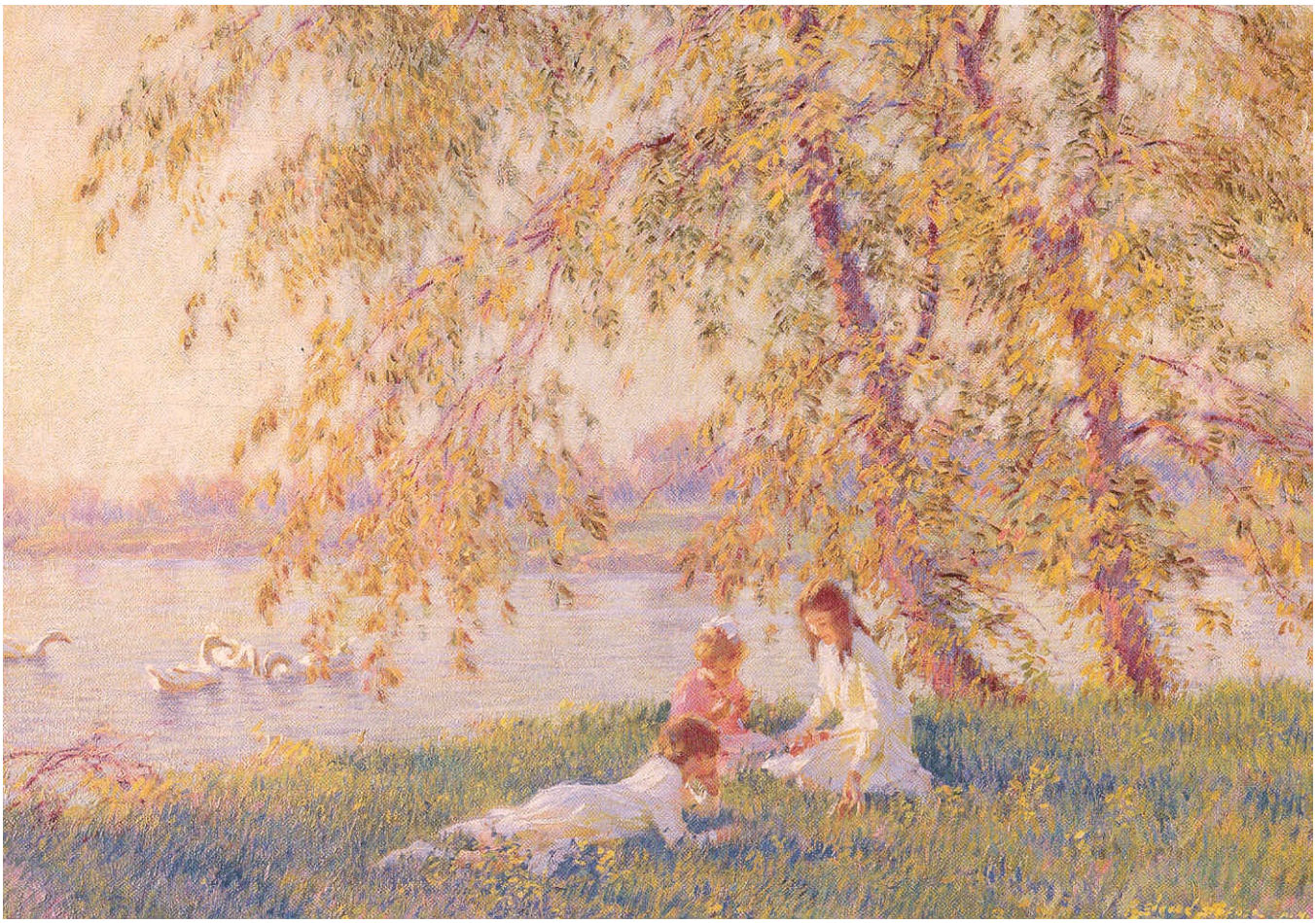

Edward Dufner: *Joyous Days*, **early-mid 1920s**

Lake Management Plan for Alimagnet Lake, Dakota County, Minnesota

March 2005

Prepared by Blue Water Science and Bonestroo, Rosene, Anderlik and Associates

with contributions from City of Apple Valley, City of Burnsville, and the Alimagnet Lake Association

Funded by the City of Apple Valley and the City of Burnsville

Lake Management Plan for Alimagnet Lake, Dakota County, Minnesota

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Lake Management Plan for
Alimagnet Lake, Dakota County, Minnesota

SUMMARY

Project Goals

The goals of this lake management report were:

- to examine existing lake conditions.
- to develop a lake management plan that protects, maintains, and enhances Alimagnet Lake water quality.
- meet the basic MPCA/EPA criteria for a TMDL

Watershed Characteristics

Alimagnet Lake's watershed is approximately 1,094 acres (includes the lake). Land use is primarily residential. Three subwatersheds (1, 6, and 7) contribute most of the watershed phosphorus to Alimagnet Lake (Table 1 and Figure 1).

Table 1. Phosphorus load by outfall based on P-8 model.

Storm Sewer Outfall	Total Drainage Area (acres)	Total Phosphorus Load (lbs/yr)	Unit Phosphorus Load (lbs/acre/yr)
1	**288.6**	**158.8**	**0.55**
2	6.6	3.8	0.58
3	7.2	3.9	0.54
4	29.0	14.5	0.50
5	3.4	1.7	0.50
6	**187.4**	**130.6**	**0.70**
7	**256.6**	**93.9**	**0.37**
8	16.0	9.2	0.58
9	30.2	10.5	0.35
10	47.7	17.4	0.36
Developed Shoreline	32.1	9.3	0.29
Undeveloped Shoreline	80.3	7.9	0.10

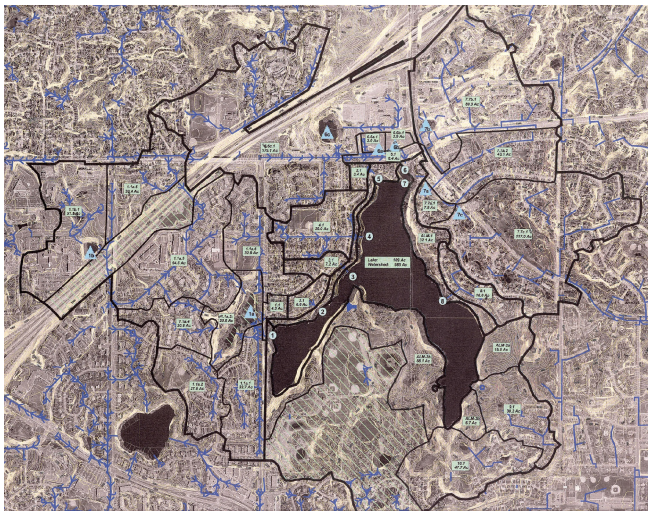


Figure 1. The Alimagnet Lake watershed and subwatersheds are outlined in black.

Shoreland Characteristics

The shoreland area is the transition area between the watershed and lake and encompass three components: the upland fringe, the shoreline, and the shallow nearshore area. Results of a shoreland inventory show over half of the parcels have existing natural conditions (Table 2). This is about average for urban lakes in the metro area.

Table 2. Summary of shoreline buffer and upland conditions in the shoreland area of Alimagnet Lake. Approximately 108 parcels were examined.

Alimagnet Lake	Natural Shoreline Condition		Natural Upland Condition		Undevel. Photo Parcels	Shoreline Structure Present	
	>50%	>75%	>50%	>75%		riprap	wall
TOTALS (no. of parcels = 108)	69% (75)	61% (66)	54% (58)	47% (51)	37% (40)	15% (16)	3% (3)

Lake Statistics

Alimagnet Lake is a 109 acre lake located in Dakota County, Minnesota with an average depth of 5 feet and a maximum depth of 11 feet.

Lake Dissolved Oxygen and Temperature

Alimagnet Lake does not strongly thermally stratify during the summer. This means that wind action can mix the entire lake during the summer. Dissolved oxygen concentrations are found throughout the water column most of the time, although there are days during the summer when dissolved oxygen is depleted on the bottom of the lake (Figure 2).

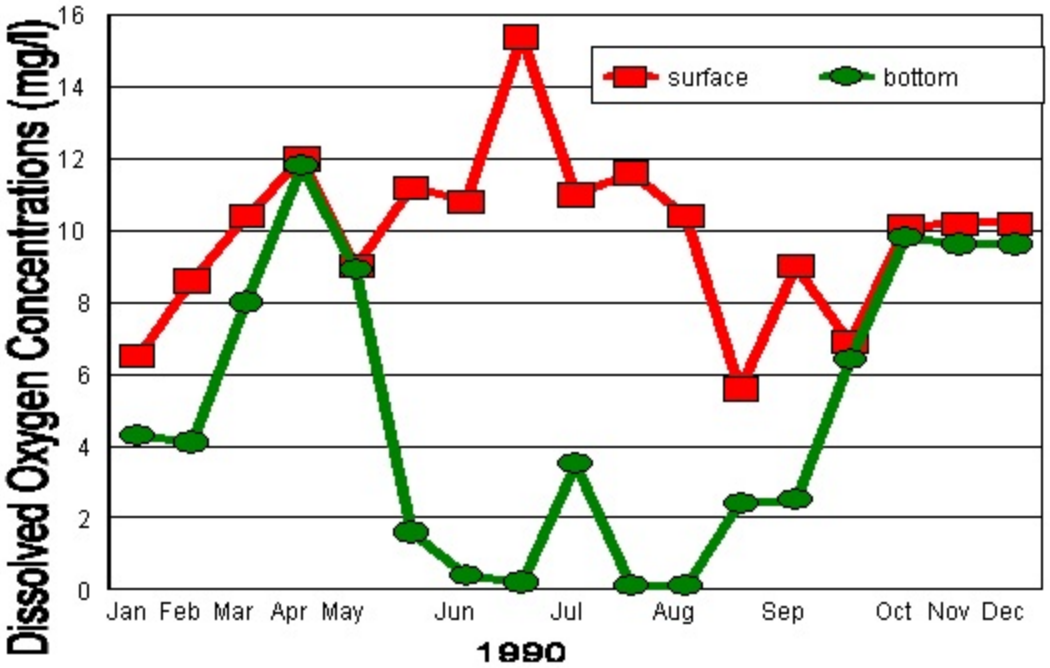


Figure 2. Monthly dissolved oxygen readings for top and bottom conditions for Alimagnet Lake in 1990 (source: JM Montgomery Engineers).

Lake Transparency and Nutrient Status

Phosphorus concentrations in Alimagnet are higher compared to other lakes in the North Central Hardwood Forest ecoregion. The 2003 growing season phosphorus average was 113 ppb. A predicted phosphorus concentration based on ecoregion values and ecoregion modeling is predicted to be 54 ppb. This indicates Alimagnet Lake has the potential to have better water quality than it presently has. Reducing lake nutrient levels is a primary goal for Alimagnet Lake.

Summer average Secchi disc readings have fluctuated over the years (Figure 3). Some of the variability may be influenced by winterkill events that have occurred in the past.

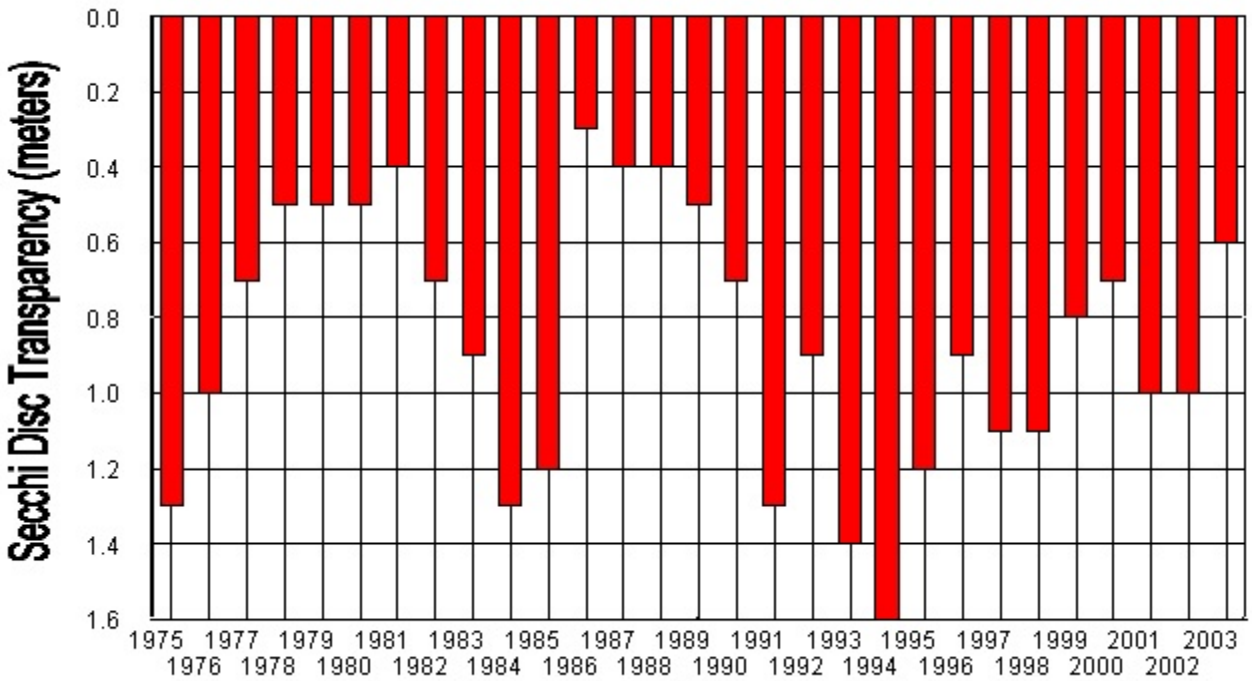


Figure 3. Summer average for Secchi disc readings from 1975-2003.

Lake Algae

Alimagnet Lake has algae species that are common to eutrophic lakes in this part of the state. By mid-summer, blue-green algae concentrations increase dramatically and water clarity decreases. Elevated phosphorus levels produce the excessive algal growth.

Lake Aquatic Plants

Alimagnet Lake has a low diversity of native aquatic plants. Elodea is common but the only other rooted native plant observed has been sago pondweed and it is rare in the lake. Curlyleaf pondweed, an exotic plant, is present in Alimagnet and grows to moderate nuisance conditions throughout the shallow waters of the lake. Lake sediment analysis predicts sediment characteristics would produce moderate nuisance conditions around most of the lake (Table 3 and Figure 4).

Table 3. Alimagnet Lake sediment data and ratings for potential nuisance curlyleaf pondweed growth.

Sample ID	Bulk density (g/cm^3)	Organic Matter (%)	pH (su)	Fe:Mn Ratio	Potential for Nuisance Curlyleaf Pondweed Growth
non-nuisance	1.04	5	6.8 (6.7-6.9)	4.5 (2-5)	Low
light nuisance	0.94	11	6.2	5.9	Med
heavy nuisance	<0.51	>20	>7.7	<1.6	High
1	1.18	2.7	6.6	9.3	Medium
2	0.71	15.8	5.9	8.0	Medium
3	1.13	2.9	6.2	5.5	Medium
4	1.2	2.3	6.3	6.5	Medium
5	1.16	2.0	6.6	5.5	Medium
6	0.88	4.6	6.2	4.7	Medium
7	0.94	4.7	6.7	9.7	Medium
8	1.01	2.7	6.9	10.9	Low
9	0.85	7.1	6.1	4.5	Medium
10	1.09	4.1	6.6	11.9	Medium
11	0.89	6.6	6.6	7.5	Medium
12	0.94	3.3	6.7	7.4	Medium
13	1.02	3.8	6.8	11.5	Low
14	1.01	3.7	6.2	8.3	Medium
15	1.29	1.3	6.2	11.0	Medium
16	0.75	22.0	6.3	9.0	Medium
17	1.44	0.5	6.6	13.5	Medium
18	0.66	10.4	6.0	9.8	Medium
19	0.70	34.1	6.4	7.9	Medium
20	0.78	12.2	6.0	10.1	Medium
21	0.38	34.2	6.0	5.6	High

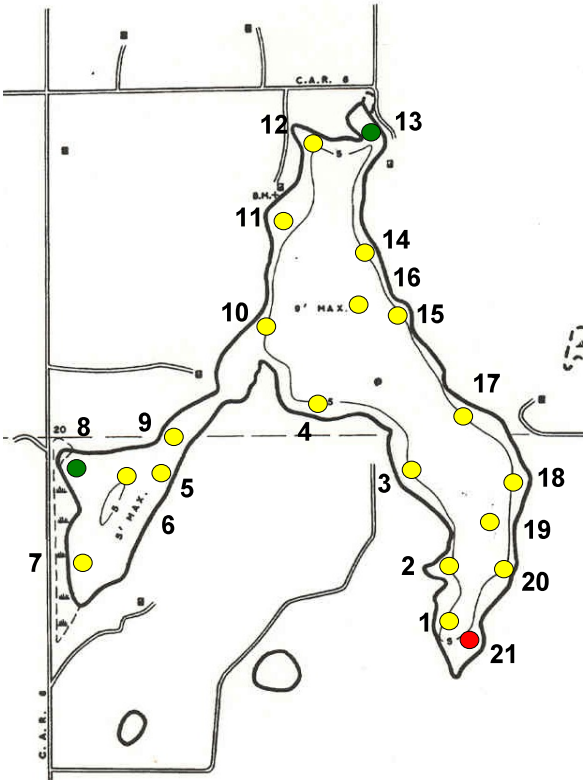


Figure 4. Areas that are predicted to support various types of curlyleaf pondweed growth are shown by colored dots. Green = non-nuisance, yellow = medium nuisance, and red = heavy nuisance.

Figure 5. The Alimagnet Lake Association has developed a curlyleaf control technique, where a cable strung between two boats, is pulled through the curlyleaf beds.

Fish

The fish community of Alimagnet Lake was last surveyed by the MnDNR in 2000. Black bullhead (at 84 fish/trapnet) were the dominant species. The black bullhead density may be even higher in 2004 and could be producing adverse impacts on lake water quality. The number of northern pike and black crappie were also above average. Largemouth bass and bluegill sunfish were also present at typical densities for a shallow lake like Alimagnet.

Lake Assessment

- Lake water quality results are below-average compared to Ecoregion values, meaning there is room for improvement.
- Phosphorus concentrations in watershed runoff are estimated at 336 ppb based on the P-8 model. This is above Ecoregion values which are around 150 ppb-P.
- The water clarity data base shows fluctuating seasonal averages over the years. However, Alimagnet Lake has the potential to get better.

Table 4. Summer average water quality characteristics for lakes in the Western Corn Belt Plains and the North Central Hardwood Forest Ecoregions compared to water quality for Alimagnet Lake.

Parameter	North Central Hardwood Forest	Alimagnet (2003)
Total phosphorus (ug/l) - top	23-50	113
Algae [as Chlorophyll (ug/l)]	5-22	45
Chlorophyll - max (ug/l)	7-37	130
Secchi disc (ft)	4.9-10.5	2.0

These comparisons indicate that the water quality of Alimagnet Lake are out of range compared to the North Central Hardwood Forest ecoregion water quality values. The challenge will be to bring water quality values within ecoregion ranges. The estimated nutrient load to Alimagnet Lake is shown in Figure 6.

Total estimated load: 600 pounds of phosphorus per year (272 kg-P/yr)

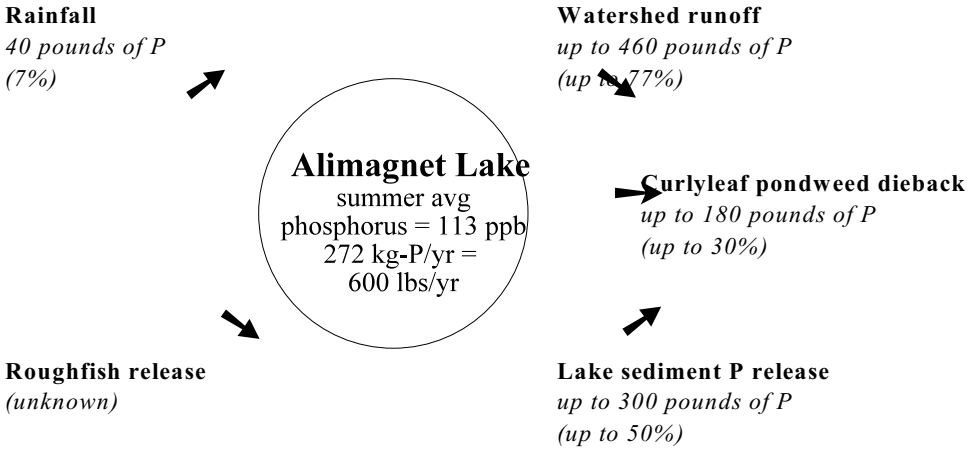


Figure 6. Estimated annual phosphorus loads to Alimagnet Lake.

Setting Water Quality Goals for Alimagnet Lake

Water quality in Alimagnet Lake has the potential to be better. Lake models were run to help determine feasible water quality goals for Alimagnet Lake. A lake model is a mathematical equation that uses phosphorus inputs along with lake and watershed characteristics to predict what a lake phosphorus concentration should be. Once a lake phosphorus concentration is determined, then seasonal water clarity and algae concentrations can be calculated as well.

Several lake models were run based on nutrient inputs using the Canfield-Bachmann natural lake model. Lake model runs were conducted for existing watershed runoff conditions (using a flow weighted mean concentrations of 336 ppb-P), predicted watershed runoff after watershed practices are implemented (FWMC 161 ppb-P), and for an ecoregion FWMC runoff P-concentration of 150 ppb. The existing observed conditions for lake phosphorus chlorophyll a, and Secchi depth are shown with red bar (Figures 7 and 8). Existing conditions are assumed to be dictated by an estimated phosphorus loading of 600 lbs/yr. The estimated phosphorus load for existing conditions was back-calculated for Alimagnet Lake based on a lake concentration of 113 ppb. The 113 ppb-P lake concentration was the summer average for 2003.

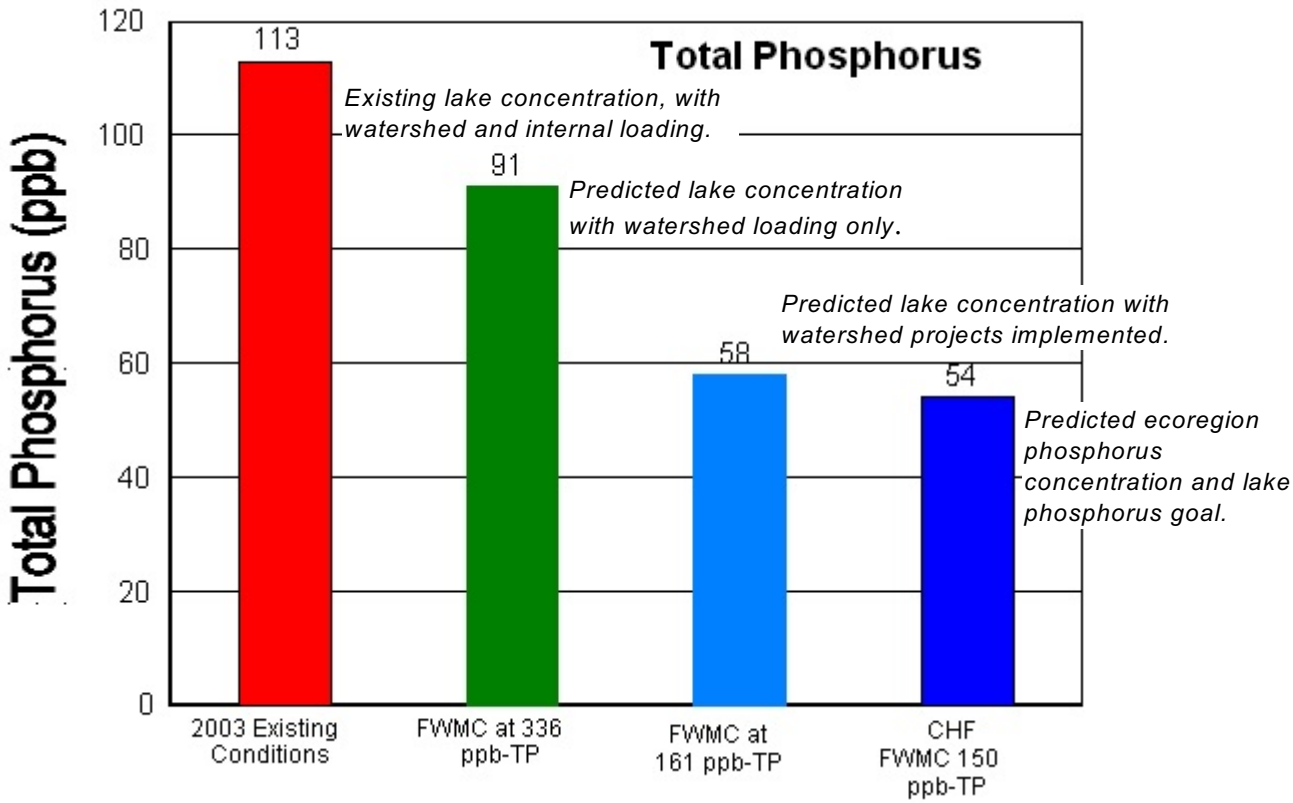


Figure 7. Comparison of total phosphorus concentration for Alimagnet Lake in 2003 to lake phosphorus concentrations based on estimated concentrations for a watershed runoff flow weighted mean concentration (FWMC) of 336 ppb-phosphorus (current watershed runoff conditions), for a watershed runoff FWMC of 161 ppb-P (predicted after watershed practices are implemented) and for a lake with a watershed the size of Alimagnet Lake situated in the Central Hardwood Forest (CHF) with a phosphorus runoff concentration of 150 ppb.

