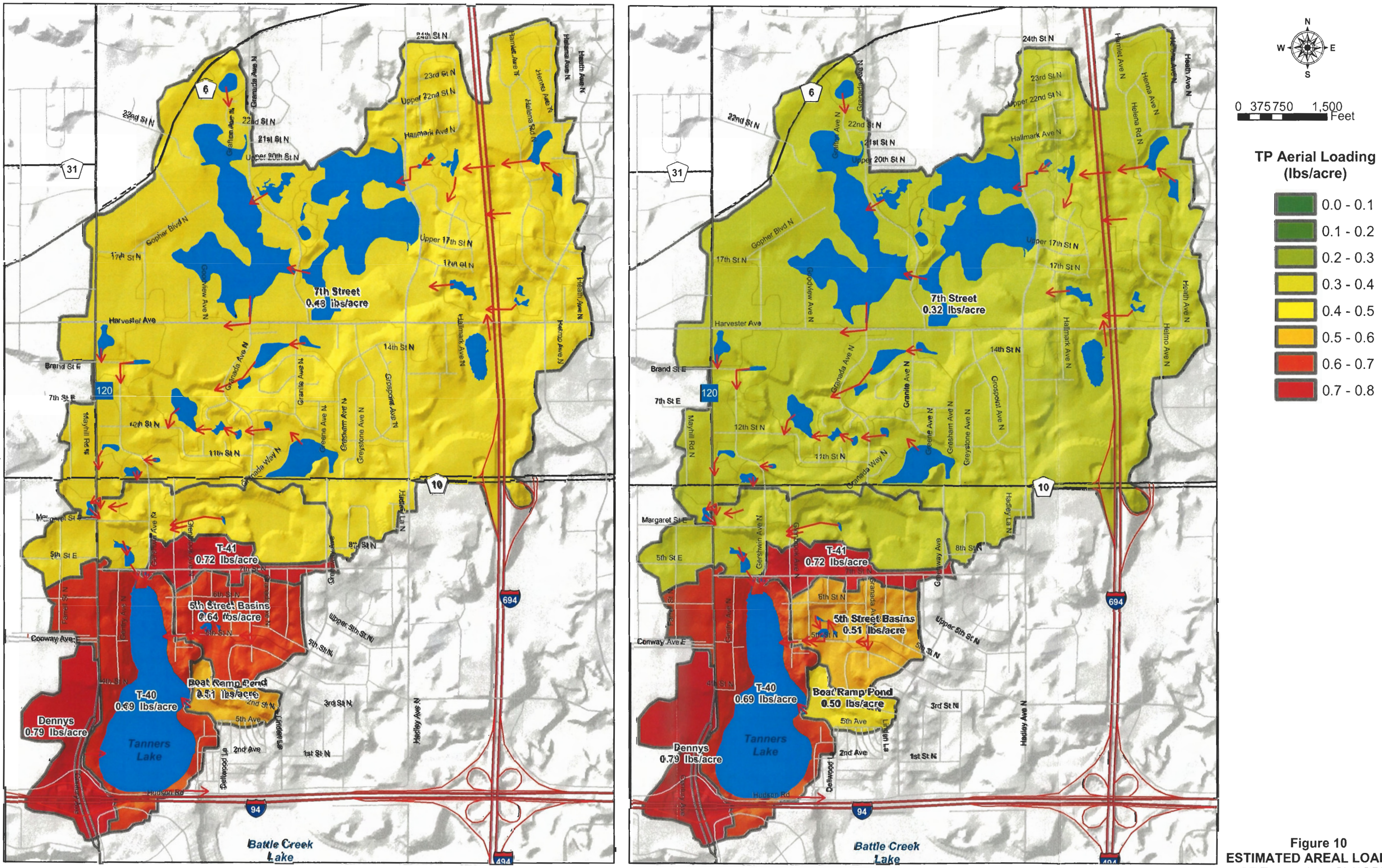
Figure 9
ESTIMATED AREAL LOADING OF TOTAL PHOSPHORUS
May 15 - October 31
2001



2002 Without Capital Improvements

2002 With Capital Improvements

Figure 10
ESTIMATED AREAL LOADING
OF TOTAL PHOSPHORUS
May 15 - October 31
2002

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4.2.2 Phosphorus in Tanners Lake

One of the primary purposes of this study was to determine how the CIPs have affected phosphorus levels in Tanners Lake. Historical monitoring data from 1997 to 2002 shows that phosphorus levels have been declining in Tanners Lake since the implementation of the treatment system (Figure 11). It also appears that the concentration of phosphorus in Tanners Lake is beginning to reach an equilibrium that resides somewhere around 0.025 mg/L.

