Long Lake Management Plan
Phases V and VI: Lake Management Plan

Prepared for
Long Lake Protection and Rehabilitation District

May 2003

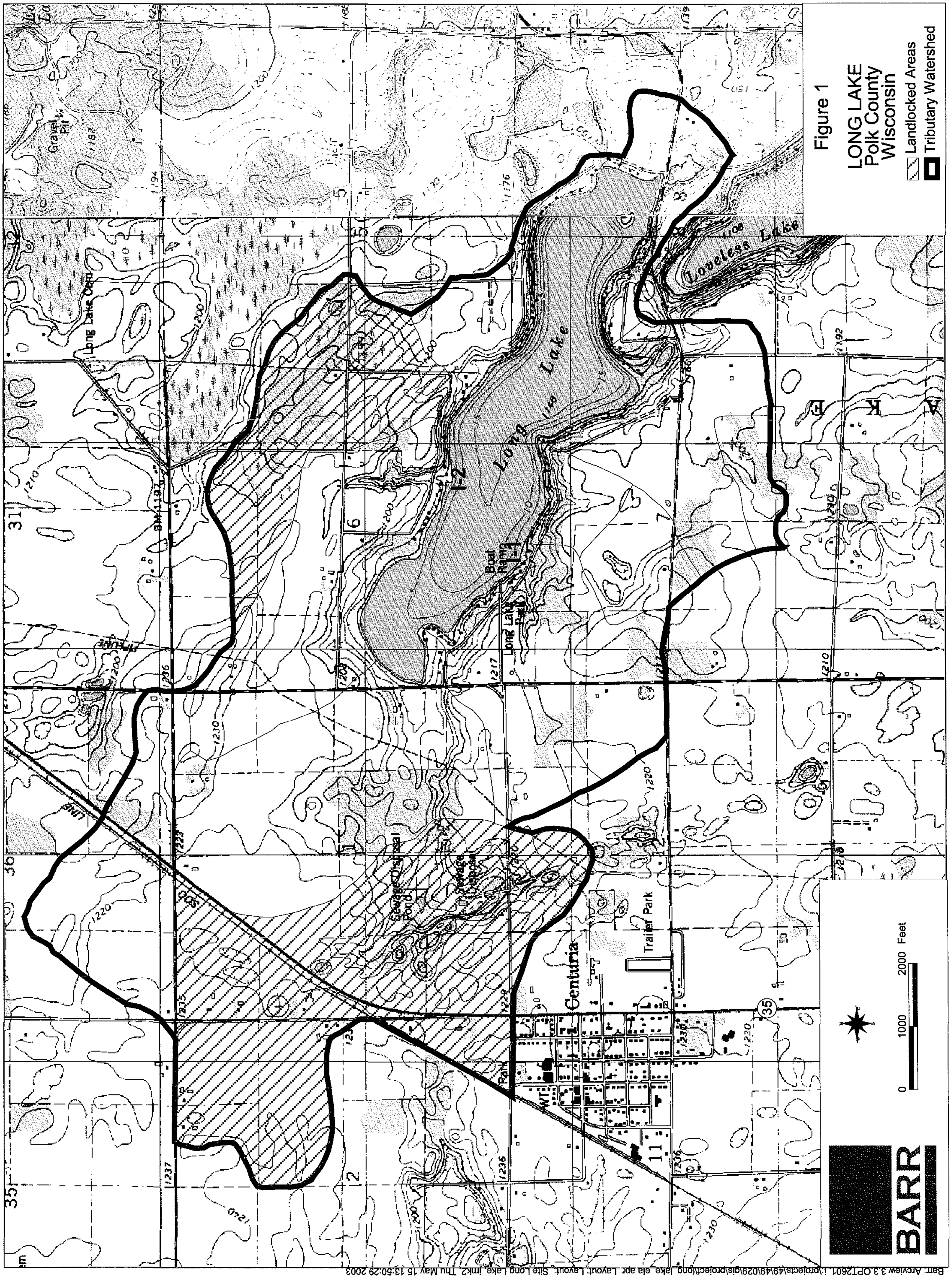
Figure 1
LONG LAKE
Polk County
Wisconsin
Landlocked Areas
Tributary Watershed
0
1000
2000 Feet
BARR
Long Lake
Loveless Lake
Centuria
Trailer Park
Boat Ramp
Long Lake Park
Sewage Disposal Pond
Gravel Pit

Long Lake Epilimnetic TP Concentration
Long Lake 2000

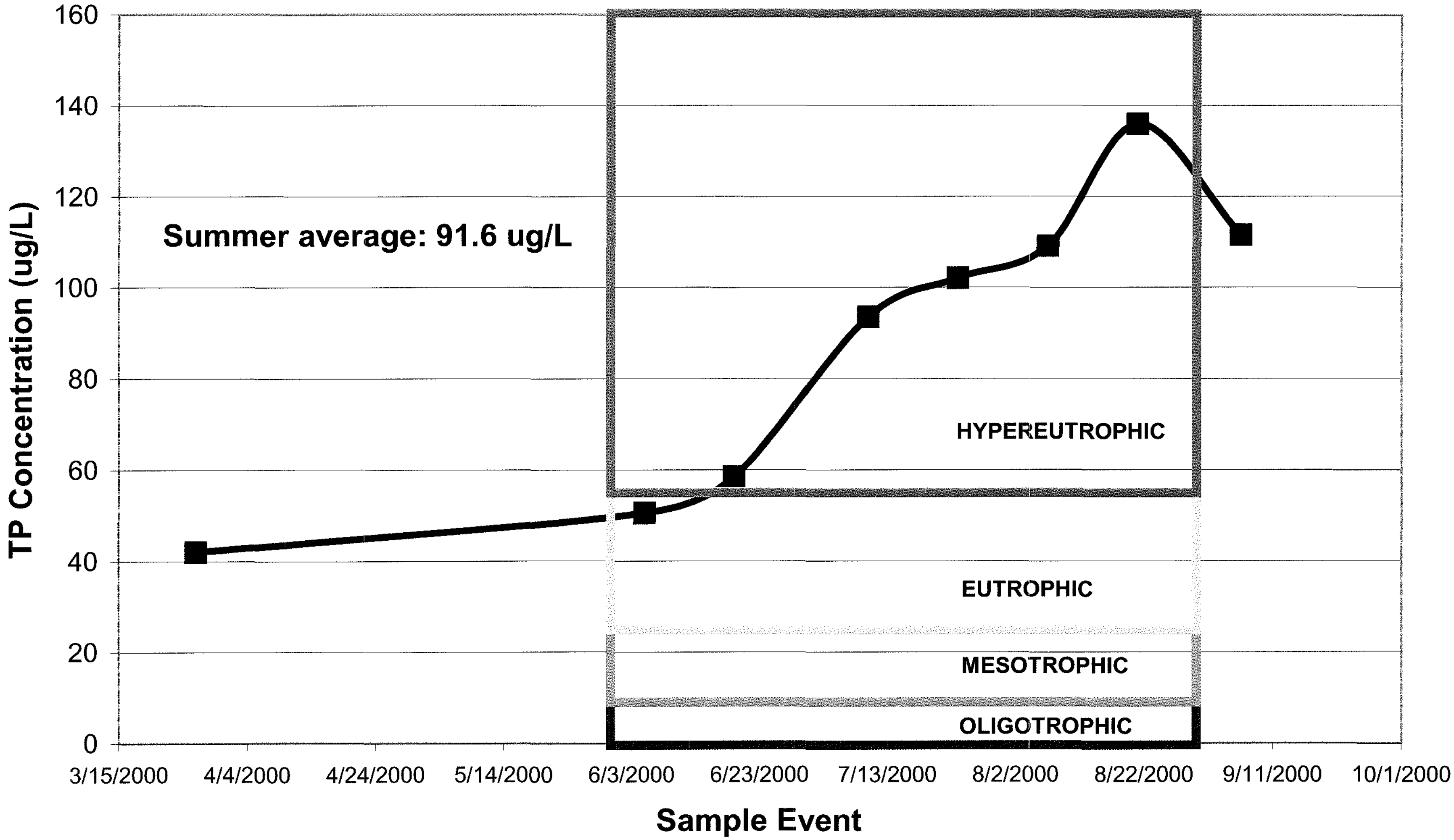

Figure 2

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Long Lake Sources of Water
2000

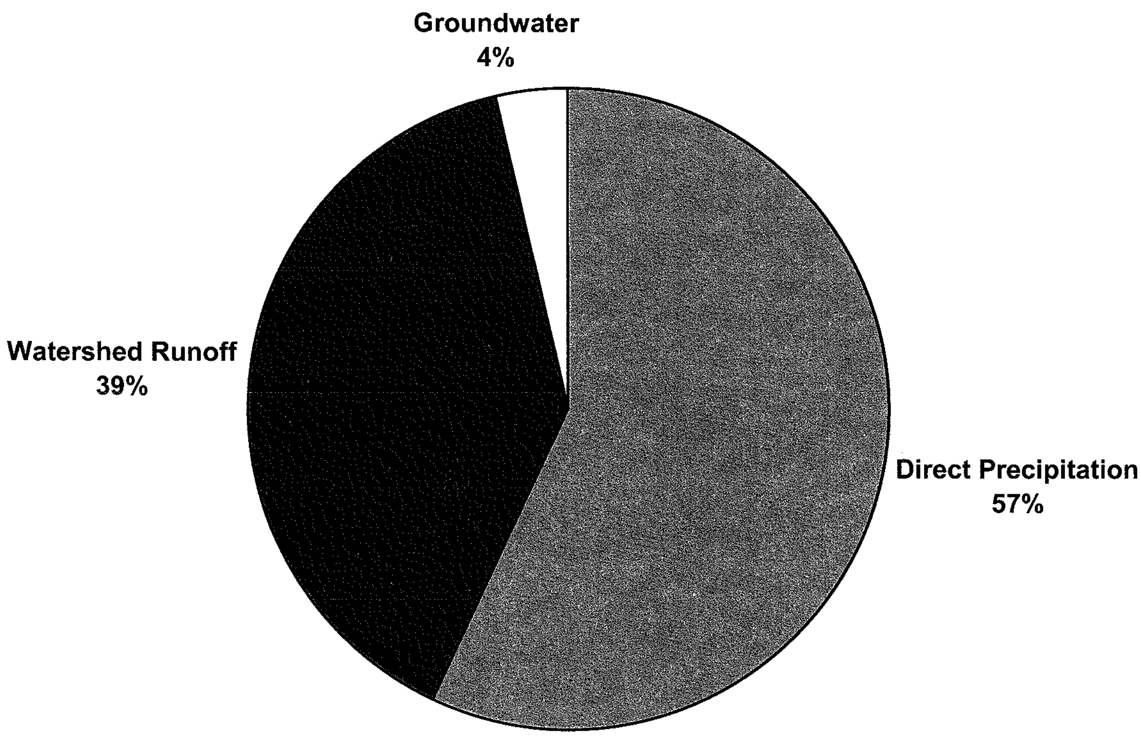

Figure 3

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Long Lake Sources of Phosphorus 2000

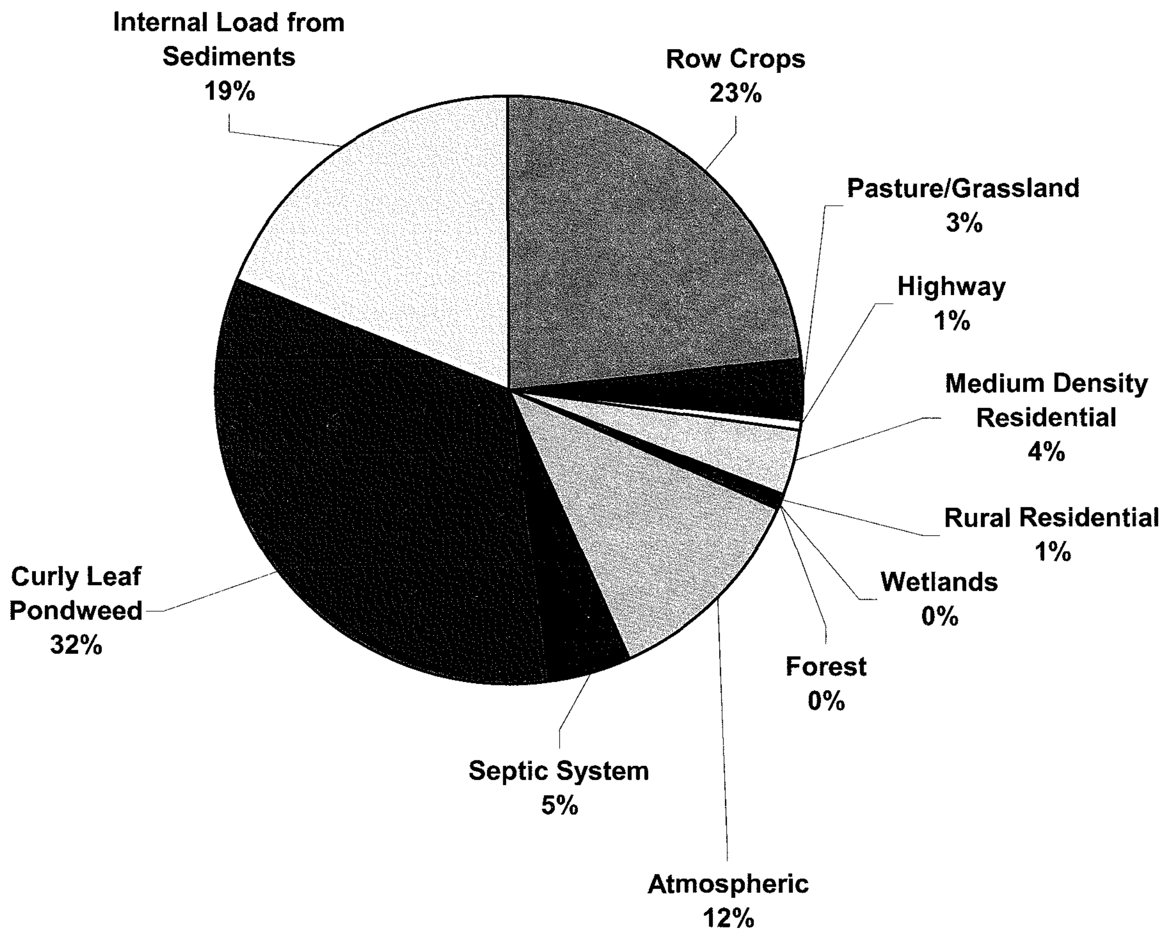

Figure 4

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Long Lake Summer Average In-Lake TP Concentration with Treatment of Internal TP Loads

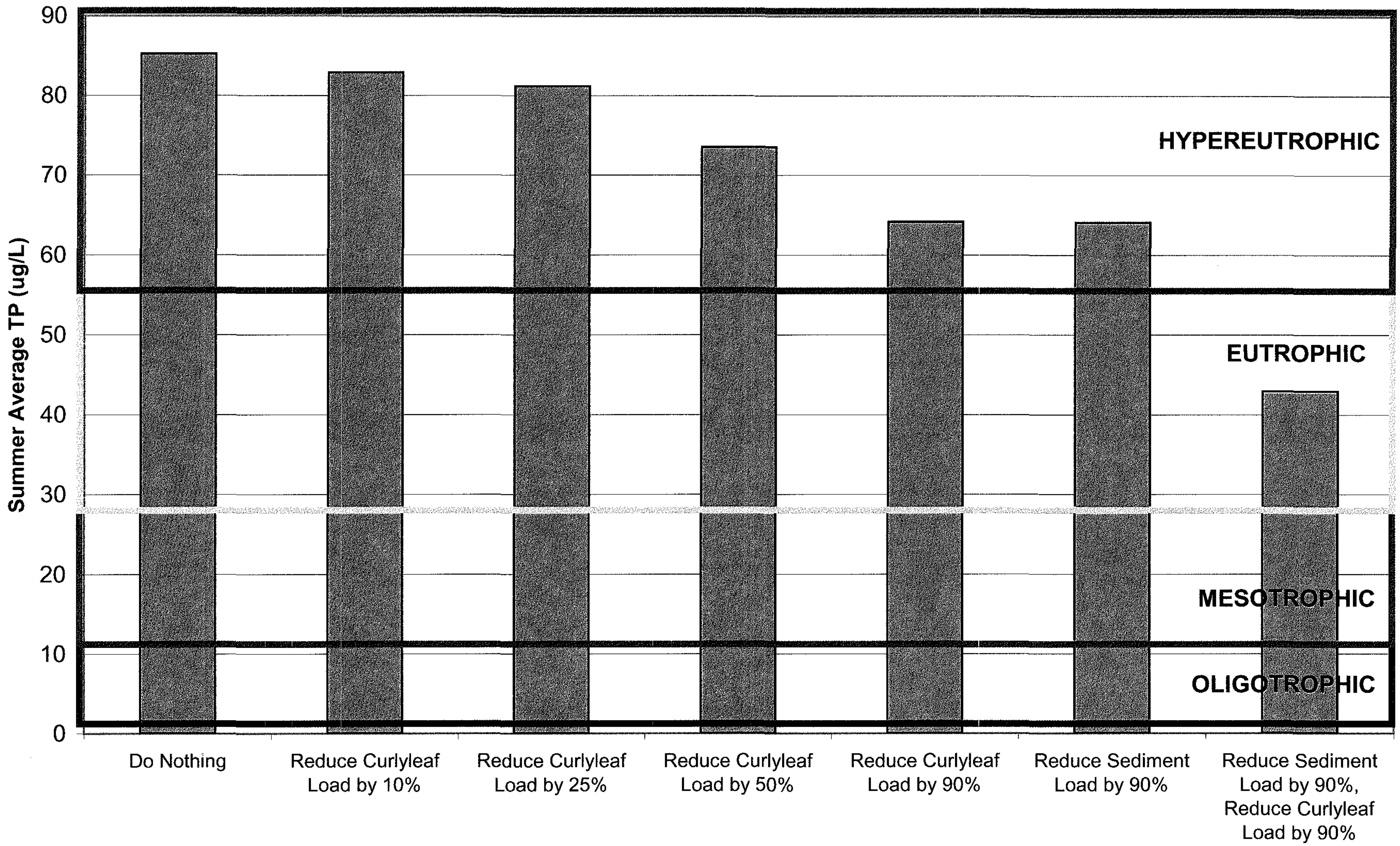

Figure 6

The Water Quality Benefit of a Change in Total Phosphorus at Different Initial Total Phosphorus concentrations

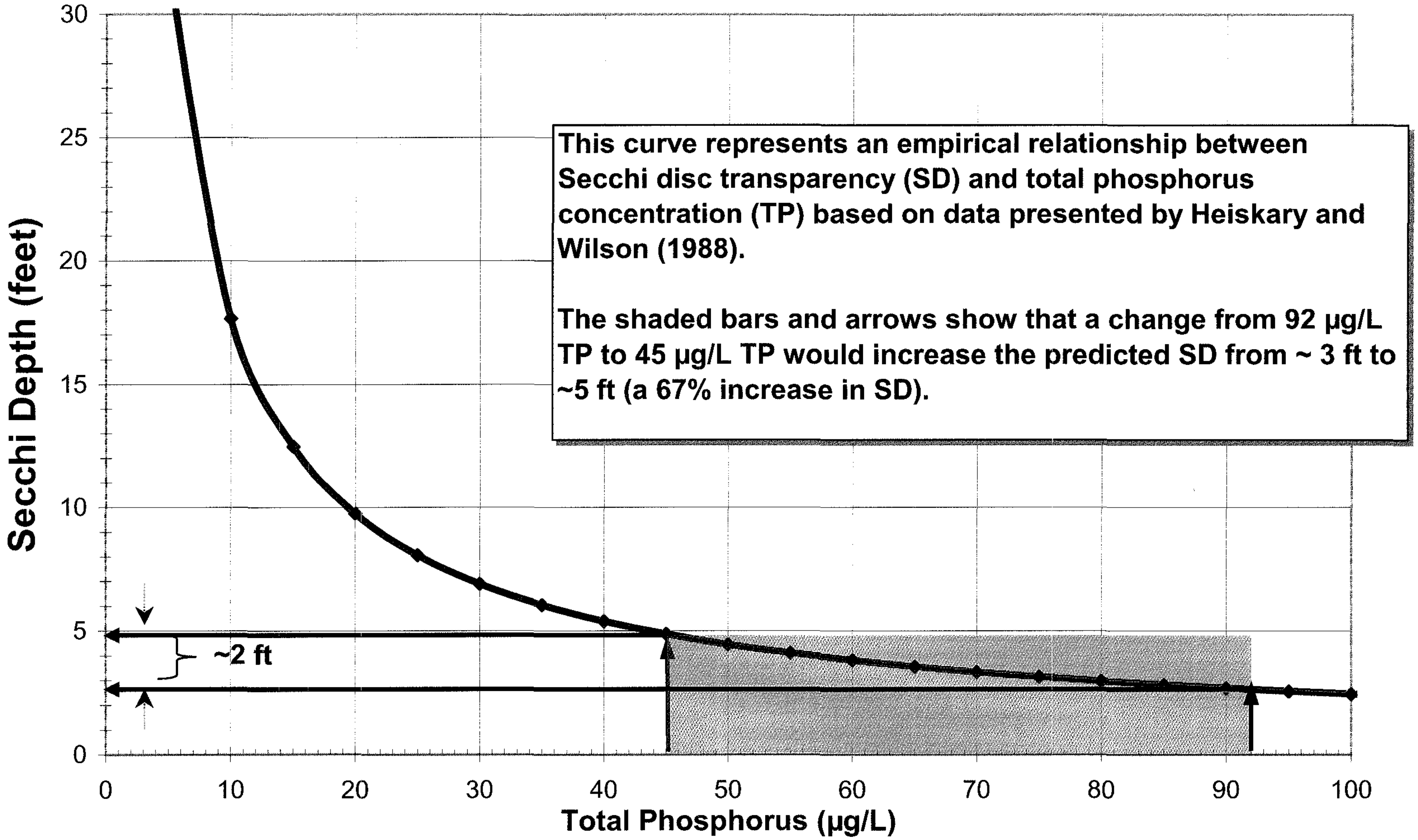

Figure 7

9
11
13
18
40-41 41

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Phases V and VI: Lake Management Plan

Prepared for
Long Lake Protection and Rehabilitation District

May 2003

BARR

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Executive Summary

The creation of the Long Lake management plan was initiated by the Long Lake Protection and Rehabilitation District to provide information to managers and citizens regarding the long-term management of Long Lake.