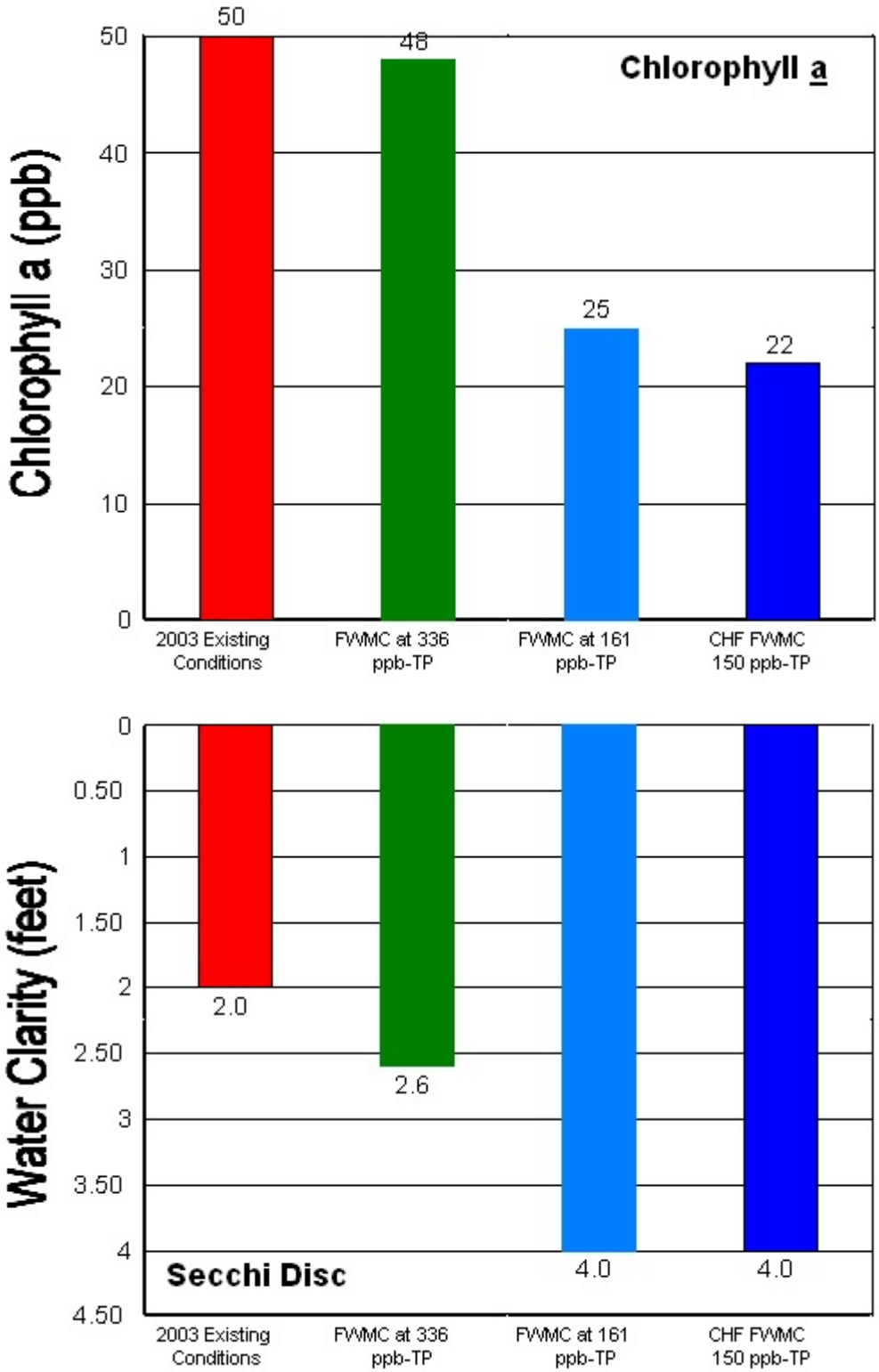


Figure 8. Comparison of chlorophyll a concentration (top) and water clarity (bottom) for Alimagnet Lake in 2003 to predicted lake chlorophyll concentrations and clarity for a watershed runoff flow weighted mean concentration (FWMC) of 336 ppb-phosphorus (current watershed runoff conditions), for a watershed runoff FWMC of 161 ppb-P (predicted after watershed practices are implemented) and for a lake with a watershed the size of Alimagnet Lake situated in the Central Hardwood Forest (CHF) with a phosphorus runoff concentration of 150 ppb.

Water Quality Improvement Strategy

There appears to be a need to reduce a significant amount of annual phosphorus loading to Alimagnet Lake in order to meet lake water quality goals.

An important finding of the watershed and in-lake modeling was that Alimagnet Lake will need both watershed and lake projects to meet the water quality goal of 54 ppb. This should produce a summer average Secchi disc reading of 1.2 m (4.0 ft). The water quality of a shallow lake system, like Alimagnet Lake, is greatly affected by in-lake processes such as internal recycling of nutrients that have accumulated in bottom sediment and relationships between fish, rooted aquatic plants, and algae. This underlines the importance of sound in-lake management programs while reducing watershed phosphorus inputs. Therefore, it will be difficult for watershed-based BMPs alone to meet lake water quality goals. The water quality improvement strategy will be to reduce watershed pollutant inputs to the maximum extent practical while implementing in-lake water quality improvement projects.

Algae blooms are an annual occurrence in Alimagnet Lake. The water quality improvement strategy will not eliminate algae blooms, but should reduce the number of days they occur as well as their intensity.

Recommended Lake Management Programs and Projects

Lake management programs are recommended to improve watershed nutrient inputs (Table 5) as well as in-lake conditions (Table 6).

Table 5. Phosphorus load reductions associated with watershed projects.

Priority Watershed Projects	Description	TP Load Reduction
1a	Barley straw treatment in Ponds 1A, 6C, and 7A.	123 lbs/yr
1b	Expand wet volume of Pond 7A (located in Apple Valley) through excavation.	16 lbs/yr
1c and 1d	Expand wet volume of north cell of Pond 1A (located in Burnsville) through excavation and develop pre-treatment basin prior to north cell of Pond 1A.	56 lbs/yr
2	Improve fertilizer management in the watershed, particularly emphasizing the urbanized direct drainage area.	13 lbs/yr

Table 6. Lake improvement benefits associated with lake projects.

Priority Lake Projects	Description	TP Load Reduction (lbs-P/yr)	Other Benefits
1	Shoreland projects	4	Wildlife enhancement, aesthetics
2a	Continue to control curlyleaf pondweed	90	Improved recreational use
2b	Harvesting nuisance aquatic plant growth	15	Improved recreational use
3a	Black bullhead removal	0 - 60	Improves fishing
3b	Stock catfish and bass	0	Improves fishing, controls roughfish
4	Organic carbon amendment	150*	No herbicides used, improved fishing

* 150 pounds of phosphorus per year is made unavailable to algae with this organic carbon amendment. This type of phosphorus redirection has been documented in lakes that used barley straw, where significant water column phosphorus concentrations have decreased.

Project Costs

Estimated project costs for the Alimagnet Lake improvement program are summarized in Table 7.

Table 7. Summary of recommended projects and costs.

	Estimated Phosphorus Reduction (pounds/year)	Capital Cost	Average Annual O & M (5 yr)	5 Year Cost
Watershed Projects				
1. Stormwater pond improvements.				
1a. Barley straw for three ponds.	123	0	4,000	20,000
1b. Excavation of pond 7A.	16	65,000	0	65,000
1c. Excavation of pond 1A.	37	150,000	0	150,000
1d. Construction of pre-treatment pond for 1A.	19	240,000	0	240,000
2. Fertilizer management and control.	13	0	2,000	10,000
Subtotal	***208***	***455,000***	***6,000***	***485,000***
Lake Projects				
1. Shoreland buffers.	4	0	3,000	15,000
2. Aquatic plant projects.				
2a. Continue curlyleaf control program	90	5,000	1,000	10,000
2b. Harvest nuisance plant growth.	--	0	3,000	15,000
3. Fish management				
3a. Black bullhead removal.	30	0	4,200	21,000
3b. Predator stocking.	--	0	800	4,000
4. Organic carbon amendment.	150	0	16,000	80,000
Subtotal	***274***	***5,000***	***28,000***	***145,000***
Watershed and Lake Programs				
1. Information and education	10	0	3,000	15,000
2. Watershed and lake monitoring	--	0	2,500	12,500
Subtotal	***10***	***0***	***5,500***	***27,500***
TOTAL	***492***	***460,000***	***39,500***	***657,500***
Margin of Safety Projects				
Street sweeping	9	0	4,500	22,500
Infiltration and rain gardens	22	300,000	0	300,000
Reserve Projects				
Lake sediment iron treatment for curlyleaf pondweed	150	30,000	0	30,000
Install winter aeration in two additional locations	100	30,000	3,000	45,000
Lake sediment alum project	150	100,000	0	150,000

Project Sequence

A five-year project sequence is summarized in Table 8. Several projects will occur annually for the next five years. After five years, lake conditions will be evaluated. It is anticipated that lake goals will be met by the end of year 5 and that several projects with high annual costs (for example the organic carbon amendment) can be curtailed or eliminated.

Table 8. Alimagnet Lake improvement project sequence, annual costs, and total project cost for a 5-year program.

	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year Cost
Watershed Projects						
1. Stormwater pond improvements.						
1a. Barley straw for 3 ponds.	4,000	4,000	4,000	4,000	4,000	20,000
1b. Excavation of pond 7A.	--	65,000	--	--	--	65,000
1c. Excavation of pond 1A.	--	60,000	90,000	--	--	150,000
1d. Construction of pre-treatment pond for 1A.	--	40,000	120,000	80,000	--	240,000
2. Fertilizer management and control.	2,000	2,000	2,000	2,000	2,000	10,000
Subtotal	***6,000***	***171,000***	***216,000***	***86,000***	***6,000***	***485,000***
Lake Projects						
1. Shoreland buffers.	3,000	3,000	3,000	3,000	3,000	15,000
2. Aquatic plant projects.						
2a. Continue curlyleaf control program	6,000	1,000	1,000	1,000	1,000	10,000
2b. Harvest nuisance plant growth.	--	--	5,000	5,000	5,000	15,000
3. Fish management						
3a. Black bullhead removal.	7,000	7,000	7,000	--	--	21,000
3b. Predator stocking.	1,500	900	800	800	--	4,000
4. Organic carbon amendment.	16,000	16,000	16,000	16,000	16,000	80,000
Subtotal	***33,500***	***27,900***	***32,800***	***25,800***	***25,000***	***145,000***
Watershed and Lake Programs						
1. Information and education	3,000	3,000	3,000	3,000	3,000	15,000
2. Watershed and lake monitoring	2,500	2,500	2,500	2,500	2,500	12,500
Subtotal	***5,500***	***5,500***	***5,500***	***5,500***	***5,500***	***27,500***
TOTAL	***45,000***	***204,400***	***254,300***	***117,700***	***36,500***	***657,500***

1. Introduction and Project Setting

Alimagnet Lake is located in the Cities of Burnsville and Apple Valley in Dakota County, Minnesota (Figure 1). Alimagnet Lake characteristics are shown in Table 1.

Table 1. Lake statistics (MPCA).

	Alimagnet Lake
Size (acres)	109
Mean depth (ft)	5
Maximum depth (ft)	11

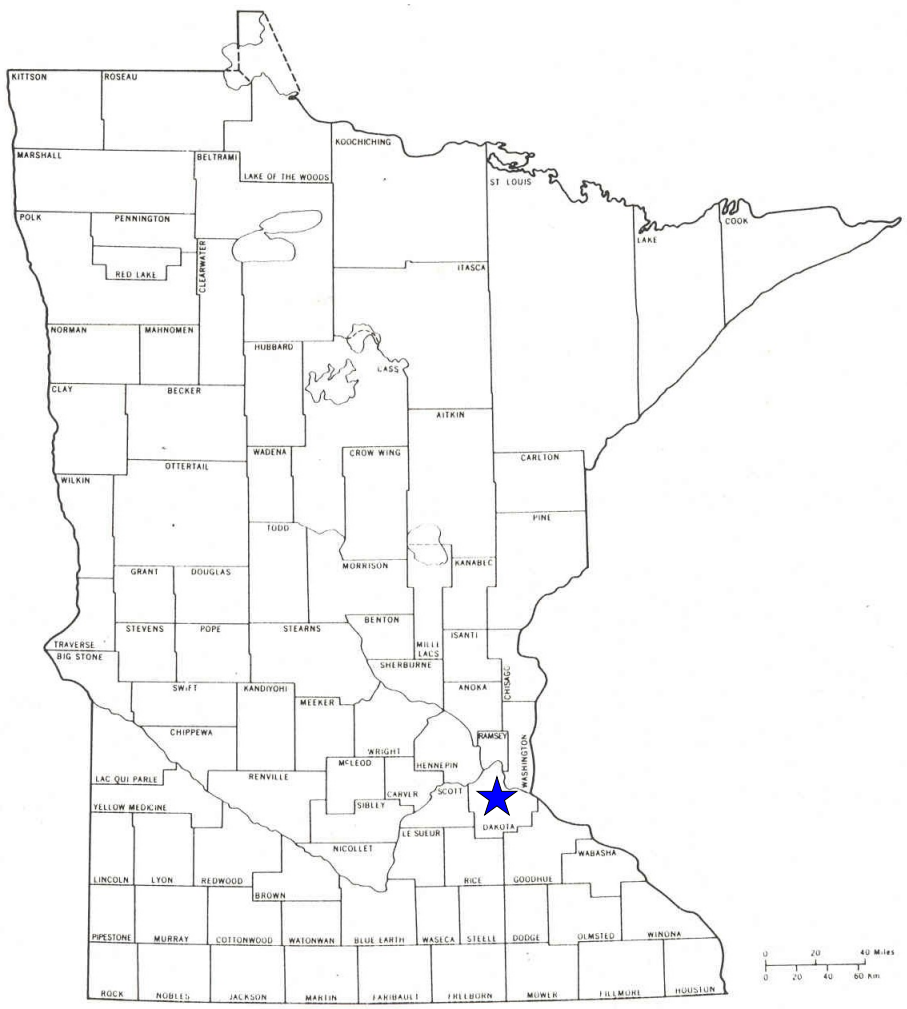


Figure 1. Alimagnet Lake is located in Dakota County, Minnesota.

Alimagnet Lake has been surrounded by intense human activities for many decades. In the early to mid-1900's, agricultural practices dominated the area around the lake. This is reflected in an aerial photograph taken in 1947 (Figure 2). Later in the 20th century, this agricultural landscape was transformed into a suburban community.

Today, Alimagnet Lake is almost entirely surrounded by urban development. Urbanization increases the amount of impervious cover in the landscape and requires a well-developed interconnected drainage network. Often the drainage network can serve to artificially increase the amount of area draining to a lake.

The presettlement size of the Alimagnet drainage area is not known so it is not possible to indicate if the watershed size has changed due to urbanization. However, an extensive storm sewer system drains the Alimagnet Lake watershed. Generally, the interconnected drainage and extent of impervious cover in the landscape have elevated the nutrient inputs to the lake, negatively affecting the quality of the lake. Currently, Alimagnet Lake has a total phosphorus concentration of approximately 100 parts per billion (ppb).

As a result, Alimagnet Lake has been listed by the MPCA as having water quality that is impaired by excess nutrients. This impairment affects recreational use of the lake, which includes swimming and other forms of water recreation. Minnesota's ecoregion-based[1] nutrient guidelines (i.e. total phosphorus, or TP) provide the initial basis for determining the impairment status of the lake.

Phosphorus is the primary nutrient of concern because of its role in the eutrophication (nutrient enrichment) of aquatic systems. This in turn affects the suitability of those systems to support desired uses. Control of phosphorus is important because the availability of this nutrient often controls the amount of algal growth in a lake ecosystem. Best management practices (BMPs) in the urbanized watershed and in the lake can be implemented to improve water quality in Alimagnet Lake.

The objective of this project was to evaluate the watershed and lake system in order to develop appropriate recommendations for implementing BMPs that improve water quality. The goal was to identify a combination of BMPs that would result in reducing Alimagnet Lake's average TP concentration to at or below the ecoregion average and to improve water clarity.

1 Ecoregions are areas of relative uniformity characterized by distinctive regional ecological factors, including land use, soils, topography and potential natural vegetation. There are seven ecoregions in Minnesota.

Figure 2. Air photo of Alimagnet Lake from 1947 showing agricultural land use in the area. (Photo courtesy of MnDNR Resource Assessment office).

2. Watershed Features

2.1. Watershed Drainage, Land Use, and Storm Ponds

Watershed Drainage: Alimagnet Lake is within the Mississippi River (Red Wing to Lake Pepin)[2] major drainage basin. Inside this major drainage basin, Alimagnet Lake generally receives drainage from areas in the 32-square mile nameless minor watershed identified as 3803201.[2]

For this study, the drainage area specific to Alimagnet Lake was delineated. This drainage area was defined based upon both height of land (2-foot contour data from Dakota County, generated in 1996) as well as storm sewer catch basins and pipe outfalls. The drainage areas that were developed were field-verified. As-built record plans were obtained from both Apple Valley and Burnsville and reviewed where appropriate. Finally, as-built record plans were obtained from the Minnesota Department of Transportation to verify highway drainage and ponding. Subwatershed drainage areas are listed in Table 2 and a map of the subwatersheds is shown in Figure 3.

Land Use: The impervious fraction of a drainage area–a function of land use–is a major input to the P-8 watershed model. Digital land use data was obtained from both Apple Valley and Burnsville for the project area. The land use data was manipulated through GIS software to determine the proportion of different types of land use within each drainage area. The data were then manually compiled to arrive at an estimate of composite impervious percentage for each drainage area (drainage areas are shown in Map 1, Figure 3). A summary of the drainage areas and the associated impervious percentages are shown in Table 2:

Table 2. Watershed imperviousness.

Watershed	Area (acres)	Percent Impervious
1.1	4.3	30%
1.1a.1	32.7	33%
1.1a.2	27.9	25%
1.1a.3	20.6	12%
1.1a.4	20.8	42%
1.1a.5	97.9	58%
1.1a.6	32.9	33%
1.1b.1	51.5	58%
1. Subtotal	**288.6**	
2.1	**6.6**	30%
3.1	**7.2**	30%
4.1	**29.0**	26%
5.1	**3.4**	30%
6.1	6.4	64%
6.6a.1	3.0	82%
6.6b.1	2.9	82%
6.6c.1	175.1	53%
6. Subtotal	**187.4**	

Watershed	Area (acres)	Percent Impervious
7.7a.1	7.5	24%
7.7a.2	43.1	32%
7.7b.1	89.0	37%
7.7c.1	117.0	37%
7. Subtotal	**256.6**	
8.1	**16.0**	30%
9.1	**30.2**	18%
10.1	**47.7**	19%
ALM-1	32.1	15%
ALM-2a	15.5	<10%
ALM-2b	6.7	<10%
ALM-2c	58.1	<10%
ALM Subtotal	**80.3**	
TOTAL	**985.1**	

[2] Based on MnDNR drainage basin classifications

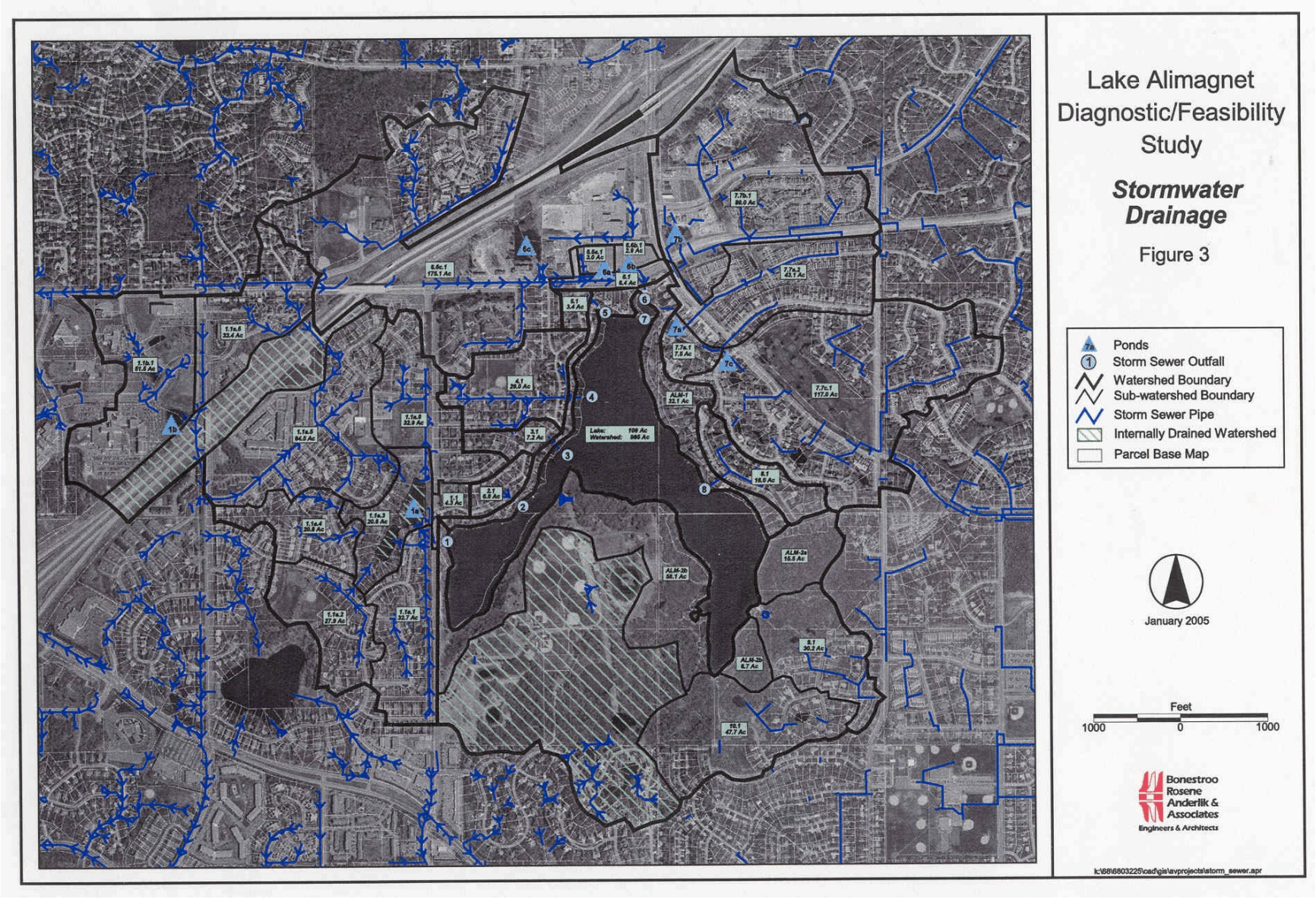


Figure 3. Drainage areas in the Alimagnet Lake watershed.