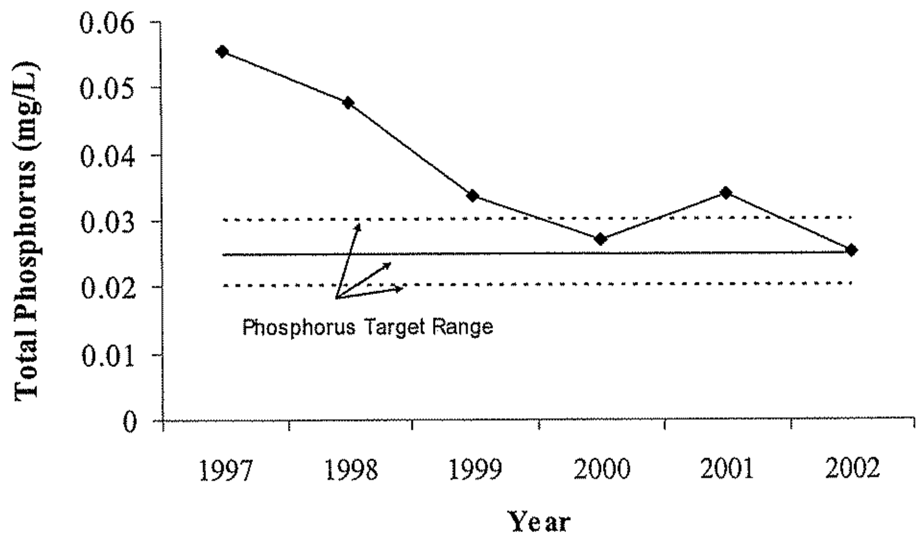

Figure 11 Average Summer Total Phosphorus in the Surface of Tanners Lake

Interpretation of historical total phosphorus data for the surface waters of Tanners Lake can sometimes be complicated by the fact that the lake can turn over (mixing of hypolimnetic water with epilimnetic water) in the fall or the spring. If turn over or mixing occurs in the spring (Figure 12), phosphorus levels can spike upwards in the spring and then decline throughout the summer and fall. Mixing also appears to occur to a lesser extent, and only occasionally, in the summer. Nonetheless, summer mixing increases the lake's summer phosphorus concentration (i.e., 2001 summer phosphorus increase was caused by summer mixing). Summer lake mixing events, caused by high winds, add phosphorus from the lake's bottom waters to its surface waters. Such mixing events result in increased phosphorus concentrations for the surface waters of Tanners Lake, despite the removal of phosphorus from the lake's inflow waters by the Alum tTreatment Facility.

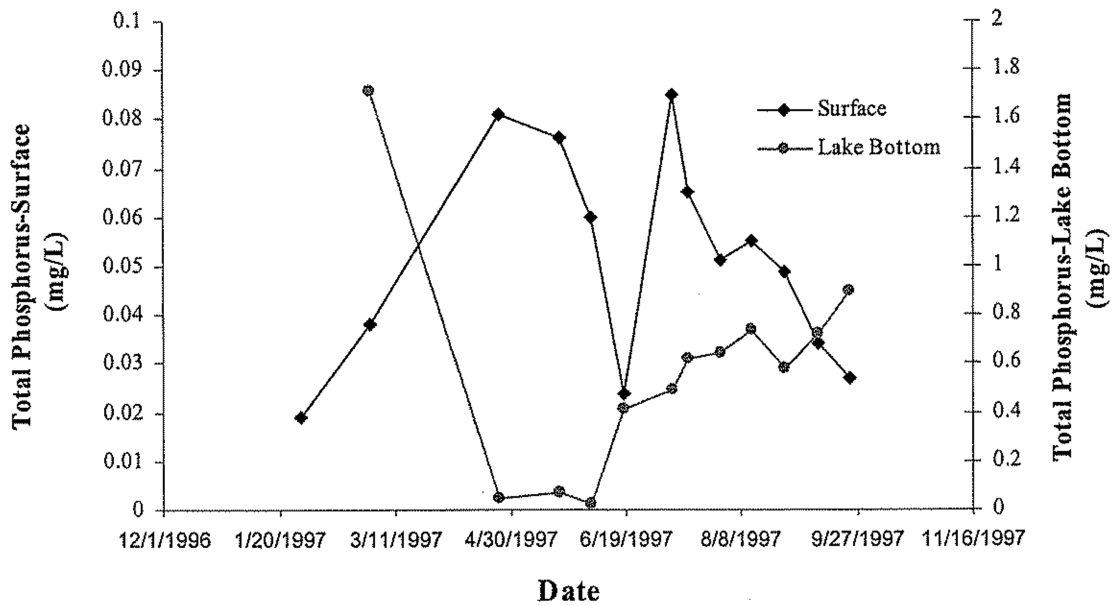

Figure 12 Effect of Spring Turnover on Total Phosphorus in the Surface of Tanners Lake

Modeling was performed to quantify the effect of the Alum Treatment Facility on phosphorus levels in Tanners Lake, irrespective of the potential effect mixing may also have on the lake's phosphorus levels. Figure 13 shows that for an average climatic year (2001), the alum treatment system had the effect of reducing the in-lake total phosphorus concentration in the epilimnion by approximately 0.014 mg/L. For a wet year (2002), the total phosphorus concentration was reduced by approximately 0.01 mg/L.