The data, results and conclusions from Phases I through IV of this project have been presented in detail in the document entitled *Long Lake Management Plan, Phases I-IV: Lake Management Plan* (Barr Engineering, 2001). A summary of Phases I-IV is presented in this report. Phases V and VI are presented here in detail for the first time. These final phases involve the establishment of a long-term water quality goal for Long Lake; the research and modeling of several management alternatives that would help the lake meet its goal, and the completion of a management plan for the lake.

Five questions were answered prior to the development of the Long Lake management plan.

1. What is the water quality of the lake under existing conditions?
2. What is the long-term water quality goal of the lake?
3. Does the current water quality of the lake achieve its water quality goal?
4. What will be the water quality of the lake if a "no action" management approach is followed?
5. What is the recommended long-term management plan for the lake?

The answers are as follows.

1. What is the water quality of the lake under existing conditions?

Data collected during 2000 were evaluated to determine the lake's current water quality. The average summer total phosphorus concentration (91.6 µg/L) from the epilimnion (i.e., surface waters) of Long Lake was within the hypereutrophic (i.e., extremely nutrient-rich) category, indicating the lake has the potential for problematic algal blooms throughout the summer period. The lake's average summer chlorophyll *a* concentration (28.2 µg/L) from the epilimnion was within the hypereutrophic (i.e., very highly productive) category, indicating undesirable algal blooms occur during the summer period. The average summer Secchi disc measurement (1.2 meters) was within the eutrophic category, indicating the average recreational-use impairment during the summer period was moderate. Secchi disc measurements during mid-July through August were within the hypereutrophic category and indicated moderate to severe recreational-use-impairment.

2. **What is the long-term water quality goal of the lake?**

   The specific goal is an average summer epilimnetic (upper 6 feet) Total Phosphorus (TP) concentration not to exceed 45 µg/L. Achieving this water quality goal would result in a 50 percent reduction in TP and a corresponding 67 percent increase in transparency.

3. **Does the current water quality of the lake achieve its water quality goal?**

   No, the current water quality of the lake does not meet this water quality goal. In 2000, Long Lake's summer average epilimnetic TP concentration was 92 µg/L. While other historical TP measurements in the lake do not exist, 10 years of Secchi disc transparency measurements from the Self Help Program indicate that the lake has typically had compromised water quality throughout the summer months.

4. **What will be the water quality of the lake if a "no action" management approach is followed?**

   If no action is taken at present, the lake's water quality would be expected to, at best, stay the same and, at worst, degrade further.

5. **What is the recommended long-term management plan for the lake?**

   Both an in-lake alum/lime slurry treatment and watershed best management practices (BMPs) are recommended for Long Lake. While watershed BMPs are good watershed stewardship, by themselves they may not make a significant impact on Long Lake's water quality since they only comprise ~30 percent of the overall TP load to the lake. However, a combination of watershed measures (a stormwater ordinance, shoreland gardens, a septic system ordinance and additional watershed best management practices) and an in-lake treatment is expected to attain the lake's water quality goal. An in-lake treatment to control Long Lake's internal loads from curlyleaf pondweed and the lake's sediments is the key to goal attainment. While alum has been used extensively throughout the world for decades, only a few select lakes have received lime and alum/lime treatments. The idea for the use of lime as a lake treatment tool is fairly recent, originating in Alberta, Canada in the late-1980s.

   Following the treatment, the lake's average annual total phosphorus concentration is expected to be 45 µg/L. Benefits from the treatment are estimated to last approximately 10 years.

The recommended alum/lime slurry dose is 32 grams of aluminum per square meter (g/m^2) of lake sediment and 300 g/m^2 lime. The estimated treatment dose was based upon the extractable phosphorus content in the upper 4 centimeters of lake sediment (i.e., a 25:1 ratio of alum to extractable phosphorus). Sediment phosphorus release experiments completed during the Phase V study confirmed that the dose effectively achieves the desired 90 percent reduction in internal phosphorus loading.

The estimated cost of this in-lake treatment is $345,000 (2003 dollars) for the whole lake treatment plus the cost of the pilot project discussed below.

Because Long Lake's sediments are especially watery, there is a chance that an alum/lime treatment could sink down within the sediment layer, rendering the treatment less effective. For this reason, a 3-year study is recommended for the lake, involving both treated and untreated (control) test plots in the lake from which duplicate sediment cores can be extracted and studied. Phase I of the study would be to treat test plots with a 25:1 alum dose, 32 g/m^2 aluminum, and a lime slurry dose of 300 g/m^2. Phase II would be an annual monitoring program involving sediment cores taken from the test plots.

For Phase I, the cost of applying alum and lime to test plots will depend upon the number of test plots selected and the sizes of individual test plots. The application cost is expected to consist of a $1,250 per acre cost for applying the alum and lime plus mobilization and demobilization costs, which are expected to be less than $15,000. For Phase II, the sediment core collection and analysis of the cores for mobile phosphorus is estimated to total around $5,000 annually. All costs are based on 2003 dollars.

Long Lake Management Plan
Phases V and VI: Lake Management

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1.0 Introduction

Long Lake (Figure 1) is considered a significant water resource by the Long Lake Protection and Rehabilitation District (District), The Wisconsin Department of Natural Resources (WDNR), and area residents. The lake is located in Polk County, Wisconsin. The lake typically experiences problematic algal blooms during the summer months.

Long Lake's surface area is approximately 277 acres with a maximum depth of 18 feet. Although Long Lake has no stream inlet or outlet, two ditches (along with overland flow from other areas of the watershed) add stormwater to the lake during storm events. Seasonal and permanent residences surround the entire lake.

In recognition of the lake's value and current water quality problems, the District has completed a study of the lake over the course of six project phases. This work culminates in a lake management plan whose primary objective is the improvement of Long Lake's water quality. Each of the six project phases is described below:

- **Phase I:** A macrophyte survey of the lake was conducted in mid-June, 2000 in order to characterize the type and extent of macrophyte coverage in the lake. Barr Engineering Company completed the macrophyte survey, with assistance from volunteers. In addition, a concentrated inflow point on the south side of the lake was monitored for flow and water quality constituents. Inflow monitoring was performed by volunteers.
- **Phase II:** A second concentrated inflow point on the north side of the lake was monitored for flow and water quality constituents. The monitoring was performed by volunteers.
- **Phase III:** A water quality survey of Long Lake was conducted during spring and summer 2000 to establish the current water quality conditions of the lake. Samples were collected by volunteers. Volunteers also collected information on the daily lake levels and precipitation in and around the lake throughout the year. A membership survey intended to determine the lake residents' opinions about Long Lake's water quality and how they are affected by it was circulated and completed by residents as well.
- **Phase IV:** All of the data gathered in Phases I through III of the project, as well as watershed land use information gathered during Phase IV, were used to estimate the lake's annual water and total phosphorus budgets.
- **Phase V:** A long-term water quality goal was defined for the lake and various potential management scenarios that would control TP sources (watershed sources as well as curlyleaf pondweed and lake sediment loads) were evaluated. Sediment core experiments were

conducted in order to determine the cost and benefit of a potential alum/lime slurry treatment of Long Lake.

- **Phase VI:** In this final phase, the Long Lake management plan was completed, using the modeling results and sediment core experiment results from Phase V and the data, results and conclusions of Phases I through IV.

The data, results and conclusions from Phases I through IV have been presented in detail in the document entitled *Long Lake Management Plan, Phases I-IV: Lake Management Plan* (Barr Engineering, 2001). A summary of Phases I-IV is presented in this report. Phases V and VI are presented here for the first time.

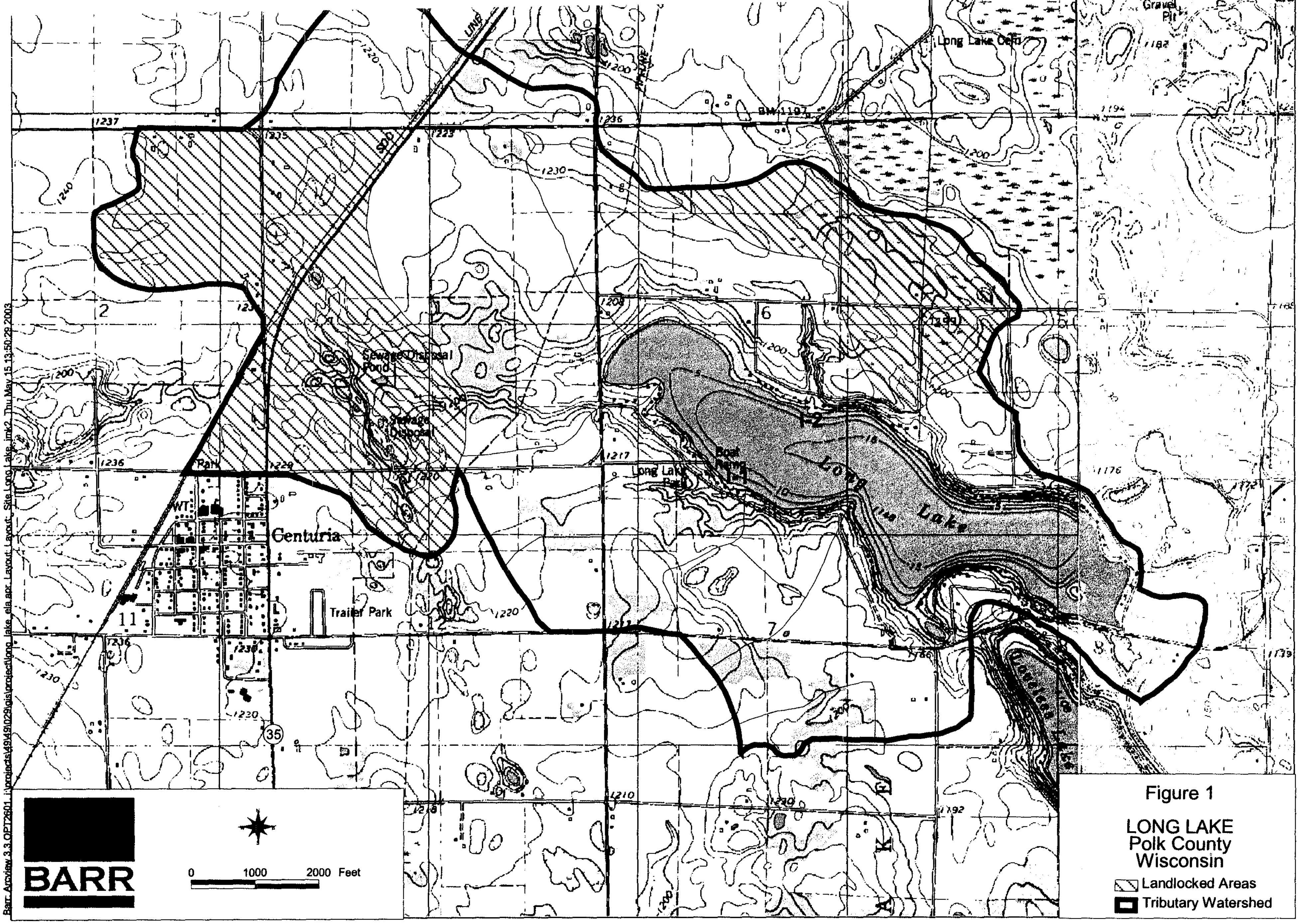

Figure 1

LONG LAKE
Polk County
Wisconsin

Landlocked Areas
Tributary Watershed

2.0 Phases I-IV Summary

Data collected during 2000 were evaluated to determine the lake's current water quality. The average summer total phosphorus concentration (91.6 µg/L) from the epilimnion (i.e., surface waters) of Long Lake was within the hypereutrophic (i.e., extremely nutrient-rich) category, indicating the lake has the potential for problematic algal blooms throughout the summer period. Figure 2 shows the TP concentration in Long Lake during 2000. The estimated TP concentration in Long Lake prior to human settlement can be estimated to be between 8 and 15 µg/L (Vighi and Chiaudani, 1985.)

The lake's average summer chlorophyll *a* concentration (28.2 µg/L) from the epilimnion was within the hypereutrophic (i.e., very highly productive) category, indicating undesirable algal blooms occur during the summer period. The average summer Secchi disc measurement (1.2 meters) was within the eutrophic category, indicating the average recreational-use impairment during the summer period was moderate. Secchi disc measurements during mid-July through August were within the hypereutrophic category and indicated moderate to severe recreational-use-impairment.

Good water quality was noted during the early-summer and poor water quality was noted during the mid-through late-summer period. Of particular interest are the significant increases in epilimnetic (surface water) phosphorus concentrations in late-June and again in mid-August. Late-June epilimnetic increases coincided with the die-off of curlyleaf pondweed within the lake. Mid-August epilimnetic phosphorus increases coincided with an apparent lake mixing event in which phosphorus-rich bottom waters were added to the lake's epilimnion (surface waters).

The watershed tributary to Long Lake is approximately 1,279 acres[1] or approximately 5 times the surface area of the lake (i.e., approximately 277 acres). The lake's watershed is largely agricultural (74 percent), but also has significant amounts of open space (8 percent), and residential areas (17 percent).

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[1] In the *Long Lake Management Plan, Phases I-IV: Lake Management Plan* report, the tributary watershed is cited as 1,411 acres. Since the release of that report, some landlocked areas have been identified in the tributary watershed. Several numbers (watershed area, land use percentages, water load magnitudes, TP load magnitudes, etc.) in this section of the report have changed accordingly. It is important to note that none of these changes affect the conclusions presented in the Phase I-IV report.

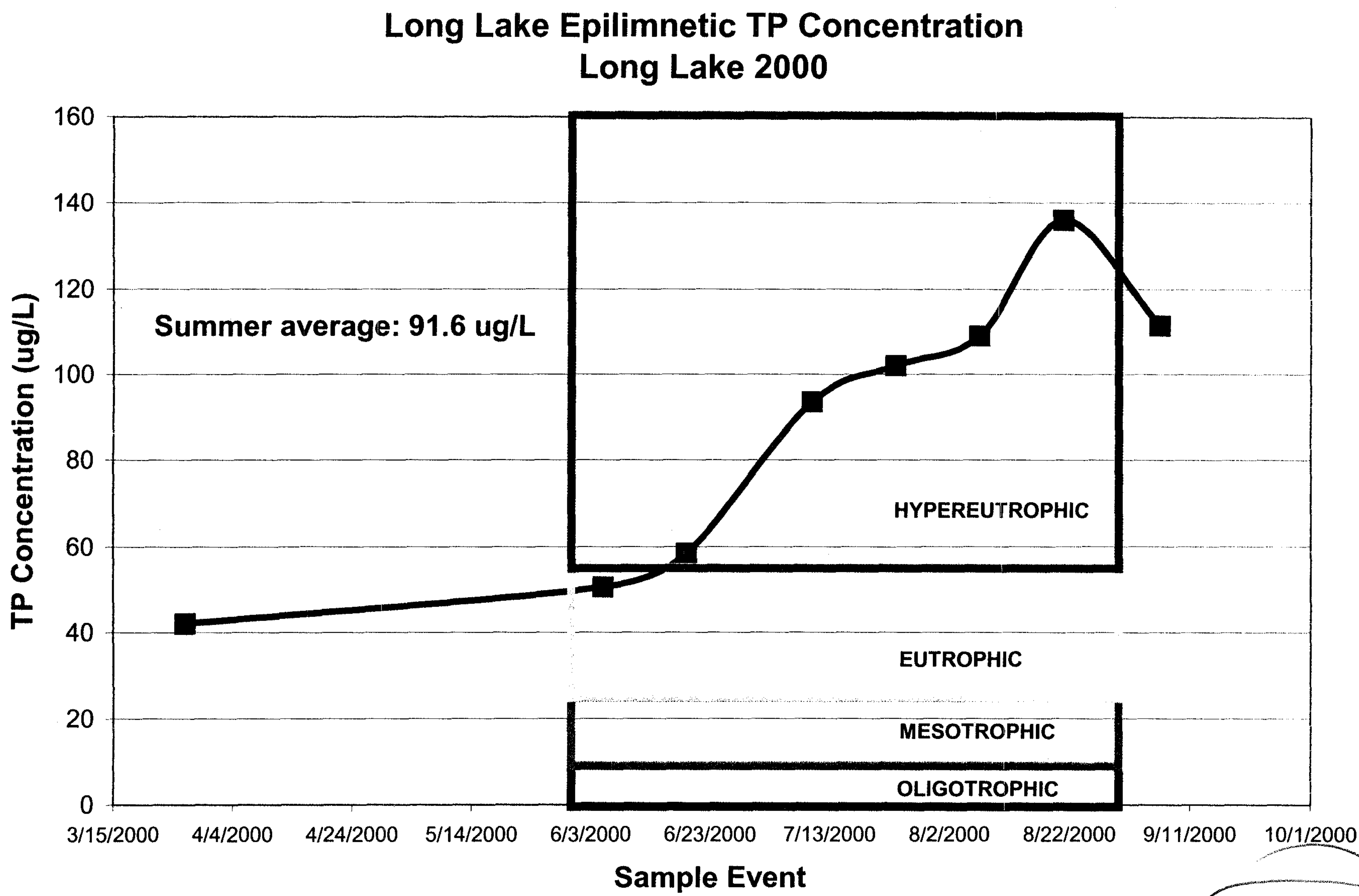

Figure 2

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The lake's annual hydrologic budget indicates Long Lake receives water from three sources:

- **Direct precipitation on the lake**—622 acre-feet (57 percent)
- **Watershed runoff**—431 acre-feet (39 percent) (includes 392 acre-feet from snowmelt runoff)
- **Net groundwater inflow**—39 acre-feet (4 percent)

Figure 3 shows the contribution of each of these water sources graphically.

Annual water loss is limited to evaporation and groundwater seepage, since the lake has no outlet.

The lake's estimated annual phosphorus budget indicates the total phosphorus load to Long Lake is 537 kilograms. Sources of phosphorus include:[2]

- **Agricultural and developed areas within the tributary watershed**—168 kg (31 percent)
- **Septic systems around the lake**—24 kg (5 percent)
- **Die-off of curlyleaf pondweed in late-June**—174 kg (32 percent)
- **Internal load of phosphorus from the sediments in mid-August**—109 kg (20 percent)
- **Atmospheric loading of phosphorus directly on the lake surface**—62 kg (12 percent)

Figure 4 shows the contribution of each of these TP sources graphically.

A membership survey of 160 property owners around Long Lake was conducted in late-2001 to evaluate local impressions of the current and desired quality of the lake, the current and desired activities in the lake, and the desired lake management goals. Twenty-six percent of the 160 property owners responded. Most of the respondents considered the current clarity of the lake to be "cloudy" or "murky" as opposed to "clear" or "crystal clear." Ninety to 100 percent of the respondents use the lake for fishing and/or viewing wildlife, and 80 to 90 percent use the lake for swimming and/or boating. Most of the respondents said that improving the lake's water quality (88 percent) and decreasing weed growth (81 percent) were important lake management goals.

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[2] In the *Long Lake Management Plan, Phases I-IV: Lake Management Plan* report, a barnyard load of 24 kg/yr was included as a TP source in the Long Lake watershed. Since the release of that report, the Polk County Land Conservation Department has stated that there are no longer any barnyard loads in this watershed. The percentage contribution of each of the remaining loads has been changed accordingly in the report.

Long Lake Sources of Water
2000

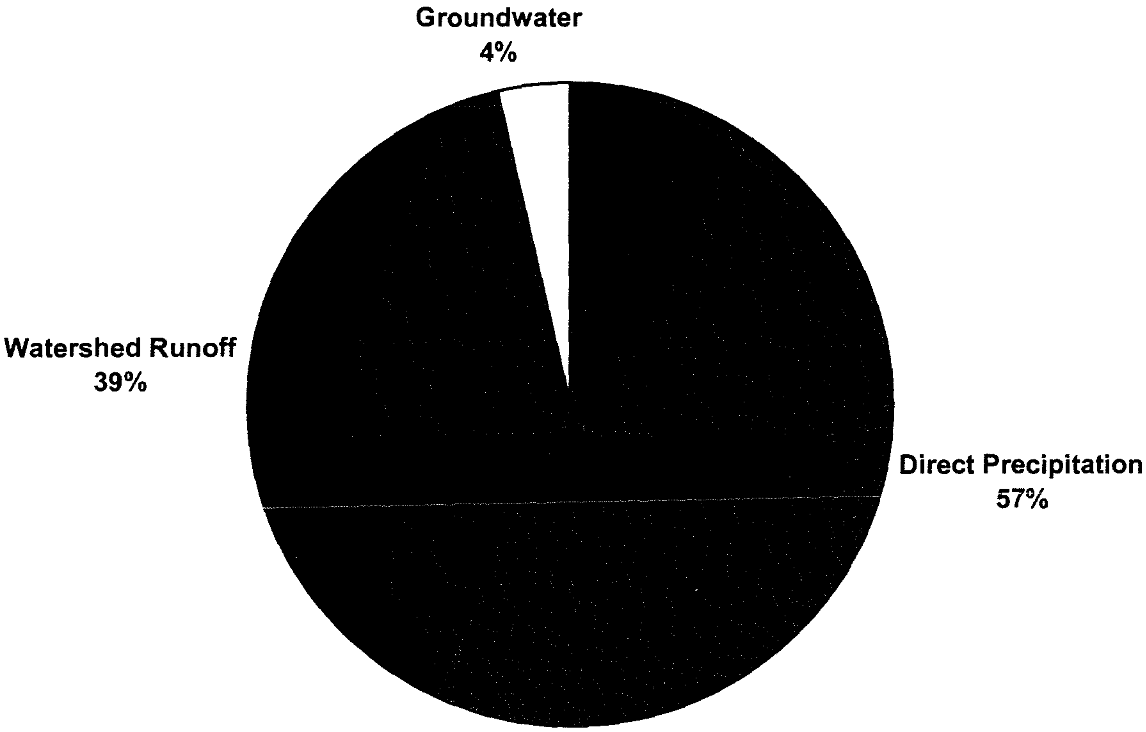

Figure 3

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Figure 4

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3.0 Phase V Methods and Results

The work performed in Phase V of this project was intended to:

- Establish a long-term water quality goal for Long Lake
- Explore various potential management scenarios and their impacts on the water quality of Long Lake, focusing on:
  - Prevention of increased watershed runoff
  - Management of curlyleaf pondweed to reduce phosphorus loading from dying plants
  - Management of internal phosphorus loading from lake sediments
  - Perform cost-benefit analysis of management scenarios

These tasks and their results are discussed in the following pages.