There are four types of drainage patterns represented in this study:

1. Direct inputs to the lake via storm sewer outfalls (i.e. no ponding prior to discharge). An example for these direct drainages is 1.1.
2. Indirect inputs to the lake via storm sewer outfalls (i.e. runoff is routed through an existing pond). The nomenclature is represented by three groupings, for example: 1.1a.1. The middle grouping reflects the identification for the pond to which the drainage flows.
3. Diffuse runoff (runoff reaching the lake that is not conveyed by storm sewers or channels) from the developed shoreline, identified as ALM-1.
4. Diffuse runoff from the undeveloped shoreline, identified as ALM-2a, ALM-2b, and ALM-2c.

2.2. Shoreland Inventory

The shoreland is the transition area between the watershed and the lake. The shoreland area encompasses three components: the upland fringe, the shoreline, and shallow water area by the shore. A photographic inventory of the Alimagnet Lake shoreland was conducted on August 6, 2003. The objectives of the survey were to characterize existing shoreland conditions which will serve as a benchmark for future comparisons and to look for shoreland areas that could be enhanced with more natural conditions..

For each photograph we looked at the shoreline and the upland condition. Our criteria for natural conditions were the presence of 50% native vegetation in the understory and at least 50% natural vegetation along the shoreline in a strip at least 15 feet deep. We evaluated shorelines and uplands at the 75% natural level as well (Figure 4 illustrates the methodology).

A summary of the inventory results is shown in Table 3. Based on our subjective criteria about 69% of the shoreline parcels and 54% of the upland parcels in the Alimagnet Lake shoreland area meet the natural ranking criteria. This is about average for other lakes found within the Metropolitan Twin City area. In the next 10 years proactive volunteer native landscaping could improve the natural aspects of a number of parcels.

Table 3. Summary of shoreline buffer and upland conditions in the shoreland area of Alimagnet Lake. Approximately 108 parcels were examined.

Alimagnet Lake	Natural Shoreline Condition		Natural Upland Condition		Undevel. Photo Parcels	Shoreline Structure Present	
	>50%	>75%	>50%	>75%		riprap	wall
TOTALS	69%	61%	54%	47%	37%	15%	3%
(no. of parcels = 108)	(75)	(66)	(58)	(51)	(40)	(16)	(3)

A comparison of Alimagnet Lake conditions to other lakes in Minnesota and Wisconsin is shown in Figure 5.

Figure 4. [top] This parcel would rate as having a shoreline with a buffer greater than 50% of the lot width and an understory with greater than 50% natural cover.

[bottom] This parcel would not qualify as having a natural shoreline buffer greater than 50% of the lot width. Also understory in the upland area would be rated as having less than 50% natural cover.

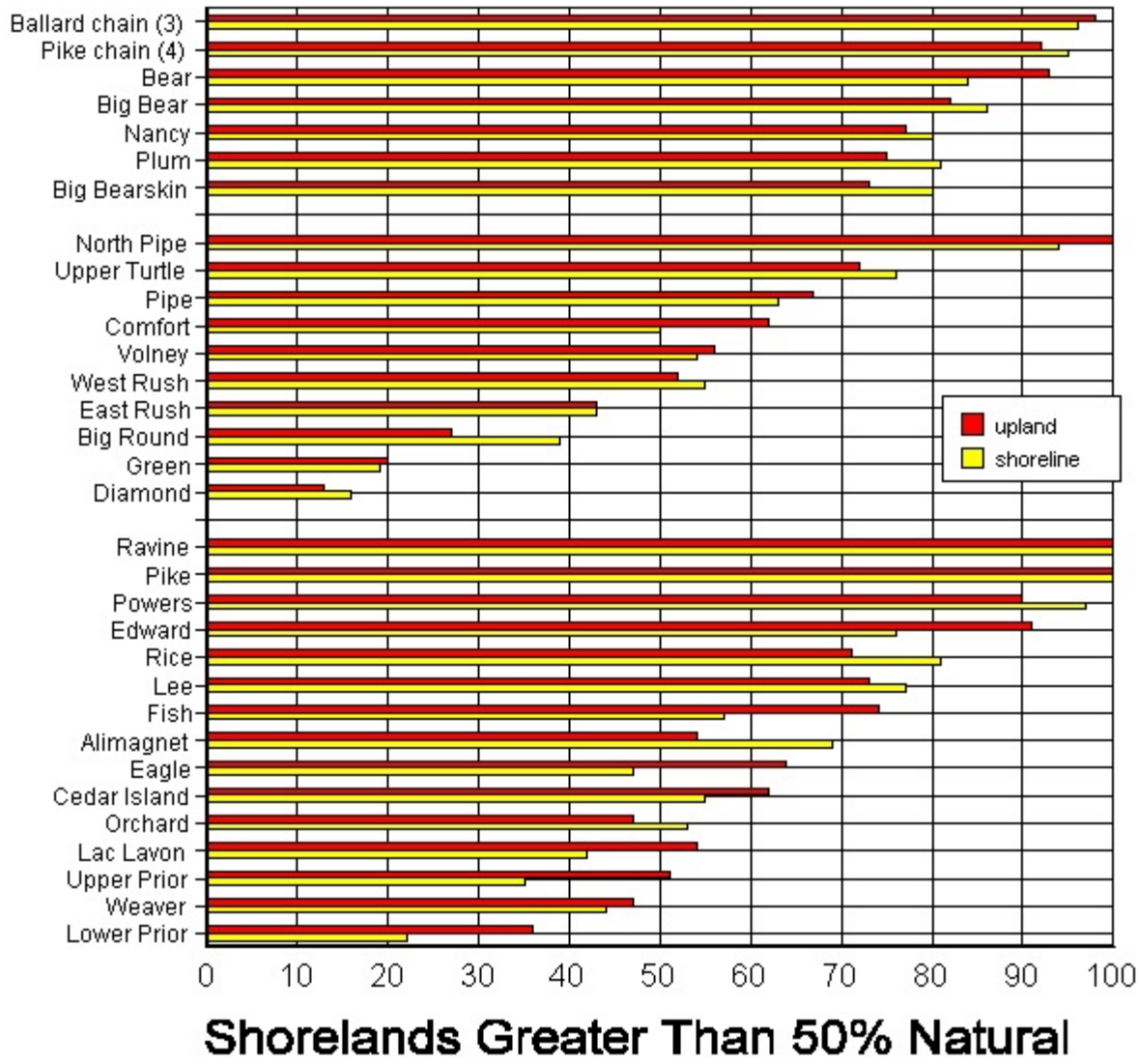


Figure 5. A summary of shoreland inventory results for lakes using an evaluation based on shoreland photographs. For each lake the percentage of shoreline and upland conditions with greater than 50% natural conditions is shown. The first tier of lakes are located in northern Wisconsin which are 4 to 5 hours from a major metropolitan area. The middle tier of lakes are about an hour's drive from the Twin Cities, and are considered to be "country" lakes. The lower tier of lakes are in the Twin City Metropolitan area and are categorized as urban lakes. Several lakes of the "urban" lakes have most of their shoreland owned by the city and there is a high percentage of natural conditions.

Alimagnet Lake is considered a Twin City Metropolitan lake for this inventory. Natural shoreland conditions for Alimagnet Lake are about average compared to the other metropolitan lakes.

2.3. Watershed Nutrient Load Estimates

Alimagnet Lake is a relatively shallow lake with a reasonably small watershed. Key summary information for the lake and watershed is presented below in Table 4.

Alimagnet Lake receives stormwater input from ten storm sewer outfall locations. In addition, three areas contributing diffuse overland runoff were defined for the lake. In total, 985 acres drain to Alimagnet Lake.

Table 4. Key summary information.

Watershed Areas	Acres
Direct Drainage	263
Indirect Drainage	722
Total Watershed	985
Lake Surface Area	109
Ratio of Watershed:Lake Area	9:1

Lake Data	
Max Depth	9 Feet
Mean Depth	5 Feet
Volume	545 Ac-Ft
Residence Time*	13 Months
Percent Littoral	100%

*Calculated based on the modeled water load for 2000, which was 506 acre-feet.

Runoff Water Quality Data: Stormwater runoff grab samples were taken for three storm events. The grab samples were taken at the outfalls for areas 1, 6 and 7. The grab samples were evaluated for total and dissolved phosphorus, total and volatile suspended solids, and total nitrogen. The water quality grab sample data is shown in Table 5.

The intent of these samples was to verify if runoff water quality was within typical ranges for urban land use, or if watershed modeling needed to be adjusted to account for potentially unusual conditions. Results of the water quality grab samples indicated that runoff water quality was within expected ranges. It should be noted that runoff samples grabbed at all locations were influenced by treatment from upstream ponds. Thus lower pollutant concentrations were expected in contrast to typical pollutant concentrations found in untreated runoff.

Table 5. Runoff grab samples for Alimagnet Lake watershed. All values are in mg/l.

Outfall #1					
	TP	**SRP**	**TN**	**TSS**	**VSS**
9/18/2003	0.401	0.003*	2.633	57	57
4/21/2004	0.136	0.014	1.187	11	11
5/13/2004	0.208	0.011	1.634	19	19
Outfall #6					
	TP	**SRP**	**TN**	**TSS**	**VSS**
9/18/2003	0.217	0.003*	1.242	24	24
4/21/2004	0.096	0.003*	1.042	6.4	6
5/13/2004	0.131	0.014	1.104	8	8
Outfall #7					
	TP	**SRP**	**TN**	**TSS**	**VSS**
9/18/2003	0.236	0.020	0.953	17	17
4/21/2004	0.186	0.023	1.264	12	12
5/13/2004	0.170	0.070	1.042	6	6
NURP Median EMC Data[1]					
	TP	**SRP**	**TN**	**TSS**	**VSS**
Residential	0.383	0.143		101	
Mixed	0.263	0.0 56		67	
Open/Non-urban	0.121	0.026		70	

[1] From EPA. *Results of the Nationwide Urban Runoff Program*. Water Planning Division, PB 84-185552, Washington, D.C. December 1983.
* These data were at or below detectable levels

TP = Total phosphorus
SRP = Soluble reactive phosphorus
TN = Total nitrogen
TSS = Total suspended solids
VSS = Volative suspended solids

Watershed Nutrient Modeling: The urban watershed model P-8 was used to predict the nutrient loads to Alimagnet Lake from its drainage area. The Canfield-Bachmann lake model was used to predict total phosphorus values in Alimagnet Lake based on the loads developed with P-8. The goal of the modeling effort was to:

a) reflect existing conditions as accurately as possible.
b) identify the critical watershed areas for management.
c) quantify the change in runoff water quality due to potential BMPs/improvements.
d) predict the resulting in-lake phosphorus levels as a result of BMP implementation.

The watershed modeling performed for this study was based on conditions measured in the year 2000. This was because the average in-lake total phosphorus (TP) concentration of 117 ppb for this year was closest to the long-term average as reported by the MPCA (120 ppb).

Nutrient loads were modeled for Alimagnet Lake drainage area. Modeling estimated that a total of 462 pounds of phosphorus were delivered to Alimagnet Lake from surface runoff, based on conditions for the year 2000. The total annual water load to Alimagnet Lake was calculated as

506 acre-feet. This value, together with the total phosphorus load, results in a flow weighted mean concentration (FWMC) of 336 ppb TP for runoff entering the lake. As a comparison, the average TP concentration for *minimally impacted* reference streams for this ecoregion is typically between 60 – 150 ppb. This reflects the inter-quartile range, comprised of the 25th to 75th percentile of reference values.

The majority (80%) of the nutrient load is from indirect drainage, which reflects runoff that is treated by a pond prior to entering the lake. Table 6 summarizes the drainage areas and phosphorus inputs for direct and indirect drainages.

Table 6. Summary of phosphorus inputs to Alimagnet Lake.

		Phosphorus Loads	
Watershed Area	**Acres**	**Total (lbs/yr)**	**Unit (lbs/ac/yr)**
Direct Drainage*	263	91	0.35
Indirect Drainage	722	371	0.51
Total Watershed	985	462	0.47

*Approximately 70% of the direct drainage is from developed shoreline areas while 30% is from undeveloped (park) areas

The existing watershed loading can also be expressed based on the outfalls that deliver stormwater to the lake. In this manner, outfalls that contribute a disproportionate amount to the overall total phosphorus load can be isolated. A summary of the identified outfalls and their respective phosphorus load is presented in Table 7. (Refer to Figure 3 for the location of the outfalls at the lake and the subwatersheds they drain.)

Table 7. Phosphorus load by outfall based on P-8 model.

Storm Sewer Outfall	Total Drainage Area (acres)	Total Phosphorus Load (lbs/yr)	Unit Phosphorus Load (lbs/acre/yr)
1	**288.6**	**158.8**	**0.55**
2	6.6	3.8	0.58
3	7.2	3.9	0.54
4	29.0	14.5	0.50
5	3.4	1.7	0.50
6	**187.4**	**130.6**	**0.70**
7	**256.6**	**93.9**	**0.37**
8	16.0	9.2	0.58
9	30.2	10.5	0.35
10	47.7	17.4	0.36
Developed Shoreline	32.1	9.3	0.29
Undeveloped Shoreline	80.3	7.9	0.10

Table 7 highlights (in bold) the total phosphorus loadings from outfalls 1, 6 and 7 which dominate the overall nutrient input to the lake from surface runoff. Together, these three outfalls capture almost 75% of drainage area to the lake and are responsible for 83% of the surface runoff phosphorus inputs to the lake. These three drainage areas are dominating the watershed impacts

to Alimagnet Lake. Focusing management efforts on these three drainage areas will yield the most effective approach to addressing water quality in Alimagnet Lake.

Storm Pond Evaluation: The P-8 watershed model predicts nutrient load reductions based on treatment provided by existing ponds. The surface areas of existing ponds were determined from aerial photographs. Cursory water depth data (bathymetry) was collected by City staff during the winter of 2003 for key stormwater ponds within the Alimagnet Lake watershed. City staff bored holes through ice to measure the depth from the ice surface to the pond bottom. Staff then estimated the ice surface elevation relative to the normal water level of the pond.

The water depth data was used to estimate isopleths, which are lines connecting depths of equal value. The isopleths indicate the pond morphometry, or shape of the pond bottom. Total pond volume and mean depths were then estimated from the morphometry and pond surface area. Of the eleven stormwater ponds that were evaluated for this study, the average mean depth equaled 1.8 feet. (Notes: The minimum mean depth considered acceptable for a stormwater treatment pond is at least 3 feet. Hourly rainfall data for the year 2000 was obtained from the National Weather Service (NWS) for the Minneapolis/St. Paul airport. This precipitation data was used in the P-8 model to simulate runoff conditions for the year 2000. The total depth of precipitation recorded for the year 2000 at the airport was 30.48 inches. This is very close to the 30-year normal of 29.41 inches recorded by the NWS at the airport.)

Stormwater ponds provide treatment for runoff that discharges at outfalls 1, 6, and 7. Three key ponds are in place immediately upstream of outfalls 1, 6 and 7. These ponds are identified as 1A, 6C and 7A in Figure 3. The efficiency of these three key ponds to remove nutrients is limited. This limitation is due to the large drainage area that each pond serves relative to the area of the pond. For ponds 1A and 7A, the efficiency is further limited by shallow conditions in the ponds. In fact, large sediment deltas were visually observed at these two ponds. Pond data and modeled phosphorus removal efficiency for the three key ponds are presented below in Table 8.

Table 8. Key stormwater pond data.

	Pond 1A	Pond 6C	Pond 7A
Surface Area (Acres)	3.46	3.24	0.81
Volume (Ac-Ft)	4.22	6.25	1.25
Mean Depth (Feet)	1.2	2.0	1.5
Drainage Area (Acres)	280	175	257
Ratio of Watershed:Pond Area*	81:1	54:1	317:1
Modeled Phosphorus Removal Efficiency**	28%	38%	16%

*Typical watershed:pond ratio for a NURP pond ranges about 15:1–20:1.
**Typical NURP pond phosphorus removal efficiency is about 50% – 60%.

As a result of the shallow conditions, coupled with the large drainage areas, the residence time within each pond is very short so it is unlikely that adequate settling of pollutants is attained. The ponds likely flush several times during even relatively small (about 1-inch) storm events. Last, the shallow depths and high degree of accumulated sediment suggests that during peak discharges, scour and re-suspension of settled pollutants is very likely to occur.

3. Lake Features

3.1. Lake Map and Lake Statistics

Alimagnet Lake is approximately 109 acres in size, with a watershed of 985 acres. The average depth of Alimagnet Lake is 5 feet with a maximum depth of 11.5 feet (source: MnDNR) (Table 9). A lake contour map is shown in Figure 6. Alimagnet Lake is surrounded by residential lots on the north end of the lake and abuts to City parks on the south end..

Figure 6. Alimagnet Lake, Dakota County, Minnesota.

Table 9. Alimagnet Lake Characteristics

Area (Lake):	109 acres (44.1 ha)
Mean depth:	5 feet (1.5 m)
Maximum depth:	11.5 feet (3.5 m)
Volume:	545 acre-feet (66.2 Ha-M)
Fetch (longest open water distance):	0.65 mile (1.1 km)
Watershed area (not including lake area):	985 acres (399 ha)
Watershed: Lake surface ratio	9 :1

3.2. Lake Sediment Status

Lake Sediment Collection: A lake soil survey was conducted on Alimagnet Lake in 2003 with two objectives: to characterize potential nuisance growth areas of curlyleaf pondweed and Eurasian watermilfoil and to characterize the mobile phosphorus content of the deep water sediments. Sediment sample locations are shown in Figure 7.

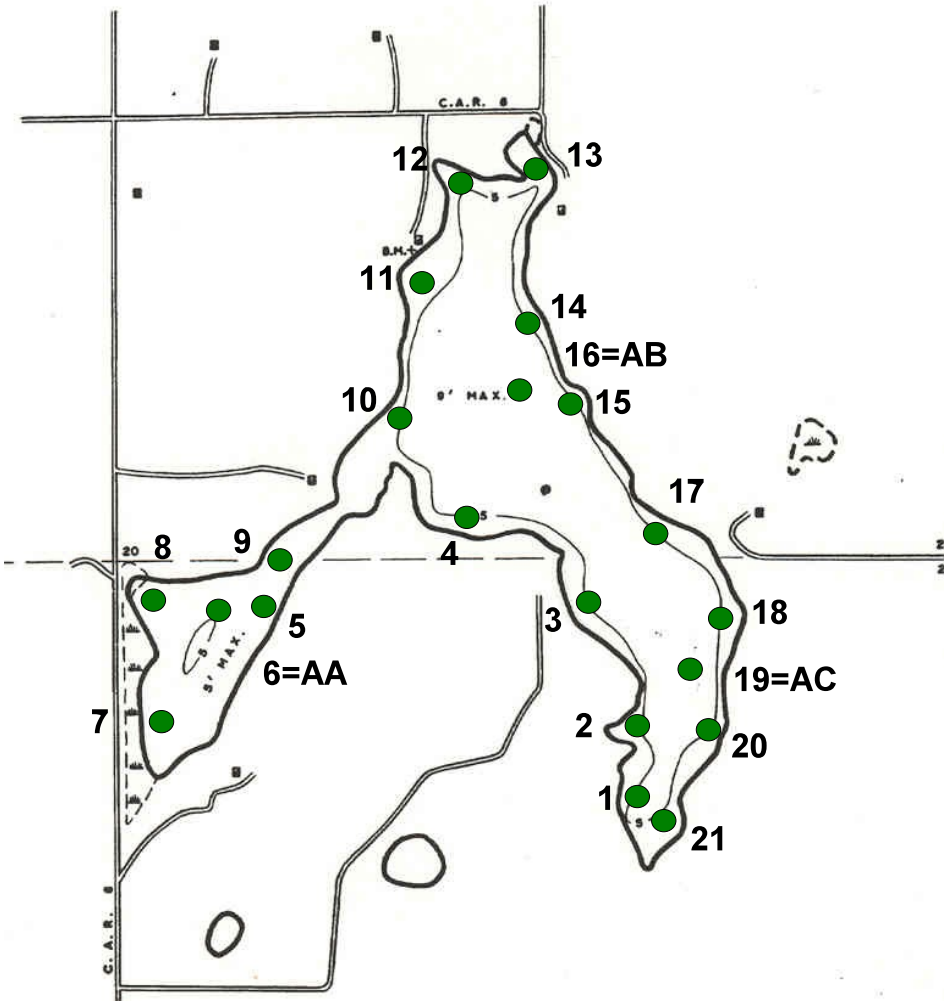


Figure 7. Lake sediment sample locations for the October 8, 2003 sediment survey.

A total of 21 lake sediment samples were collected in Alimagnet Lake from depths ranging from 2 to 10 feet on October 8, 2003. Samples were collected using a modified soil auger, 5.2 inches in diameter. Soils were sampled to a depth of 6 inches. The lake soil from the sampler was transferred to 1-gallon zip-lock bags and delivered to a soil testing laboratory.

At the lab, the littoral zone sediment samples were air dried at room temperature, crushed and sieved through a 2 mm mesh sieve. Sediment samples were analyzed using standard agricultural soil testing methods. Fifteen parameters were tested for each soil sample. A summary of extractants and procedures is shown in Table 10. Routine soil test results are given on a weight per volume basis as a dry bulk density (g/cm^3-dry).

Table 10. Soil testing extractants used by University of Minnesota Soils Laboratory. These are standard extractants used for routine soil tests by most Midwestern soil testing laboratories (reference: Western States Laboratory Proficiency Testing Program: Soil and Plant Analytical Methods, 1996-Version 3).

Parameter	Extractant
P-Bray	0.025M HCL in 0.03M NH_4F
P-Olsen	0.5M $NaHCO_3$
NH_4-N	2N KCL
K, Ca, Mg, Na	1N NH_4OA_c (ammonium acetate)
Fe, Mn, Zn, Cu	DTPA (diethylenetriamine pentaacetic acid)
B	Hot water
SO_4-S	$Ca(H_2PO_4)_2$
pH	water
Organic matter	Loss on ignition at 360°C

Figure 8. Soil auger used to collect lake sediments.

Deep water sediments were collected at three locations in Alimagnet Lake (locations are shown in Figure 7). Although Alimagnet Lake is only 11-feet at the deepest, there are areas from 6 to 10 feet where no plants grow. These are defined as deep water sediments for this study.

A phosphorus fractionation analysis was conducted as an initial step toward determining an alum dose that would be used to immobilize bioavailable sediment phosphorus. The phosphorus fractionation followed the methods of Rydin and Welch(1999) and was conducted by Brian Husar at the University of Minnesota. Several types of phosphorus fractions were tested and include: mobile-P, Al-P, Ca-P, organic P, and total P.

3.2.1. Littoral Zone Sediments

Results of the lake sediment analyses for Alimagnet Lake are listed in Table 11. It appears the lake sediments of Alimagnet Lake are relatively fertile based on sediment phosphorus and nitrogen concentrations. However, as is typical with other studies, high phosphorus does not always correlate with nuisance rooted aquatic plant growth.

Organic matter is relatively low in the lake sediments and several high phosphorus readings are found. The sediment pH ranges from 5.9 to 6.9 putting the sediments just into the acidic side.

Soil results indicate the lake soils are not polluted and are fairly representative of other lake sediments. Additional analysis were conducted on the littoral zone sediments using various sediment parameters to predict areas of curlyleaf and Eurasian watermilfoil nuisance growth. Those results are found in Section 3.6.1.

Figure 9. At five sediment sample locations, elodea was present. Here elodea is at a density of "4".

Table 11. Alimagnet Lake littoral zone sediment results from October 16, 2003. Results are in ug/cm^3 (which is similar to ppm) except for bulk density (g/cm^3), OM (organic matter in %), and pH (standard units).