The Alum Treatment Facility also provides the benefit of controlling large spikes in total phosphorus concentrations in Tanners Lake which can lead to algal blooms. For example, without the treatment system, a 3.6-inch rain storm during June 2001 would have increased the lake's phosphorus concentration to 0.09 mg/L. However, phosphorus removal by the Tanners Lake Alum Treatment Facility reduced the magnitude of the lake's phosphorus increase to under 0.07 mg/L. Modeling results show and monitoring data confirm that the treatment facility has an additional benefit of limiting large increases of phosphorus loading that can lead to large spikes in the phosphorus concentration in Tanners Lake following storm events, including the June 2001 event.

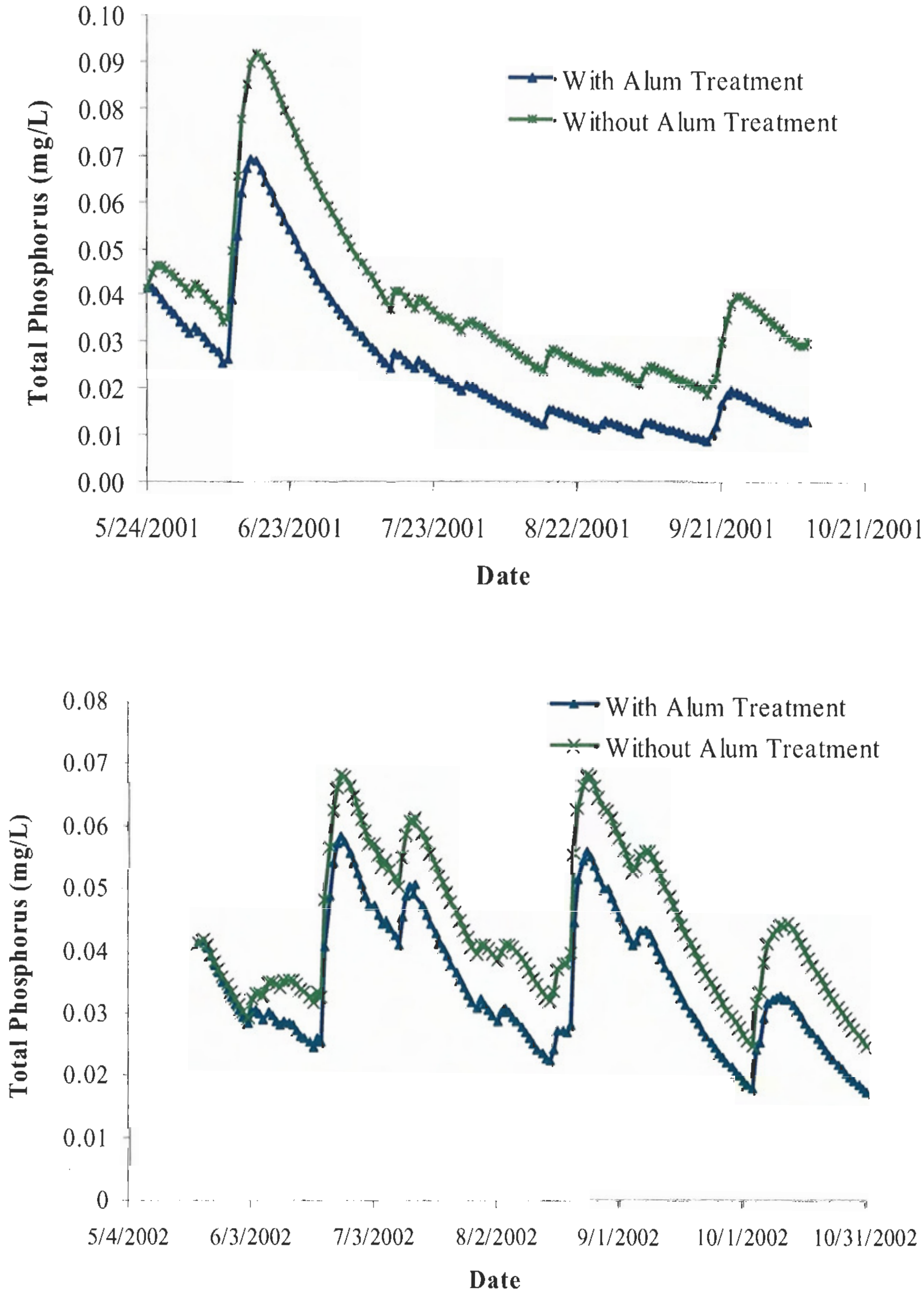

Figure 13 Expected Phosphorus Levels in Tanners Lake With and Without Alum Treatment

4.2.3 Chlorophyll *a* and Secchi Disk Depth

The Alum Treatment Facility was constructed in 1997 and in 1998 there were various start-up adjustments with the system. The mixer was installed in 1999 and the alum dose was increased in 2000. The Alum Treatment Facility has been operating properly since 2000. There was a significant improvement in the clarity of Tanners Lake in 1999 (Figure 14), however, this could have been due to climatic conditions rather than a response to reduced phosphorus levels in Tanners Lake. In 2000, although total phosphorus concentrations continued to decline, algal populations (chlorophyll *a*) increased relative to 1999. This same pattern of high algal populations in 1998, followed by low populations in 1999, and high populations again in 2000 was observed for other lakes in the Twin Cities Metropolitan Area. Since 2000, phosphorus levels have remained low and decreasing algal populations (decreasing chlorophyll *a*) and increasing water transparency (increasing Secchi disc depth) have been observed. Also, algal blooms have not been observed in the lake since the implementation of the CIPs.