3.1 Creating a Long-Term Water Quality Goal for Long Lake

Perhaps the most important part of developing the Long Lake management plan is establishing a water quality goal for the lake. The target TP concentration (in terms of epilimnetic TP concentration) was based largely upon results from the 2001 membership survey and the knowledge of the lake's existing water quality from the 2000 data collection program.

Most of the respondents from the 2001 membership survey indicated that they used the lake for fishing, viewing wildlife, swimming and boating. All of these water-intensive activities would benefit from improved water quality. In fact, most of the respondents said that improving the lake's water quality and decreasing weed growth were important lake management goals. The survey results indicate how strongly Long Lake residents desire to improve water transparency (through fewer algal blooms) and limit nuisance macrophyte growth to maximize recreational-use of the lake throughout the summer. Also, residents greatly wish to protect the habitat of the lake's fisheries. A lake water quality goal was set with these wishes in mind.

It is important, however, to set a water quality goal that is attainable given the current water quality in the lake. Based on 2000 monitoring results, the lake's water quality (in terms of TP) is considered to be in the hypereutrophic (i.e., very highly productive) category, indicating that undesirable algal blooms occur frequently during the summer period. Although it is not reasonable to expect the lake to attain an "oligotrophic" or "mesotrophic" state, moving the lake from hypereutrophic to eutrophic (only moderate recreational-use impairment) would still be a vast improvement.

It is also important to consider the water quality that is required by the desired uses of the lake. While water quality requirements for swimming or boating are essentially subjective (the clearer the better), some Minnesota Department of Natural Resources (MDNR) research does indicate that the health of a lake's fishery is directly dependent upon water transparency that is greater than 3 feet. After compiling the results of over 6,109 fisheries surveys conducted since 1980, the MDNR discovered that at transparencies less than 3 feet, populations of pan fish crashed and undesirable rough fish (carp, bullheads, suckers) increased (Figure 5). Long Lake's 2000 water transparency (Secchi disc) ranged from 2.0 to 8.2 feet (summer average was 3.9 feet). Therefore, it is in the interests of Long Lake's fishery to increase the lake's average transparency, further above the 3-foot threshold.

With all of these factors in mind, the water quality goal for Long Lake was established to reduce epilimnetic TP by about 50 percent (to a summer average of 45 µg/L). This TP reduction is expected to increase water transparency about 67 percent (about 2 feet).

3.2 Reducing Watershed Loads

Watershed management was evaluated as a potential lake improvement measure. The Polk County Land Conservation Department was consulted to identify potential watershed management measures throughout the Long Lake tributary watershed. While there are currently no watershed projects underway, there are various watershed BMPs that are recommended for lake watersheds. These BMPs are described in the lake management plan section of this report (Phase VI).

Although these BMPs would serve to benefit the lake, it is important to note that because watershed loads represent only about a third of the lake's total TP load, they cannot be expected to significantly improve the lake's water quality by themselves. Without an in-lake treatment of the lake's sediments, Long Lake will not meet its water quality goal.

3.3 Modeling

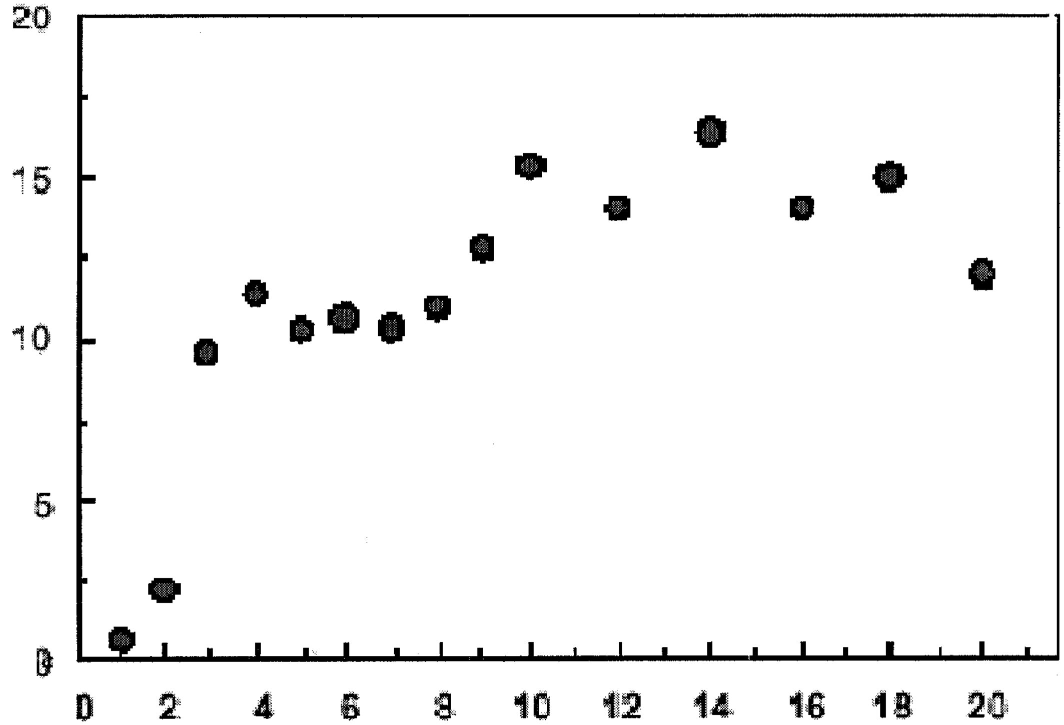
The model used to determine Long Lake's phosphorus budget was used here to evaluate the water quality benefit of reducing the lake's internal phosphorus load from both lake sediments and from curlyleaf pondweed senescence. Several different scenarios were evaluated, assuming:

- 90 percent removal of the lake's internal phosphorus load from its sediments.
- 10 percent, 25 percent, 50 percent, and 90 percent removal of the internal load from curlyleaf pondweed senescence.
- 90 percent removal of the lake's internal load from both the sediments and curlyleaf pondweed senescence.

These removal efficiencies are within an observed range of alum/lime slurry treatment performances.

Fisheries Quality vs. Water Transparency

Median Catch of Small Centrarchids
(# of Fish Per Trap Net)



Secchi Disc Transparency (ft)

Figure 5

Figure 6 shows the modeling results. Only the 90 percent reduction of sediment, plus curlyleaf internal TP loads, resulted in lowering the lake's water quality classification from hypereutrophic to eutrophic states.

Modeling efforts addressing the estimated effectiveness of an in-lake alum/lime slurry treatment of the lake (described below) have indicated that the epilimnetic TP concentration could feasibly be reduced to 45 µg/L (Figure 6). This concentration would bring the lake from a hypereutrophic state to a eutrophic state during the summer. In terms of transparency, such a TP reduction could result in a 2-foot increase (on average) in transparency during the summer months (Figure 7).

3.4 Sediment Core Experiments

Treatment of Long Lake with alum and lime is expected to reduce the lake's internal phosphorus load by reducing sediment phosphorus release and the decay of curlyleaf pondweed. This section briefly summarizes the sediment core experiments that were conducted in order to determine an effective alum and lime dose treatment of Long Lake. It is important to choose the correct dose of alum for this kind of treatment—too little will render the treatment ineffective, too much will result in unnecessary cost. A detailed description of the sediment core experiments is included in Appendix A of this report.

3.4.1 Alum Dose Determination

The District analyzed the lake's sediments to determine two possible alum doses for effective control of the lake's internal load. The District's consultant (Barr Engineering Company) collected two sediment cores from the lake's deepest point on January 29, 2003 and analyzed the top 4 centimeters of each core for different types of phosphorus and solid material (extractable phosphorus, total phosphorus (TP), percent solids, and percent organics).

Extractable phosphorus is comprised of labile phosphorus (phosphorus that is loosely attached to sediment particles) and iron-bound phosphorus. The quantity of alum required to effectively control sediment phosphorus release is based upon the quantity of extractable phosphorus in the lake's upper layer of sediment. Hence, the extractable phosphorus content of Long Lake's 0 to 4 centimeter sediment samples was used to determine the amount of alum needed for two different doses. One dose achieved a ratio of alum to extractable phosphorus of 25:1. The second dose achieved a ratio of alum to extractable phosphorus of 50:1. These doses have been shown to effectively bind extractable phosphorus in laboratory experiments (Pilgrim, 2002).

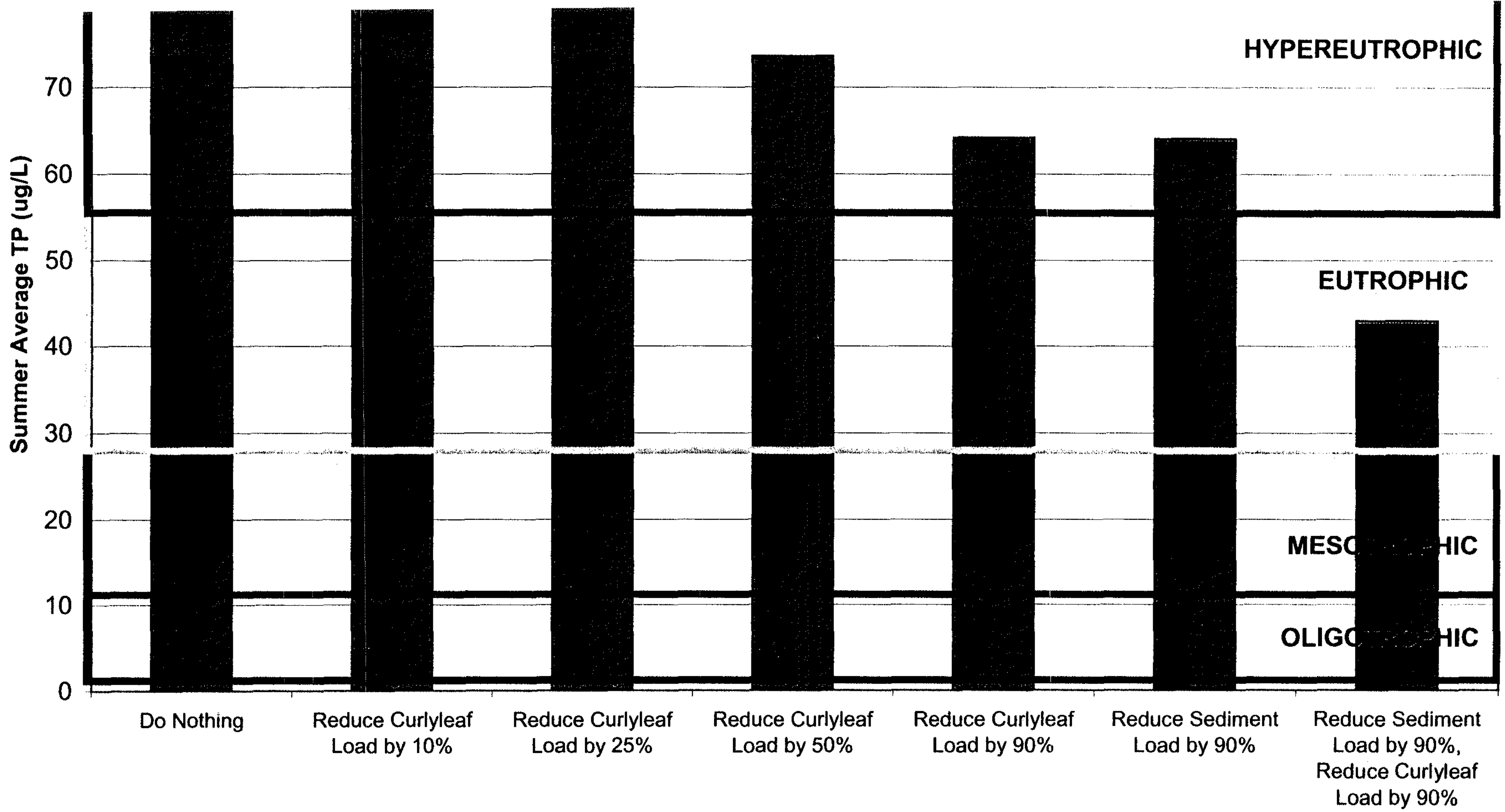


Figure 6

Total Phosphorus (µg/L)

Figure 7

3.4.2 Microcosm Experiment

The District completed a microcosm laboratory experiment to assess the effectiveness of the two proposed alum doses in controlling the lake's internal phosphorus load. This set of experiments measured the difference in sediment phosphorus release between treated sediment microcosms (25:1 and 50:1 doses) and untreated (control) sediment microcosms.

Lime was also added to the alum-dosed microcosms. Because Long Lake is relatively shallow and notes widespread growth of curlyleaf pondweed, a concurrent treatment of alum and lime slurry is proposed. The alum will control phosphorus release from the lake's sediments. The lime slurry will hold the alum floc in place, preventing wind movement of the floc. The lime slurry is also expected to reduce macrophyte density and restore the lake's native community by selection against curlyleaf pondweed.

The sediment phosphorus release rates in the two control microcosms were compared with the sediment phosphorus release rates in the four treated microcosms. The conclusion of the microcosm experiments was that the 25:1 alum dose was sufficient to control the release of P from Long Lake's sediments (Figure 8).

Figures 9a through 9f show these results in more detail—the areal P release rate in each individual microcosm over the course of the experiment.

3.4.3 Sediment Experiments

A last set of sediment experiments was conducted to evaluate the effectiveness of three possible alum-lime treatments to reduce the extractable phosphorus content of the lake's sediments and to assess the stability of the alum/lime slurry layer in the lake. This experiment gives an idea of both the longevity of an alum/lime slurry treatment in Long Lake, as well as another indication of the magnitude of the appropriate dose. If the alum/lime sinks too quickly into the sediment layer, additional doses might be necessary.

After the alum/lime slurry was added to the sediment and the samples, both treated and untreated, were shaken (to simulate lake mixing), the experiment consisted of measuring extractable P concentrations. The experiment determined whether the proposed doses achieved the estimated effect of extractable phosphorus immobilization.

These sediment experiments confirmed that the 25:1 dose effectively achieves the desired 90 percent reduction in internal phosphorus loading (Figure 10). However, these experiments also showed that Long Lake's sediments are quite watery and that there is a potential for the alum/lime floc layer to sink within the sediments over time.

Long Lake (Polk County, WI)
Average Areal Sediment Phosphorus Release Rate

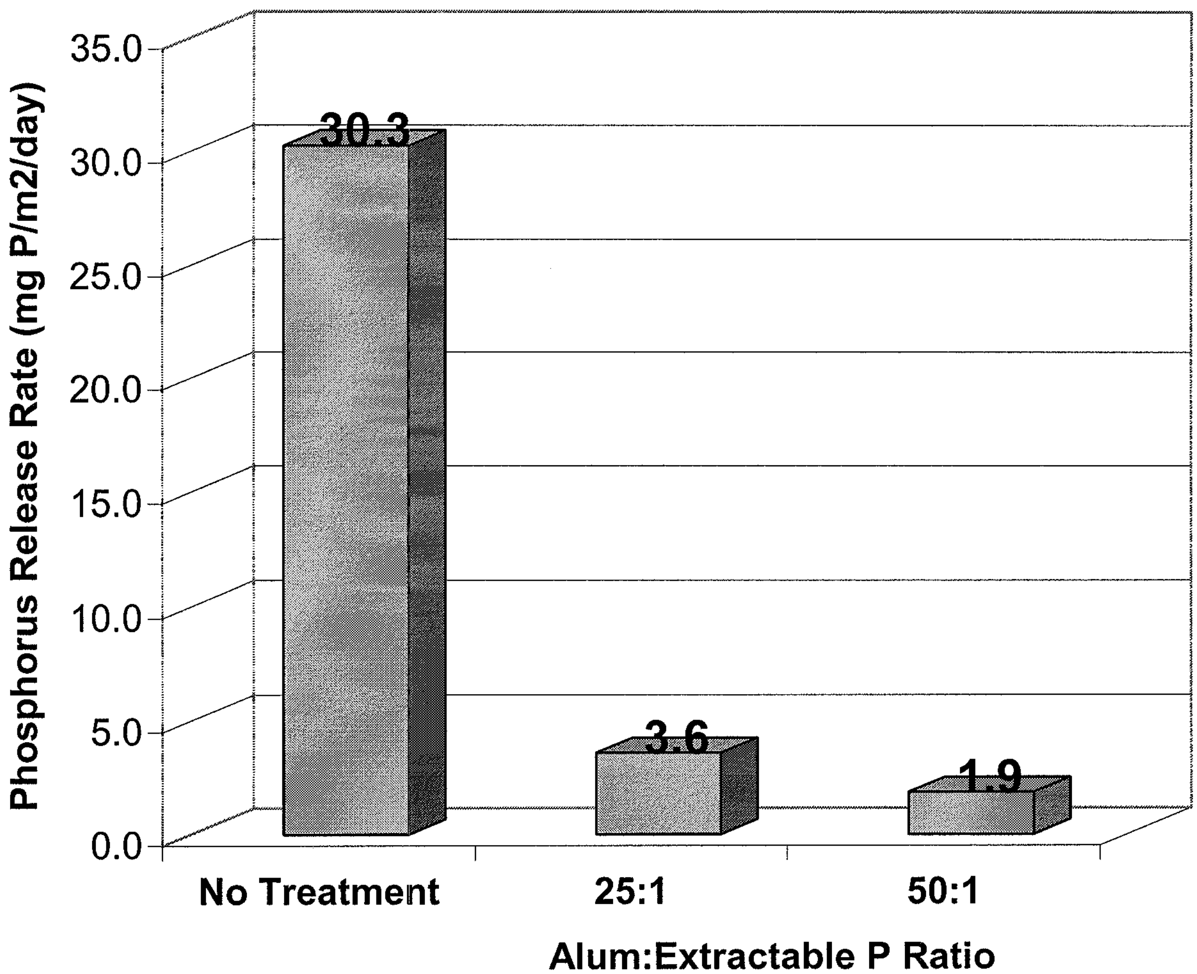
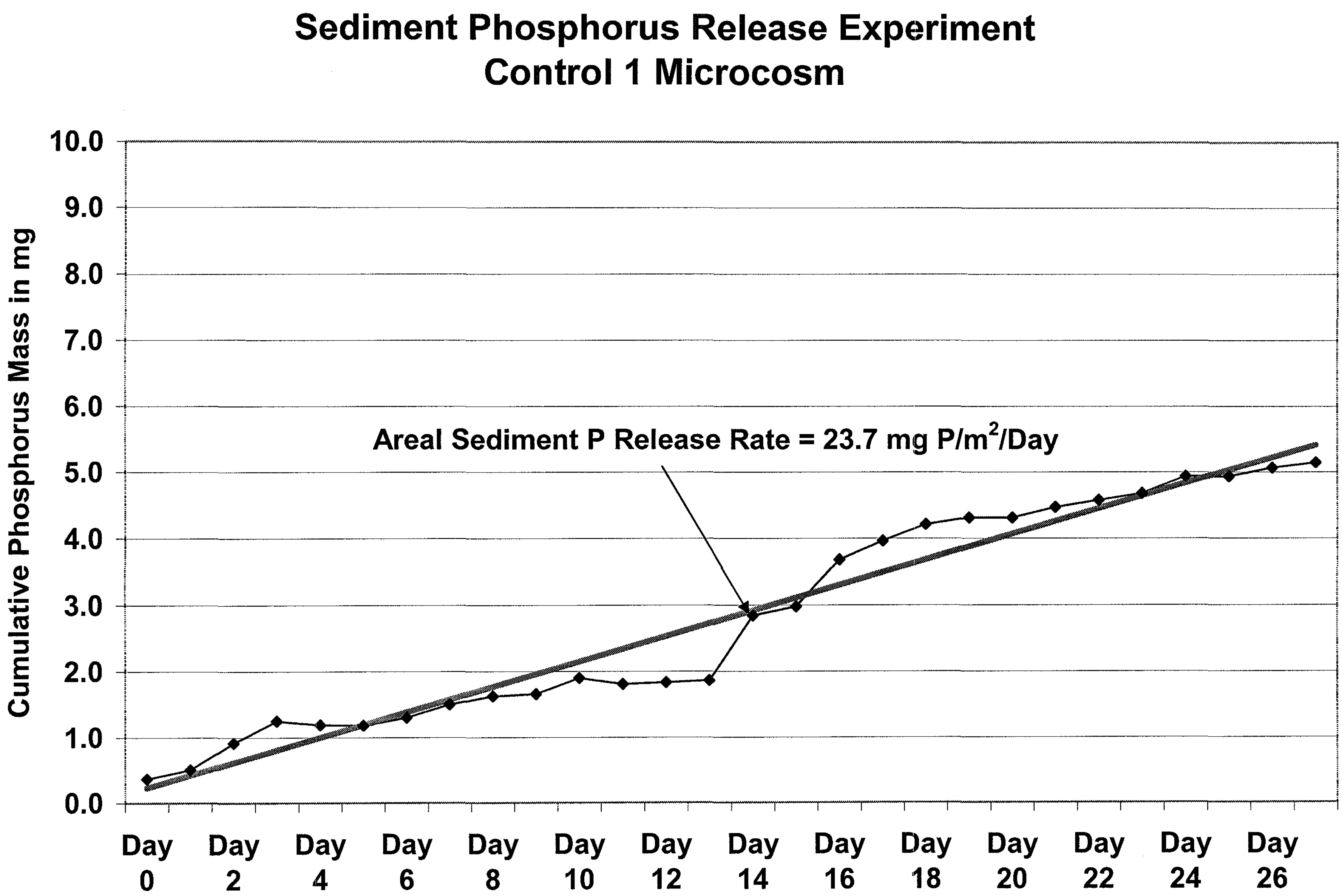