Sample ID	Sediment Depth (ft)	Bulk density (dry) g/cm^3	NH_4 corrected	P_Bray corrected	P_Olsen corrected	K corrected	OM %	Ca corrected	Mg corrected	S corrected	Zn corrected	Cu corrected	Mn corrected	Fe corrected	B corrected	pH su	Bottom Characteristics
A 1	5.5	1.18	27.8	18.1	5.5	37	2.7	800	121	39	2.2	2.8	15.1	141	0.3	6.5 / 6.6	Sandy silt
A 2	6.5	0.71	66.4	9.0	6.0	52	15.8	1111	138	39	3.8	5.4	35.2	280	0.8	5.9	
A 3	6	1.13	17.4	14.5	4.8	45	2.9	746	106	16	1.9	1.8	36.2	199	0.4	6.2	
A 4	6	1.2	13.5	13.3	5.1	36	2.3	577	67	16	1.1	2.0	19.9	129	0.2	6.3	
A 5	5	1.16	26.8	14.8	11.8	87	2.0	994	165	20	1.3	4.9	50.6	276	0.4	6.6	Black organic muck - fine grain, organic
A 6	6	0.88	50.2	5.3	23.3	158	4.6	1338	250	40	1.9	6.8	95.5	447	0.6	6.2	Deep sample A. Black organic muck.
A 7	6	0.94	58.5	3.2	20.8	164	4.7	1680	348	53	4.4	13.5	36.6	357	0.5	6.7	
A 8	5	1.01	46.8	3.4	16.3	100	2.7	1424	224	54	2.3	13.5	25.3	276	0.3	6.9	
A 9	6	0.85	67.7	9.4	15.1	118	7.1	1277	205	17	3.4	5.4	85.8	388	0.7	6.1	
A 10	6	1.09	42.1	18.6	8.4	46	4.1	1084	172	66	3.3	8.2	18.3	218	0.5	6.6	Black muck
A 11	6.5	0.89	44.2	9.8	8.3	57	6.6	1273	142	61	2.3	9.5	35.4	266	0.5	6.6	Black muck
A 12	5	0.94	9.2	16.8	7.2	50	3.3	817	142	24	1.8	5.5	19.8	147	0.3	6.7	Muck 2-3 inches thick on top of sand
A 13	2	1.02	51.0	16.5	7.0	80	3.8	1281	218	70	4.1	11.9	15.7	182	0.4	6.8	Mucky
A 14	6.5	1.01	20.9	14.6	4.3	31	3.7	664	102	48	2.3	3.4	15.8	131	0.4	6.2	Black, peaty muck
A 15	6	1.29	10.6	14.3	4.4	26	1.3	399	58	18	1.4	1.8	9.9	110	0.2	6.2	Sand
A 16	10	0.75	67.8	12.1	8.9	99	22.0	1435	225	49	4.0	8.7	33.9	307	1.1	6.3	Deep sample B. Very soft sediments.
A 17	5	1.44	6.0	17.1	3.7	10	0.5	291	53	24	1.0	1.7	3.9	53	0.1	6.6	Greyish sand
A 18	8	0.66	34.2	8.5	4.5	23	10.4	689	66	19	2.0	4.0	17.7	173	0.6	6.0	Peaty sediment, different from other bag, more peat
A 19	10	0.70	81.8	11.4	7.8	78	34.1	1748	237	26	3.8	4.4	32.6	257	1.3	6.4	Deep sample C
A 20	8	0.78	53.5	9.9	5.3	33	12.2	824	120	36	2.9	9.3	21.6	219	0.9	6.0	Sand (middle of diffuser area)
A 21	8	0.38	52.2	5.5	3.6	19	34.2	499	58	7	1.0	1.5	22.9	129	0.8	6	(middle of bay)

3.2.2. Deep Water Sediments

The "deep" water sediment samples for Alimagnet Lake consist of a 6-foot deep sample in the west arm (AA and #6 -- split sample), a 10-foot deep sample in the central basin (AB and #12 – split sample), and a 10-foot deep sample in the east arm (AC and #19 -- split sample). The highest mobile phosphorus concentration was found in the west arm (Table 12) and overall, the highest total phosphorus concentration is also found in the west arm.

Sediment samples were split at the three sample sites and analyses were conducted using the Rydin and Welch fractionization and the conventional agricultural Bray and Olsen phosphorus tests. The Olsen-P test results correlate with the mobile-P results of the Rydin and Welch method.

Table 12. Alimagnet Lake deep water sediment results for three sites from October 16, 2003. Two types of tests were conducted on sediments from each of the three sites.

	AA (#6) (West Arm)	AB (#16) (Central basin)	AC (#19) (East Arm)
Water Depth (ft)	6	10	10
Rydin and Welch 1999 Sediment Analysis			
Water content (%)	58.1	84.7	91.0
Loss on ignition (%)	0.07	0.25	0.47
Organic (%)	6.9	25.5	47.1
Inorganic (%)	0.9	0.7	0.5
Bulk density (g/cm^3-wet)	1.02	1.02	1.03
Mobile-P (µg/cm^3-wet)	78.0	25.0	15.1
Al-P (µg/cm^3-wet)	54.9	7.5	4.7
Ca-P (µg/cm^3-wet)	54.4	24.8	13.9
Organic-P (µg/cm^3-wet)	73.7	49.3	30.4
Total-P (µg/cm^3-wet)	261.0	106.6	64.1
Agricultural Soil Test Results			
Loss on ignition (%)	4.6	22.0	34.1
Organic (%)	4.6	22.0	34.1
Inorganic (%)	95.4	78.0	65.9
Bulk density (g/cm^3-dry)	0.88	0.75	0.70
Bray-P (µg/cm^3-dry)	5.3	12.1	11.4
Olsen-P (µg/cm^3-dry)	23.3	8.9	7.8
pH	6.2	6.3	6.4

3.3. Dissolved Oxygen and Temperature

Dissolved oxygen concentrations for top and bottom water over the course of a year are shown in Figure 10. A profile was obtained each month from January through December, 1990 in conjunction with a Phase I study. Over the course of the summer there were periods when dissolved oxygen was depleted in the bottom water. Therefore, there is a potential for phosphorus to be released from the lake sediments.

Because Alimagnet Lake is relatively shallow, it appears the lake can mix over the summer. This is how phosphorus that is released from the lake sediments can be transported up into the water column.

Alimagnet Lake will weakly stratify. Thermally stratified means that the water column of the lake is segregated into different layers of water based on their temperature. Just as hot air rises because it is less dense than cold air, water near the surface that is warmed by the sun is less dense than the cooler water below it and it "floats" forming a layer called the *epilimnion*, or *mixed layer*. The water in the epilimnion is frequently mixed by the wind, so it is usually the same temperature and is saturated with oxygen.

Below this layer of warm, oxygenated surface water is a region called the *metalimnion*, or *thermocline* where water temperatures decrease precipitously with depth. Water in this layer is isolated from gas exchange with the atmosphere. The oxygen content of this layer usually declines with depth in a manner similar to the decrease in water temperature.

Below the thermocline is the layer of cold, dense water called the *hypolimnion*. This layer is completely cut off from exchange with the atmosphere and light levels are very low. So, once the lake stratifies in the summer, oxygen concentrations in the hypolimnion progressively decline due to the decomposition of plant and animal matter and respiration of benthic (bottom-dwelling) organisms.

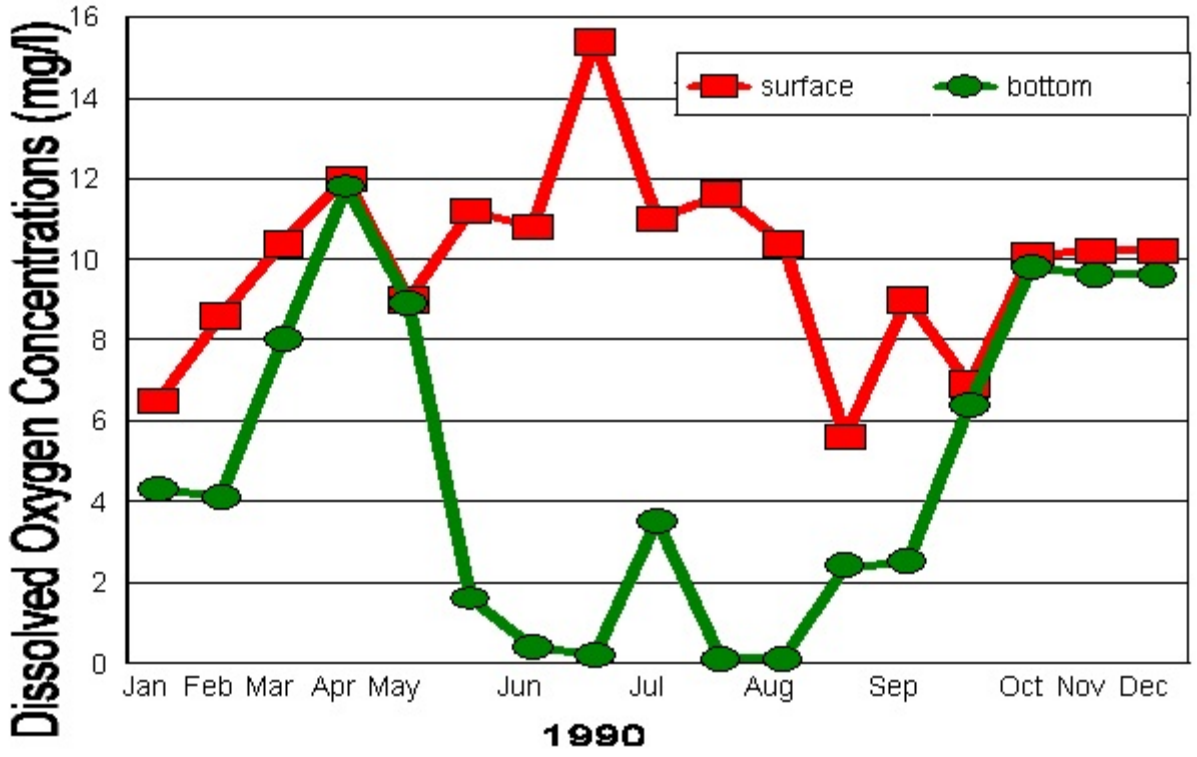


Figure 10. Monthly dissolved oxygen readings for top and bottom conditions for Alimagnet Lake in 1990.

In the past, winter dissolved oxygen levels were depleted in some years producing a winterkill condition. A winter aeration system was installed in the east arm of Alimagnet Lake in 2002.

Table 13. Winter dissolved oxygen measurements made by Jeff Kehrer, City of Apple Valley.

	Depth	Aeration Arm	Burnsville Arm
1/2/03	1 ft	11.6	12.5
	5 ft	10.9	12.0
2/5/03	2 ft	12.3	14.6
	6 ft	11.8	6.8
3/5/03			16.2 15.7

3.4. Lake Water Quality Summary

Three water quality parameters from CAMP sampling results are listed in Table 14. Viewing the results of Secchi disc summer averages from 1995 through 2003 indicates clarity has been declining since 1995 (Table 14). Phosphorus levels and chlorophyll a have been high since 1999. Overall, these three parameters indicate Alimagnet Lake is eutrophic.

Table 14. CAMP data for Secchi, total phosphorus, and chlorophyll a for Alimagnet Lake. The average is from May-September.

Secchi disc (m)

	May				June				July				August				September				October				Ave
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
2003	1			1		0.5	0.5			0.6/ 0.5		0.5		0.9		0.5			0.3		0.3			0.3	0.6
2002				0.8		0.6/ 0.5		0.3					0.5					0.5		0.5			0.5		0.6
2001	1		0.3				1		1				0.8			0.8			0.5			0.3			0.8
2000					1			0.5		0.5		0.4		0.4		0.5		0.5			0.3			0.8	0.5
1999	2	2.1				1		0.5		0.7		0.5		0.5		0.8				0.5		0.7			0.9
1998		2.2/ 2.0		1.8			1.8			0.9				0.5			0.5			0.5			0.5		1.1
1997		1	1.2	1		3.5		1.5				0.8				0.5		0.8		0.8	1.5				1.1
1996			1.3/ 1.3	2.2				1.8	1			0.5	0.6			0.5			0.8			1.2			1.1
1995	3		3		2.4	2.1	1.7		1.2	1.2		0.6	1		1				0.6						1.5

Total Phosphorus (ppb)

	May				June				July				August				September				October				Ave
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
2003	76			57		82	71			87/ 97		98		196		119			207		215			161	113
2002				81		120/ 112		86					140					135		145/ 137			96		142
2001	50		140				40		70				50			70			120			160			77
2000					80			130		130		180		110		130		120			110			60	125
1999	40	20				90		140		140		150		240		110				150		110			123
1998		30/ 30		40			70			60				150			110			80			140		82
1997		70	20	20		40		50				60				110		100		90	100				69
1996			50/ 60	50				40	70			150	150			140			100			70			90
1995	20		5		20	20	80		120	80		140	170		140				100						84

Chlorophyll a (ppb)

	May				June				July				August				September				October				Ave
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
2003				23		41	33			31/36		44		13		55			130		120			80	45
2002				9		22/34							54					67		59/64			31		46
2001	19		52				9		12				17			26			88			90			32
2000					26			102		97		57		22		30		32			50			23	52
1999	7					48		65		74		82		100		57				50		66			54
1998		7/5		12			14			26				67			71			26			44		29
1997		6	6	9		3		11				39				77		56		32	14				27
1996		13/4		4				1	42			51	27			77			41			30			29
1995	5		1		2	2	8		6	8		4	8		36				22						12

3.4.1. Secchi Disc Transparency

Secchi disc transparency, as characterized by summer averages, has fluctuated over the years of record, from 1975-2003 (Figure 11). The fluctuating seasonal average could represent the effect of occasional winterkills over the years.

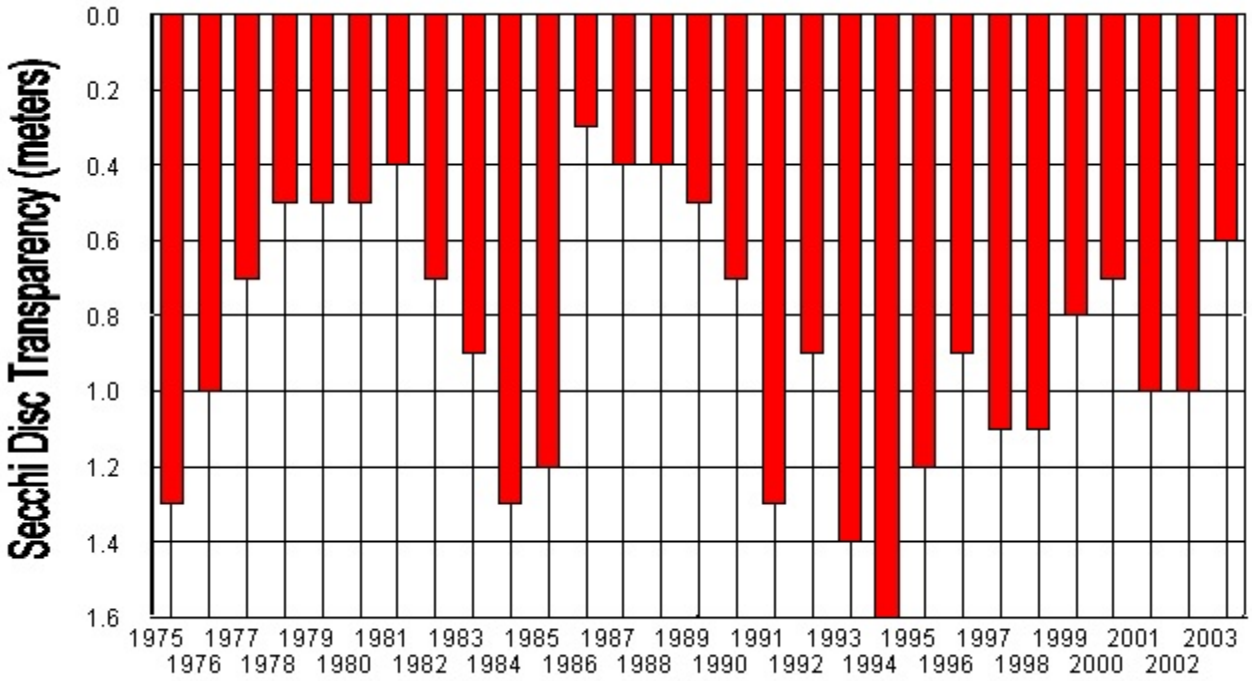


Figure 11. Summer average for Secchi disc readings from 1975-2003.

3.4.2. Total Phosphorus

Phosphorus is the nutrient most often associated with stimulating nuisance algae growth. Lake phosphorus concentrations for the summers of 1995 through 2003 are shown in Figure 12. Phosphorus concentrations in Alimagnet Lake in early summer are moderate. However, by the end of the summer they are high enough to produce significant algae blooms.

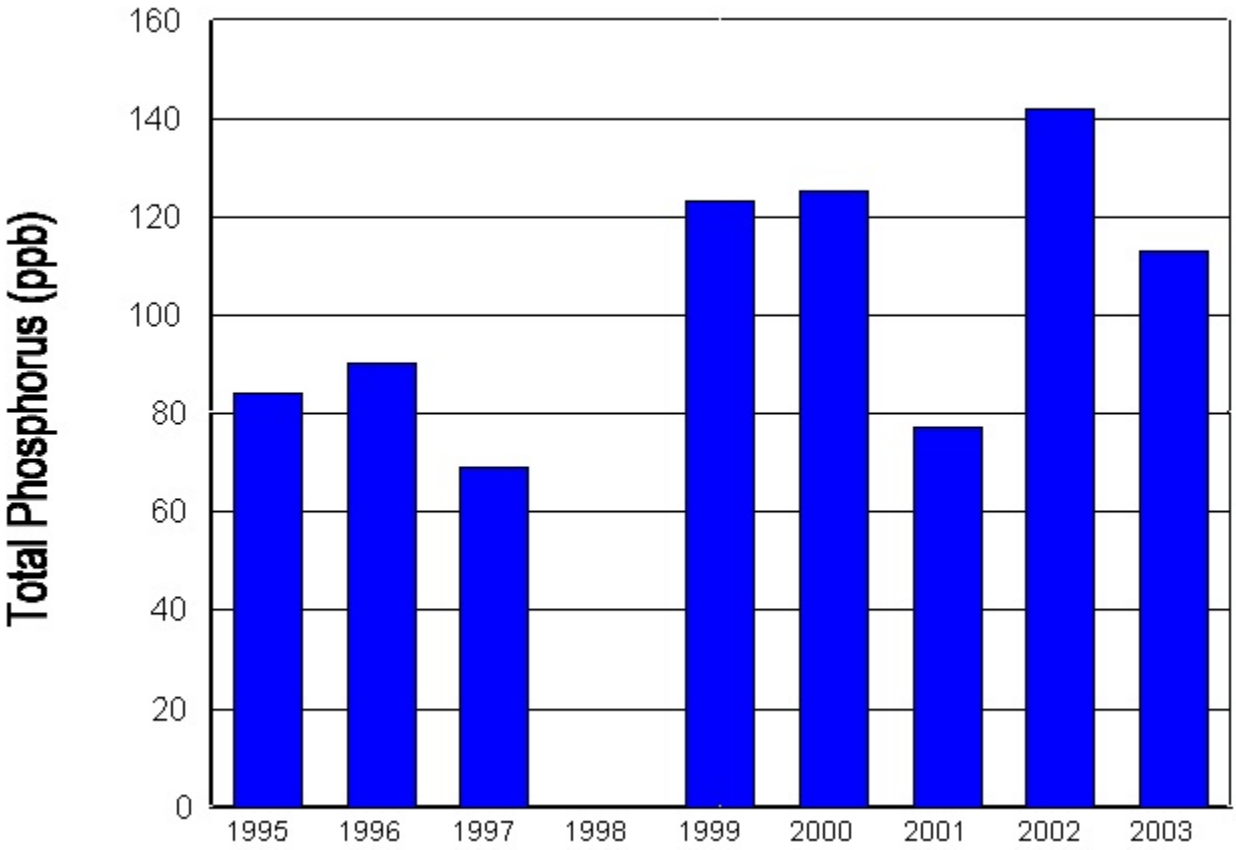


Figure 12. Surface total phosphorus concentrations from 1995 - 2003.

3.4.3. Chlorophyll and Algae

Algae are small green plants, often consisting of single cells or grouped together in filaments (strings of cells). Algae blooms are significant in Alimagnet Lake by the middle of the summer. The amount of algae can be characterized by measuring the chlorophyll content in lake water. Summer average chlorophyll results for 1995 through 2003 are shown in Figure 13. Chlorophyll levels are high and represent levels associated with a eutrophic lake.

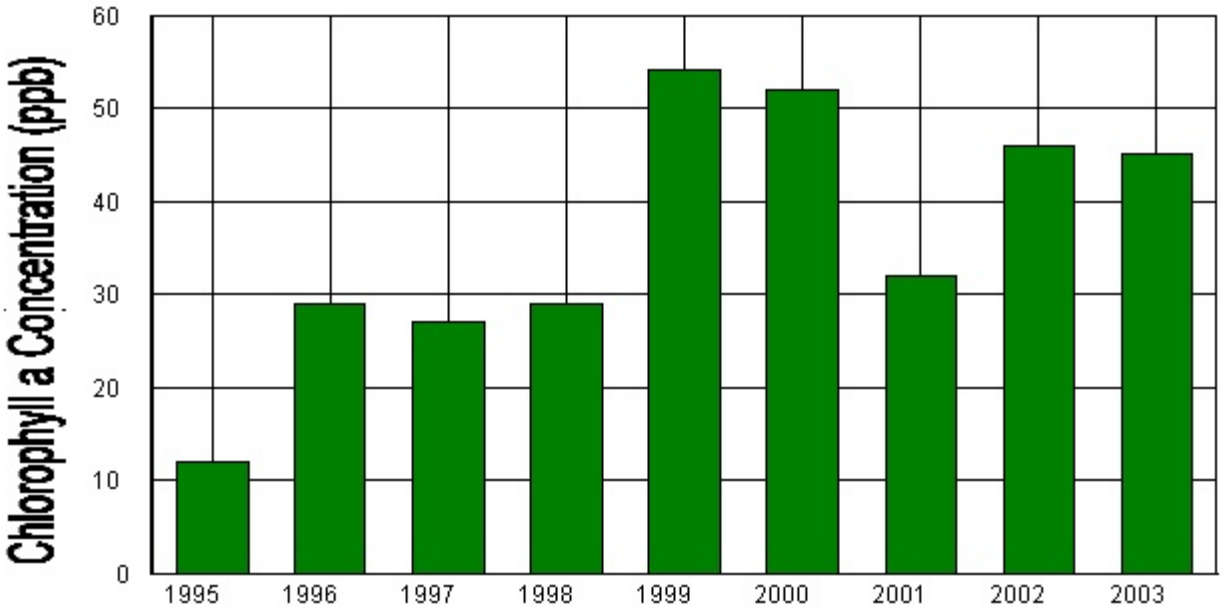


Figure 13. Annual chlorophyll concentrations in Alimagnet Lake from 1995 to 2003.

In mid to late summer, algae numbers increase and reduce transparency in Alimagnet Lake. The dominant late summer algal species in Alimagnet Lake in 2003 was *Microcystis* (Figure 14). This is a common bloom forming species in eutrophic lakes.