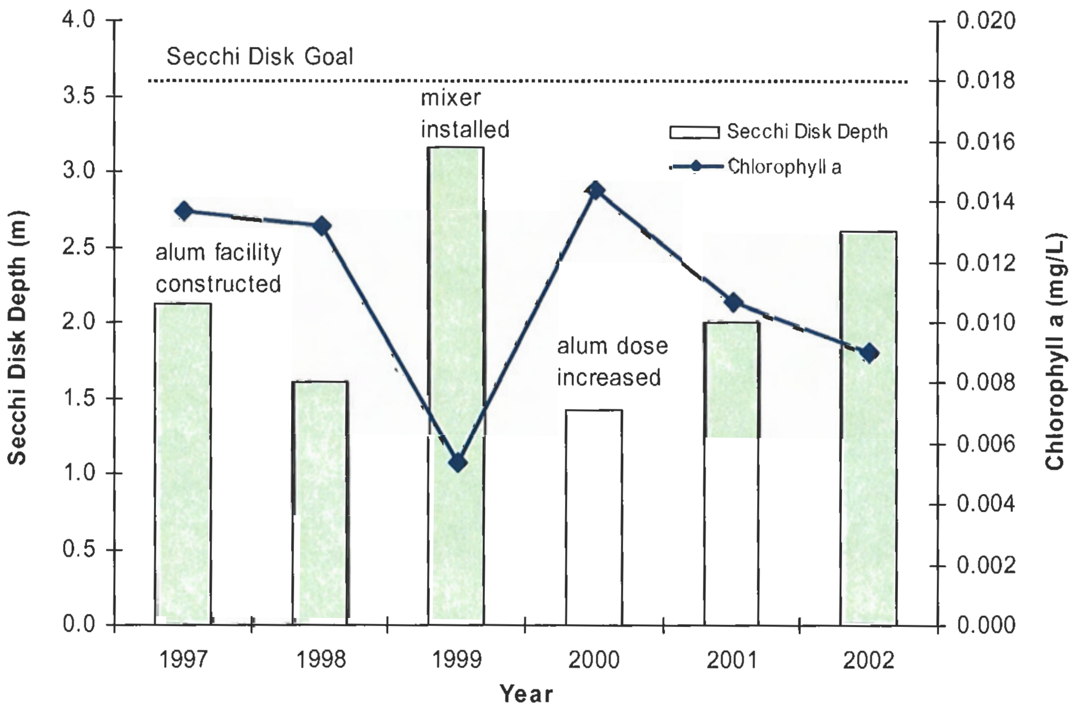

Figure 14 The Average Summer Concentration of Chlorophyll *a* in the Surface of Tanners Lake and the Average Summer Secchi Disc Depth

5.0 Tanners Lake Alum Treatment Facility: Fate of Aluminum

Alum is a chemical that consists of aluminum, sulfate, and water. Because aluminum has been shown to be toxic at high concentrations and under extreme pH conditions (low pH such as 5.5 and below, and high pH such as 8.5 and above), aluminum has been monitored at several locations near the Alum Treatment Facility. The monitoring locations include: (1) treatment facility inlet, (2) treatment facility outlet, (3) Tanners Lake inlet at 7th Street, and (4) Tanners Lake. Total and dissolved aluminum measured at the treatment facility inflow and outflow locations are shown in Figure 15.