Figure 8



Sediment Phosphorus Release Experiment
Control 1 Microcosm
Cumulative Phosphorus Mass in mg
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Areal Sediment P Release Rate = 23.7 mg P/m2/Day
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Day 12
Day 14
Day 16
Day 18
Day 20
Day 22
Day 24
Day 26

Figure 9a

Sediment Phosphorus Release Experiment
Control 2 Microcosm

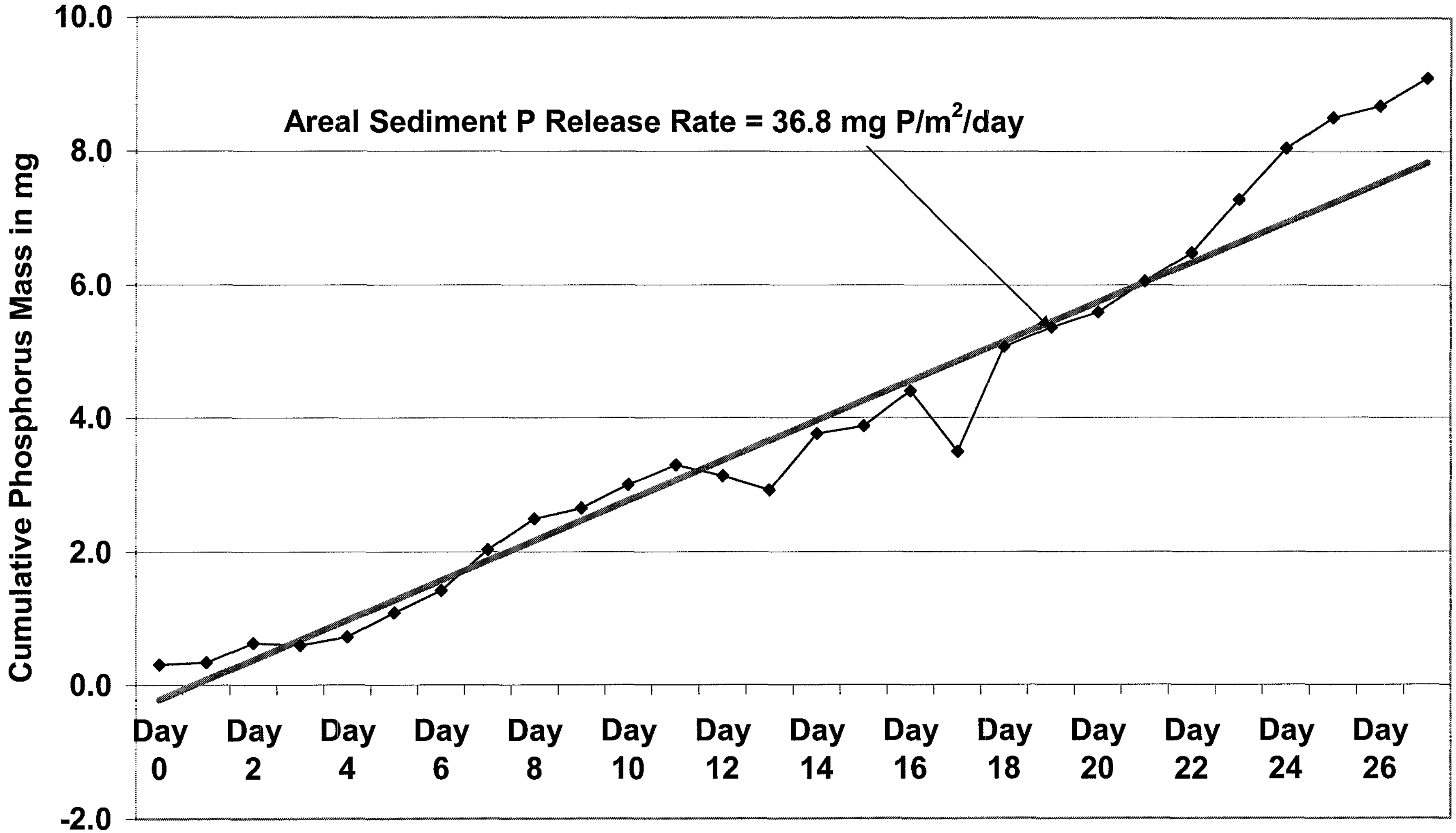


Figure 9b

Sediment Phosphorus Release Experiment
Treated 1 Microcosm

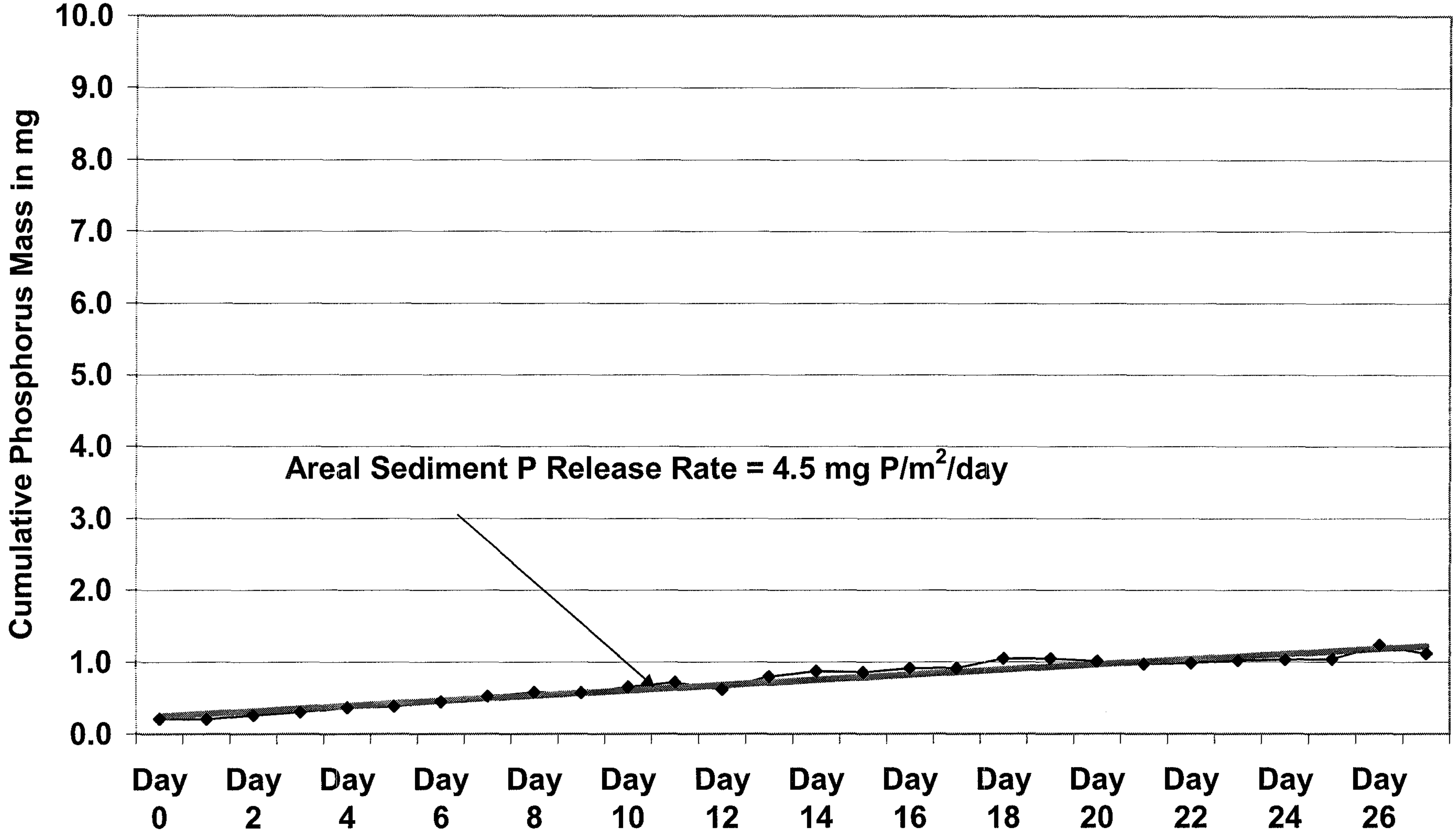


Figure 9c

Sedient Phosphorus Release Experiment
Treated 2 Microcosm

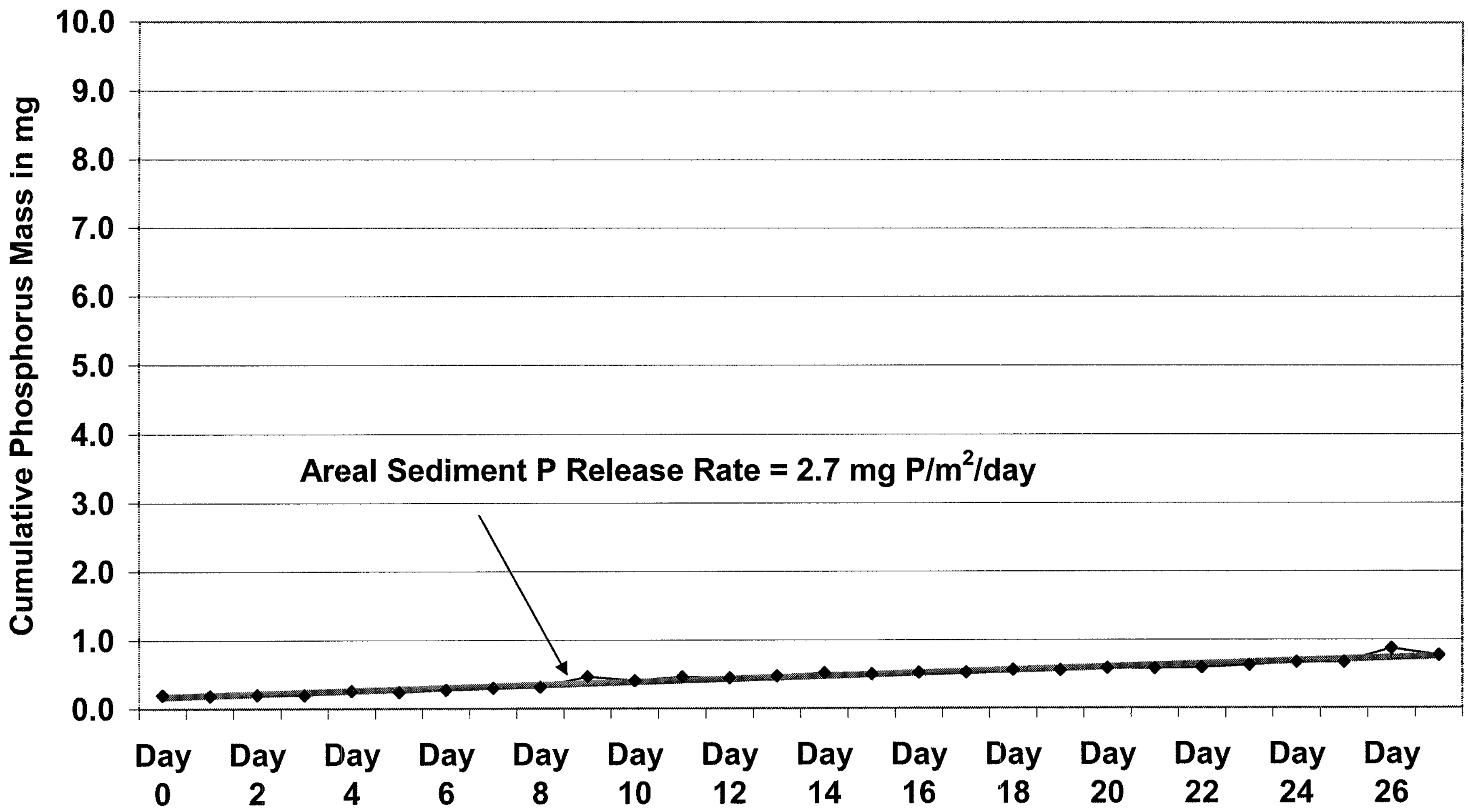


Figure 9d

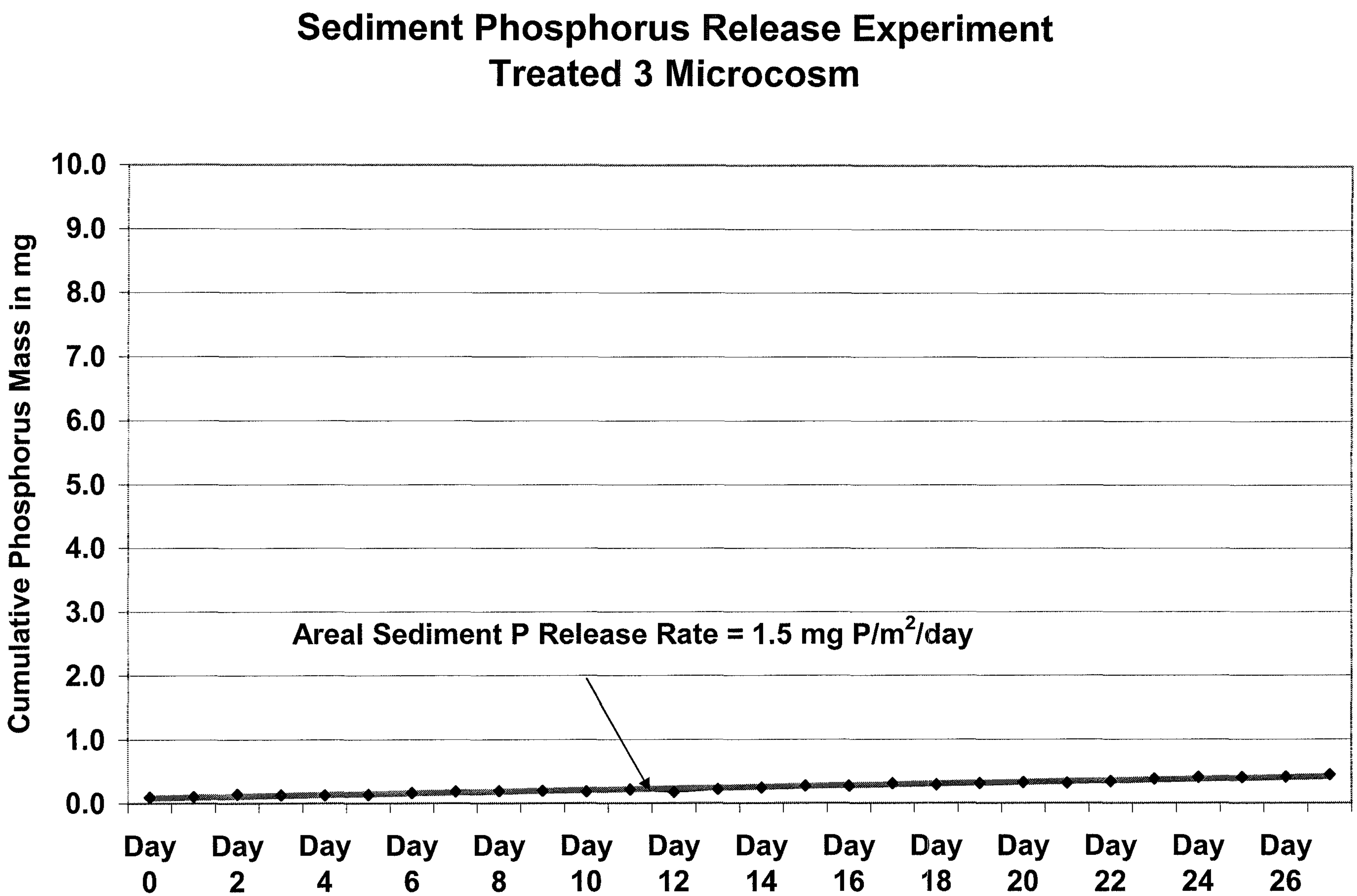

Sediment Phosphorus Release Experiment
Treated 3 Microcosm
Cumulative Phosphorus Mass in mg
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Areal Sediment P Release Rate = 1.5 mg P/m2/day
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Day 12
Day 14
Day 16
Day 18
Day 20
Day 22
Day 24
Day 26

Figure 9e

Sediment Phosphorus Release Experiment
Treated 4 Microcosm

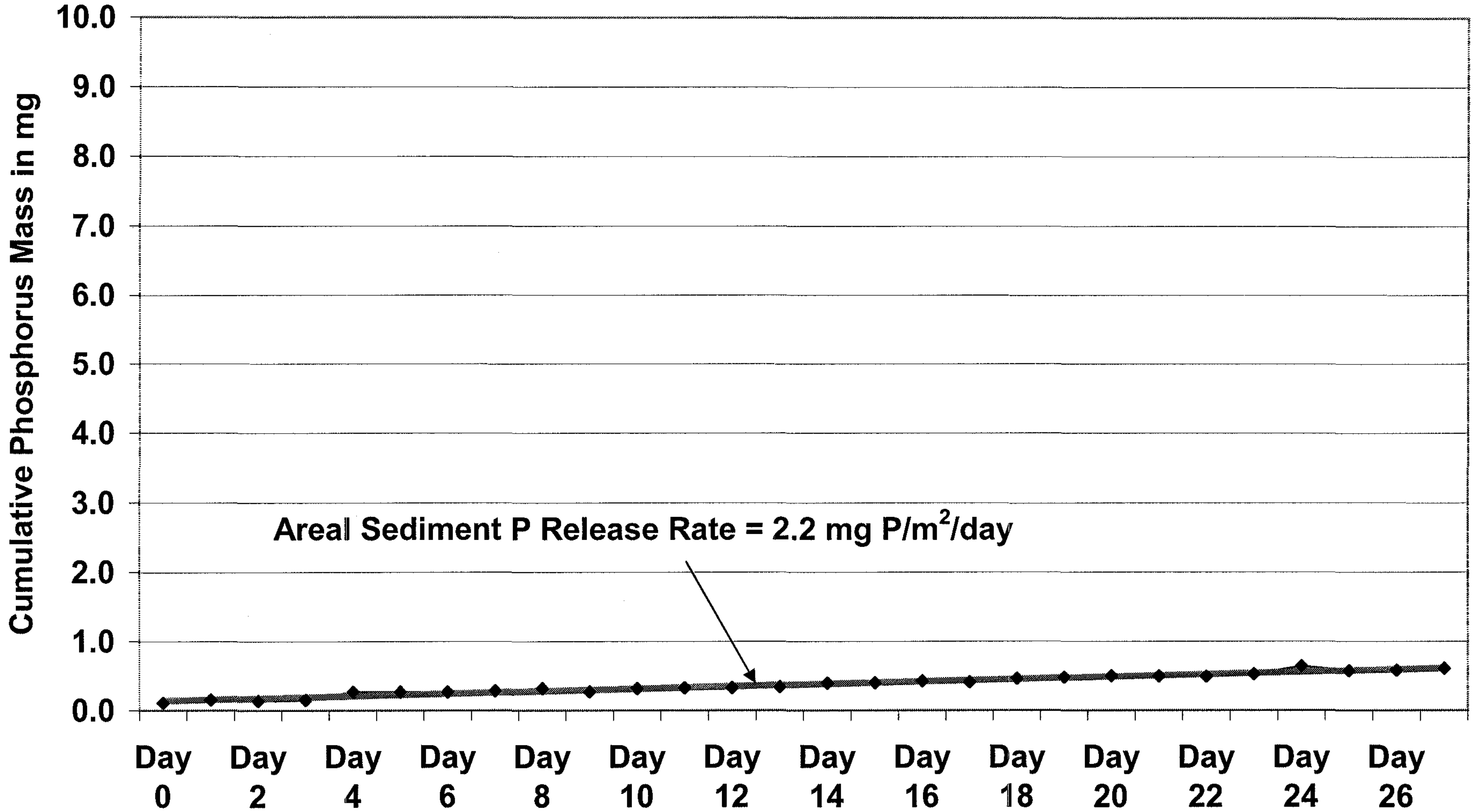


Figure 9f

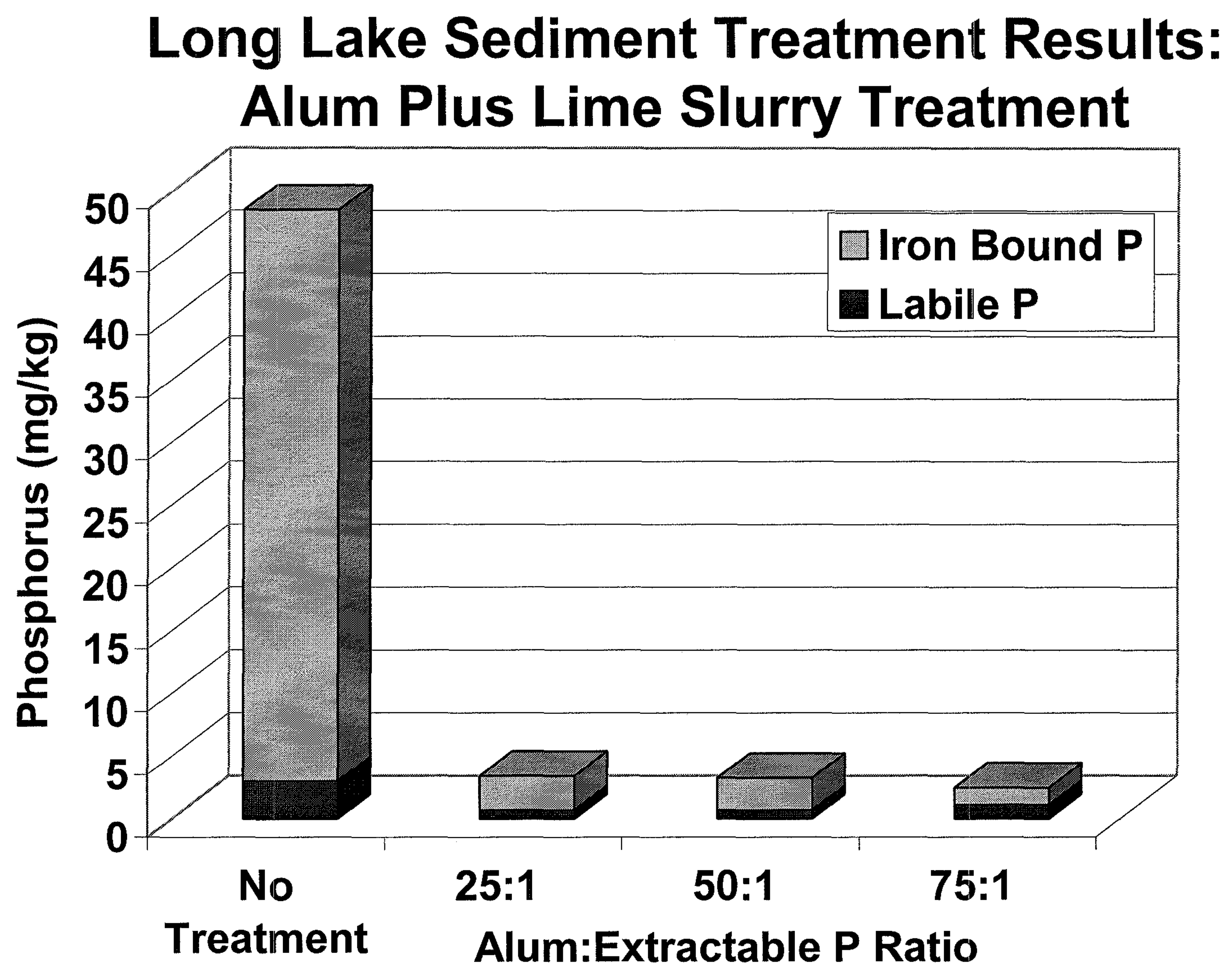

Long Lake Sediment Treatment Results:
Alum Plus Lime Slurry Treatment
Phosphorus (mg/kg)
50
45
40
35
30
25
20
15
10
5
0
Iron Bound P
Labile P
No Treatment
25:1
50:1
75:1
Alum:Extractable P Ratio

Figure 10

4.0 Phase VI: Long Lake Management Plan

Five questions were answered prior to the development of the Long Lake management plan.