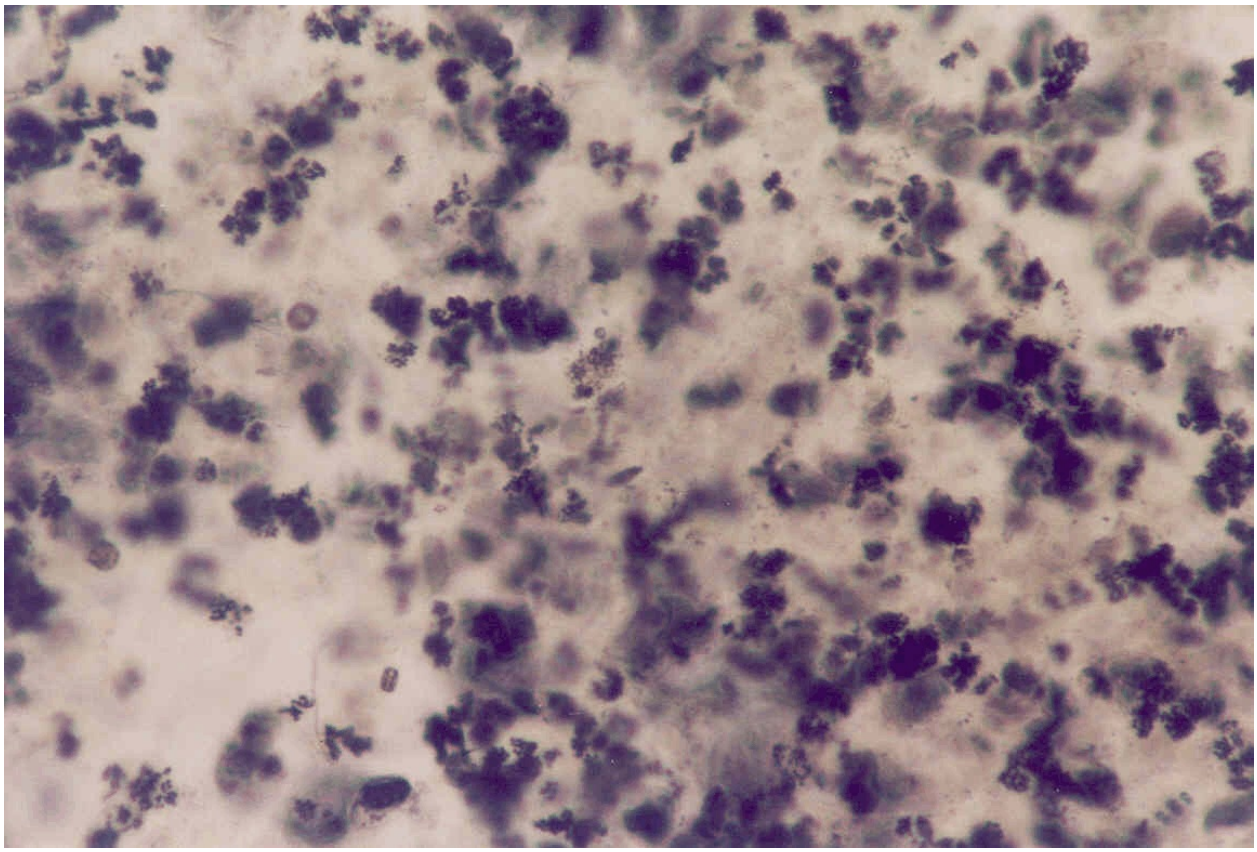


Figure 14. Blue-green algae from Alimagnet Lake in October 2003. *Microcystis*, a blue-green algae species, is the dominant blue-green species.

3.5. Zooplankton

Zooplankton are small crustaceans that can feed on algae. A variety of different zooplankton are commonly found in lakes. An example of a large-sized zooplankton species from Alimagnet Lake is shown in Figure 15. The zooplankton community in Alimagnet Lake is typical for shallow eutrophic lakes.

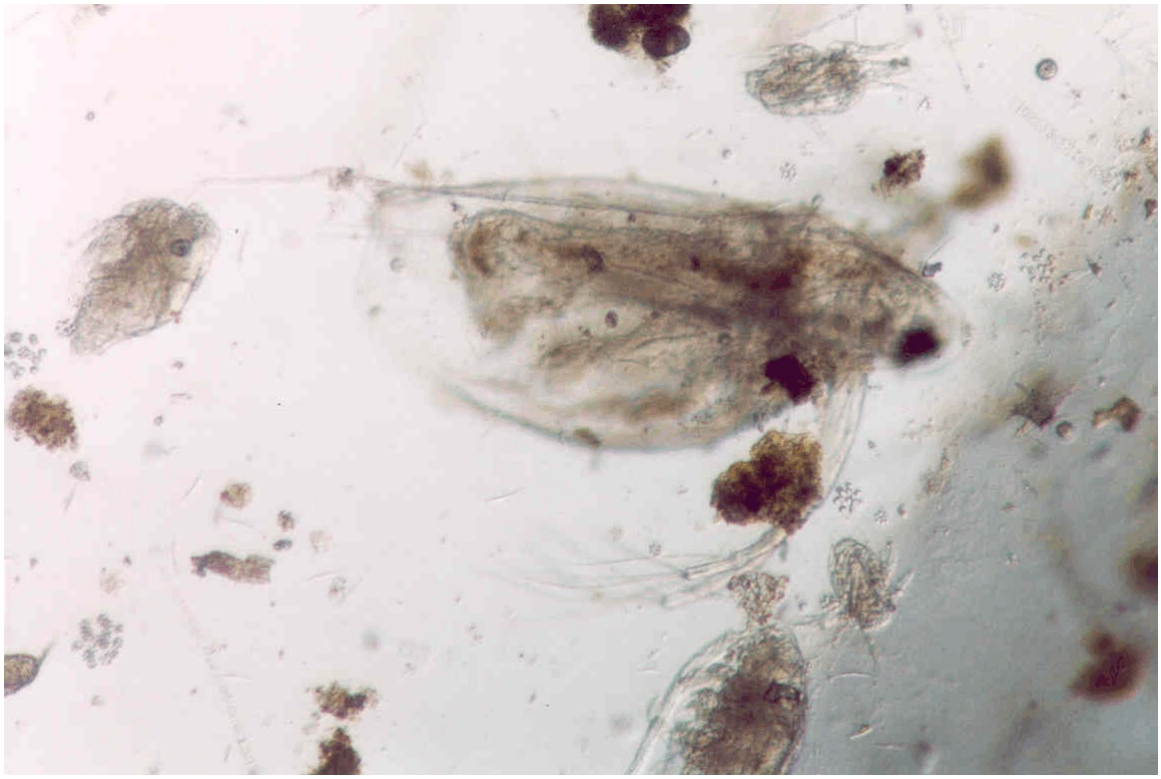


Figure 15. The animal in the middle of the picture is a *Daphnia*, a relatively large zooplankton (1-2 mm in length) that feeds on algae (daphnia is magnified 150x).

Zooplankton in Alimagnet Lake were sampled on three dates in 2003 and results are shown in Table 15. In many lakes, the big Daphnids are present in the early summer, but their numbers decline as the summer progresses. However, in Alimagnet Lake, large daphnids were still present in August. Large daphnids are desirable because they are efficient grazers on algae. Although large daphnids are found in late summer, algae blooms are still occurring. Daphnids are not very efficient grazers on colonial blue-green algae.

Table 15. Zooplankton counts for Alimagnet Lake in numbers per liter.

Date	5.16.03	8.6.03 East	8.6.03 West	10.8.03
Tow Depth (ft)	7	5	5	5
Cladoceran	692	325	185	233
Big Daphnids	23	102	34	21
Little Daphnids	6	113	32	13
Bosmina	358	38	97	144
Chydorus	305	72	22	55
Copepods	298	79	75	21
Calonoids	0	34	2	5
Cyclopoids	212	15	17	16
Nauplii	86	30	56	0
Rotifers	172	0	24	0
Total Zooplankton	1162	404	284	254

3.6. Aquatic plant status

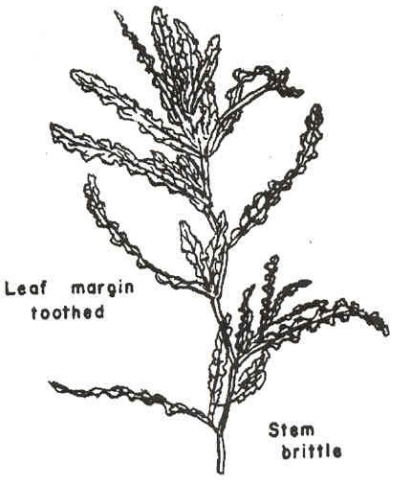
Aquatic plants are important to lakes. They act as nurseries for small fish, refuges for larger fish, and they help to keep the water clear. Currently, Alimagnet Lake has a low diversity of native aquatic plants. An exotic plant, curlyleaf pondweed, is found in Alimagnet Lake and can grow to nuisance conditions. The Lake Association has maintained a curlyleaf control program since 1996.

Aquatic plants were monitored on two occasions in 2003. A point intercept method was used and 100 sites were sampled. In the first survey, in early summer, the exotic species, curlyleaf pondweed was the most common plant encountered. In the second survey, later in the summer, the systematic plant survey found elodea was the most common plant.

In May of 2003, curlyleaf pondweed distribution was estimated to be at 60 acres (Figure 16). Of that coverage, roughly 40 acres grow to light nuisance conditions where the plant tops out at the lake surface but does not form a continuous canopy. The 60 acres of coverage is down from the 1996 estimate of 75 acres. The Alimagnet Lake Association has been uprooting curlyleaf pondweed using a unique cable system they developed starting in 1996. Curlyleaf is noticeably reduced in its nuisance coverage since the control program has been in effect.

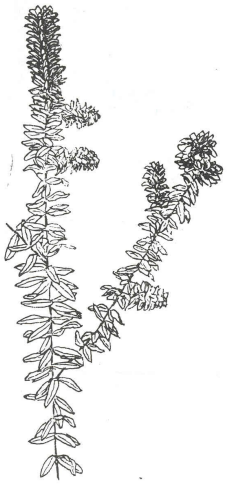
Line drawings of common Alimagnet Lake aquatic plants are shown below.

Curlyleaf pondweed



Curlyleaf pondweed (*Potamogeton crispus*) is an exotic plant found in Alimagnet Lake.

Elodea



Elodea (*Elodea canadensis*) is a native plant found in Alimagnet Lake.

Figure 16. Curlyleaf pondweed, present in May, dies back in mid summer. Shown above is curlyleaf in May, 2003 . It was just starting to resprout in the September 2003 survey.

Details of the Aquatic Plant Surveys: Aquatic plants were surveyed on May 16 and August 6, 2003 using 100 sample points on a grid system. The grid layout is shown in Figure 17. Aquatic plant results are summarized in Tables 16 through 19.

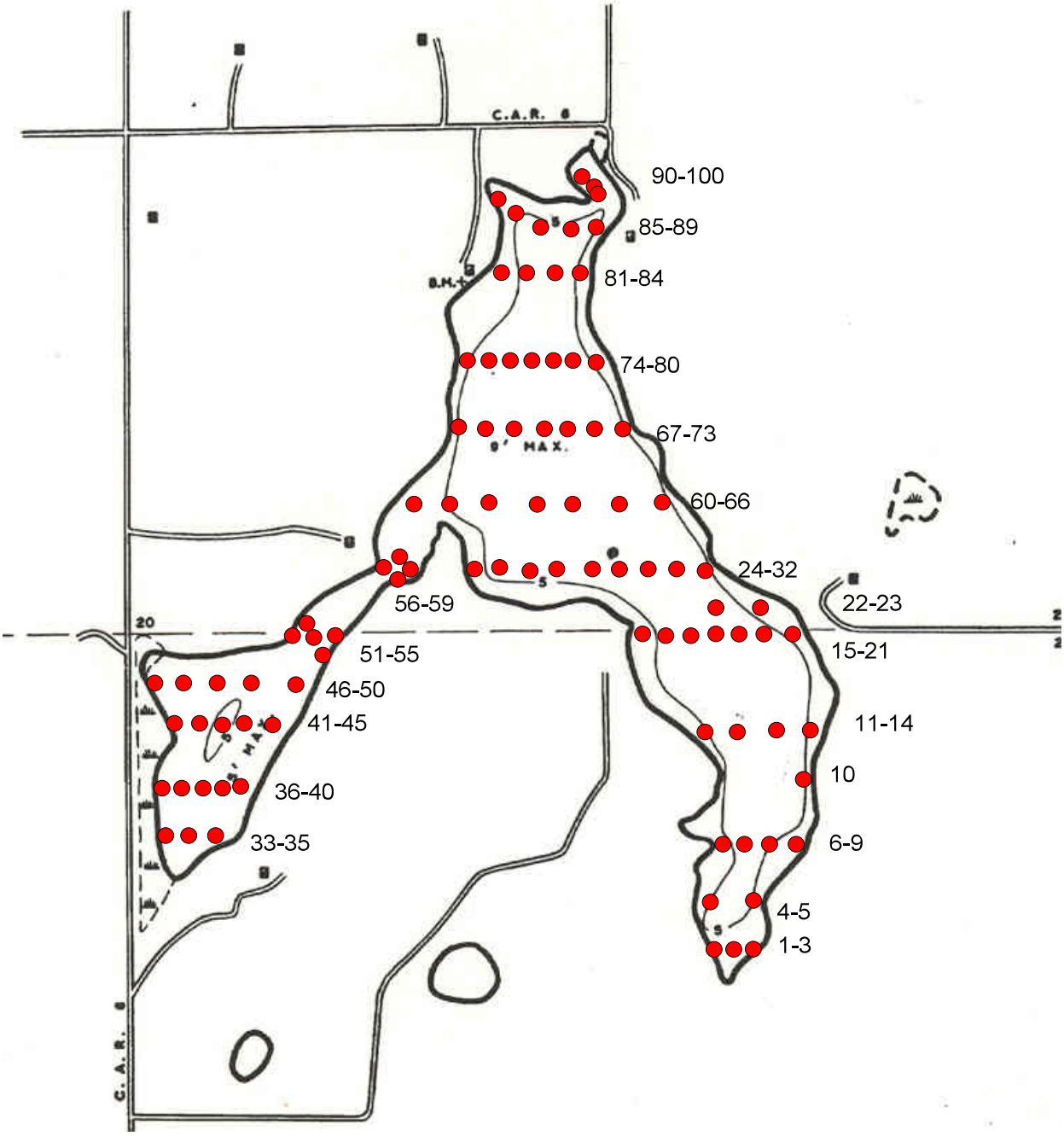


Figure 17. Stations used in the May and August 2003 aquatic plant surveys. Red dots show sample locations and numbers on the side indicate station sites.

Table 16. Alimagnet Lake aquatic plant occurrences and densities on May 16, 2003 at 100 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	All Stations (n= 100)		
	Occur	% Occur	Density
Elodea (*Elodea canadensis*)	30	30	1.4
Curlyleaf pondweed (*Potamogeton crispus*)	69	69	1.9

Table 17. Individual point-intercept data for Alimagnet Lake for May 16, 2003. Sample sites are shown in green. The number associated with the plants is a density rating on a scale from 1 to 5 with 5 the most dense.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Depth (ft)	1	3	3	8	8	4	9	8	3	8	3	11	9	4	3	11	11	11	10	6	4	3		8	9
Elodea (*Elodea canadensis*)						1																			
Curlyleaf pondweed (*Potamogeton crispus*)		2	1	2		2	1	3	2	2			3	2						3	2		1	1	

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Depth (ft)	11	10	10	7	9	7	5	3	5	5	5	7	7	6	4	5	8		6	4	5	6	4	7	5
Elodea (*Elodea canadensis*)								1	3	1	1	2	4		1	1		1	2		2	2		1	1
Curlyleaf pondweed (*Potamogeton crispus*)			1	1	1	1	2	1		1	1	1		2	1		2	3	5	5			3	2	2

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Depth (ft)	1	5	5	5	2	5	6	6	4	4	9	10	12	12	10	4	5	9	11	11	9	7	4	2	7
Elodea (*Elodea canadensis*)		1	3			1			1	1						1									
Curlyleaf pondweed (*Potamogeton crispus*)		4		1	1	1	4	4			2	1				2	1	1	1	1	2	3	4		2

	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Depth (ft)	9	9	9	8	3	2	7	9	4	5	5	7	7	7	2	4	4	4	3	2	3	3	3	3	4
Elodea (*Elodea canadensis*)					3				3						1		1		1		1	1	1	1	
Curlyleaf pondweed (*Potamogeton crispus*)	2	2	2	2			3	2	1	1	2	1	1	3	1	4	3	3	3	1	1				0.5

Table 18. Alimagnet Lake aquatic plant occurrences and densities on August 6, 2003 at 100 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	All Stations (n= 100)		
	Occur	% Occur	Density
Elodea (*Elodea canadensis*)	51	51	1.9
Nitella (*Nitella sp*)	1	1	0.5
Sago pondweed (*Stuckenia pectinata*)	2	2	0.8

Table 19. Individual point-intercept data for Alimagnet Lake for August 6, 2003.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Depth (ft)	3	4	3	5	4	4	8	8	4	4	3	8	6	3	3	7	8	9	9	7	4	5	6	4	7
Elodea (*Elodea canadensis*)	1			2	3	3			1													1			
Sago pondweed (*Stuckenia pectinata*)					1																				

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Depth (ft)	9	8	6	6	5	4		4	4	4	4	6	6	6	4	4	6	7		4	3	6	6	6	3
Elodea (*Elodea canadensis*)						1		3	2	2	3	3	5	3	1	2	3	5	5	3	2	5	4	3	1.5
Sago pondweed (*Stuckenia pectinata*)												1													

	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Depth (ft)	3	4	6	6	4	2	5	7	3	4	7	8	7	10	6	3	5	7	10	10	9	8	4	4	5
Elodea (*Elodea canadensis*)	3	1		3	5	1	1	1	2	1						1	1						1	1	1
Nitella (*Nitella sp*)									1																

	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Depth (ft)	9	10	9	9	4	4	8	6	4	5	5	7	6	5	3	2	2	3	3	2	2	2	2	3	3
Elodea (*Elodea canadensis*)					1	2				1				1	2	1		1	1	1	1	1		1	

Figure 18. Two common plants found in Alimagnet Lake are elodea (top) and curlyleaf pondweed (bottom). (Pictures taken in Alimagnet Lake in 1998 by Steve McComas).

3.6.1. Alimagnet Lake Soil Survey Used to Evaluate Potential Exotic Aquatic Plant Growth

The objective of the Alimagnet Lake soil fertility survey was to characterize Alimagnet soils in the littoral zone in order to better predict where nuisance areas of curlyleaf pondweed and milfoil growth could occur in the future.

Since 1994, lake soil testing methods have been evolving to help predict where the potential nuisance growth of curlyleaf pondweed and Eurasian watermilfoil could occur in a lake. Lake sediment testing results on over 30 lakes indicates that four sediment parameters can be used to predict nuisance growth of curlyleaf pondweed.

Based on other lake research, it appears that the potential nuisance growth of the exotic plant, curlyleaf pondweed, can be predicted in a lake based on several key sediment parameters. The four key parameters are: sediment bulk density, pH, organic matter, and the Fe:Mn sediment ratio. These parameters were analyzed in this Alimagnet study. Although this curlyleaf evaluation method is still experimental, it has correctly predicted heavy nuisance growth for several lakes in the Central Hardwood Forest Ecoregion (McComas, unpublished).

For Eurasian watermilfoil there are two key sediment parameters: nitrogen (as exchangeable ammonia) and organic matter content. Based on other lake research it is predicted that the combination of organic matter and high nitrogen values (as exchangeable ammonium) will sustain nuisance Eurasian watermilfoil growth in shallow water on an annual basis unless some other factor limits growth. Limiting factors include things such as herbicide use, milfoil weevils, light penetration, sediment density, and even lake bottom slopes. When lake bottoms have moderate fertility (less than 10 ppm of exchangeable nitrogen), it is predicted that potential nuisance growth could occur in some years, but not on a continuous basis.

Organic matter is another leading indicator for potential nuisance milfoil growth and this is probably because organic matter and nitrogen are related so when there is also high organic matter there is also high nitrogen. However, at high levels of organic matter (greater than 20%), Eurasian watermilfoil does not exhibit nuisance growth (Barko and Smart 1986; Barko et al 1991).

Based on the littoral zone sediment data, maps of predicted growth conditions for curlyleaf pondweed (present in Alimagnet) and Eurasian watermilfoil (not present at this time) have been prepared.

Predicting Areas of Nuisance Curlyleaf Pondweed Growth in Alimagnet Lake

Curlyleaf pondweed was first reported in Alimagnet Lake in the 1980s. It has produced nuisance growth through the 1990s. Lake sediment sampling indicates sediment fertility will support light nuisance growth throughout most of the lake covering an estimated 60 acres (Table 20). The Alimagnet Lake Association has conducted a curlyleaf control program since 1996. They have successfully been able to reduce the coverage of nuisance growth with their control program. If no control program was in place, it is expected most of the lake would sustain moderate nuisance growth on an annual basis.

Table 20. Alimagnet Lake sediment data and ratings for potential nuisance curlyleaf pondweed growth.

Sample ID	Bulk density (g/cm^3)	Organic Matter (%)	pH (su)	Fe:Mn Ratio	Potential for Nuisance Curlyleaf Pondweed Growth
non-nuisance	1.04	5	6.8 (6.7-6.9)	4.5 (2-5)	Low
light nuisance	0.94	11	6.2	5.9	Med
heavy nuisance	<0.51	>20	>7.7	<1.6	High
1	1.18	2.7	6.6	9.3	Medium
2	0.71	15.8	5.9	8.0	Medium
3	1.13	2.9	6.2	5.5	Medium
4	1.2	2.3	6.3	6.5	Medium
5	1.16	2.0	6.6	5.5	Medium
6	0.88	4.6	6.2	4.7	Medium
7	0.94	4.7	6.7	9.7	Medium
8	1.01	2.7	6.9	10.9	Low
9	0.85	7.1	6.1	4.5	Medium
10	1.09	4.1	6.6	11.9	Medium
11	0.89	6.6	6.6	7.5	Medium
12	0.94	3.3	6.7	7.4	Medium
13	1.02	3.8	6.8	11.5	Low
14	1.01	3.7	6.2	8.3	Medium
15	1.29	1.3	6.2	11.0	Medium
16	0.75	22.0	6.3	9.0	Medium
17	1.44	0.5	6.6	13.5	Medium
18	0.66	10.4	6.0	9.8	Medium
19	0.70	34.1	6.4	7.9	Medium
20	0.78	12.2	6.0	10.1	Medium
21	0.38	34.2	6.0	5.6	High

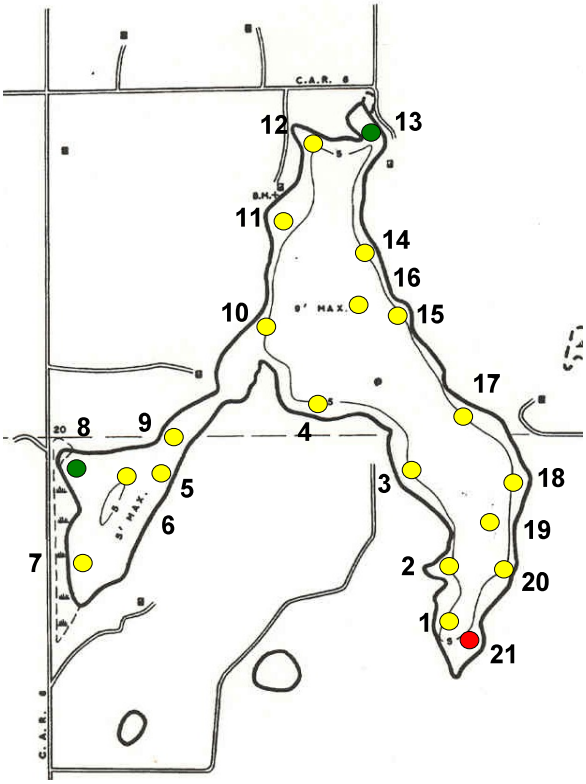


Figure 19. Areas that are predicted to support various types of curlyleaf pondweed growth are shown by colored dots. Green = non-nuisance, yellow = medium nuisance, and red = heavy nuisance.

Predicting Areas of Nuisance Eurasian Watermilfoil Growth in Alimagnet Lake

As of 2004, Eurasian watermilfoil has not been found in Alimagnet Lake. However, a question by lake residents has been what would happen if milfoil did invade Alimagnet Lake? Based on results from other studies conducted by Blue Water Science, there has been a correlation of sediment exchangeable ammonia concentrations over 10 ppm with nuisance growth of Eurasian watermilfoil. Using the 10 ppm threshold as a basis for prediction (Table 21), we have constructed a map showing the areas in Alimagnet Lake that have the potential to support nuisance milfoil growth (Figure 20). We predict that 51 acres of lake bottom could support matting EWM growth, if light penetration was not a limiting factor.

Table 21. Sediment depths at collection sites, sediment bulk density, sediment nitrogen, and occurrence of elodea for the sediment survey conducted on October 16, 2003.