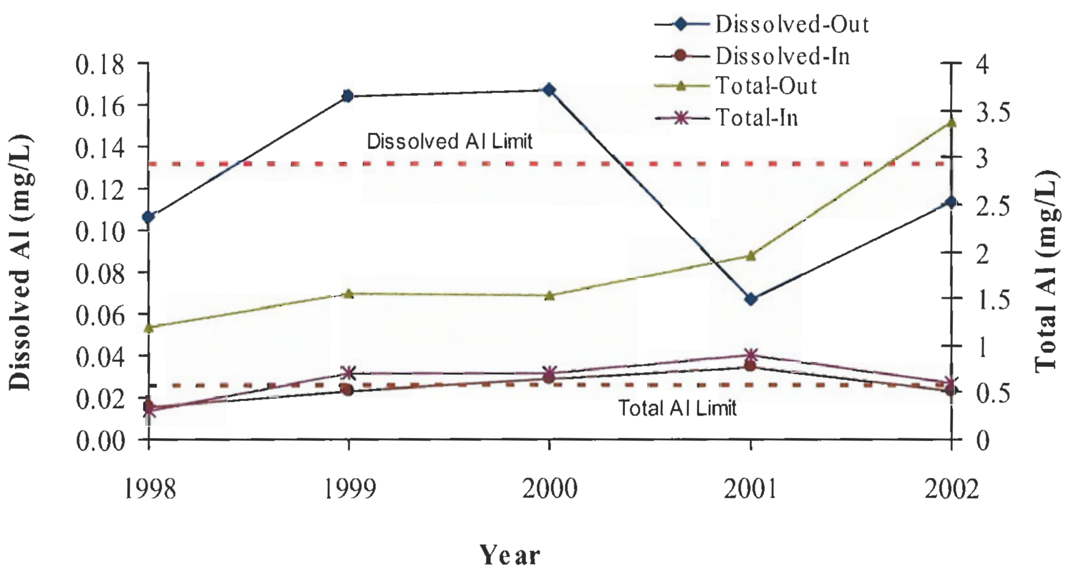

Figure 15 Total and Dissolved Aluminum at the Inlet to the Alum Treatment Facility and the Outlet of the Floc Settling Pond

From 1998 to 2001, it can seen that, after considering the concentration of aluminum entering the treatment facility, and the settling of aluminum in the floc pond, the Alum Treatment Facility resulted in a ***net*** addition of approximately 1 mg/L of total aluminum to the stormwater (Figure 15). In 2002, the treatment facility resulted in a ***net*** increase of approximately 2.5 mg/L of total aluminum to stormwater. The concentration of alum that was added to stormwater by the treatment plant in 2001 and 2002 ranged from 6.6 to 10.5 mg/L ***as aluminum***.

Most of the aluminum that is added to stormwater is removed by the floc settling pond. Figure 16 shows the concentration of aluminum in treated stormwater as it reaches 7th Street. Using aluminum data from 2000 and flow data from 2001 (hydrology was not evaluated for 2000), it is estimated that 10 to 20 percent of the alum that is added at the treatment facility was captured by the downstream wetlands. This estimate should be regarded as very approximate. However, it can be concluded that some fraction of the aluminum leaving the floc pond outlet is depositing in the wetlands between the floc pond and Tanners Lake.

Water treated by the Alum Treatment Facility reaches public waters at the northern end of Tanners Lake. This is the 7th Street monitoring location. Compliance with the permit limit is based upon an annual flow-weighted average aluminum concentration.

The 2003 permit issued by the Minnesota Department of Natural Resources reads:

> *"During periods of operation in 2003, the dissolved aluminum concentration in the effluent water at the point it reaches public waters shall not exceed 0.131 mg/L, and the total aluminum concentration shall not exceed 0.571 mg/L."*

Monitoring data at 7th Street from 2000 suggest that, under normal operating conditions, the total aluminum concentration will be below 0.571 mg/L total aluminum. Based upon the data presented in Figure 15, the concentration of dissolved aluminum will be below 0.131 mg/L.

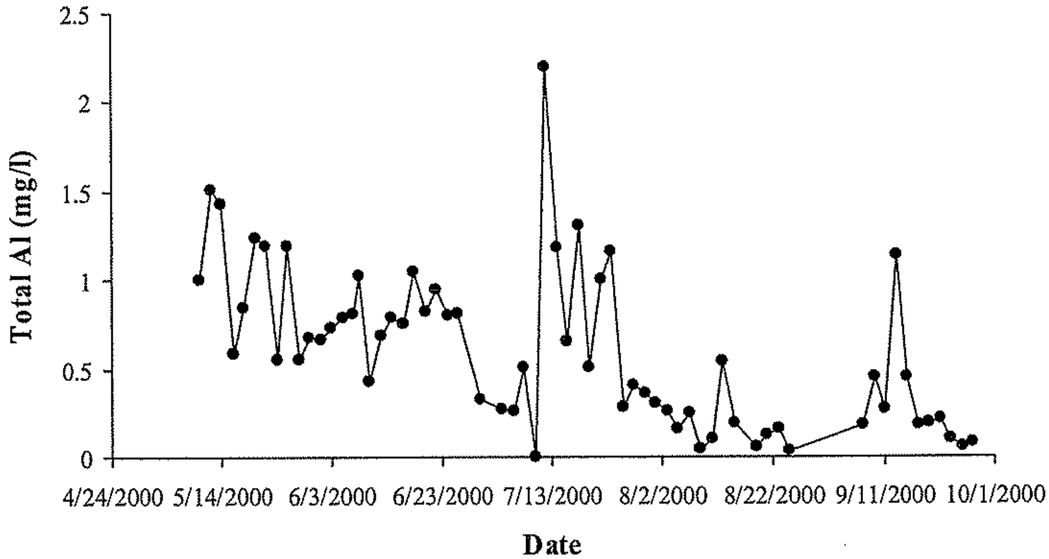

Figure 16 Concentration of Aluminum Entering Tanners Lake at the 7th Street Inlet

Experience with jar tests and published studies suggests that adjustments can be made to reduce the concentration of aluminum that is leaving the alum floc settling pond. The key to removing aluminum is to produce alum floc that rapidly settles. Potential adjustments that can be made to the treatment facility include: (1) improve mixing of alum and water in the mixing chamber to improve floc development, (2) adjust the alum dose to improve floc development, and (3) provide more time for the floc to settle. It may be noted that those conditions that result in good phosphorus removal (see Section 3.2) also result in good aluminum removal.