1. What is the water quality of the lake under existing conditions?

2. What is the long-term water quality goal of the lake?

3. Does the current water quality of the lake achieve its water quality goal?

4. What will be the water quality of the lake if a "no action" management approach is followed?

5. What is the recommended long-term management plan for the lake?

The answers are as follows.

1. What is the water quality of the lake under existing conditions?

Data collected during 2000 were evaluated to determine the lake's current water quality. The average summer total phosphorus concentration (91.6 µg/L) from the epilimnion (i.e., surface waters) of Long Lake was within the hypereutrophic (i.e., extremely nutrient-rich) category, indicating the lake has the potential for problematic algal blooms throughout the summer period. The lake's average summer chlorophyll *a* concentration (28.2 µg/L) from the epilimnion was within the hypereutrophic (i.e., very highly productive) category, indicating undesirable algal blooms occur during the summer period. The average summer Secchi disc measurement (1.2 meters) was within the eutrophic category, indicating the average recreational-use impairment during the summer period was moderate. Secchi disc measurements during mid-July through August were within the hypereutrophic category and indicated moderate to severe recreational-use-impairment.

Figure 11 shows the Self Help Volunteer program's Long Lake data from 1992 to 2002. This Secchi disc data is superimposed over one season to show the general trend in Long Lake's transparency from early- to late-summer. Although the data varies widely (R^2=0.5), there is a general trend of worsening transparency from June to August. The overall summer average Secchi disc in Long Lake, based on this data, is 5.6 feet.

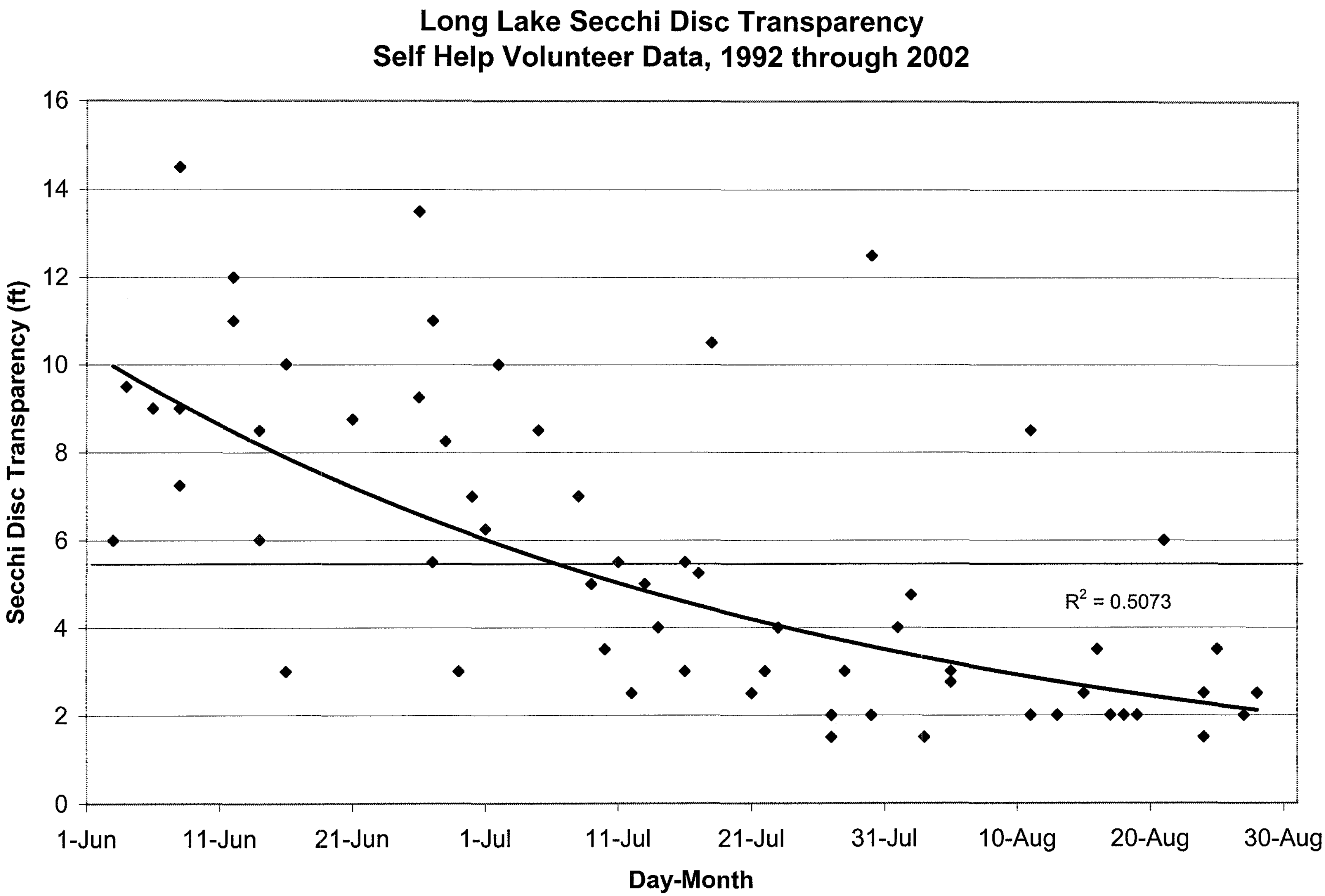

Long Lake Secchi Disc Transparency
Self Help Volunteer Data, 1992 through 2002
Secchi Disc Transparency (ft)
16
14
12
10
8
6
4
2
0
$R^2 = 0.5073$
1-Jun
11-Jun
21-Jun
1-Jul
11-Jul
21-Jul
31-Jul
10-Aug
20-Aug
30-Aug
Day-Month

Figure 11

WQ Stat II (a water quality statistics program)was used to perform a nonparametric seasonal Kendall analyses (Philips et al., 1989) to determine whether the lake's declining transparency over the last 10 years is statistically significant. The results of this analysis indicate that the Secchi disc water transparency of Long Lake has changed significantly (95 percent confidence interval) over the period of record. On average, the lake's transparency has declined annually at a rate of 0.4 feet per year. Hence, the lake's water quality has significantly degraded during the past 10 years.

2. What is the long-term water quality goal of the lake?

The specific goal is an average summer epilimnetic (upper 6 feet) TP concentration not to exceed 45 µg/L. Figure 7 shows the estimated change in Long Lake's transparency (in terms of Secchi disc) following this reduction. Achieving this water quality goal would result in a 50 percent reduction in TP and a corresponding 67 percent increase in transparency.

3. Does the current water quality of the lake achieve its water quality goal?

No, the current water quality of the lake does not meet this water quality goal. In 2000, Long Lake's summer average epilimnetic TP concentration was 92 µg/L. While other historical TP measurements in the lake do not exist, 10 years of Secchi disc transparency measurements from the Self Help Program indicate that the lake has typically had compromised water quality throughout the summer months. In 2000, the lake's Secchi disc transparency ranged from 1.5 feet and 7.3 feet during the summer months (average 3.9 feet). Between 1992 and 2002, the lake's Secchi disc transparency ranged from 1.5 feet to 14.5 feet during the summer months.

4. What will be the water quality of the lake if a "no action" management approach is followed?

If no action is taken at present, the lake's water quality would be expected to, at best, stay the same and, at worst, degrade further.

It is possible that the lake could receive greater loadings of TP (both external and internal) in the future that would increase the lake's TP concentration. Because of the high fertility of the lake's sediments, increased coverage and density of curlyleaf pondweed may occur. Increased mass of curlyleaf pondweed would result in increased TP loading to the lake. If the conditions experienced in the last 10 years are representative of the lake's future, the lake could continue a trend toward declining transparency of, on average, 0.4 feet/year.

Future water quality goals could be harder to meet if the lake's TP increases significantly in future years. Referring back to Figure 7, one can see that the higher the lake's initial TP concentration, the less benefit one gets from reducing the TP concentration. In other words, the higher the lake's TP concentration, the greater the necessary TP reduction in order to see a significant increase in transparency. This is an important consideration for the future of Long Lake.

5. **What is the recommended long-term management plan for the lake?**
Both an in-lake alum/lime slurry treatment and watershed BMPs are recommended for Long Lake. While watershed BMPs are good watershed stewardship, by themselves they may not make a significant impact on Long Lake's water quality since they only comprise ~30 percent of the overall TP load to the lake. However, a combination of watershed measures and an in-lake treatment is expected to attain the lake's water quality goal. An in-lake treatment to control Long Lake's internal loads from curlyleaf pondweed and the lake's sediments is the key to goal attainment. The sections below outline the proposed watershed and in-lake practices recommended for the long-term management of Long Lake.

4.1 Watershed Best Management Practices

Watershed best management practices are recommended to help improve the water quality of Long Lake, and perhaps more importantly, to help prevent future lake degradation. Four watershed management practices are proposed:

- Stormwater Ordinance
- Shoreland Gardens
- Septic System Ordinance
- Additional Watershed Best Management Practices

4.1.1 Stormwater Ordinance

A Polk County ordinance to regulate development/redevelopment is proposed to mitigate the impacts of watershed development on the lake's water quality. Such an ordinance to restrict phosphorus loading from the lake's watershed will protect the lake from degradation under all watershed development conditions. A proposed stormwater ordinance, presented in Appendix B, provides erosion control design standards, has lawn fertilizer regulations, and requires submission of a stormwater management plan and performance bond. The proposed ordinance should apply to the entire Long Lake watershed. A key feature of the ordinance is the requirement to treat all stormwater runoff from all developed/redeveloped sites, except shoreland development. All nonshoreland owners/developers will be required to construct an on site detention basin or contribute money towards the construction of a regional facility. A 60 percent total phosphorus removal efficiency will be required for all on-site and regional detention basins. Treatment of all watershed runoff resulting from watershed development is necessary to achieve the Long Lake water quality goal under future watershed development conditions. Therefore, it is recommended that Polk County pass the proposed ordinance presented in Appendix B. An additional model ordinance that may be considered is included in the *Wisconsin Construction Site Best Management Practice Handbook* (WDNR, 1994).

4.1.2 Shoreland Gardens

Shoreland residents should be encouraged through education to create shoreland gardens that would protect and or improve the lake's water quality.

A shoreland garden is a permanently vegetated area (i.e., not mowed grass) whose function is to remove pollutants from runoff waters and to slow the flow of runoff waters, thereby encouraging infiltration. Shoreland gardens remove phosphorus from runoff waters and, therefore, restrict phosphorus loading to lakes from shoreland property. Shoreland gardens provide a means of mitigating impacts from redevelopment by removing additional pollutants from runoff waters. Schueler (1995) recommends a minimum base width of at least 10 feet to provide adequate stream protection relative to phosphorus removal; a similar width would be appropriate here. Other effective and attractive designs are presented in *Lakescaping for Wildlife and Water Quality* (Henderson, et. al., 1999). A detailed description of shoreland gardens (also called rainwater gardens) and other on-lot infiltration practices is presented in an excerpt from the Metropolitan Council's BMP Manual (Barr Engineering and Metropolitan Council, 2001) in Appendix C of this report.

Development of shoreland gardens should be voluntary, although residents should be highly encouraged to participate- their participation means that they are personally and directly helping to improve the water quality of their lake. The District should encourage lakeshore owners to work with the Polk County Land Conservation Department and request funding, if available, to help residents establish shoreland gardens. This practice will become especially important as redevelopment of shoreland property occurs in the future.

4.1.3 Septic System Ordinance

The District should work with Polk County to establish a septic system ordinance for the Long Lake watershed. All septic systems must be tested when properties change hands or building permits are issued for development or redevelopment. Systems failing to pass the test must be brought into compliance before sale of property can take place or issuance of a building permit.

4.1.4 Additional Watershed Best Management Practices

In addition, it is recommended that watershed residents refrain from using phosphorus fertilizers unless soil testing indicates the soil is deficient in phosphorus. An education program to discourage the use of phosphorus fertilizers is recommended. Locations where non-phosphate fertilizers may be purchased should be communicated to watershed residents. Scott's brand currently offers a phosphorus-free fertilizer.

4.2 In-Lake Alum/Lime Slurry Treatment of Long Lake

It is proposed that Long Lake be treated with a chemical alum/lime slurry to improve its water quality. The alum treatment will provide safe, effective and long-term control of the amount of algae in Long Lake. The lime slurry will hold the alum floc in place, preventing wind movement of the floc. The lime slurry is also expected to reduce macrophyte density and restore the lake's native community by selection against curlyleaf pondweed. Consequently, the treatment will result in cleaner, clearer water and a more pleasurable environment for recreation on and around Long Lake.

However, due to the conditions of Long Lake's sediment (very loose and watery), a phased approach that begins with experimental test plots in the lake is recommended. The sections below provide a description of alum/lime slurry treatments and the phased approach that is recommended specifically for an alum/lime slurry treatment of Long Lake.

4.2.1 Description of Alum/Lime Slurry Treatments

Alum (aluminum sulfate) is a compound derived from aluminum, the earth's most abundant metal. Alum has been used in water purification and wastewater treatment for centuries and in lake restoration for decades.

Alum is used primarily to control the internal loading of phosphorus from the sediments of the lake bottom. Alum reduces the growth of algae by trapping the nutrient phosphorus, the algae's food source, in sediments. Like most other plants, algae require phosphorus to grow and reproduce. Algal growth is directly dependent on the amount of phosphorus available in the water. Without available phosphorus, algae cannot continue to grow and reproduce.

Alum is injected into water several feet below the surface. On contact with water, alum becomes aluminum hydroxide (the principal ingredient in common antacids such as Maalox). This fluffy substance, called floc, settles to the bottom of the lake.

On the way down, it interacts with phosphorus to form an aluminum phosphate compound that is insoluble in water. As a result, phosphorus in the water is trapped as aluminum phosphate and can no longer be used as food by algae. An added bonus occurs as the floc settles downward through the water. It collects other suspended particles in the water, carrying them down to the bottom and leaving the lake noticeably clearer.

On the bottom of the lake, the floc forms a layer that acts as a kind of phosphorus barrier by combining with (and trapping) the phosphorus as it is released from the sediments. This reduces the amount of internal recycling of phosphorus in the lake.

While alum has been used extensively throughout the world for decades, only a few select lakes have received lime and alum/lime treatments. The idea for the use of lime as a lake treatment tool is fairly recent, originating in Alberta, Canada in the late-1980s.

As a part of a 7-year Canadian research project, lime ($Ca(OH)_2$) was mixed with water to form a slurry and was added to Canadian lakes, ponds (dugouts), irrigation canals, and microcosm experiments. Lime slurry and liquid alum were added to three storm water retention lakes in Edmonton, Alberta. Results were published in several journals, including *Freshwater Biology* 2001, Volume 46 (8). Results of the alum/lime treatment of stormwater retention lakes were published in *Water Poll. Res. J.* Canada, 1992, Volume 27, No. 2, 365-381.

The Canadian project determined:

- When water pH was kept in its natural range (i.e., <10), macrophyte biomass was controlled and invertebrate communities were unaffected.
- Application of a combination of alum and lime effectively controlled filamentous and planktonic algal growth by reducing phosphorus concentrations.
- A combination of lime, which elevates pH, and alum, which lowers pH, maintains the natural pH range of a lake during treatment.
- Lime controls macrophytes, precipitates algal cells, and removes phosphorus from the water column. However, it does not prevent sediment phosphorus release.
- A combination of lime and alum controls internal phosphorus loading by controlling sediment phosphorus release and macrophyte growth.

- Following a reduction in plant density, plants do not appear to rebound and the community seems to remain at a lower density.

Further studies in Minnesota and Wisconsin have cited similar findings. Lime's mode of action, however, is yet to be determined. Several hypotheses have been suggested:

- Lime slurry treatment alters the lake's sediment chemistry. Specifically, the calcium in the lime may bind to phosphorus in the sediment or in the pore waters (water between sediment particles) making the phosphorus unavailable to plants. Immobilization of mobile phosphorus may create a phosphorus-limiting situation, thereby controlling the number of plants per square meter that may grow. Hence, lime treatment may control plant density by phosphorus limitation.
- Ammonia is vulnerable to change with changing pH conditions. The temporary change in pH resulting from the lime application may cause a change from NH_4 to NH_3. This change may create a nitrogen-limiting situation by changing available nitrogen to a form that is not available for plant growth. Hence, lime treatment may control plant density by nitrogen limitation.
- The temporary change in pH resulting from lime application may reduce carbon availability to plants, thereby interfering with plant photosynthesis. Hence, lime treatment may control plant density by carbon limitation.
- Lime precipitation on the plant leaves may interfere with plant photosynthesis. Hence, lime treatment may control plant growth by light limitation.

Curlyleaf pondweed is an exotic macrophyte species. In studies of exotic species in forest environments, growth of exotics has been closely tied to nutrient content of soils. Nutrient limitation has been known to limit the growth of exotic plant species in forest environments (Dijkstra, 2002.) This may explain why curlyleaf can be particularly responsive to control through an in-lake alum/lime slurry treatment.

4.2.2 Expected Water Quality Benefit and Cost of an Alum/Lime Slurry Treatment of Long Lake

Following the treatment, the lake's average annual total phosphorus concentration is expected to be 45 µg/L. Benefits from the treatment are estimated to last approximately 10 years.

The recommended dose is 32 grams of aluminum per square meter (g/m^2) of lake sediment and 300 g/m^2 lime. The estimated treatment dose was based upon the extractable phosphorus content in the upper 4 centimeters of lake sediment (i.e., a 25:1 ratio of alum to extractable phosphorus).

Sediment phosphorus release experiments completed during the Phase V study confirmed that the dose effectively achieves the desired 90 percent reduction in internal phosphorus loading.

The estimated cost of this in-lake treatment is $345,000 for the whole lake treatment plus the cost of the pilot project discussed below. The whole lake treatment is expected to include a $15,000 mobilization and demobilization cost and application costs of alum and lime slurry at $625 per acre for each substance or $1,250 per acre for the combined alum and lime slurry application. All costs are based on 2003 dollars.

4.2.3 Proposed Project Implementation

Because Long Lake's sediments are especially watery, there is a chance that an alum/lime treatment could sink down within the sediment layer, rendering the treatment less effective. For this reason, a 3-year study is recommended for the lake, involving both treated and untreated (control) test plots in the lake from which duplicate sediment cores can be extracted and studied.

Phase 1 of the study would be to treat test plots with a 25:1 alum dose, 32 g/m^2 aluminum, and a lime slurry dose of 300 g/m^2. Phase 2 would be an annual monitoring program involving sediment cores taken from the test plots. The location of the alum/lime layer in the sediment cores, as well as the extractable phosphorus, aluminum-bound phosphorus and the calcium-bound phosphorus present in the 0-4 cm, and 5-8 cm depth would be measured and recorded. If the alum/lime layer has sunk deeper than 8 cm, testing could also be conducted at deeper levels.

If the floc settles and the extractable phosphorus content of the sediment at or above the floc layer warrants additional treatment to achieve the lake's goals then additional treatment would be tested and/or recommended for the whole lake.