Sample Number	Water Depth at Sample Location (ft)	NH_4 Based on Corrected Weight-Volume ($\mu g/cm^3$)	Organic Matter	Potential for Nuisance Eurasian Watermilfoil Growth
non-nuisance or light nuisance	--	<10	>20	Low (green) to Medium (yellow)
heavy nuisance	--	>10	<20	High (red)
1	5.5	27.8	2.7	High
2	6.5	66.4	15.8	High
3	6	17.4	2.9	High
4	6	13.5	2.3	High
5	5	26.8	2.0	High
6	6.5	50.2	4.6	High
7	6	58.5	4.7	High
8	5	46.8	2.7	High
9	6	67.7	7.1	High
10	6	42.1	4.1	High
11	6.5	44.2	6.6	High
12	5	9.2	3.3	High
13	2	51	3.8	High
14	6.5	20.9	3.7	High
15	6	10.6	1.3	High
16	10	67.8	22.0	Medium
17	5	6	0.5	High
18	8	34.2	10.4	High
19	10	81.8	34.1	Medium
20	8	53.5	12.2	High
21	8	52.2	34.2	Medium

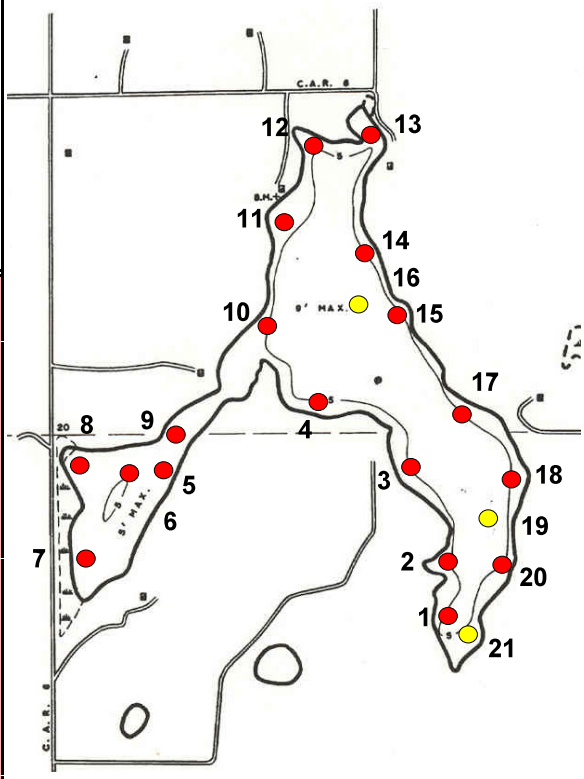


Figure 20. Areas that have the potential to support nuisance growth of Eurasian watermilfoil are shown with red dots. Areas of moderate growth are shown with yellow dots. Currently, Eurasian watermilfoil has not been found in Alimagnet Lake.

3.7. Fishery Status (prepared by MnDNR)

The fishery status of Alimagnet Lake has been summarized by the MnDNR.

Name: ALIMAGNET

Nearest Town: Apple Valley & Burnsville
Primary County: Dakota

Survey Date: 08/15/2000
Inventory Number: 19-0021-00

Lake Characteristics

Lake Area (acres): 109 (89 is also referenced)
Littoral Area (acres): 109
Maximum Depth (ft): 11.5
Water Clarity (ft): 3.00

Dominant Bottom Substrate : sand, rubble (3-10"), gravel
Abundance of Aquatic Plants : abundant
Maximum Depth of Plant Growth (ft): 5.00

Table 22. Fish sampled up to the 2000 survey year (MnDNR).

Species	Gear Used	Number of fish per net		Average Fish Weight (lbs)	Normal Range(lbs)
		Caught	Normal Range		
Black Bullhead	Gill net	177.5	9.6 - 91.4	0.07	0.2 - 0.5
	Trap net	83.8	2.2 - 60.5	0.09	0.2 - 0.5
Black Crappie	Gill net	26.5	1.5 - 14.7	0.10	0.1 - 0.3
	Trap net	4.6	2.4 - 15.1	0.14	0.2 - 0.4
Bluegill	Trap net	3.9	1.9 - 29.5	0.18	0.2 - 0.3
Largemouth Bass	Gill net	0.5	0.5 - 1.0	0.99	0.2 - 1.5
	Trap net	0.5	0.3 - 1.2	2.53	0.4 - 1.2
Northern Pike	Gill net	17.5	1.5 - 7.0	2.53	1.5 - 3.4
	Trap net	3.9	N/A - N/A	2.21	N/A - N/A
Pumpkinseed Sunfish	Gill net	0.5	N/A - N/A	0.06	N/A - N/A
	Trap net	0.3	0.8 - 8.4	0.06	0.1 - 0.2
Walleye	Trap net	0.3	0.4 - 1.9	2.50	0.6 - 2.6
Yellow Bullhead	Trap net	0.1	0.8 - 6.2	0.80	0.4 - 0.7
Yellow Perch	Gill net	1.0	3.0 - 26.5	0.08	0.1 - 0.3

Normal Ranges represent typical catches for lakes with similar physical and chemical characteristics.

Table 23. Length of selected species sampled for all gear for the 2000 survey year (MnDNR).

Species	Number of fish caught in each category (inches)								
	0-5	6-8	9-11	12-14	15-19	20-24	25-29	>29	Total
Black Bullhead	148	45	3	0	0	0	0	0	196
Black Crappie	75	11	4	0	0	0	0	0	90
Bluegill	9	22	0	0	0	0	0	0	31
Largemouth Bass	0	0	0	3	2	0	0	0	5
Northern Pike	0	0	0	0	7	46	6	2	61
Pumpkinseed Sunfish	3	0	0	0	0	0	0	0	3
Walleye	0	0	0	0	2	0	0	0	2
Yellow Bullhead	0	0	1	0	0	0	0	0	1
Yellow Perch	2	0	0	0	0	0	0	0	2

Fish Consumption Advisory

Meal Advice for Pregnant Women, Women who may become pregnant and Children under age 15

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Black Bullhead	◔	■	■	■	■
Bluegill Sunfish	◔	■	■	■	■

Meal Advice for the General Population

Species	less than 15"	15" to 20"	20" to 25"	25" to 30"	greater than 30"
Black Bullhead	○	■	■	■	■
Bluegill Sunfish	◔	■	■	■	■

Symbol Key	unlimited	1 meal per week	1 meal per month	1 meal every 2 months	do not eat
Mercury	○	◔	◑	■	●
PCBs	□	◸	◹	◥	■

Status of the Fishery (as of 08/15/2000)

Alimagnet offers shore fishing and canoe/light boat fishing from a carry-in access in the soutwest corner of the lake. Black bullhead was the most abundant species sampled, with most between 5 and 6 inches. Northern pike were also abundant. Northern pike up to 35 inches were sampled and lengths averaged 23 inches. Black crappie were abundant. Most black crappies between 5 and 6.5 inches, but a group of 9.5 to 11.5 inch fish was also sampled. Bluegill abundance was low, with an average length of 6.2 inches, but none were over 7 inches. Largemouth bass appear to be at moderate to low abundance, with fish between 13 and 18 inches. Two 19 inch walleye were sampled. These have not previously been sampled in the lake, and were most likely the result of a citizen introduction. Yellow perch abundance was low, with most fish between 5.5 and 6 inches.

3.8. In-Lake Nutrient Load Estimates

When evaluating lake water quality and then formulating improvement projects it is important to know where excessive phosphorus is coming from. Watershed nutrient inputs were described in Section 2.3. However there are additional nutrient inputs from within the lake itself.

Additional sources of in-lake nutrients that contribute to Alimagnet Lake algae blooms are from the die back activities of curlyleaf pondweed, from phosphorus release from the lake sediments, and from roughfish activities.

From curlyleaf research conducted by Steve McComas (unpublished) a reasonable phosphorus load from the dieback of curlyleaf pondweed is 2-3 pounds of phosphorus per acre of curlyleaf. Since there are about 60 acres of curlyleaf in Alimagnet Lake, the phosphorus contribution from curlyleaf pondweed dieback could be up to 120-180 pounds per year. However, with curlyleaf management, curlyleaf biomass is reduced and curlyleaf dieback probably contributes less than 180 pounds/year.

The phosphorus loading from the lake sediments is estimated based on a typical phosphorus release rate of 4 mg-P/m^2/day for 100 days. The lake sediment phosphorus release estimated is up to 300 pounds/year. The 300 pounds was checked by back calculating the overall phosphorus load from a lake model that used a lake phosphorus concentration of 113 ppb.

It is suspected, but not confirmed, that there are excessive numbers of black bullheads in Alimagnet Lake. A fish survey would help quantify the bullhead density. The last survey was conducted in 2000. Since then, winter aeration has been established and the bullhead population may have increased. For estimating in-lake nutrient loads, the roughfish impacts and their potential nutrient loading are combined into the lake sediment phosphorus release component until more information is acquired.

The total annual in-lake phosphorus load could be up to 480 pounds. This sediment input is equivalent to 610 mg of phosphorus per $meter^2$ of lake bottom per year or 6 mg-P/m^2/day for 100 days. That is a rate within known lake phosphorus release rates.

4. Lake and Watershed Assessment

4.1. Alimagnet Lake Status

The status of Alimagnet Lake is eutrophic meaning it has high fertility. Alimagnet has higher phosphorus concentrations than many other lakes in the Twin City metropolitan area. One way to compare the status of Alimagnet Lake is to compare it to other lakes in a similar setting or ecoregion.

Ecoregions are geographic regions that have similar geology, soils, and land use. The continental United States has been divided into 84 ecoregions, and there are seven ecoregions in Minnesota. A map of Minnesota ecoregions is shown in Figure 21. Alimagnet Lake is in the North Central Hardwood Forest ecoregion but close to the Western Corn Belt Plains ecoregion (Figure 21). Lakes in this area of the state are moderately fertile and have slightly eutrophic water quality values. A range of ecoregion values for lakes in the two ecoregions along with actual Alimagnet Lake data are shown in Table 24.

Table 24. Summer average quality characteristics for lakes in the Northern Lakes and Forest ecoregion (Minnesota Pollution Control Agency, 1988).

Parameter	Western Corn Belt Plains	North Central Hardwood Forest	Alimagnet (2003)
Total phosphorus (ug/l) - top	65-150	23-50	113
Algae [as Chlorophyll (ug/l)]	30-80	5-22	45
Chlorophyll - max (ug/l)	60-140	7-37	130
Secchi disc (ft)	1.6-3.3	4.9-10.5	2.0

These comparisons indicate that the water quality of Alimagnet Lake are out of range compared to the North Central Hardwood Forest ecoregion water quality values. The challenge will be to bring water quality values within ecoregion ranges.

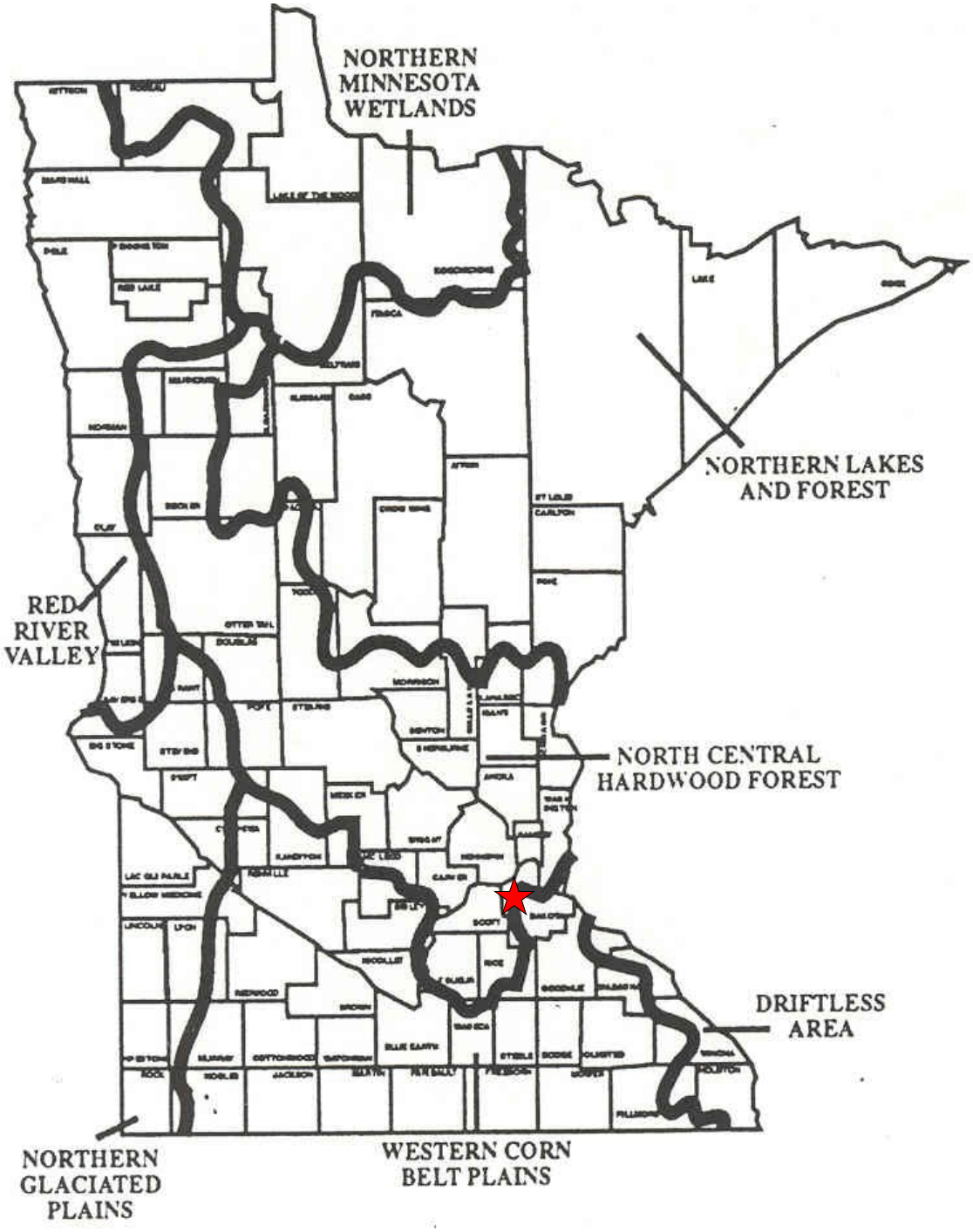


Figure 21. Ecoregion map for Minnesota. Alimagnet Lake, located in central Dakota County is officially in the Central Hardwood Forest Ecoregion but close to the Western Corn Belt Plains Ecoregion.

4.2. Alimagnet Lake Nutrient Budget

Based on North Central Hardwood Forest Ecoregion ranges, Alimagnet Lake has been found to have phosphorus levels higher than expected for a lake in this ecoregion.

The reason for the high lake phosphorus concentration is due to the amount of phosphorus coming into Alimagnet Lake. A summary of estimated phosphorus loads from a variety of sources is shown in Figure 22. A total annual phosphorus load of 600 pounds of phosphorus is estimated based on a lake phosphorus concentration of 113 ppb (2003 May-September average). Watershed runoff appears to be the biggest nutrient contributor.

The actual amount of phosphorus loading from the watershed and from lake sources varies from year to year. The amount of rainfall for a year will affect the watershed loading and weather factors will also effect phosphorus release from lake sediments as well as from curlyleaf pondweed dieback. The influence of the roughfish population could be significant, but the fishery status is unknown at this time.

Total estimated load: 600 pounds of phosphorus per year (272 kg-P/yr)

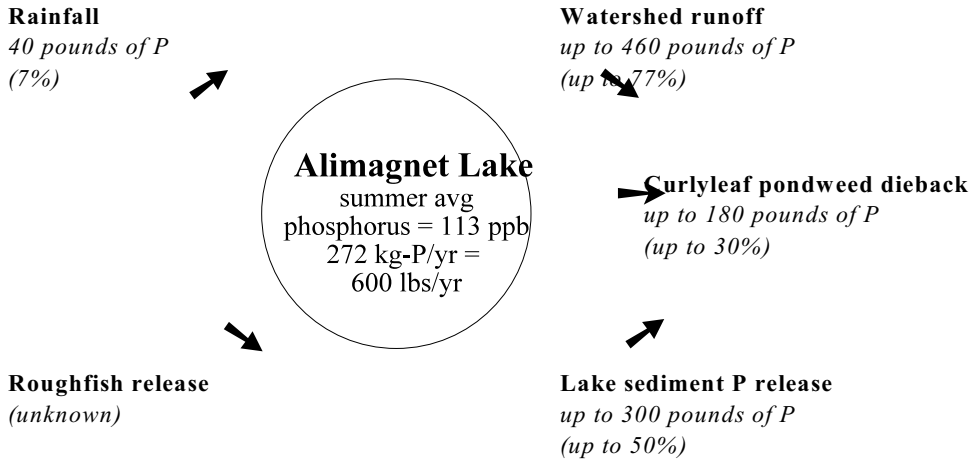


Figure 22. Estimated annual phosphorus loads to Alimagnet Lake.

Evaluating Lake Phosphorus Goals: Based on lake modeling considerations (using the MNLEAP model) it appears Alimagnet Lake has the potential for better water quality conditions.

The proposed water quality goal for lake phosphorus is 54 ppb which would produce a Secchi disc clarity of 1.2 m (4.0 ft). This goal is based on NCHF ecoregion model of 150 P-ppb in runoff (Table 25). The key to reaching this lake phosphorus goal will be to reduce both watershed and internal lake phosphorus loading. It appears a significant decrease in phosphorus loading is needed, with an estimated annual phosphorus reduction of around 400 pounds of phosphorus to achieve the water quality goal. An annual phosphorus loading of 200 pounds per year is the lake phosphorus loading goal.

An earlier water quality goal for Alimagnet Lake was 1.7 m (5.6 ft). However, lake model results indicated a flow weighted mean concentration (FWMC) of 85 ppb would be necessary to achieve a 1.7 m seasonal average Secchi disc. The lake phosphorus concentration would be 37 ppb. Because the FWMC needed to meet the 1.7 m clarity objective is far less than the ecoregion FWMC of 150 ppb, the new goal was reset at the ecoregion FWMC of 150 which should result in a Secchi disc average of 1.2 m.

Table 25. Phosphorus loading and lake phosphorus concentrations for existing conditions and modeled conditions.

	Phosphorus Load (lbs/yr)	Lake P-conc	Comments
Existing Conditions 2003 Observed (assume typical watershed and in-lake loads under existing conditions)	600 (estimated from lake P-conc)	113	Total phosphorus load was determined from running a lake model with 113 ppb as the lake concentration. It would take 600 pounds of phosphorus per year to produce an observed lake phosphorus concentration of 113 ppb.
Watershed Inputs at 336 ppb-FWMC* (conditions in 2000 based on P-8 model, no internal load)	460	91	Estimated watershed phosphorus input under current conditions (using the 2000 year conditions) is 460 pounds of P/yr using the P-8 model. This would produce a lake phosphorus concentration of 91 ppb. Since the lake is observed to have a higher phosphorus concentration in some years it is likely that internal sources are a contributor.
Watershed inputs at 161 ppb-FWMC (external load only based on P-8 model using best practical watershed management practices)	240	58	Estimated watershed phosphorus input with best practical management practices implemented using the P-8 model. Also, it is assumed internal P loading is minimal.
Watershed Inputs at Ecoregion Runoff Values of 150 ppb - FWMC includes low level of internal loading	200	54	At an ecoregion runoff concentration of 150 ppb, the predicted lake phosphorus concentration is 54 ppb. This is about as low of a lake phosphorus concentration that could be expected. The lake model includes a low level of internal loading plus extra water quality benefits are assumed from establishing a thriving native aquatic plant community.

* FWMC = flow weighted mean concentration

4.3. Setting Water Quality Goals for Alimagnet Lake

Water quality in Alimagnet Lake has the potential to be better. Lake models were run to help determine feasible water quality goals for Alimagnet Lake. A lake model is a mathematical equation that uses phosphorus inputs along with lake and watershed characteristics to predict what a lake phosphorus concentration should be. Once a lake phosphorus concentration is determined, then seasonal water clarity and algae concentrations can be calculated as well.

Several lake models were run based on nutrient inputs using the Canfield-Bachmann natural lake model. Lake model runs were conducted for existing watershed runoff conditions (using a flow weighted mean concentrations of 336 ppb-P), predicted watershed runoff after watershed practices are implemented (FWMC 184 ppb-P), and for an ecoregion FWMC runoff P-concentration of 150 ppb. The existing observed conditions for lake phosphorus, chlorophyll a, and Secchi depth are shown in red bars (Figures 23 and 24). Existing conditions are assumed to be dictated by an estimated phosphorus loading of 600 lbs/yr. The estimated phosphorus load for existing conditions was back-calculated for Alimagnet Lake based on a lake concentration of 113 ppb. The 113 ppb-P lake concentration was the summer average for 2003.

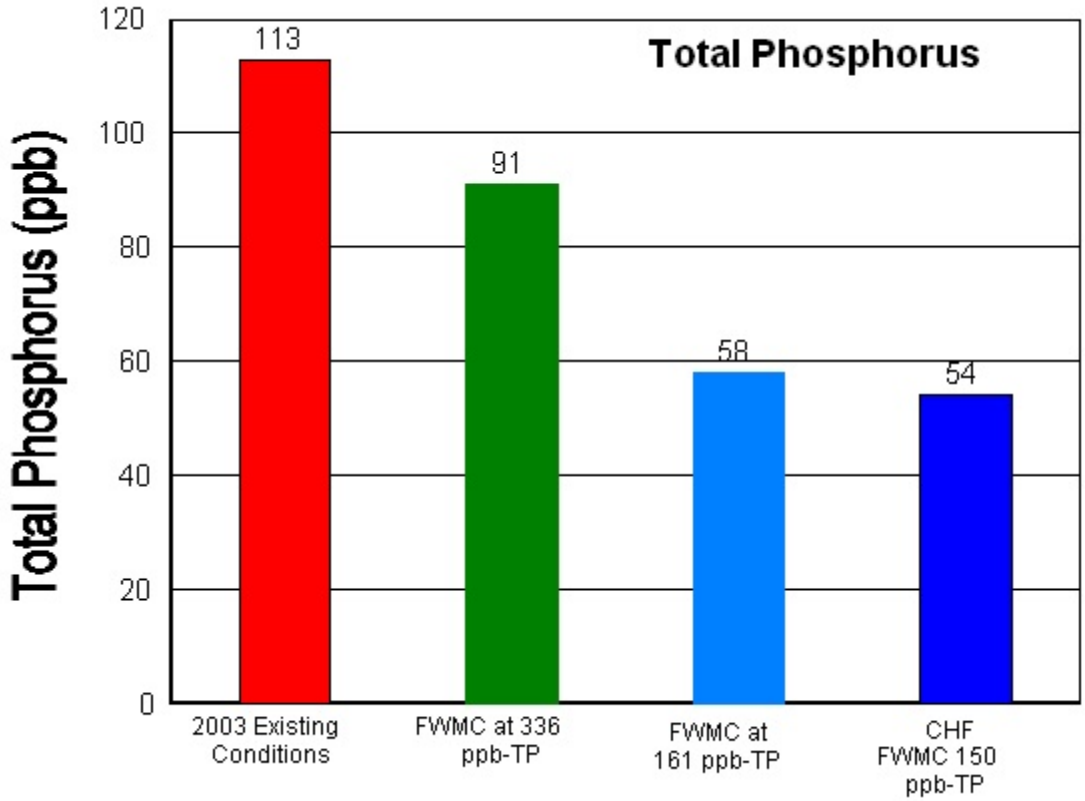


Figure 23. Comparison of total phosphorus concentration for Alimagnet Lake in 2003 to lake phosphorus concentrations based on estimated concentrations for a watershed runoff flow weighted mean concentration (FWMC) of 336 ppb-phosphorus (current watershed runoff conditions), for a watershed runoff FWMC of 161 ppb-P (predicted after watershed practices are implemented) and for a lake with a watershed the size of Alimagnet Lake situated in the Central Hardwood Forest (CHF) with a phosphorus runoff concentration of 150 ppb.