A brief field examination of the Tanners Lake Alum Treatment Facility was conducted on May 23, 2003. Alum floc development at the Alum Treatment Facility was measured during this examination. Alum floc development in this context means the size of floc formation. The rate of alum injection to the mixing chamber was incrementally changed and then water was collected at the weir exiting the mixing chamber and put in a clear jar for observation. There was little observable floc formation at the current alum treatment dose of 6.6 mg/L as Al. However, when the dose was slightly increased to 7.5 mg/L as Al, the observable floc formation increased significantly. This floc (at 7.5 mg/L Al) is often described as "pin floc." This floc size settles well, but does not settle as quickly as larger floc. Hence, it does not settle at the maximum potential settling rate of alum floc. When the alum dose was increased to 12 mg/L, large alum floc particles were produced. These large floc particles will settle more rapidly, but there may not be a significant improvement in overall floc removal at this dose compared to the 7.5 mg/L alum dose. This test demonstrates that a small increase in alum dose near the 7.5 mg/L alum dose tested will improve floc formation. This will lead to improved alum floc (aluminum), a lower concentration of aluminum passing through to Tanners Lake, as well as improved phosphorous removal by the settling pond. This test also demonstrates that the system is providing the optimum level of mixing required for good floc development. Because of the relatively small size of the pond, good floc development is needed to capture a significant fraction of the alum added by the treatment system.

Increasing the alum dose approximately 14 percent is expected to increase the annual cost of alum used at the Tanners Alum Treatment Facility by about $2,600 during a typical climatic year (2001) and $2,700 during a wet year (2002). Hence, a 14 percent increase in alum dose is expected to result in annual alum costs ranging from $20,000 (18,357 gallons of alum) during a typical climatic year to $24,000 (22,029 gallons of alum) during a wet year. Annual alum costs during 2001 and 2002 were $17,380 (16,000 gallons of alum) and $21,283 (19,535 gallons of alum), respectively (Rob Langer, 2003).

Other methods that can be applied to remove residual amounts to aluminum at the outlet of the pond include filtration and ion exchange. Filtration is commonly used for drinking water and wastewater treatment. However, it is very expensive and requires constant maintenance. This system requires that the filtration units be periodically backwashed and the backwash brine must be disposed of properly. This system is not appropriate for the treatment of the residual aluminum at the pond outlet. There are systems available that are specifically designed to remove metals from storm water through ion exchange. Stormwater Management Inc. has developed the "Stormfilter" system to remove metals. The system comes as a 11 by 28 foot or a 15 by 100 foot vault that contains several cartridges that remove the metals. The smaller vault, which has an approximate cost of $100,000, contains 80 cartridges and can treat up to 1.5 cfs of water. The cartridges will need to be replaced approximately three times a year at a cost of $19,000. The larger vault can treat up to 5 cfs of water, costs approximately $220,000 and contains 300 cartridges. It would cost $72,000 each year to replenish spent cartridges.

After treated water passes through the treatment pond and the downstream wetlands, it enters Tanners Lake. The concentration of aluminum in Tanners Lake is significantly lower than the concentration leaving the treatment pond and the wetlands (Figure 17). This is the result of dilution and the deposition of aluminum from the lake water column to the lake sediments. Overall, the concentration of aluminum in Tanners Lake is low. Although concentrations have fluctuated during the 1998 through 2003 period, data collected thus far in 2003 were similar to 1998 values.