Test plots will include areas with heavy and light boat traffic to assess the impacts of boat traffic on the alum/floc layer. Resuspension of sediments by boat traffic may cause a deeper mixing of the alum floc layer than would occur in the absence of boat traffic. The results of the test plots analyses will determine whether the 25:1 dose will accomplish the District goal or whether additional alum and lime may be needed to compensate for boat traffic mixing of sediments.

During these 3 years, a continuation of the Self Help Monitoring Program for Long Lake Secchi disc transparency would be extremely helpful. If TP and chlorophyll *a* could also be included in the program during these 3 years, the study would benefit as well.

This approach has several benefits:

1. After 3 years, alum/lime slurry may have become a more common practice, making it easier to get permits from regulatory agencies.
2. The District will have a better idea of the dose needed for Long Lake.
3. The District has a few years to levy the money needed for a lake-wide alum/lime treatment.
4. The District can be more assured of the expected benefit of their alum/lime slurry investment on the lake.
5. The District can work with WDNR staff regarding funding opportunities to assist the District in funding the whole lake treatment. Currently, WDNR offers lake protection grants, up to $200,000 per lake. Lake organizations are required to fund 25 percent of the project costs.

The cost of applying alum and lime to test plots will depend upon the number of test plots selected and the sizes of individual test plots. The application cost is expected to consist of a $1,250 per acre cost for applying the alum and lime plus mobilization and demobilization costs, which are expected to be less than $15,000.

The sediment core collection and analysis of the cores for mobile P is estimated to total around $5,000 annually. The estimate assumes around $1,900 in core collection/extrusion labor, $400 for sample expenses, $1,700 in lab analyses costs, and around $1,000 in data evaluation and letter report preparation costs. Costs will depend upon the number of test plots selected. Costs are based on 2003 dollars.

4.3 Recommended Long Term Monitoring

The success or failure of a lake management plan is determined from the plan's ability to achieve the water quality goal of the lake being managed. Therefore, a long-term water quality monitoring program is needed to determine goal achievement of the Long Lake management plan. Continued participation in the Self Help Program is recommended to determine any changes in the lake's water quality that may occur. In addition, monitoring the mixed surface waters (i.e., 0-2 meter composite sample) for total phosphorus and chlorophyll *a* 1 year per every 3 years is recommended. A growing season monitoring frequency similar to the 2000 monitoring program is recommended.

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Appendices

Appendix A

Sediment Core Experiment Methodology

Appendix A
Sediment Core Experiment Methodology

Treatment of Long Lake with alum and lime is expected to reduce the lake's internal phosphorus load by reducing sediment phosphorus release and the decay of curlyleaf pondweed. This section outlines the methodology for the work tasks completed to determine an effective alum and lime dose lake's treatment.

Alum Dose Determination

The District analyzed the lake's sediments to determine two possible alum doses for e of the lake's internal load. The District's consultant (Barr Engineering Company) coll sediment cores from the lake's deepest point on January 29, 2003 and analyzed the top 4 of each core for different types of phosphorus and solid material-extractable phosphorus, t phosphorus (TP), percent solids, and percent organics.

Extractable phosphorus is comprised of labile phosphorus (phosphorus that is loosely attached to sediment particles) and iron-bound phosphorus. The quantity of alum required to effectively control sediment phosphorus release is based upon the quantity of extractable phosphorus in the lake's upper layer of sediment. Hence, the extractable phosphorus content of Long Lake's 0 to 4 centimeter sediment samples was used to determine the amount of alum needed for two different alum doses for an alum treatment of the lake. One dose achieved a ratio of alum to extractable phosphorus of 25:1. The second dose achieved a ratio of alum to extractable phosphorus of 50:1.

These doses have been shown to effectively bind extractible phosphorus in laboratory experiments (Pilgrim, 2002).

Microcosm Experiment

The District completed a microcosm laboratory experiment to assess the effectiveness of the two proposed alum doses to control the lake's internal phosphorus load. This set of experiments measured the difference in sediment phosphorus release between treated cores (25:1 and 50:1 doses) and untreated (control) sediment cores.

Lime was also added to the alum-dosed microcosms. Because Long Lake is relatively shallow and notes widespread growth of curlyleaf pondweed, a concurrent treatment of alum and lime slurry is proposed. The alum will control phosphorus release from the lake's sediments. The lime slurry will hold the alum floc in place, preventing wind movement of the floc. The lime slurry is also expected to reduce macrophyte density and restore the lake's native community by selection against curlyleaf pondweed.

Six sediment samples were collected from a single location in the lake at its deepest point. The samples were collected on January 29, 2003 in 4-inch diameter plexiglass tubes using a piston coring apparatus. In addition, a 0- to 2-meter composite water sample was collected from the lake. This composite sample was placed in a carboy. Sediment and water samples were transported to the laboratory and kept cold until the experiments were set up.

The top 6 inches of sediment from each core were extruded directly into a 4-inch diameter microcosm, thus minimizing handling of the sediment. The procedure was repeated until the six microcosms each contained a sediment sample. The 0- to 2-meter composite lake sample was then placed on a stirrer and stirred by a 3-inch stirrer bar. While the sample was being stirred, a siphon tube was used to slowly drip water into each microcosm until approximately 3 liters of lake water overlay the sediment in the 3-foot tall microcosms. Despite attempts to avoid resuspension of sediment, some resuspension occurred. Sediment was allowed to settle before proceeding on to the next step.

When all sediment had settled, each microcosm was aerated until the alum/lime slurry was added to the treated microcosms. Alum, then lime slurry, was added to each of the four treated microcosms. Two microcosms received a dose with a 25:1 alum/extractable phosphorus ratio. Two other microcosms received a 50:1 alum/extractable phosphorus ratio. All microcosms received the same lime dose. The control microcosms received neither alum nor lime. Alum and lime doses are shown in Table 1.

Table 1. Alum and Lime Doses For Microcosm Experiment

Microcosm Type	Alum Dose (mLs)	Lime Dose (Grams)
Control	0	0
Treat 1—25:1 Alum:Extractable P	4.4	2.4
Treat 2—50:1 Alum:Extractable P	10.6	2.4

During alum and lime slurry addition, the microcosms were mixed continuously using aeration and a magnetic stirring apparatus which propels a teflon stirring bar positioned 8 inches above the sediment/water interface. Keeping the sediments oxygenated in this manner prevented the release of phosphorus before the experiment was underway. Following the addition of alum and lime slurry, the stirring apparatus and aerators were turned off until the alum floc and lime slurry had settled completely. Then, the six microcosms (four treated and two controls) were capped with 1-inch mineral oil seals to block the diffusion of any oxygen from the air.

The microcosms were incubated in a darkened chamber at 70 degrees Fahrenheit for 28 days. The microcosms were mixed continuously throughout the experiment. The slowly revolving stirring bar in each microcosm kept the water layer completely mixed without suspending sediment particles. Small water samples (50 to 100 mL) were extracted daily from each microcosm through a sampling port at mid-depth in the water column. Samples were frozen immediately following collection. The concentrations of TP in each sample were analyzed and cumulative TP mass was plotted against days of incubation to determine sediment phosphorus release rates using linear regression. The sediment phosphorus release rates in the two control microcosms were compared with the sediment phosphorus release rates in the four treated microcosms.

Sediment Experiments

Sediment experiments were completed to determine the effectiveness of three possible alum-lime treatments to reduce the extractable phosphorus content of the lake's sediments. Experiment details follow. The third, higher dose of alum:extractable P (75:1) was evaluated here to evaluate whether a higher dose might be needed to counteract a sinking alum/lime floc layer.

Eight twenty-gram samples (4 samples from each of two cores) were placed in pre-weighed glass jars. Two samples (one sample from each core) received no treatment and served as controls for the experiment. Six samples (three from each core) were treated with varying alum doses and a constant lime dose to assess changes in extractable phosphorus content of the sediments. Treatment doses are summarized in Table 2.

Table 2. Treatment Doses for Sediment Experiments

Sample	Undiluted Alum Dose (mLs)	Alum Dilution	Diluted Alum Dose (mLs)	Lime Dose (Grams)
Core 1A—Control	0	--	--	0
Core 1B—25:1 Alum:Extractable P	0.27	100X	27.34	2.4
Core 1C—50:1 Alum: Extractable P	0.66	50X	33.21	2.4
Core 1D—75:1 Alum: Extractable P	1.12	25X	27.94	2.4
Core 2A—Control	0	--	--	0
Core 2B—25:1 Alum:Extractable P	0.14	100X	13.96	2.4
Core 2C—50:1 Alum: Extractable P	0.34	50X	16.88	2.4
Core 2D—75:1 Alum: Extractable P	0.58	25X	14.46	2.4

The alum solution (i.e., diluted alum dose) was poured over each treated sample. Then the lime was dissolved in water and evenly distributed over each treated sample. Following addition of the alum and lime, per the above table, all samples were shaken every 15 minutes over a 2-hour period. The samples were then analyzed for labile and iron bound phosphorus (sum equals extractable phosphorus). The experiment results indicated the quantity of extractable phosphorus immobilized by the treatment. The shaking caused some of the alum and lime to get worked into the sediment rather than remain confined to the upper 4 centimeters. The experiment determined whether the proposed doses achieved the estimated effect of extractable phosphorus immobilization.

The experiment was repeated a second time. Due to insufficient sediment volume, the Core 2A Control was not included in the second experiment.

Data from the two experiments were evaluated to determine the extractable phosphorus content of the control samples and each of the three alum doses. The evaluation determined treatment effectiveness.

Appendix B

Model Stormwater Management Ordinance

5. SCOPE AND EFFECT

5.1 Applicability. Every applicant for a building permit, subdivision approval, or a permit to allow land disturbing activities must submit a storm water management plan to the [planning department, department of community development, zoning administrator]. No building permit, subdivision approval, or permit to allow land disturbing activities shall be issued until approval of the storm water management plan or a waiver of the approval requirement has been obtained in strict conformance with the provisions of this ordinance. The provisions of section 9 of this ordinance apply to all land, public or private, located within the [City, Town, County] of ___________.

5.2 Exemptions. The provisions of this ordinance do not apply to:

a) Any part of a subdivision if a plat for the subdivision has been approved by the [City Council, County Board, Town Board] on or before the effective date of this ordinance;

b) Any land disturbing activity for which plans have been approved by the watershed management organization within six months prior to the effective date of this ordinance;

c) A lot for which a building permit has been approved on or before the effective date of this ordinance;

d) Installation of fence, sign, telephone, and electric poles and other kinds of posts or poles; or

e) Emergency work to protect life, limb, or property.

5.3 Waiver. The [City Council, Town Board, County Board], upon recommendation of the Planning Commission, may waive any requirement of this ordinance upon making a finding that compliance with the requirement will involve an unnecessary hardship and the waiver of such requirement will not adversely affect the standards and requirements set forth in Section 6. The [City Council, Town Board, County Board] may require as a condition of the waiver, such dedication or construction, or agreement to dedicate or construct as may be necessary to adequately meet said standards and requirements.

6. STORM WATER MANAGEMENT PLAN APPROVAL PROCEDURES

6.1 Application. A written application for storm water management plan approval, along with the proposed storm water management plan, shall be filed with the [planning department, department of community development, zoning administrator] and shall include a statement indicating the grounds upon which the approval is requested, that the proposed use is permitted by right or as an exception in the underlying zoning district, and adequate evidence showing that the proposed use will conform to the standards set forth in this ordinance. Prior to applying for approval of a storm water management plan, an applicant may have the storm water management plans reviewed by the appropriate departments of the [city, town, county].

Two sets of clearly legible blue or black lined copies of drawings and required information shall be submitted to the [planning department, department of community development, zoning administrator] and shall be accompanied by a receipt from the ___________ [governmental unit's chief financial officer] evidencing the payment of all required fees for processing and approval as set forth in Section 7.5, and a bond when required by Section 7.4

in the amount to be calculated in accordance with that section. Drawings shall be prepared to a scale appropriate to the site of the project and suitable for the review to be performed. At a minimum the scale shall be 1 inch equals 100 feet.

6.2 Storm water management plan. At a minimum, the storm water management plan shall contain the following information.

a) Existing site map. A map of existing site conditions showing the site and immediately adjacent areas, including:

1) The name and address of the applicant, the section, township and range, north point, date and scale of drawing and number of sheets;

2) Location of the tract by an insert map at a scale sufficient to clearly identify the location of the property and giving such information as the names and numbers of adjoining roads, railroads, utilities, subdivisions, towns and districts or other landmarks;

3) Existing topography with a contour interval appropriate to the topography of the land but in no case having a contour interval greater than 2 feet;

4) A delineation of all streams, rivers, public waters and wetlands located on and immediately adjacent to the site, including depth of water, a description of all vegetation which may be found in the water, a statement of general water quality and any classification given to the water body or wetland by the Minnesota Department of Natural Resources, the Minnesota Pollution Control Agency, and/or the United States Army Corps of Engineers;

5) Location and dimensions of existing storm water drainage systems and natural drainage patterns on and immediately adjacent to the site delineating in which direction and at what rate storm water is conveyed from the site, identifying the receiving stream, river, public water, or wetland, and setting forth those areas of the unaltered site where storm water collects;

6) A description of the soils of the site, including a map indicating soil types of areas to be disturbed as well as a soil report containing information on the suitability of the soils for the type of development proposed and for the type of sewage disposal proposed and describing any remedial steps to be taken by the developer to render the soils suitable;

7) Vegetative cover and clearly delineating any vegetation proposed for removal; and

8) 100 year floodplains, flood fringes and floodways.

b) Site construction plan. A site construction plan including:

1) Locations and dimensions of all proposed land disturbing activities and any phasing of those activities;

2) Locations and dimensions of all temporary soil or dirt stockpiles;

3) Locations and dimensions of all constructions site erosion control measures necessary to meet the requirements of this ordinance;

4) Schedule of anticipated starting and completion date of each land disturbing activity including the installation of construction site erosion control measures needed to meet the requirements of this ordinance; and

5) Provisions for maintenance of the construction site erosion control measures during construction.

c) Plan of final site conditions. A plan of final site conditions on the same scale as the existing site map showing the site changes including:

1) Finished grading shown at contours at the same interval as provided above or as required to clearly indicate the relationship of proposed changes to existing topography and remaining features;

2) A landscape plan, drawn to an appropriate scale, including dimensions and distances and the location, type, size and description of all proposed landscape materials which will be added to the site as part of the development;

3) A drainage plan of the developed site delineating in which direction and at what rate storm water will be conveyed from the site and setting forth the areas of the site where storm water will be allowed to collect;

4) The proposed size, alignment and intended use of any structures to be erected on the site;

5) A clear delineation and tabulation of all areas which shall be paved or surfaced, including a description of the surfacing material to be used; and

6) Any other information pertinent to the particular project which in the opinion of the applicant is necessary for the review of the project.

7. PLAN REVIEW PROCEDURE

7.1 Process. Storm water management plans meeting the requirements of Section 6 shall be submitted by the [planning department, department of community development, zoning administrator] to the Planning Commission for review in accordance with the standards of Section 8. The Commission shall recommend approval, recommend approval with conditions, or recommend denial of the storm water management plan. Following Planning Commission action, the storm water management plan shall be submitted to the [City Council, Town Board, County Board] at its next available meeting. [City Council, Town Board, County Board] action on the storm water management plan must be accomplished within 120 days following the date the application for approval is filed with the [planning department, department of community development, zoning administrator].

[COMMENTARY: The process outlined in Section 7.1 can be modified to be consistent with the regulatory process of the particular local government unit. For example, one local government may have a particular department which reviews land use regulatory matters except the final decision to approve or deny a land use plan or permit which is reserved for the governing body of the local government unit. Another local governmental unit may provide the department which reviews land use regulatory matters with full authority to take final action on the application. Other local governments may use a hybrid process where some permits are acted upon by the appropriate regulatory department while other land use matters are left to the governing body for final approval.]

7.2 Duration. Approval of a plan submitted under the provisions of this ordinance shall expire one year after the date of approval unless construction has commenced in accordance with the plan. However, if prior to the expiration of the approval, the applicant makes a written request to the [planning department, department of community development, zoning administrator] for an extension of time to commence construction setting forth the reasons for the requested extension, the planning department may grant one extension of not greater than one single year. Receipt of any request for an extension shall be acknowledged by the [planning department, department of community development, zoning administrator] within 15 days. The [planning department, department of community development, zoning administrator] shall make a decision on the extension within 30 days of receipt. Any plan may be revised in the same manner as originally approved.

7.3 Conditions. A storm water management plan may be approved subject to compliance with conditions reasonable and necessary to insure that the requirements contained in this ordinance are met. Such conditions may, among other matters, limit the size, kind or character of the proposed development, require the construction of structures, drainage facilities, storage basins and other facilities, require replacement of vegetation, establish required monitoring procedures, stage the work over time, require alteration of the site design to insure buffering, and require the conveyance to the [City, Town, County] of ________ or other public entity of certain lands or interests therein.

7.4 Performance bond. Prior to approval of any storm water management plan, the applicant shall submit an agreement to construct such required physical improvements, to dedicate property or easements, or to comply with such conditions as may have been agreed to. Such agreement shall be accompanied by a bond to cover the amount of the established cost of complying with the agreement. The agreement and bond shall guarantee completion and compliance with conditions within a specific time, which time may be extended in accordance with Section 7.2.

The adequacy, conditions and acceptability of any agreement and bond shall be determined by the ____________ [City Council, Town Board, County Board] or any official of the [City, Town, County] of __________ as may be designated by resolution of the __________ [City Council, Town Board, County Board].

7.5 Fees. All applications for storm water management plan approval shall be accompanied by a processing and approval fee of $ __________.

8. APPROVAL STANDARDS

8.1 No storm water management plan which fails to meet the standards contained in this section shall be approved by the [City Council, Town Board, County Board].

[COMMENTARY: Sections 8.2 through 8.16 are an example of how best management practices for handling storm water runoff and design criteria for detention ponds can be included within an ordinance. Additional best management practices and design criteria can be found in the MPCA publication "Protecting Water Quality in Urban Areas."

8.2 Site dewatering. Water pumped from the site shall be treated by temporary sedimentation basins, grit chambers, sand filters, upflow chambers, hydro-cyclones, swirl concentrators or other appropriate controls as appropriate. Water may not be discharged in a manner that causes erosion or flooding of the site or receiving channels or a wetland.

8.3 Waste and material disposal. All waste and unused building materials (including garbage, debris, cleaning wastes, wastewater, toxic materials or hazardous materials) shall be properly disposed of off-site and not allowed to be carried by runoff into a receiving channel or storm sewer system.

8.4 Tracking. Each site shall have graveled roads, access drives and parking areas of sufficient width and length to prevent sediment from being tracked onto public or private roadways. Any sediment reaching a public or private road shall be removed by street cleaning (not flushing) before the end of each workday.

8.5 Drain inlet protection. All storm drain inlets shall be protected during construction until control measures are in place with a straw bale, silt fence or equivalent barrier meeting accepted design criteria, standards and specifications contained in the MPCA publication "Protecting Water Quality in Urban Areas."

8.6 Site erosion control. The following criteria (a. through d.) apply only to construction activities that result in runoff leaving the site.

a) Channelized runoff from adjacent areas passing through the site shall be diverted around disturbed areas, if practical. Otherwise, the channel shall be protected as described below. Sheetflow runoff from adjacent areas greater than 10,000 square feet in area shall also be diverted around disturbed areas, unless shown to have resultant runoff rates of less than 0.5 $ft.^3$/sec. across the disturbed area for the one year storm. Diverted runoff shall be conveyed in a manner that will not erode the conveyance and receiving channels.

b) All activities on the site shall be conducted in a logical sequence to minimize the area of bare soil exposed at any one time.

c) Runoff from the entire disturbed area on the site shall be controlled by meeting either subsections 1 and 2 or 1 and 3.

1) All disturbed ground left inactive for fourteen or more days shall be stabilized by seeding or sodding (only available prior to September 15) or by mulching or covering or other equivalent control measure.

2) For sites with more than ten acres disturbed at one time, or if a channel originates in the disturbed area, one or more temporary or permanent sedimentation basins shall be constructed. Each sedimentation basin shall have a surface area of at least one percent of the area draining to the basin and at least three feet of depth and constructed in accordance with accepted design specifications. Sediment shall be removed to maintain a depth of three feet. The basin discharge rate shall also be sufficiently low as to not cause erosion along the discharge channel or the receiving water.

3) For sites with less than ten acres disturbed at one time, silt fences, straw bales, or equivalent control measures shall be placed along all sideslope and downslope sides of the site. If a channel or area of concentrated runoff passes through the site, silt fences shall be placed along the channel edges to reduce sediment reaching the channel. The use of silt fences, straw bales, or equivalent control measures must include a maintenance and inspection schedule.

d) Any soil or dirt storage piles containing more than ten cubic yards of material should not be located with a downslope drainage length of less than 25 feet from the toe of the pile to a roadway or drainage channel. If remaining for more than seven days, they shall be stabilized by mulching, vegetative cover, tarps or other means. Erosion from piles which will be in existence for less than seven days shall be controlled by placing straw bales or silt fence barriers around the pile. In-street utility repair or construction soil or dirt storage piles located closer than 25 feet of a roadway or drainage channel must be covered with tarps or suitable alternative control, if exposed for more than seven days, and the stormdrain inlets must be protected with straw bale or other appropriate filtering barriers.