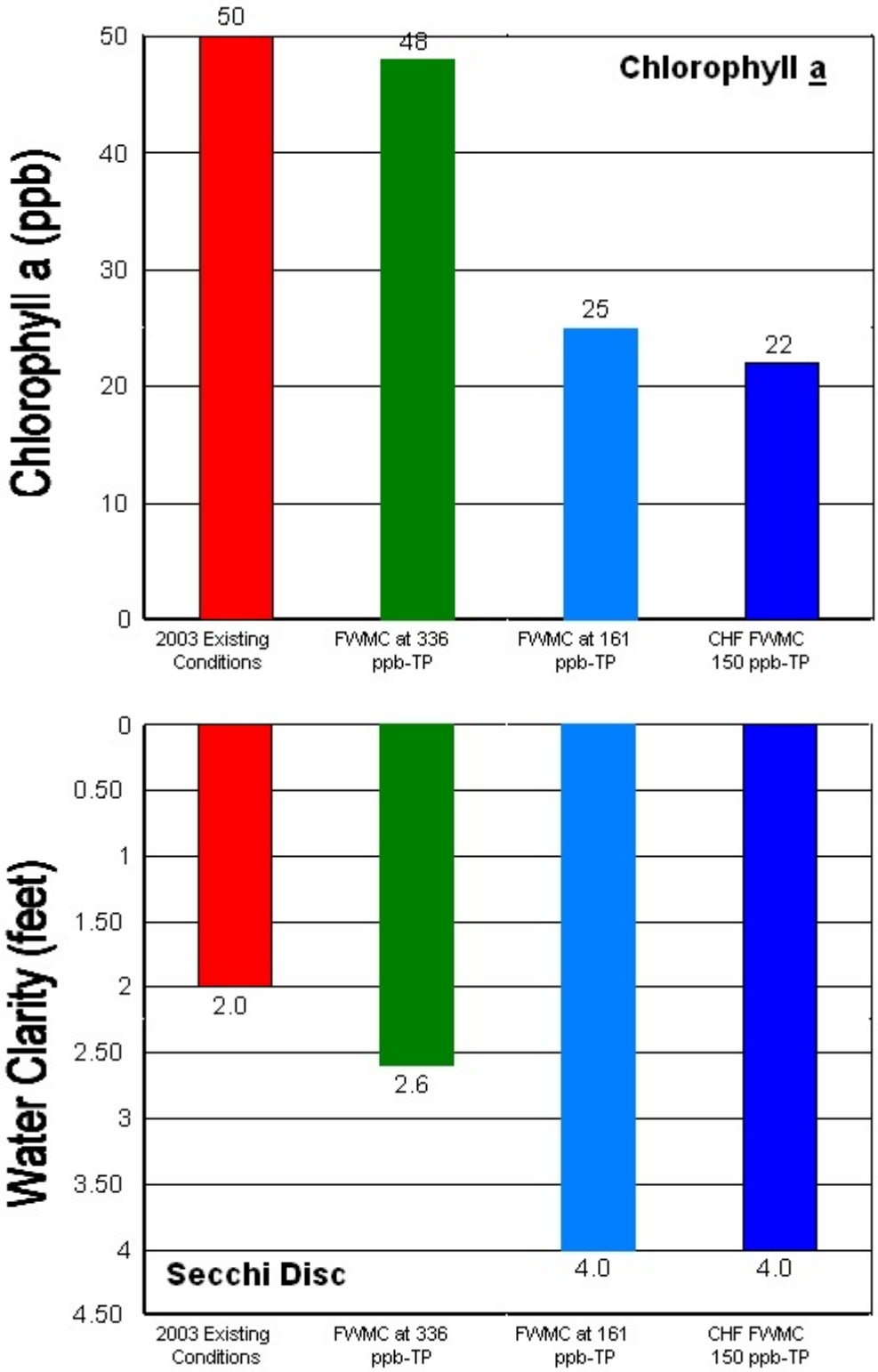


Figure 24. Comparison of chlorophyll a concentration (top) and water clarity (bottom) for Alimagnet Lake in 2003 to predicted lake chlorophyll concentrations and clarity for a watershed runoff flow weighted mean concentration (FWMC) of 336 ppb-phosphorus (current watershed runoff conditions), for a watershed runoff FWMC of 161 ppb-P (predicted after watershed practices are implemented) and for a lake with a watershed the size of Alimagnet Lake situated in the Central Hardwood Forest (CHF) with a phosphorus runoff concentration of 150 ppb.

If watershed phosphorus loading is reduced to a ecoregion estimate of 200 pounds of phosphorus per year (watershed runoff FWMC of 150 ppb), there will be a noticeable improvement in water clarity in Alimagnet Lake. Under current conditions, the number of days of algae blooms (water clarity of 3 feet or less) found in the lake can be up to 90% of the summer. In the future, after implementation of projects, with an average lake phosphorus concentration down to 60 ppb or less, the number of days with algae blooms should be around 40% (60 days) of the summer or less (Figure 25).

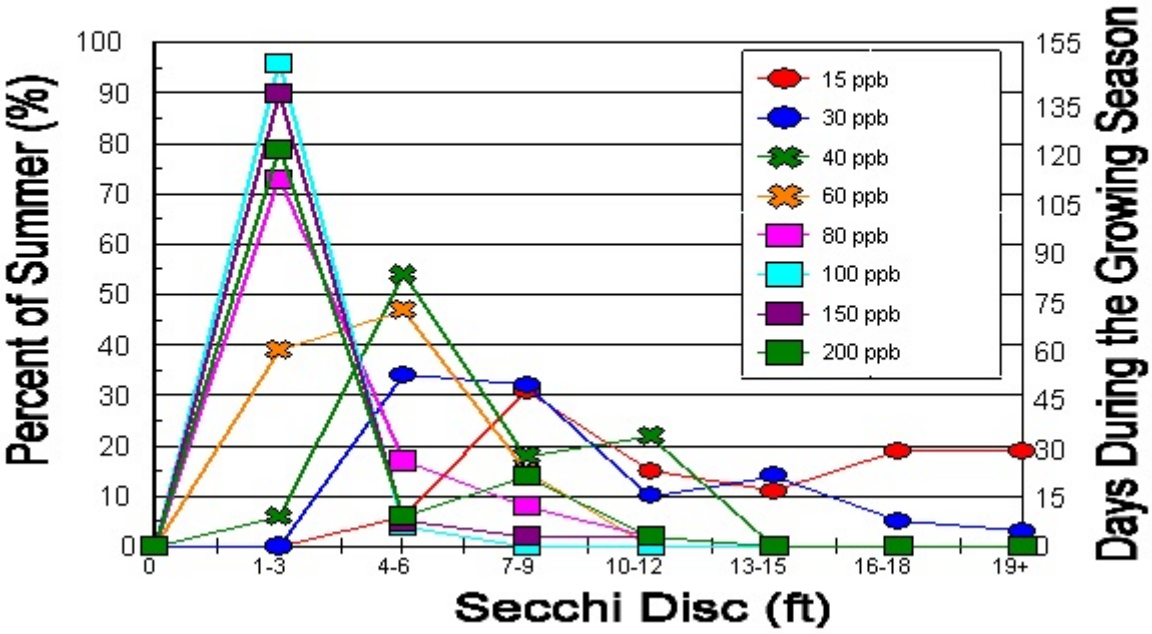


Figure 25. Estimated Alimagnet Lake water clarity potential based on a summer average phosphorus concentration. The percent of the summer with an algae bloom (Secchi disc of 3 feet or less) is high with a summer average of 100 ppb. Algae bloom occurrence drops significantly if the summer lake phosphorus average drops to 50 or 40 ppb (source: graphs were prepared from Met Council CAMP data for 2002 and 2003).

4.4. Water Quality Improvement Strategy

There is a need to reduce a significant amount of annual phosphorus loading to Alimagnet Lake in order to meet lake water quality goals.

An important finding of the watershed and in-lake modeling was that Alimagnet Lake will need both watershed and lake projects to meet the water quality goal of 54 ppb which will translate to a seasonal average Secchi disc reading of 1.2 m. This goal is based on an ecoregion flow weighted mean concentration of 150 ppb.

The water quality of a shallow lake system, like Alimagnet Lake, is greatly affected by in-lake processes such as internal recycling of nutrients that have accumulated in bottom sediments; relationships between fish, rooted aquatic plants, and algae; etc. This underlines the importance of sound in-lake management programs while reducing watershed phosphorus inputs. Therefore, it will be difficult for watershed-based BMPs alone to meet lake water quality goals. The water quality improvement strategy will be to reduce watershed pollutant inputs to the maximum extent practical while implementing in-lake water quality improvement projects.

4.5. Evaluation of Watershed and Lake Projects

4.5.1. Evaluation of Watershed Projects

Several approaches were evaluated for potential watershed Best Management Practices for Alimagnet Lake. These approaches included:

1. Stormwater pond creation/improvement
2. Education and outreach focusing on fertilizer management and control
3. High efficiency street sweeping
4. Infiltration galleries
5. Storm sewer diversion

The BMPs were evaluated on the basis of TP load reduction from the watershed, lake response, technical feasibility and overall anticipated cost. Load reductions from BMPs were analyzed on an individual BMP basis. Cumulative load reductions were also analyzed based on various combinations of practices. Findings from individual evaluations are presented in this section. A summary of proposed conditions (cumulative analysis) is presented after this section, in section 4.5.2.

1. Stormwater Pond Improvement

Three within this BMP were found to have a reasonable improvement in nutrient loads to the lake. These approaches to stormwater pond improvement as a BMP include:

1a. Barley straw for Ponds 1A, 6C, and 7A (see Figure 3)
1b. Excavation of Pond 7A (See Figure 3)
1c. Excavation of Pond 1A (See Figure 3)
1d. Construction of pre-treatment basin immediately north of Pond 1A (See Figure 3)

1a. Carbon amendments for Ponds 1A, 6C, and 7A.

Historically the primary use of barley straw has been to control algal growth in ponds. Recent research results (McComas and Anhorn, in prep) indicate barley straw acts as an organic amendment and based on field monitoring data, it appears that the use of barley straw in ponds can enhance nutrient removal. Based on field data, it may be possible to achieve a 50% overall reduction in phosphorus effluent concentrations from stormwater ponds (Steve McComas, unpublished).

Of the total watershed area of 985 acres for Alimagnet Lake, runoff from 712 acres (over 70% of total watershed area and 83% of the total nutrient load) flows through these three ponds. Barley straw would be applied to the three ponds to improve their nutrient removal performance.

Expected Benefit: Nutrient reductions were estimated for barley straw applications in ponds 1A, 6C and 7A. A relatively conservative phosphorus load reduction of 123 pounds annually (about a 25% reduction) has been assigned to this management measure.

Cost Range: $4,000 per year (includes monitoring costs as well).

Figure 26. Barley straw is relatively easy to install. Here, Burnsville City staff is installing barley straw into Twin Lake in 2003.

1b. Pond Excavation: Expand wet volume of Pond 7A (located in Apple Valley) through excavation.

Pond 7A has a total drainage area of 257 acres, including a direct drainage area of about 51 acres. Based on depth measurements taken by City staff, the pond has a mean depth of 1.5 feet and a large delta has formed in the pond off the end of the main storm sewer inlet. The proposed action will increase the mean depth to 4 feet. This mean depth is targeted based on generally accepted recommendations that detention basins have a minimum mean depth of 3-4 feet in order to provide adequate standing water volume to avoid problems with scour and re-suspension of settled material.

Expected Benefit: Modeling indicates that the proposed excavation will have a minor impact on loading to the lake (about 16 lb/yr reduction).

Cost Range: $41,500 - $65,500
(assumes $8-$12/CY for excavation, $5,000-$10,000 for mobilization and a 35% factor for design, administration and contingency)

Figure 27. Pond excavation can be conducted in winter, using the ice as a platform. This is a pond excavation in Lakeville in 2003.

1c. Pond Excavation - Expand wet volume of north cell of Pond 1A (located in Burnsville) through excavation.

Pond 1A has a total drainage area of 280 acres, including a direct drainage area of about 230 acres. Of the total drainage to the Pond 1A, 65% of the pond's watershed enters its north cell. Based on depth measurements taken by City staff, the north cell of the pond has a mean depth of under 1 foot and a large delta has formed in the pond off the end of the main storm sewer inlet. The proposed action will increase the mean depth to just over 6 feet. The mean depth proposed for excavation is based on the large size of the upstream drainage and the lack of significant ponding in the drainage, which suggests that sedimentation rates will be high. Thus, a more aggressive expansion of wet volume expansion is warranted. It should be noted that Pond 1A is a DNR protected water, and that it seems to make sense to limit the impact of excavation to that portion of the pond where it is most needed.

Pond 1A is identified in the City of Burnsville's Water Resource Management Plan (WRMP) (2002) as a wetland community. The wetland community (Pond 1A) is classified for low protection thereby establishing it as a management area. Within the City's plan, Policy 4.14 states that "Management Area wetlands having existing direct storm water discharges will be managed primarily for the purpose of storm water storage and treatment."

Excavating the "management area" wetland (Pond 1A) to enhance stormwater treatment and protect Lake Alimagnet is also consistent with Policy 2.7 of the Water Resource Management Plan. This policy states that the "City will balance protection of wetlands

and utilization of wetlands to protect the water quality of other water resources (i.e., wetland, lake, stream) based on wetland classifications in the City Comprehensive Wetland Protection and Management Plan."

Expected Benefit: Modeling indicates that the proposed excavation will have a moderate impact on loading to the lake (37 lb/yr reduction).

Cost Range: $98,000 - $150,000
(assumes $8-$12/CY for excavation, $5,000-$10,000 for mobilization and a 35% factor for design, administration and contingency).

1d. Construct a stormwater pre-treatment basin immediately north of Pond 1A (in conjunction with recommendation 1c).
It is recommended that the City of Burnsville consider constructing a pre-treatment basin for Pond 1A. While pre-treatment is not required under the City's stormwater management plan given the classification of Pond 1A nor do present wetland protection laws appear to require it, the advantages of constructing this improvement are:

- it would enhance estimated total phosphorus removal of improvements to this part of the watershed system by almost 20 pounds/year. This is significant because the opportunities for watershed phosphorus load reduction are limited for the Lake
- it would make easier long term protection of the treatment capacity of Pond 1a by trapping heavy sediment in the upland pond where it is much easier to access and remove.

Two storm sewer outfalls are located at the north end of Pond 1A. Together these outfalls convey runoff from approximately 180 acres of land. Over 70 percent of the area (130 acres) drained by these two outfalls is directly routed to Pond 1A without any treatment. Diverting runoff from low magnitude, frequently occurring storm events to a pre-treatment basin will allow for primary sedimentation and pollutant removal before flows enter Pond 1A. The first flush of runoff large storm events, which tend to have higher pollutant concentrations, will also be diverted while the remainder of the "cleaner" runoff goes to Pond 1A.

The pipes leading to the outfall structures are positioned favorably (i.e. existing slope and alignment) to allow for construction of new lateral pipes to divert runoff to a pre-treatment basin. The landscape topography immediately north of Pond 1A is favorable for constructing a pre-treatment basin, requiring only minimal berming to contain and isolate a pre-treatment basin from Pond 1A. There are no structures on this land and property ownership/acquisition is not expected to be an issue. Because the pond could affect the hillside to the north, the City should consider taking one or more borings to make sure that slope stability will not be an issue, once the final layout of the pond has been established.

Based on existing contour data and aerial photography, a pre-treatment basin could be constructed with a normal water level at elevation 962. This would provide a surface area

of approximately 0.27 acres. At a maximum depth of 10 feet, the wet volume would be approximately 1 acre-foot with a mean depth of roughly 3.6 feet. It is proposed to divert runoff from a 2-inch, 24-hour storm event. Further detailed technical analysis is warranted to optimize the sizing of the diversion structure.

Expected Benefit: P-8 modeling estimates that together the two storm sewer outfalls deliver over 48,700 pounds of TSS and over 140 pounds of TP on an annual basis to Pond 1A. Diverting this pollutant input to a pre-treatment basin will reduce the TSS load from this source to Pond 1A by an estimated 43%. The model estimated that together, the pre-treatment pond and the excavation of Pond 1A as proposed would decrease loading to Alimagnet Lake by approximately 56 pound/yr. under average precipitation conditions. The pre-treatment basin would substantially enhance the longevity of any improvements (i.e. deepening through sediment removal) made to Pond 1A.

To maintain adequate mean depths in the pre-treatment basin (3-4 feet), regular inspections and periodic maintenance will be required. The accumulated sediment will be easier to reach, since the pond area within which it will accumulate is small compared to Pond 1A. Finally, this pond will provide greater protection to Pond 1 than exists under current conditions.

Cost Range: $200,000 - $240,000
(assumes costs for pipe installation and retrofit, site preparation, pond and upland excavation at $8-$12/CY, restoration, berming, and a 35% factor for design, administration and contingency. This cost estimate is separate from the estimate for recommendation 1c, conservatively assuming that both projects are developed and bid independently.)

2. Fertilizer Management and Control - Improve fertilizer management in the watershed, emphasizing in particular the urbanized direct drainage area.

In recognition of the contribution of phosphorus fertilizer use to high phosphorus loads in urban runoff, the 2002 Legislature passed a law that banned the use of lawn fertilizers containing phosphorus in the Twin Cities Metro area unless a soil test proved that supplemental phosphorus was necessary. The ban was to have gone into effect on January 1, 2004. However, lawn fertilizers containing phosphorus are still widely available at retail outlets and many consumers are not aware of the ban. Thus, education of those consumers as well as the retail outlets that serve them is still highly desirable, especially in sensitive watersheds like that of Alimagnet Lake.

Residential lawn soil testing was performed extensively in Burnsville in 1995-1996. Results indicated that the phosphorus content of all soils were high to very high. Thus, fertilizer applications containing phosphorus are generally not warranted.

A paired-watershed research project is currently underway in the Twin Cities Metro Area to quantify the impact of fertilizer control (Lake Access, 2004). Specifically, this study is looking at the potential difference between urban runoff from areas where phosphorus fertilizer is

restricted versus areas where there is no control on phosphorus fertilizer. Preliminary data from one year of monitoring in this study suggests a large difference between the two fertilizer circumstances. Phosphorus loads in areas where fertilizer use is controlled appear to be almost 50% below the areas where there is no control.

Management of turf grass clippings can also contribute to downstream phosphorus loads. For instance, grass clippings from a ½-acre residential lawn can generate up to 30 pounds of phosphorus per year (Connecticut Department of Environmental Protection, Fagerness 2001). Mowing practices can result in lawn clippings (grass and leaf debris) being blown onto driveways streets. Rain events quickly transport the lawn clippings into the storm sewer system and downstream lakes, contributing to nutrient enrichment and algal blooms. It will be beneficial to address this potential source of phosphorus while managing fertilizer applications.

Options to reduce loading from the 183-acre urbanized direct drainage to Alimagnet Lake are limited. It makes sense to focus education efforts regarding fertilizer use on the direct drainage because any reduction achieved has a direct benefit on load reduction to the lake and the fact that there appear not be any other cost-effective load reduction options for this area.

Expected Benefit: A 15% reduction in loading from the direct drainage was conservatively estimated, which equates to about 12.5 pounds/year. Incidental reductions associated with the impact of education and fertilizer management *in other parts* of the drainage area would be considered part of the margin of safety.

Cost Range: Cost is estimated at 20-30 hours of staff time per year plus $500 for printing of fliers or similar literature.

3. Street Sweeping - Implement a high frequency, high efficiency sweeping program for the direct drainage areas to Alimagnet Lake (*reserve project*).

Currently the Cities of Apple Valley and Burnsville have a street sweeping program which utilizes mechanical sweepers. Burnsville sweeps its streets twice each spring and once in the fall. Apple Valley performs street sweeping in both the fall and spring seasons.

Recently, significant improvements have been made in street sweeper technology. New "high efficiency" street sweepers can remove a much greater degree of grit and debris from street surfaces than conventional (e.g. mechanical) sweepers. Also referred to as regenerative air sweepers, these high efficiency machines use directed air nozzles to lift particles out of street cracks and potholes. The grit particles are then filtered and captured by the machine. These sweepers are much more effective at collecting very fine particles of grit than the conventional sweepers. This is important because sediment-bound phosphorus is typically associated with small particle sizes. Although the machines are highly efficient, they have a slow operating speed. They are also not as effective at sweeping up large objects (i.e., litter).

Apple Valley and Burnsville can implement a customized street sweeping program to help reduce nutrient loads to Alimagnet Lake. A customized program would be based on a relatively high frequency of sweeping that is restricted to the direct developed drainage areas around the

lake. The primary rationale for this approach is that there are few alternatives to decrease nutrient loading from the direct drainage area. The direct developed drainage areas do not have room to incorporate new stormwater ponds. As well, retrofitting the existing sewer system with end-of-pipe options such as swirl concentrators is quite costly and has not been shown to be a cost effective method of phosphorus reduction where mechanical sweeping is already being done at critical times of the year (spring and fall).

Suggested general guidance for Alimagnet Lake street sweeping includes the following:

- Focus high frequency sweeping in the developed direct drainage areas: 1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 8.1, 9.1, and 10.1. A gross estimate of the total length of street distance in these areas is approximately 13,800 feet (2.6 miles).
- Streets should be swept at least monthly through out the growing season (April through October). How often and what roads to sweep are determined by the program budget and the level of pollutant removal the program wishes to achieve. Computer modeling in the Pacific Northwest suggest that from the standpoint of pollutant removal, the optimum sweeping frequency appears to be once every 1-2 weeks (Claytor, 1999).
- Implement more than one pass on each street during each sweeping round. Even with high efficiency sweepers, there often is some residual grit left after a single sweeping pass. A second pass enhances the effectiveness of the sweeper.
- Incorporate "tandem" sweeping, utilizing both mechanical and high efficiency sweepers. Both cities currently own mechanical sweepers which are effective at picking up large debris and coarse particles (e.g. sand). In contrast, high efficiency sweepers are more effective at removing fine particles (dust). A tandem effort with a mechanical sweeper that pre-cleans the street, followed by a high efficiency sweeper, aids the function of the high efficiency sweeper and provides a balanced approach.
- Provide proper, proactive maintenance on the sweeping equipment. This will maintain the high efficiency performance of the unit and promote its useful life.

Expected Benefit: A joint study was completed in June 2002 in Wisconsin to quantify the performance and watershed impact of high efficiency street sweeping (WiDOT, 2002). Statistical analysis of the data indicated that, at the 90% confidence interval, there was a significant reduction in total suspended sediment (TSS) due to the sweeping program. Reductions in TSS concentrations—not load—ranged from 1% to 280%. Due to financial constraints, modeling to predict TSS load reductions and associated reductions in phosphorus load was not performed.

Yet results from one study in 1999 in Virginia (USEPA, 1999) indicated that high efficiency sweepers removed over 9 pounds of phosphorus from two passes on a 2.65 mile stretch of road. Other studies show that high efficiency sweepers can reduce nutrient loads by 15% to 40% (The Terrene Institute, 1998). A cursory map measurement of the Alimagnet direct drainage area reflects that there are approximately 2.5 miles of linear road cover. Thus it was conservatively assumed that 9 pounds of phosphorus reduction (approximately 2% of the overall load) could be attained in the direct drainage area by more intensive street sweeping. In context of the TMDL approach, this project assigned the increased benefit entirely to the margin of safety component of the nutrient load allocation.

Cost Range: Operating costs range from $15 - $40 per curb mile. The lower range of the operational costs is typically associated with the high efficiency sweepers, which have a higher capital cost. It is estimated that an additional operating cost of about $4,500 per year would be incurred to implement a more aggressive sweeping program. To estimate the incremental cost of a more aggressive sweeping program, the following assumptions were made:

- a mid-range operating cost of $30 per curb mile
- costs only for sweeping in the direct drainage area (2.6 miles of road, thus 5.2 curb miles)
- an existing street sweeping program of two times per year
- an aggressive street sweeping program of 15 times per year (every other week April through October), at two passes (10.4 curb miles) per sweeping activity.

4. Infiltration - Pursue infiltration opportunities as a retrofit to an existing open area or during re-development of a particular parcel of land (*reserve project*).

Generally, infiltration as a BMP consists of engineering a system whereby stormwater runoff is allowed to filter through soil and recharge the local groundwater. Through this approach, pollutants are removed and the overall downstream water load is reduced.