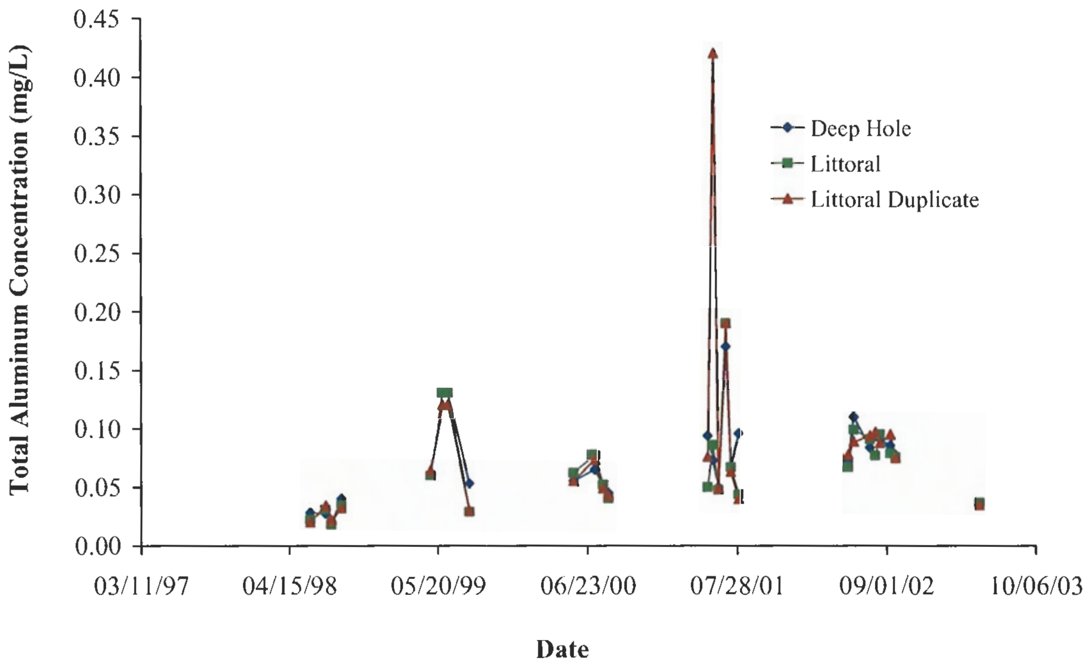

Figure 17 Concentrations of Aluminum in Tanners Lake.

5.1 Effect of pH on Potential Aluminum Toxicity

The chemistry of aluminum is complex. Aluminum has many different forms as it combines with water. Depending on the pH of the water that aluminum resides, aluminum can combine with water to make the following aluminum complexes: Al^{+3}, $Al(OH)^{+2}$, $Al(OH)_2^{+}$, $Al(OH)_{3(solid)}$, and $Al(OH)_4^{-}$. Aluminum also combines with organic matter, clays, silts, and phosphorus. When pH is in the near neutral range, for example, 6.3 to 7, most of the aluminum is $Al(OH)_{3(solid)}$, the non-toxic form, which is often seen as aluminum floc. If pH drops below 6.0, more of the aluminum is Al^{+3}, $Al(OH)^{+2}$, $Al(OH)_2^{+}$. A high concentration of these forms can be toxic. It is understood that these forms have the ability to stick to fish gills (because the fish gills are negatively charged), and any other species that has gills, and effectively cause suffocation.

In light of this discussion, it is important to look at the pH as well as the concentration of aluminum in waters downstream of the Tanners Lake Alum Treatment Facility. The pH in Tanners Lake was, on average, 8.1 in 2001 and 7.9 in 2002. Lakes in this region have a high buffering capacity and it is expected that the pH in Tanners Lake will remain near the 2001 and 2002 levels. The average pH at the outlet of the treatment pond in 2001 was 7.3, and in 2002 and through June 10, 2003 was 6.8. Aluminum at this pH is primarily in the form of $Al(OH)_{3(solid)}$, and $Al(OH)_4^-$. There is little risk of aquatic toxicity from these aluminum complexes. This pH data also suggests that a small increase in the alum dose by 1 to 2 mg/L would not result in increased potential for adverse effects. However, a large increase in the alum dose by 5 to 6 mg/L may cause a great decline in pH and lead to the potential for adverse effects.

6.0 Tanners Lake Alum Treatment Facility: Alum Floc Accumulation and Disposal

After 5 years of plant operation, there has been significant alum floc accumulation in the Tanners Lake Alum Treatment Facility settling pond. This floc accumulation demonstrates that the settling pond is removing a significant fraction of the alum floc produced by the Alum Treatment Facility. From a survey of the pond in February/March 2003, it is estimated that the pond contains 1.5 acre-feet of alum floc. The total pond volume is about 2.5 to 3.0 acre-feet. Sediment cores were collected from three locations in the settling pond to evaluate the solids and aluminum content of the alum floc sludge. Results are as follows.

- At the inlet to the pond, the solids content of the sludge was 3.0 percent (i.e., alum floc sludge was 97 percent water).
- In the middle of the pond, the solids content of the sludge was 5.2 percent (i.e., alum floc sludge was 94.8 percent water).
- At the pond's outlet, the solids content of the sludge was 7.1 percent (i.e., alum floc sludge was 92.9 percent water).

The aluminum content of the sludge ranged from 3,000 to 5,300 mg per kg of dry sludge material.

There are many potential methods to dispose of the alum floc material that has accumulated in the pond. Some of the potential options that were investigated include: (1) discharge to a sanitary sewer system, (2) composting, (3) landfill disposal, and (4) land application. Evaluation of the four options resulted in the following conclusions.

1. Discharge to a sanitary sewer system is not feasible because the Metropolitan Council Environmental Services (MCES) refuses to accept this waste. MCES based its refusal on the association of the waste with stormwater and issues relating to the separation of storm sewers and sanitary sewers.

2. The cost to dispose of the alum sludge by composting is equivalent to the cost to dispose of the material in a landfill. Hence, there is no financial advantage to composting.