8.7 Storm water management criteria for permanent facilities.

a) An applicant shall install or construct, on or for the proposed land disturbing or development activity, all storm water management facilities necessary to manage increased runoff so that the two-year, ten-year, and 100-year storm peak discharge rates existing before the proposed development shall not be increased and accelerated channel erosion will not occur as a result of the proposed land disturbing or development activity. An applicant may also make an in-kind or monetary contribution to the development and maintenance of community storm water management facilities designed to serve multiple land disturbing and development activities undertaken by one or more persons, including the applicant.

b) The applicant shall give consideration to reducing the need for storm water management facilities by incorporating the use of natural topography and land cover such as wetlands, ponds, natural swales and depressions as they exist before development to the degree that they can accommodate the additional flow of water without compromising the integrity or quality of the wetland or pond.

c) The following storm water management practices shall be investigated in developing a storm water management plan in the following descending order of preference:

1) Infiltration of runoff on-site, if suitable soil conditions are available for use;

2) Flow attenuation by use of open vegetated swales and natural depressions;

3) Storm water retention facilities; and

4) Storm water detention facilities.

d) A combination of successive practices may be used to achieve the applicable minimum control requirements specified in subsection (a) above. Justification shall be provided by the applicant for the method selected.

8.8 Design standards. Storm water detention facilities constructed in the [City, Town, County] of ________ shall be designed according to the most current technology as reflected in the MPCA publication "Protecting Water Quality in Urban Areas", and shall contain, at a minimum, the following design factors:

a) A permanent pond surface area equal to two percent of the impervious area draining to the pond or one percent of the entire area draining to the pond, whichever amount is greater;

b) An average permanent pool depth of four to ten feet;

[COMMENTARY: An alternative to subsections (a) and (b) would be to require that the volume of the permanent pool be equal to or greater than the runoff from a 2.0-inch rainfall for the fully developed site.]

c) A permanent pool length-to-width ratio of 3:1 or greater;

d) A minimum protective shelf extending ten feet into the permanent pool with a slope of 10:1, beyond which slopes should not exceed 3:1;

e) A protective buffer strip of vegetation surrounding the permanent pool at a minimum width of one rod (16.5 feet) *[this width is consistent with the draft rules developed by the Board of Water and Soil Resources under the Wetland Conservation Act of 1991]*;

f) All storm water detention facilities shall have a device to keep oil, grease, and other floatable material from moving downstream as a result of normal operations;

g) Storm water detention facilities for new development must be sufficient to limit peak flows in each subwatershed to those that existed before the development for the 10 year storm event. All calculations and hydrologic models/information used in determining peak flows shall be submitted along with the storm water management plan;

h) All storm water detention facilities must have a forebay to remove coarse-grained particles prior to discharge into a watercourse or storage basin.

8.9 Wetlands.

a) Runoff shall not be discharged directly into wetlands without presettlement of the runoff.

b) A protective buffer strip of natural vegetation at least one rod (16.5 feet) in width shall surround all wetlands. *[This width is consistent with the draft rules developed by the Board of Water and Soil Resources under the Wetland Conservation Act of 1991.]*

c) Wetlands must not be drained or filled, wholly or partially, unless replaced by restoring or creating wetland areas of at least equal public value. Replacement must be guided by the following principles in descending order of priority:

1) Avoiding the direct or indirect impact of the activity that may destroy or diminish the wetland;

2) Minimizing the impact by limiting the degree or magnitude of the wetland activity and its implementation;

3) Rectifying the impact by repairing, rehabilitating, or restoring the affected wetland environment;

4) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the activity; and

5) Compensating for the impact by replacing or providing substitute wetland resources or environments. *[Compensation, including the replacement ratio and quality of replacement should be consistent with the requirements outlined in the rules which will be adopted by the Board of Water and Soil Resources to implement the Wetland Conservation Act of 1991.]*

8.10 Steep slopes. No land disturbing or development activities shall be allowed on slopes of 18 per cent or more.

8.11 Catch basins. All newly installed and rehabilitated catch basins shall be provided with a sump area for the collection of coarse-grained material. Such basins shall be cleaned when they are half filled with material.

8.12 Drain leaders. All newly constructed and reconstructed buildings will route drain leaders to pervious areas wherein the runoff can be allowed to infiltrate. The flow rate of water exiting the leaders shall be controlled so no erosion occurs in the pervious areas.

8.13 Inspection and maintenance. All storm water management facilities shall be designed to minimize the need of maintenance, to provide access for maintenance purposes and to be structurally sound. All storm water management facilities shall have a plan of operation and maintenance that assures continued effective removal of pollutants carried in storm water runoff. The director of public works, or designated representative, shall inspect all storm water management facilities during construction, during the first year of operation, and at least once every five years thereafter. The inspection records will be kept on file at the public works department for a period of 6 years. It shall be the responsibility of the applicant to obtain any necessary easements or other property interests to allow access to the storm water management facilities for inspection and maintenance purposes.

8.14 Models/methodologies/computations. Hydrologic models and design methodologies used for the determination of runoff and analysis of storm water management structures shall be approved by the director of public works. Plans, specification and computations for storm water management facilities submitted for review shall be sealed and signed by a registered professional engineer. All computations shall appear on the plans submitted for review, unless otherwise approved by the director of public works.

8.15 Watershed management plans/groundwater management plans. Storm water management plans shall be consistent with adopted watershed management plans and groundwater management plans prepared in accordance with Minnesota Statutes section 103B.231 and 103B.255 respectively, and as approved by the Minnesota Board of Water and Soil Resources in accordance with state law.

8.16 Easements. If a storm water management plan involves direction of some or all runoff off of the site, it shall be the responsibility of the applicant to obtain from adjacent property owners any necessary easements or other property interests concerning flowage of water.

9. LAWN FERTILIZER REGULATIONS

9.1 Use of impervious surfaces. No person shall apply fertilizer to or deposit grass clippings, leaves, or other vegetative materials on impervious surfaces, or within storm water drainage systems, natural drainage ways, or within wetland buffer areas.

9.2 Unimproved land areas. Except for driveways, sidewalks, patios, areas occupied by structures or areas which have been improved by landscaping, all areas shall be covered by plants or vegetative growth.

9.3 Fertilizer content. Except for the first growing season for newly established turf areas, no person shall apply liquid fertilizer which contains more than one-half percent by weight of phosphorus, or granular fertilizer which contains more than three percent by weight of phosphorus, unless the single application is less than or equal to one-tenth pound of phosphorus per one thousand square feet. Annual application amount shall not exceed one-half pound of phosphorus per one thousand square feet of lawn area.

9.4 Buffer zone. Fertilizer applications shall not be made within one rod (16.5 feet) of any wetland or water resource. *[This distance is consistent with the draft rules developed by the Board of Water and Soil Resources under the Wetland Conservation Act of 1991.]*

10. PENALTY

Any person, firm or corporation violating any provision of this ordinance shall be fined not less than five dollars nor more than five hundred dollars for each offense, and a separate offense shall be deemed committed on each day during or on which a violation occurs or continues.

11. OTHER CONTROLS

In the event of any conflict between the provisions of this ordinance and the provisions of an erosion control or shoreland protection ordinance adopted by the [City Council, Town Board, County Board], the more restrictive standard prevails.

12. SEVERABILITY

The provisions of this ordinance are severable. If any provision of this ordinance or the application thereof to any person or circumstance is held invalid, such invalidity shall not affect other provisions or applications of this ordinance which can be given effect without the invalid provision or application

13. EFFECTIVE DATE

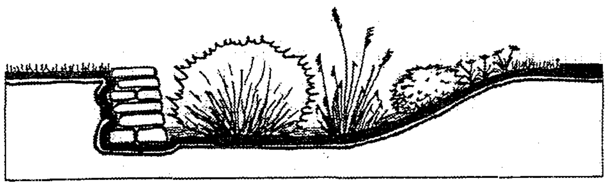
This ordinance shall be effective the _______ day of _________, 199__.

Appendix C

On-Lot Infiltration: Excerpt from the Metropolitan Council's BMP Manual

(Barr Engineering and Metropolitan Council, 2001)

On-Lot Infiltration



General Description

On-lot infiltration systems promote infiltration at the individual lot level, controlling runoff at its source. These systems are off-line and generally receive sheet flow runoff. The main feature that distinguishes these systems from other infiltration systems (such as infiltration basins and trenches) is scale. These small systems accept runoff from a single residential lot. Although infiltration basins and trenches have many design features in common with on-lot infiltration systems, the Infiltration Basins and Infiltration Trenches BMP Sections refer to larger lot, end-of-pipe facilities.

On-lot infiltration systems' primary function is to mitigate the normal impacts of urbanization on the natural water balance. This is done by turning water that would normally become surface runoff (a waste product) into a resource that waters trees, recharges groundwater and provides stream baseflows. On-lot infiltration systems also function to improve water quality by removing some pollutants from the runoff as it infiltrates. Also, because these systems serve to reduce the volume of runoff, they contribute to both erosion protection and flood control. Lastly, the use of these systems reduces the size and cost of downstream water control facilities.

On-lot infiltration systems include:

- Reduced lot grading (Figure 1)
- Directing roof leaders to soakaway pits (Figures 2 through 4)
- Directing roof leaders to rain barrels (Figure 6)
- Directing roof leaders or other surface runoff to other vegetated areas, such as rainwater gardens (Figures 7 through 10)

These source controls address measures that can be applied by the developer or the homeowner. Public education programs within municipalities can help to educate citizens on the role they can play in the application of these systems.

On-lot infiltration systems are not to be used for infiltrating any

Purpose

Water Quantity	
Flow attenuation	◧
Runoff volume reduction	■
Water Quality	
Pollution Prevention	
Soil erosion	N/A
Sediment control	N/A
Nutrient loading	N/A
Pollutant Removal (Soakaway Pits and Rainwater Gardens)	
Total suspended sediment (TSS)	■
Total phosphorus (P)	■
Nitrogen (N)	■
Heavy metals	■
Floatables	◧
Oil and grease	■
Other	
Fecal coliform	◧
Biochemical oxygen demand (BOD)	◧

■	Primary design benefit
◧	Secondary design benefit
□	Little or no design benefit

On-Lot Infiltration

runoff that could be significantly contaminated with sediment and other pollutants, such as runoff from high-potential pollutant loading areas like garages and gas stations.

In general, on-lot infiltration systems can be implemented for soil types of loam and coarser. Some authorities discourage infiltration systems at sites where soils have 30 percent or greater clay content, or 40 percent or greater silt content. A soils analysis is helpful in assessing the viability of infiltration systems. More detailed information on procedures for testing infiltration rates can be found in the Infiltration Basins and Infiltration Trenches BMP Sections. If native soils are considered to have a low infiltration capacity, filtration systems should be considered as an alternative to infiltration (see the Filtration Systems BMP Sections).

Advantages

- Can reduce the volume of runoff from a site, thereby reducing the size and cost of downstream stormwater control facilities.
- Can be utilized in retrofit areas where space is limited and where additional runoff control is necessary.
- Rainwater gardens can provide an aesthetically pleasing amenity when designed to support perennial flowers in the summer and display vividly colored or patterned shrubs in the winter.
- The potential for clogging of rainwater gardens is reduced compared to end-of-pipe infiltration techniques (infiltration basins and trenches) because these systems generally accept runoff only from roofs (roof drainage contains fewer suspended solids than road runoff) or driveways, lawns and sidewalks.
- Can be used at sites where storm sewers are not available.
- Can provide groundwater recharge.
- Flowering plants and ornamental grasses incorporated into the design of rainwater gardens are attractive to birds and butterflies.

Limitations

- Only applicable in small drainage areas of a half-acre or less.
- Water ponded on lots may take 24 to 48 hours to drain, which may restrict some of the use of the land.
- Some maintenance (unclogging soakaway pits, periodically removing sediment from rain barrels and rainwater gardens) is required to ensure the proper functioning of these systems. However, sediment accumulation is an indication that the infiltration techniques are working. This sediment would otherwise have washed downstream to a larger water body.
- Not recommended for lots with high sediment loadings or contaminated runoff.
- If the infiltration rate of the native soils is low, these systems may not function as desired.
- The bottom of these structures (with the exception of rain barrels) should be a minimum of 3 feet above the seasonally high groundwater table to prevent the possibility of groundwater contamination.

Reduced Lot Grading

Description

Development standards often require minimum lot grades of 2 percent for adequate drainage of stormwater away from a building. Some authorities, however, have proposed reducing minimum lot grades from 2 to 0.5 percent to promote infiltration. This option is mainly intended to promote infiltration by slowing stormwater runoff from the roofs and yards and allowing it to soak into the lawn.

A reduction in the lot grading is generally a viable option if the land is naturally flat. In hilly areas, alterations to the natural topography should be minimized. Developers and homeowners should check the acceptability of this practice with the local municipality, because some municipalities may not permit its use.

Similarly, shallow depressions can be graded into lawns. Depressions need not be very deep to make a significant contribution to overall surface storage capacity and stormwater quality. For example, a square lawn area 50 feet on a side, sloping 2 percent toward the center, will create a low point 6 inches below the outside rim. This 6-inch slope over 25 feet of distance is barely noticeable, and is similar to standard grading practice for lawn areas. This 50-foot by 50-foot by 6-inch-deep lawn area creates a storage capacity of 413 cubic feet. If adjacent impervious surfaces, such as sidewalks, rooftops, and roads are designed to sheet flow into this concave lawn, their runoff can gradually infiltrate into the soil as well. Catch basins located at the upper edge of the concave vegetated surfaces can collect runoff from larger storms.

Figure 1 illustrates these lot grading changes on a residential lot.

Design Guidelines

- In order to ensure that foundation drainage problems do not occur, the grading within 6 to 12 feet of a building should be maintained at 2 percent or higher (local municipal standards should be reviewed to ensure that the grading around a building is in compliance). Areas outside of this boundary may be graded at less than 2 percent to create greater depression storage and promote natural infiltration.

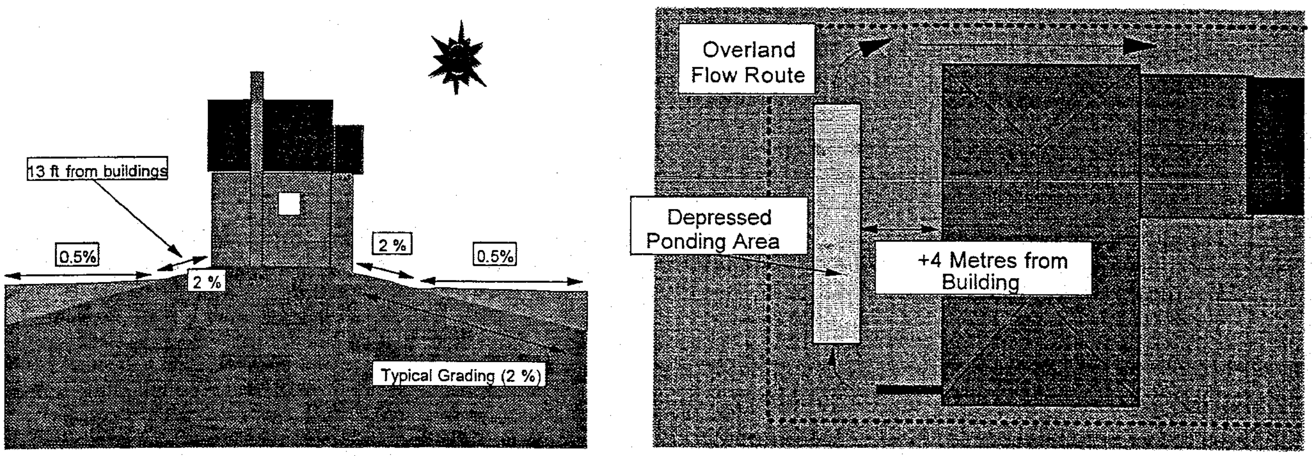


Figure 1: Examples of Lot Grading Changes

Source: Ontario Ministry of the Environment, 1999

Reduced Lot Grading (continued)

- Infiltration can be improved by tilling (scarification) of the lots with flatter grading to a depth of approximately 12 to 24 inches before sod is laid. This would also be of general benefit in all residential areas to address the problems associated with soil compaction (loss of recharge potential) which occurs during construction. The incorporation of compost or manure into the soil also increases infiltration. It should be noted that tilling this deep may require special equipment.
- In areas where flatter lot grading is implemented, roof leaders that discharge to the surface should extend 6 feet away from the building.

Construction

- Soil compaction must be avoided wherever possible. For example, vehicles should never be parked on the future lawn during construction.
- Mass grading should be avoided to keep native soil profiles intact and to minimize the area of soil compaction.
- If soils become compacted through construction activities, the soil should be tilled to 18 inches and 6 to 12 inches of organic compost should be incorporated into the soil.

Soakaway Pits

Description

Soakaway pits, also known as downspout infiltration systems, roof leader infiltration systems and dry wells, can be distinguished from infiltration trenches in terms of scale and sophistication of design. Soakaway pits are designed to receive runoff from individual roof leaders, whereas infiltration trenches are used for large-lot applications (see the Infiltration Trenches BMP section for more detail).

Soakaway pits are small, excavated pits, backfilled with aggregate, used to infiltrate "good quality" stormwater runoff, such as uncontaminated roof runoff. Rooftop runoff is discharged to the soakaway pit through the roof leader, which extends directly into a stone-filled reservoir. Figures 2 through 4 show examples of soakaway pit designs.

The use of soakaway pits is limited by a number of site constraints, including soil type, contributing drainage area, depth to bedrock, and depth to groundwater. Rooftop gutter screens are needed to trap particles, leaves and other debris, and must be cleaned regularly.

Soakaway pits for roof leader drainage have been implemented in Toronto, Maryland and Europe. A monitoring study indicated that 60 percent of 25 soakaway pits studied were operating as designed (Lindsey et al., 1992).

Design Guidelines

If a formal, detailed design is required by local permitting authorities, the design requirements presented in the Infiltration Trench BMP section can be followed for the design of soakaway pits (although no pretreatment other than gutter screens is required of a soakaway pit that receives only roof runoff). Other design considerations include:

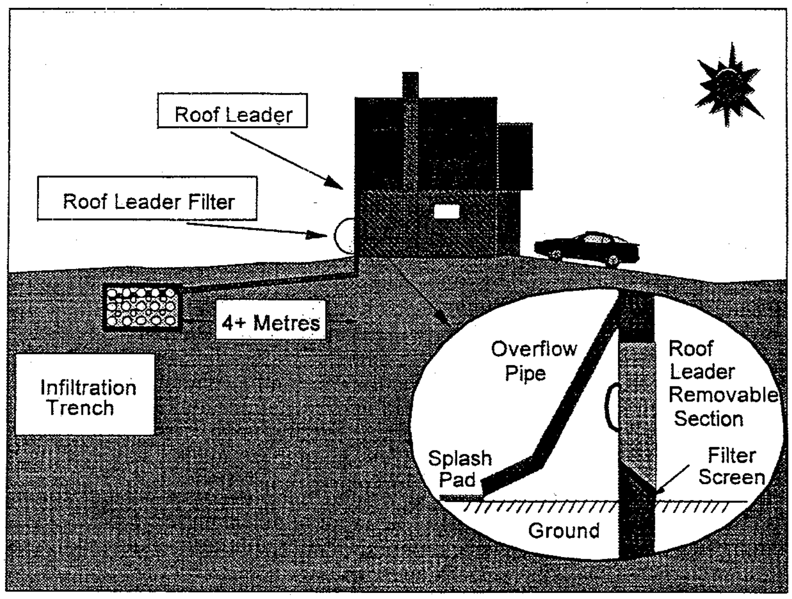


Figure 2: Roof Leader Discharge to Soakaway Pit
Source: Ontario Ministry of the Environment, 1999

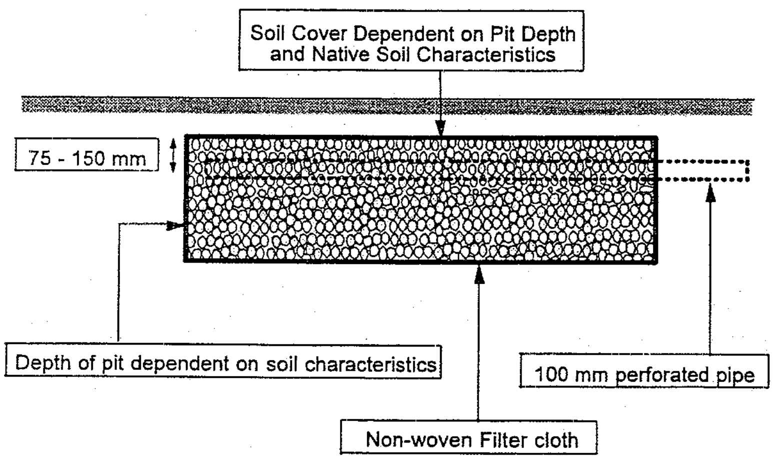


Figure 3: Soakaway Pit Details
Source: Ontario Ministry of the Environment, 1999

Soakaway Pits (continued)

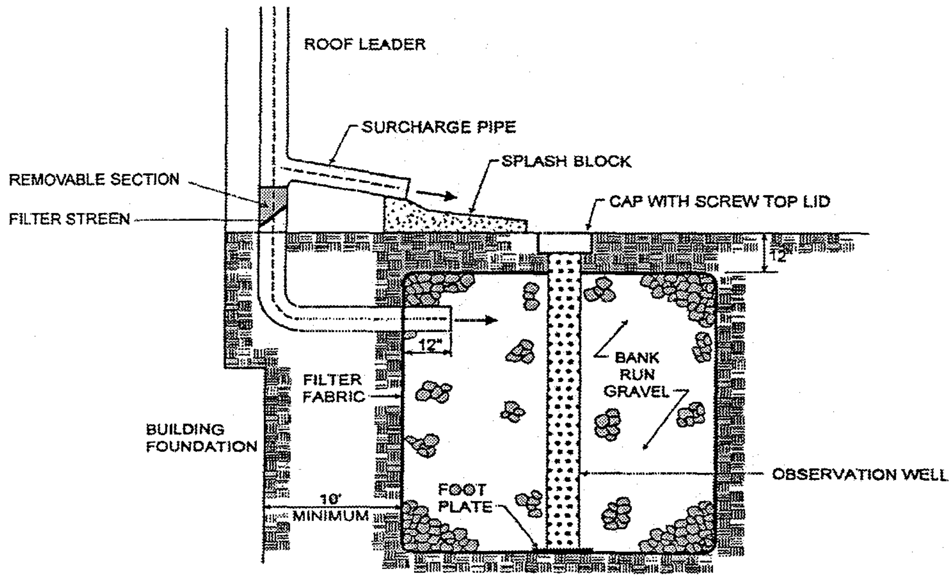


Figure 4: Soakaway Pit Profile
Source: Adapted from Maryland Department of the Environment, 1998.