3. The alum sludge can be disposed in a landfill if the sludge can pass the "paint filter test" and there is no free water associated with the sludge. Hence, before the material can be

put in a landfill some degree of dewatering is required. As noted previously, the water content of the sludge ranges from 92.9 to 97 percent.

4. Because of the relatively low aluminum content of the alum sludge, land application is a viable option. It appears that land application is the most cost-effective option. However, additional time must be allotted as this option requires 3 to 4 months for planning and permitting. Facilities that will receive the alum sludge, dewater it, and then land apply it have been identified.

In summary, disposal in a landfill is a good option if time for planning is limited. Nonetheless, land application will be more cost-effective if time can be allotted for planning and permitting.

7.0 Discussion and Recommendations

The concentration of total phosphorus in Tanners Lake has been steadily declining since the implementation of the Tanners Lake Water Quality CIPs. The results of the hydrologic and phosphorus mass balance modeling study show that the Alum Treatment Facility, in particular, is removing a significant fraction of phosphorus loading to Tanners Lake. According to the modeling results, 141 kg of phosphorus (47 percent of the total loading to the lake) was removed by the treatment facility in 2001 (from May 11 to October 31) and 96 kg (25 percent of the total loading to the lake) was removed in 2002 (from May 11 to October 31). Phosphorus loading from the watershed tributary to the Tanners Lake Alum Treatment Facility is now more typical of non-urban, forested systems when consideration is given to the phosphorus removal provided by the facility.

In-lake modeling showed that without alum treatment, average phosphorus concentrations in the epilimnion of Tanners Lake would have been higher by 0.014 mg/L in 2001 and 0.001 mg/L in 2002 (from mid-May to October 31).

Phosphorus concentrations in the surface of Tanners Lake have been steadily declining since the construction of the Alum Treatment Facility, and it appears that the lake has been responding to the lower phosphorus levels since 2000. Algal populations (chlorophyll *a*) have generally declined and water transparency (Secchi disc depth) has generally increased with declining phosphorus concentrations. Although climatic factors have had the effect of varying the response of algae to reduced phosphorus levels, algal blooms have not been observed on the lake since the implementation of the CIPs. An additional benefit of lower phosphorus levels is the potential for a shift in the type of algae in Tanners Lake. This shift could consist of a loss of blue-green algae and an increase in green algae. An increase in the green algae population would potentially improve the fisheries of Tanners Lake.

The operation of the Alum Treatment Facility resulted in approximately a 1 mg/L ***net*** increase in the concentration of aluminum in stormwater that was treated by the plant from 1998 to 2001. In 2002, the net increase was 2.5 mg/L. The amount of aluminum that passed through the settling pond was likely the result of the build up of 1.5 acre-feet of alum floc in the pond. The reduced pond volume resulted in a lower volume for floc settling and a lower floc removal rate. Nonetheless, most of the alum that is added at the Alum Treatment Facility is removed by the settling pond. A very approximate estimate of 10 to 20 percent of the alum added at the alum treatment plant is potentially depositing in the downstream wetlands.

A small increase in the alum dose (e.g., from 6.6 mg/L to around 7.5 mg/L) would likely improve alum floc development and increase the overall removal of alum floc by the settling pond. This would also result in improved phosphorus removal. A large increase in the alum dose is not recommended because of the potential to suppress the pH below 6.0 at the outlet of the pond. On average the pH of water exiting the treatment facility has been approximately 7.2. At this pH there is little risk of alum toxicity to aquatic organisms.

Increasing the alum dose approximately 14 percent is expected to increase the annual cost of alum used at the Tanners Lake Alum Treatment Facility by about $2,600 during a typical hydrologic year (2001) and $2,700 during a wet year (2002). Hence, a 14 percent increase in alum dose is expected to result in annual alum costs from $20,000 during a typical hydrologic year to $24,000 during a wet year. Annual alum costs during 2001 and 2002 were $17,380 (16,000 gallons of alum) and $21,283 (19,535 gallons of alum), respectively (Rob Langer, 2003).

Recommendations

- Monitor for dissolved and total aluminum at 7th Street in 2004. This is the permit compliance point for the Alum Treatment Facility.
- Remove the accumulated alum sludge from the alum floc settling pond before the start up of the 2004 treatment season. Remove alum sludge from the settling pond every three to five years to ensure that the pond operates properly. Begin planning now to identify the least expensive method to dispose of the sludge material in the future.
- Investigate methods available that can be used to reduce the required frequency of alum sludge removal from the floc settling basin.
- If possible, relocate the pH probe located at the outlet of the settling pond so that it can be serviced more frequently. This will ensure that the pH readings are accurate.

- Occasionally monitor for alkalinity and pH at the inflows to the treatment facility. This data will be used to determine whether the alum dose used at the facility has the potential to suppress the pH at the outlet of the floc settling pond.
- Perform three one-week tests (spring, summer, and fall) at the treatment facility in 2004 to determine the alum dose that will maximize alum floc capture by the floc settling pond but will not cause pH to be suppressed below 6.0.

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