- The soakaway pit should be located at least 10 feet away from the foundation of the nearest building to prevent foundation damage.
- The extension of a roof leader into a pit may span the full length of the pit (Figures 2 and 3). This extension consists of a perforated pipe, allowing water to fill the pit along the length of the pipe. The perforated pipe should be located near the surface of the trench (3 to 6 inches from the top of the pit).
- An overflow pipe should be installed from the roof leader to discharge to a splash pad. A removable filter should be incorporated into the roof leader below the overflow pipe.
- Typically the pit should be located close to the ground surface; however, this will depend on the depth of storage in the pit, the potential for frost heave, and the stratification of the surrounding soil media. The potential for frost heave is dependent on the surrounding native soils and the potential volume of water in the trench that can freeze. Figure 5 provides guidance on the recommended minimum soil cover for various subsurface trench depths and native soil media. This curve has been produced based on professional opinion, the expansion of water due to freezing, and the potential availability of water to freeze (Ontario, 1999).
- Barring other site considerations, the maximum depth of the pit can be determined from the infiltration rate, the allowable storage time, and the void space. Since the soakaway pit is filled with stone, only the space between the stones is available for runoff storage. Soakaway pits are to be filled with 1.5- to 3-inch-diameter clean-washed stone. This size stone will yield a void space of approximately 30 to 40 percent.

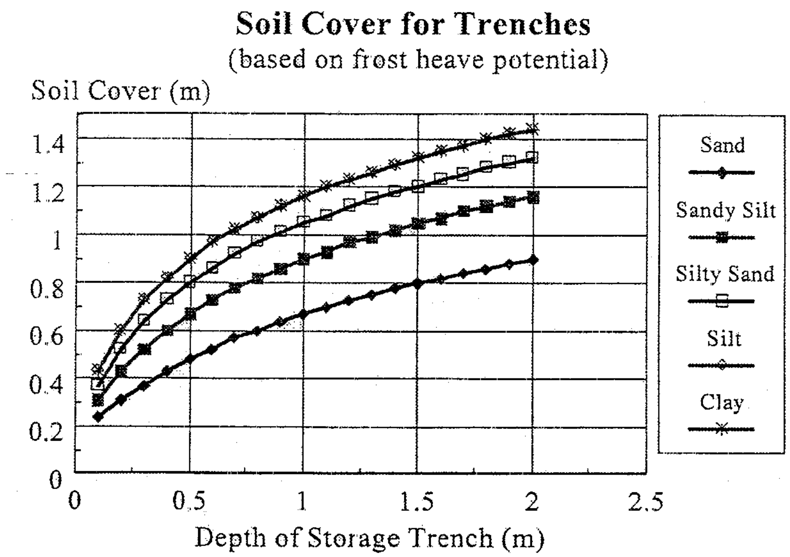


Figure 5: Recommended Soil Cover for Soakaway Pits
Source: Ontario Ministry of the Environment, 1999

- Storage depths greater than 5 feet are generally not recommended for soakaway pits from both a cost and a compaction perspective. The weight of the water in a deep soakaway pit will compact the surrounding native soil and decrease the infiltration capacity. There are exceptions, however, to this maximum depth recommendation. In areas with deep sand lenses or significant horizontal soil stratification, deep soakaway pits may be preferred. Soils investigations should be undertaken to determine whether these situations exist.
- A maximum storage time of 72 hours is recommended. It is recommended that a conservative drawdown time (such as 24 hour) be chosen for design in recognition of the fact that the percolation rates into the surrounding soil will decrease over time and that there will likely be a lack of maintenance in some cases.
- The length of trench (in the direction of inflow) should be maximized compared to the width to ensure the proper distribution of water into the entire trench and to minimize the potential for groundwater mounding (groundwater mounding is a local increase in the water table due to the infiltration of water and is more prevalent if a greater volume of water infiltrates in a localized area; square trenches will have greater groundwater mounding).
- A minimum storage volume of 0.2 inches over the rooftop area should be accommodated in the soakaway pit without overflowing. The maximum target storage volume should be approximately 0.8 in over the rooftop area since a vast majority of all daily rainfall depths are less than this amount.

Maintenance

- Since these structures are often installed at single-family dwellings, it is important that developers outline the maintenance requirements to property purchasers clearly.
- A removable filter should be incorporated into the roof leader below the overflow pipe. The filter should have a screened bottom to prevent leaves and debris from entering the soakaway pit. It should be easy to remove so

that a homeowner can clean the filter. Frequent use of the overflow pipe will indicate the need for filter screen maintenance.

- See the Infiltration Trench BMP Section for more detailed information on construction and maintenance criteria.

Rain Barrels

Description

Rain barrels, also known as cisterns, are aboveground storage vessels that receive roof runoff from roof leaders. Rain barrels have either a manually operated valve or a permanently open outlet that allows storage and slow release of roof runoff.

If the rain barrel has an operable valve, the valve can be closed to store stormwater for irrigation use or infiltration between storms. This is particularly useful in areas with tight soils, where infiltration is slow, resulting in wet areas for an extended period of time. If water is stored inside for long periods, the rain barrel must be frequently monitored and should be covered to prevent mosquitoes from breeding.

If the rain barrel's valve is kept open, and if the barrel's outlet is significantly smaller than the size of the downspout inlet (for example, a quarter- or half-inch diameter outlet), runoff will build up inside the rain barrel during storms, and will empty out slowly after peak intensities subside. This is a feasible way to mitigate the peak flow increases caused by rooftop impervious land coverage, especially for frequent, small storms.

Figure 6 shows a typical rain barrel.

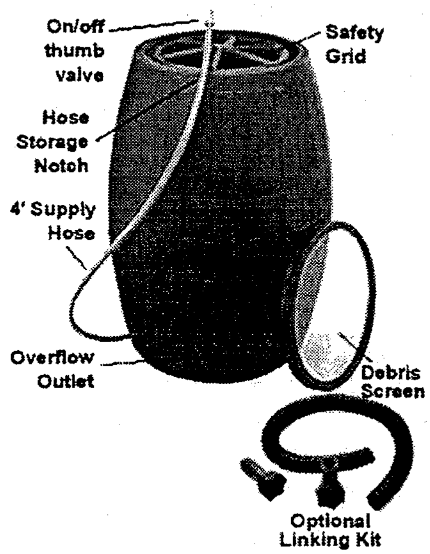


Figure 6: Typical Rain Barrel
Source: Gardener's Supply Company, 2001

Design Guidelines

- Rain barrels can be incorporated into the aesthetics of buildings and gardens. Japanese, Mediterranean and American southwest architecture provide many examples of attractive rain barrels made of a variety of materials.
- If a rain barrel holds more than a 6-inches depth of water, it should be covered securely or have a top opening of 4 inches or less to prevent small children from gaining access to the standing water.
- The rain barrel should be designed and maintained to minimize clogging by leaves and other debris.
- Small rain barrels and rain barrel disinfection systems are available commercially.

Maintenance

- In cold winter climates, the barrel and outlet hose should be completely drained and the barrel placed upside-down to avoid freezing and cracking during the winter.
- The rain barrel should be cleaned out once per year.

Rainwater Gardens

Description

Rainwater gardens are small, vegetated depressions used to promote infiltration of stormwater runoff. Runoff enters the gardens via sheet flow. Rainwater gardens can be planned and integrated into both new and existing developments. A rainwater garden combines shrubs, grasses, and flowering perennials in depressions (about 6 to 18 inches deep) that allow water to pool for only a few days after a rain. Vegetation is vital to the proper function of a rainwater garden. Water is detained in the ponding area until it either infiltrates or evaporates. The plants in the rainwater garden help to infiltrate the water and trap pollutants for a very low cost.

Rainwater gardens placed along the front-yard public easement can capture runoff from city streets and lawns and filter it before it enters local lakes, wetlands, streams or groundwater.

Rainwater gardens can be incorporated into many different areas, such as:

- Front and back yards of residential areas
- Parkway planting strips
- Road shoulder rights-of-way
- Parking lot planter islands
- Under roof downspouts

Figures 7 through 10 show some examples of rainwater garden designs.

Design Guidelines

Design of rainwater gardens can be simple or complex, depending on the level of effort one is willing to put into it. Some general design guidelines include:

- The area for ponding should be a shallow depression of 6 to 18 inches.
- The area of ponding should be greater than 10 feet away from any building foundations to ensure that the ponded water does not drain to foundations.
- There are several alternative combinations of parts for constructing front-yard easement gardens that make them more attractive to people. The essential elements include perennial flowers, ornamental grasses, shrubs and neat edges created by attractive walls, pavers or a band of turf. Many combinations of these elements are shown in *Bringing Garden Amenities Into Your Neighborhood* (Nassauer et al., 1997); a few examples are shown in Figures 8 through 10.
- Plants in the easement gardens can be selected to reduce maintenance and to tolerate snow storage and winter salt and sand. The suggested plant list on the last page of this BMP section provides recommendations for appropriate plants based on different site conditions (Rozumalski, 2001).
- Rainwater gardens should be designed with the tallest flowers and shrubs in the deepest part of the swale. However, these plants should stay short enough that they will not obstruct the view to houses. Shrubs should be pruned annually to keep a low profile, set within the swale.

Rainwater Gardens (continued)

- In order to maintain treatment effectiveness and storage volume, runoff from roads and other impervious surfaces must be pretreated before entering the basin. The simplest pretreatment scheme is to move water via sheet flow over at least 4 feet of turfgrass that slopes no more than 10 percent.
- Compaction of the soil in a rainwater garden should be avoided during construction in order to maintain basins' infiltration capacity. If compaction does occur, soils should be ripped to a depth of 18 inches, with 6 to 12 inches of organic compost incorporated into the till prior to planting.

Maintenance

- If gardens are properly planned and designed (protected from sediment and compaction and incorporating a sufficient turf pretreatment area), a rainwater basin is likely to retain its effectiveness for well over 20 years. After that time, inspection will reveal whether sedimentation warrants scraping out the basin and replanting it (possibly with salvaged plants).
- In the first year, rainwater gardens require vigilant weeding (monthly during the growing season). The need for weeding will decrease as plants become established.
- In the spring, standing dead plant debris will need to be removed.
- The rainwater garden should be inspected annually for sediment trapped in the pretreatment area and in the garden itself.
- Shrubs should be pruned as necessary to keep a neat appearance.

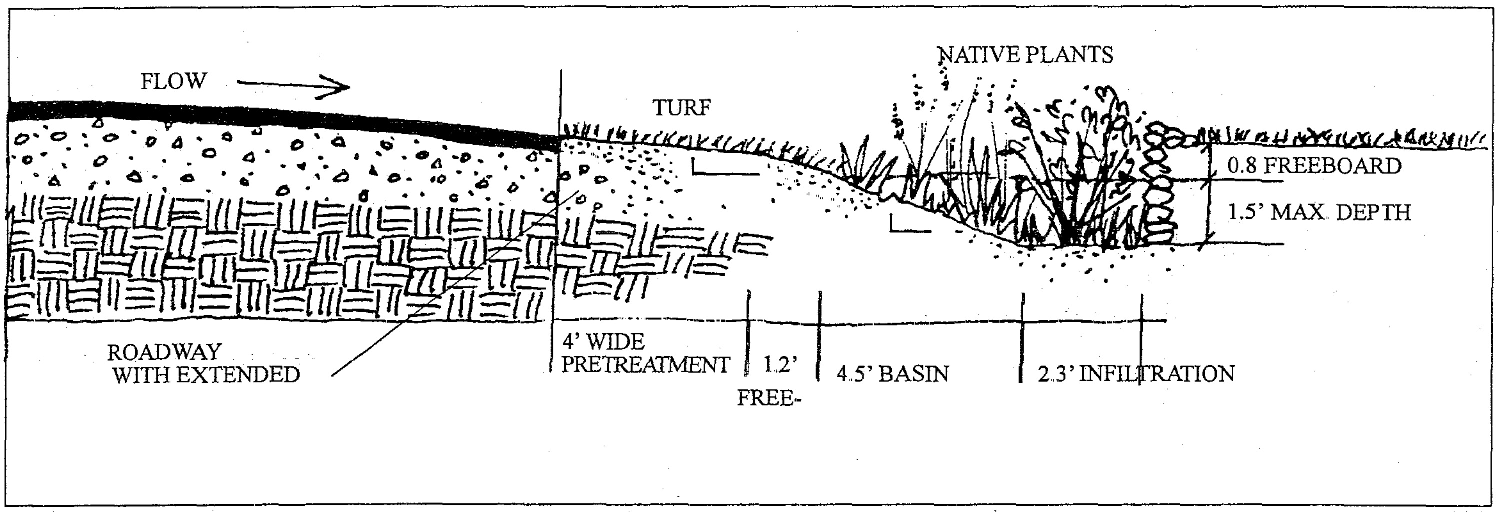


Figure 7: Profile of a Typical Rainwater Garden
Source: Valley Branch Watershed District, 2000

On-Lot Infiltration

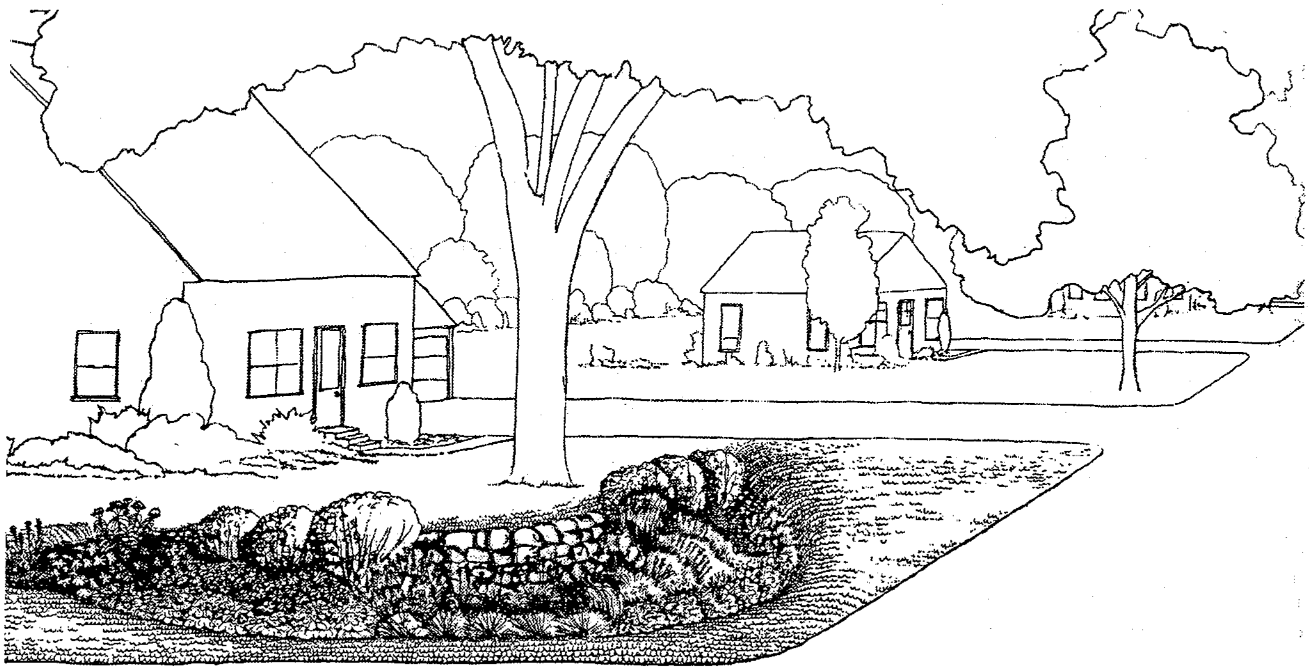


Figure 8: Typical Rainwater Garden Layout
Source: Adapted from Nassauer et al., 1997.

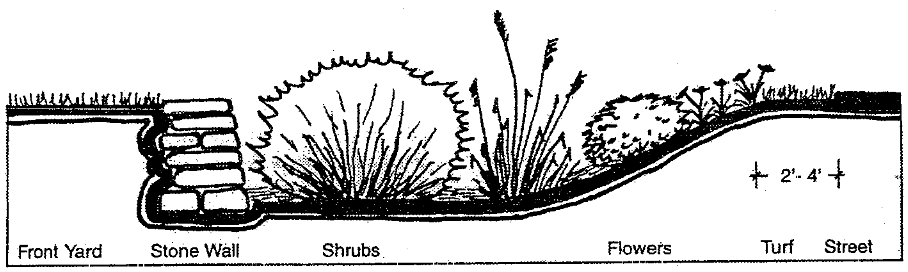


Figure 9: High-Volume, Asymmetrical Rainwater Garden with Masonry Wall
Source: Adapted from Nassauer et al., 1997.

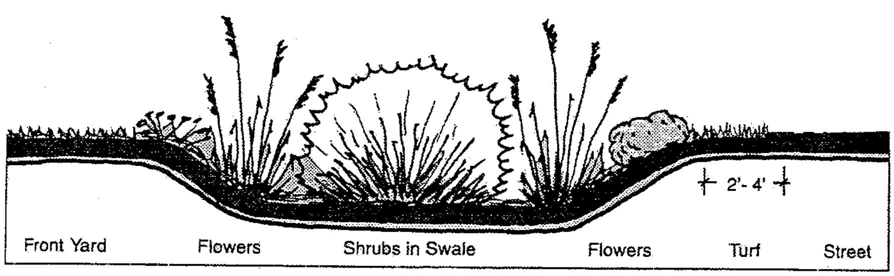


Figure 10: High-Volume, Symmetrical Rainwater Garden
Source: Adapted from Nassauer et al., 1997.

Rainwater Gardens Plant List

Source:Fred Rozumalski

Mesic-Dry Soils (Sunny)

Native		*Non-Native*	
Butterfly Flower	*Asclepias tuberosa*	Yarrow "Coronation Gold"	*Achillea "Coronation Gold"*
Purple Prairie Clover	*Dalea purpureum*	Feather Reed Grass "Karl Foerster"	*Calamogrostis "Karl Foerster"*
Purple Coneflower	*Echinacea purpurea*	Daylily	*Hemerocallis spp.*
Bee balm	*Monarda fistulosa*	Blazingstar "Kobold"	*Liatris "Kobold"*
Little Bluestem	*Schizachyrium scoparium*	Silverfeather Grass	*Miscanthus sinensis*
Spiderwort	*Tradescantia bracteata*	Garden Phlox	*Phlox paniculata*
		Black-Eyed Susan "Goldsturm"	*Rudbeckia fulgida "Goldsturm"*

Mesic-Dry Soils (Shady)

Native		*Non-Native*	
Wild Columbine	*Aquilegia canadensis*	White Comfrey	*Symphytum grandiflorum*
Wild Geranium	*Geranium maculatum*	Tufted Hair Grass	*Deschamsia caespitosa*
Obedient Plant	*Physostegia virginiana*	Bigroot Geranium	*Geranium macrorrhizum*
Jacob's Ladder	*Polemonium reptans*	Daylily	*Hemerocallis spp.*
Solomon's Seal	*Polygonatum biflorum*	Hosta "Royal Standard"	*Hosta "Royal Standard"*
Zigzag Goldenrod	*Solidago flexicaulis*	Tigerlily	*Lilium tigrinum*
Canada Violet	*Viola canadensis*		
Culver's Root	*Veronicastrum virginium*		

Wet Soil (Sunny)

Native		*Non-Native*	
Giant Hyssop	*Agastache foeniculum*	Joe-Pye "Gateway"	*Eupatorium purpurescens "Gateway"*
Canada Anemone	*Anemone canadensis*	Daylily	*Hemerocallis spp.*
Marsh Milkweed	*Asclepias incarnata*	Siberian Iris	*Iris sibirica*
New England Aster	*Aster novae-angliae*	Tigerlily	*Lilium tigrinum*
Turtlehead	*Chelone glabra*	Switchgrass "Heavy Metal"	*Panicum virgatum "Heavy Metal"*
Joe-Pye Weed	*Eupatorium maculatum*		
Obedient Plant	*Physostegia virginianum*		
Boneset	*Eupatorium perfoliatum*		
Queen of the Prairie	*Filpendula rubra*		
Blueflag Iris	*Iris versicolor*		
Great Blue Lobelia	*Lobelia siphilitica*		
Switchgrass	*Panicum virgatum*		
Mountain Mint	*Pycnanthemum virginianum*		
Tall Meadow Rue	*Thalictrum dasycarpum*		
Culvers Root	*Veronicastrum virginicum*		
Golden Alexander	*Zizia aurea*		

On-Lot Infiltration

Wet Soils (Shady)

Native

Cardinal Flower	*Lobelia cardinalis*
Ostrich Fern	*Matteuccia struthiopteris*
Virginia Bluebells	*Mertensia virginica*
Sensitive Fern	*Onoclea sensibilis*

Non-Native

Pink Turtlehead	*Chelone layonii*
Daylily	*Hemerocallis spp.*
Obedient Plant	*Physostegia virginiana*

Shrubs (Sunny)

Black Chokeberry	*Aronia melanocarpa*
Red-Osier Dogwood	*Cornus serecia*
Low Bush Honeysuckle	*Diervilla Ionicera*
Annabelle Hydrangea	*Hydrangea arborescens "Annabelle"*
Pussy Willow	*Salix discolor*
High Bush Cranberry	*Viburnum trilobum*

Shrubs (Shady)

Black Chokeberry	*Aronia melanocarpa "alata"*
Red-Osier Dogwood	*Cornus sericia*
Low Bush Honeysuckle	*Diervilla Ionicera*
Annabelle Hydrangea	*Hydrangea arborescens "Annabelle"*

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