Infiltration BMPs must be employed with caution. Infiltration serves to recharge groundwater features. It is therefore important to consider the nature of pollutants in the stormwater and the relative sensitivity of the groundwater resources in the area. For instance, it is not advisable to infiltrate stormwater from industrial areas since the runoff can potentially have high amounts of organochlorines that can contaminant groundwater supplies. However, phosphorus is quickly immobilized by soil particles and presents no concerns for groundwater contamination.

Another caveat is that the soils in the area must be amenable to infiltration BMPs. Poorly drained, clay soils impede infiltration dynamics. The native soils in the Alimagnet Lake watershed are classified in the Kingsley-Mahtomedi association. Soils in this association are described as well drained and excessively drained. The sandy nature of this soil association is well-suited to using infiltration approaches for storm water management. However, surface soils in the urban and suburban environment can differ markedly from those in the soil survey due to grading activity, waste soil disposal, etc. Use of infiltration BMPs should be preceded by site-specific soil evaluation as part of the planning and design process.

Infiltration BMPs are often incorporated underground, yet can require a relatively large amount of space. Also as a result of the space requirement, infiltration practices are typically limited to small (less than ten acres) drainage areas. Finally, infiltration BMPs focus on treating runoff from small storm events (about 1-inch or less). These rainfall events produce a relatively small amount of runoff. However, they occur frequently through any given year. As a result, rainfalls of small magnitude but high frequency can cumulatively contribute a majority of the pollutant load to a downstream resource. In fact, research has shown that storms less than 1.5 inches are responsible for conveying approximately 90% of the annual pollutant load in stormwater runoff, during an average year (MPCA, 2002).

When incorporating infiltration features for stormwater management, it is essential to provide some form of pre-treatment for stormwater prior to infiltration. Pre-treatment can be provided through several mechanisms such as a structural swirl concentrator or a grassed swale. Without a pre-treatment, the grit in stormwater can prematurely clog an infiltration system. It is important to reduce the amount of grit that enters an infiltration system in order to enhance the longevity and functionality of the system.

The native local soils appear very compatible with use of infiltration BMPs as opportunities arise within the watershed. The existing level of development within the Alimagnet Lake watershed will constrain opportunities for implementing infiltration BMPs.

There are several sites within the study area that could be retrofitted as infiltration galleries. Some examples of candidate sites observed were located:

- at the school ball field area in drainage area 1.1a.6
- adjacent to parking lots for the hospital facility in drainage area 1.1b.1
- adjacent to parking lots for the church complex north of I-35E in drainage area 6.6c.1

An example of how these features can be incorporated into a parking lot landscape is shown by the Alimagnet Lake Park parking lot island bioretention area. Infiltration can also be considered for incorporation into public improvement projects as well as in re-development projects within the watershed.

Expected Benefit: Reductions in nutrient loads due to infiltration practices were estimated for the Alimagnet watershed. For calculation purposes, it was conservatively assumed that a 25% reduction in phosphorus could be achieved from approximately 20% of the developed watershed (about 180 acres) if infiltration techniques were fully employed. This assumption is conservative in that the phosphorus reduction is based on infiltrating runoff from storms of up to ½-inch in depth. Infiltrating runoff from storms up to 1-inch of depth can yield phosphorus reductions approaching 45% on an average annual basis. However, the footprint for an infiltration gallery for this design storm is much greater and may not be feasible to attain in many of the potential retrofit areas of the Alimagnet watershed.

Based on the conservative ½-inch storm depth approach, calculations indicated that potentially up to 22 pounds of phosphorus could be removed on an average annual basis. This equates to almost 5% of the nutrient budget for the developed watershed. It may be possible to achieve a higher reduction in TP, depending on the size of the infiltration system, the configuration of the hydraulics (e.g. by-pass device), and other variables. The water quality benefit from implementing future infiltration practices was assigned to the margin of safety. This is because the extent to which opportunities will arise to incorporate infiltration is not clear.

Cost Range: $200,000 - $400,000
A rainwater garden that is approximately 15’ x 38’ (570 square feet) in surface area is adequate to hold and infiltrate runoff from a 1-inch precipitation event for a ½-acre of impervious area. Given that the average imperviousness within 20% of the developed drainage area (180 acres) is approximately 37%, about 1.75 acres of well distributed, strategically located rainwater gardens would be necessary to serve the entire developed drainage area. This equates to about 133

rainwater sites. The estimated construction cost for a singe rainwater garden ranges from $1,500 - $3,000. However, this does not include any land acquisition costs nor any costs to retrofit or modify the storm sewer infrastructure to accommodate a rainwater garden.

5. Storm Sewer Diversion - Considered, Not Recommended

The storm sewer network that drains Apple Valley and Burnsville to Alimagnet Lake is extensive. The potential to divert a portion of the storm sewer network to more appropriate waterbodies outside of the existing drainage area was evaluated. This approach would improve conditions in the Alimagnet Lake system because both the nutrient load as well as the water load would be reduced. However, this approach did not appear to be feasible. In part this is because where the Alimagnet storm sewer network was adjacent to other drainage networks, re-routing flows to another network would only divert a small upstream drainage area. The cost would be high relative to a low net benefit. The other constraint to this approach is that any diversion options may cause a negative impact to other waterbodies; no appropriate stormwater ponds were identified.

4.5.2. Estimated Water Quality Benefits of Proposed Watershed Projects

Several possible Best Management Practices (BMPs) were evaluated for potential reductions in watershed phosphorus loading to Alimagnet Lake. Load reductions were estimated either through direct modeling (P-8 model) or by mass-balance computations. The WiLMS in-lake water quality model was used to quantify the magnitude of in-lake water quality improvement due to reductions in watershed loading.

As noted earlier, modeling data indicates that Lake Alimagnet is not highly sensitive to reductions in watershed loads. As a shallow lake system the quality of Lake Alimagnet is greatly affected by in-lake processes such as internal nutrient recycling. Still it is critical to reduce watershed loads to the greatest extent practical to give in-lake improvements a better chance for improving lake conditions over the long term.

Load reductions have been explicitly allocated to four out of the six recommended watershed BMPs. If all of the explicit load reduction measures (i.e. BMPs not assigned to the margin of safety category) are followed, watershed loads to the lake would be reduced by an estimated 45%. The proposed watershed BMPs and the cumulative reductions in phosphorus loading to the lake are summarized in Table 26 below.

Table 26. Load reductions allocated to recommended watershed BMPs.

Scenario[1]	Description	External Phosphorus Load			Mean Pond Outflow[2] Conc. (ppb)	Mean Runoff Influent[3] Conc. (ppb)	Cumulative Watershed Load Reduction
		External Direct (lbs/yr)	External Indirect (lbs/yr)	Total External to Lake (lbs/yr)			
--	Existing Conditions	91	371	462	0.278	0.336	--
ALT 1	Barley straw applied to ponds 1a, 6c and 7a	91	248	339	0.185	0.216	27%
ALT 2	ALT 1, but include 15% reduction in *direct* TP load due to P-control	78	248	326	0.186	0.208	29%
ALT 3[4]	ALT 2, but include pond excavation on 1a and 7a and pre-treatment north of pond 1a	78	175	253	0.130	0.161	45%

[1]The abbreviations in this column represent management alternatives, with each successive alternative incorporating the benefit of the previous alternative.
[2]This represents a net value for all three of the ponded drainage areas (1, 6, and 7) combined.
[3]This value is an overall FWMC calculated from all the loads entering the lake (both direct and ponded/indirect).
[4]This incorporates BMP recommendations #2, #3a and #3b and accounts for the application of barley straw as shown in alternative 1.

Since the water budget from the ponded drainage areas (outfalls 1, 6 and 7) dominates the watershed system, controlling phosphorus concentrations in this part of the system will have the greatest impact on load reduction. As shown in alternative 3 in Table 26, the mean TP concentration discharging to the lake from the ponded drainage areas would be reduced to about 130 ppb. This is within the ecoregion inter-quartile range for a *reference* stream's TP discharge concentration. As such, the total external load of 253 pounds per year of phosphorus as an end-point associated with the third alternative in Table 26 appears to be reasonable and attainable for overall watershed discharge to Alimagnet Lake.

In summary, the 45% phosphorus reduction associated with this 253 pound per year total maximum load would be achieved through implementing the following recommendations:

Table 27. Phosphorus load reductions associated with watershed projects.

Priority Watershed Projects	Description	TP Load Reduction[1]
1a	Barley straw treatment in Ponds 1A, 6C, and 7A.	123 lbs/yr
1b	Expand wet volume of Pond 7A (located in Apple Valley) through excavation.	16 lbs/yr
1c and 1d	Expand wet volume of north cell of Pond 1A (located in Burnsville) through excavation and develop pre-treatment basin prior to north cell of Pond 1A.	56 lbs/yr
2	Improve fertilizer management in the watershed, particularly emphasizing the urbanized direct drainage area.	13 lbs/yr

[1]These values do not total 257 pounds as shown in Table26 because the load reductions here are calculated independently whereas Table 6 is a cumulative calculation.

Additionally, the load reduction measures assigned to the reserve projects are referred to as "Margin of Safety" (MOS) projects in the context of the Total Maximum Daily Load (TMDL) program. These MOS projects provide the potential to achieve lower overall TP loads to the lake when they are implemented. For example intensified high-efficiency street sweeping will be carried out by both cities while infiltration retrofit projects will be pursued as opportunities arise. More importantly, these MOS items provide a management buffer in the event that the load reductions assigned to the BMPs designed to achieve the total maximum 257 pounds per year total phosphorus load are not fully effective. These MOS allocations include the following recommendations (Table 28).

Table 28. Two margin of safety projects.

Margin of Safety Projects	Description	TP Load Reduction
3	Implement a high frequency, high efficiency sweeping program for the direct drainage areas to Lake Alimagnet.	9 lbs/yr
4	Pursue infiltration opportunities as a retrofit to an existing open area or during re-development of land parcels.	22 lbs/yr

4.5.3. Evaluation of Lake Projects

Several lake projects were evaluated to supplement the watershed projects. These project areas included:

1. Shoreland Projects
2. Aquatic Plant Projects
3. Fish Management Options
4. Whole Lake Organic Carbon Amendment
5. Lake Sediment Alum Treatment

The lake projects were designed to address several lake related components which included lake use, water quality, and aesthetics. Details of proposed lake projects are described in this section. A summary of project effects and benefits is presented in Section 4.5.4.

1. Shoreland Projects

The shoreland area is valuable for promoting a natural lake environment and a natural lake experience for lake users. The shoreland is defined as the upland area about 300 to 1,000 feet back from the shoreline, and out into the lake about 30 to 50 feet (Figure 28). A shoreland with native vegetation offers more wildlife and water quality benefits than a lawn that extends to the lake's edge.

Figure 28. The three components of the shoreland area.

Three Approaches for Native Landscaping for Buffers Has Three Approaches: Native landscaping efforts can be put into three categories:

1. Naturalization
2. Accelerated Naturalization
3. Reconstruction

1. Naturalization: With this approach, the resident is going to allow an area to go natural. Whatever is present in the seedbank is what will grow. If they want to install a buffer along the shoreline, let a band of vegetation grow at least 15 feet deep from the shoreline back and preferably 25 feet or deeper. Just by not mowing will do the trick. Residents can check how it looks at the end of the summer. It will take up to three years for flowers and native grasses to grow up and be noticed. Residents can also select other spots on their property to "naturalize".

2. Accelerated Naturalization: After developing a plant list of species from the area, residents may want to mimic some features right away. They can lay out a planting scheme and plant right into existing vegetation. Several Minnesota nurseries can supply native plant stock and seeds. The nurseries can also help select plants and offer planting tips. Wildflowers can be interspersed with wild grasses and sedges. Mulch around the new seedlings. With this approach lake residents can accelerate the naturalization process.

3. Reconstruction: To reestablish a native landscape with the resident's input and vision, another option is to reconstruct the site with all new plants. Again plant selection should be based on plants growing in the area. Site preparation is a key factor. Residents will want to eliminate invasive weeds and eliminate turf. This can be done with either herbicides or by laying down newsprint or other types of paper followed by 4 to 6 inches of hardwood mulch. Plantings are made through the mulch. This is the most expensive of the three native landscaping categories. Residents can do the reconstruction all at once, or phase it in over 3 to 5 years. This allows them to budget annually and continue evolving the plan as time goes by.

Also mixing and matching the level-of-effort categories allows planting flexibility. Maybe a homeowner employs naturalization along the sides of the lot and reconstruction for half of the shoreline and accelerated naturalization for the other half. Examples of the three approaches are shown in Figure 29.

1. Naturalization: The easiest way to implement a natural shoreline setting is to select an area and leave it grow back naturally.

2. Accelerated Naturalization: To accelerate the naturalization, plant shrubs, wild flowers, or grasses into a shoreland area.

3. Restoration: This involves removing existing vegetation through the use of paper mats and/or mulching and planting a variety of native grasses, flowers, and shrubs into the shoreland area.

Figure 29. Examples of three shoreland management options.

Expected Benefits: Enhancing natural conditions in the shoreland area will improve aesthetic conditions, enhance wildlife habitat, and serve as a water quality improvement technique by filtering and removing excessive nutrients before they run off into the lake.

When a vegetative buffer is at least 15-feet deep, and preferably 25-feet deep, sediments and nutrients in runoff will be intercepted before they reach the lake. This buffer is the last line of defense before nutrients enter the lake.

Of the estimated 263 acres of direct drainage (primarily shoreland areas), about 32 acres is assigned to developed shorelines (listed in Table 7) and represents a phosphorus load of 8 pounds/year. About 70 of the shoreline parcels have vegetative buffers in place, but 33 parcels do not. If 50% of these parcels (16 out of 33) installed buffers, phosphorus loading would be cut 50%, down to 4 pounds of phosphorus/year.

Cost Range: A volunteer shoreland improvement program has similarities to the Adopt-A-Pond program. It is recommended that this shoreland improvement program be run in parallel with the Adopt-A-Pond program. Grants up to $1,000 are available to lake residents from Burnsville. It is estimated that 15 homes over the next 5 years could be enrolled in this effort. This would be $3,000/year for 5 years for a total of $15,000.

2. Aquatic Plant Projects

A high priority lake improvement recommendation is to decrease the extent of the exotic curlyleaf pondweed and to enhance the native aquatic plant communities in Alimagnet Lake. Currently, Alimagnet Lake has a low diversity of emergent and submergent aquatic plant growth. Aquatic plants are vital for helping sustain clear water conditions and they contribute to fish habitat as well as to other components in the lake ecosystem. However, curlyleaf pondweed, though it is an aquatic plant, contributes to detrimental lake conditions and needs to be controlled on an annual basis.

The challenge is to maintain and/or protect native submerged aquatic plants in Alimagnet Lake. Several plant improvement ideas are included in this project area.

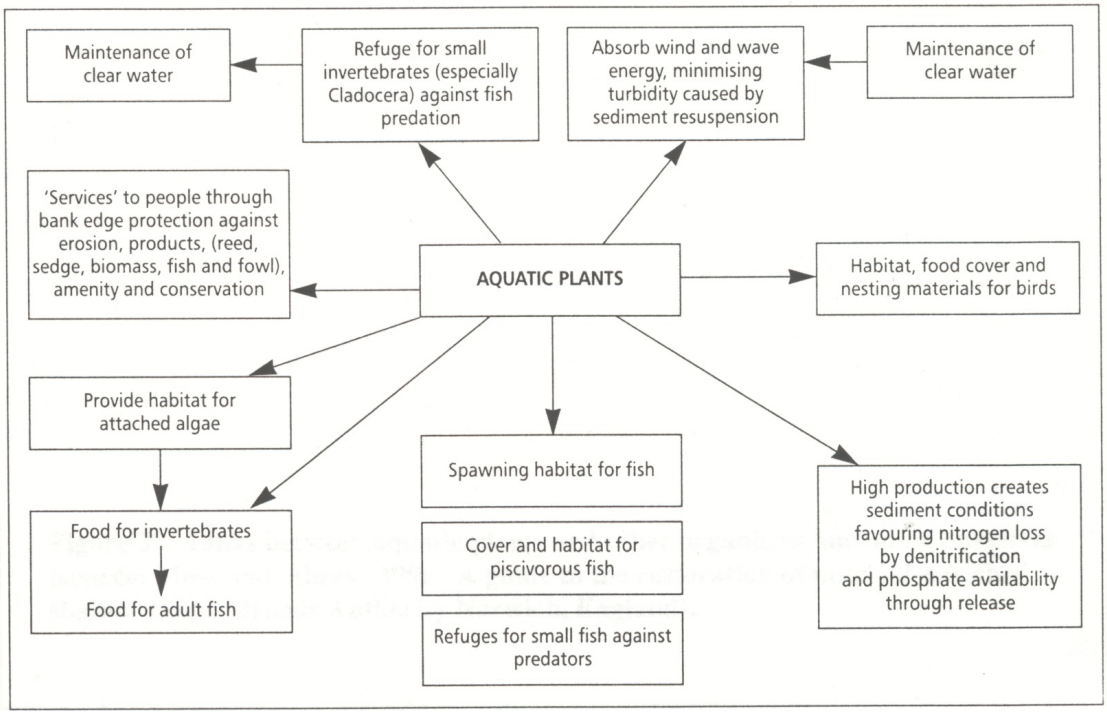


Figure 30. Links between aquatic plants and other organisms, including ourselves (source: Moss and others. 1996. A guide to the restoration of nutrient-enriched shallow lakes. Broads Authority Norwich, England).

2a. Continue to Control Curlyleaf Pondweed

The Alimagnet Lake Association has successfully conducted a curlyleaf pondweed control management program since 1996. They developed their own unique technique using a cable strung between two boats to uproot curlyleaf pondweed. By conducting this annual project, the Lake Association volunteers have reduced the extent of the heavy nuisance growth of curlyleaf.

Examples of the dense growth in the past are shown in Figure 31. Annual control efforts have reduced the heavy growth to a less dense lighter growth which is more manageable as well. It is recommended to continue this program.

Figure 31. [top and bottom] Curlyleaf pondweed conditions in Alimagnet Lake in May of 1997. Annual removal techniques conducted by the Lake Association have dramatically reduced the nuisance acreage of curlyleaf pondweed.

Figure 32. [top] The Alimagnet Lake Association uses a cable pulled between two boats to uproot curlyleaf pondweed.
[bottom] A minimum of 70 hp outboard or inboard motor is needed to pull the cable through the curlyleaf beds.

Figure 33. Over the years several techniques were employed to pick up the floating curlyleaf after it was uprooted. The three options shown above proved to be inefficient. Currently lake residents manually remove the curlyleaf when it floats to shore.

Demonstration project: Lake Sediment Iron Treatment for Long Term Curlyleaf Control
Long term control of curlyleaf pondweed in Alimagnet Lake would be desirable. Currently, annual efforts conducted by lake association volunteers reduce nuisance growth of curlyleaf, but do not eliminate it. This has been a cost effective method compared to conventional approaches such as herbicides and mechanical harvesting.

However, the use of iron filings applied to lake sediments as a one-time dose has shown some ability to control the nuisance growth of curlyleaf pondweed (McComas, unpublished). Analysis of Alimagnet Lake sediments indicates there is the potential for an iron treatment to be successful. The approach is to select two 1-acre plots to treat curlyleaf with iron filings and then select two 1-acre curlyleaf areas to serve as a reference. Three seasons of follow-up monitoring will help to determine the effect of the iron addition. If iron can control curlyleaf in those 1-acre plots a whole-lake iron treatment could be considered in the future.

Expected Benefit: Curlyleaf pondweed is a phosphorus source when it dies back and decomposes in the lake in June or early July. By reducing the curlyleaf density through the volunteer removal efforts, a phosphorus source is reduced as well. It is estimated that curlyleaf dieback currently contributes 140 pounds of phosphorus/year. Before removal efforts were initiated it is estimated the denser growing curlyleaf dieback was 230 pounds of phosphorus/year. The existing curlyleaf program that relies on the cable system reduces the phosphorus loading by 90 pounds per year compared to pre-project conditions.

If the iron treatment demonstration is successful, it could be worth scaling up to a whole lake treatment project.

Cost Range:

Curlyleaf control using cables: $1,000-$2,000 per year. Costs are for DNR permits and supplies.

Demonstration project: using an iron application: $5,000. Costs include the iron product and the iron application and three seasons of follow-up monitoring.

2b. Harvesting Nuisance Aquatic Plant Growth
If watershed and lake improvement projects are successful, water clarity should improve in Alimagnet Lake. Its is anticipated that native aquatic plant growth would increase in distribution and in abundance.

For example, in the past after an Alimagnet fish kill, elodea has grown to nuisance conditions. A similar growth pattern could occur again if water clarity improves in Alimagnet.

Therefore, if nuisance plant conditions develop, a harvester should be used to cut navigational channels to open water. It is estimated up to 10 acres could be harvested per summer. It is expected that the extreme growth conditions would not last longer than 3 years.

Expected Benefit: Enhanced aquatic plant growth following a water clarity improvement is common. Elodea has a history in Alimagnet of growing to nuisance conditions, hindering motor boat use over much of the lake. Mechanical harvesting would allow full lake use for fishing, skiing, and viewing. About 3 pounds of phosphorus/acre would be removed as well, although p-removal is not the primarily objective.

Cost Range: Mechanical harvesting can be contracted for about $500/ac and an estimated 10 ac/year for 3 years would be harvested for a total of $15,000.

Figure 34. A mechanical harvester may be needed for cutting navigational channels through vegetation if water clarity improves. This harvester is working on Crystal Lake.

2c. Whole Lake Iron Sediment Treatment Project for Long-Term Curlyleaf Control (*reserve project*)

Currently, there are few successful long-term control options for curlyleaf pondweed. Conventional use of herbicides and harvesting are effective annual treatments but it remains to be seen if long term control can be accomplished with those methods.

Although the cable system employed by the Lake Association has reduced curlyleaf nuisance densities, it remains an annual task.

If the results from the demonstration iron treatment project are successful, a whole lake iron treatment could be considered. This project is classified as a "reserve project" at this time, meaning it could be implemented in the future if needed.

Expected Benefit: A long-term curlyleaf control project would aid the water quality improvement program and be cost-effective compared to herbicide or harvesting annual expenses.

Cost Range: The current application cost is approximately $400/acre. Assuming there are 75 acres of curlyleaf, the sediment iron treatment would cost $30,000.

3. Fish Management Options

3a. Black Bullhead Removal

Based on lake research publications, excessive numbers of black bullheads can have adverse impacts on lake water quality. The last fish survey conducted in Alimagnet Lake was in 2000. Results indicated black bullheads were abundant.

This project has two objectives: conduct a fish survey and remove black bullheads if they are found at 20 fish/net or greater.

Expected Benefit: Black bullheads are omnivores and will feed on bottom sediments if their densities are too high. They also limit the distribution of aquatic plants. Reducing bullhead density should reduce internal nutrient loading and help to reestablish native aquatic plant coverage.

Cost Range: This is a 3-year project. The first year is a combination fish survey and bullhead removal project. The cost is $7,000 and it is repeated in years 2 and 3 at $7,000. The total cost is $21,000.

Figure 35. Bullheads can be removed using fyke nets. Here commercial fishermen are removing bullheads from Lake Susan, Chanhassen.

3b. Stock Catfish and Bass

Because winter aeration in Alimagnet has been successful, the fish community now survives through the winter. However, one disadvantage of this is that the black bullhead community, which was well established prior to aeration in 2002 based on the 2000 fish survey, probably has a higher density now, in 2004. Although a black bullhead removal project is proposed, in order to reduce bullhead numbers, and to ensure that numbers stay down, stocking predator fish recommended. A combination of adult channel catfish and largemouth bass species should be stocked at one fish of each species per two acres of lake.

Expected Benefit: A good way to exert long-term control on a species like black bullhead is by predation pressure. It is expected that channel catfish and largemouth bass can control bullheads which will help improve water quality. The stocked fish will also present better fishing opportunities.

Cost Range: Stocking is recommended for four years out of the next five with the highest stocking rate occurring in the first year. Total stocking cost from private fish hatcheries is about $4,000.

3c. Install One to Two Additional Winter Aeration Systems (*reserve project*)

The single winter aeration system become operational in Alimagnet in January 2000 and has successfully maintained dissolved oxygen in the east arm (Apple Valley side) of Alimagnet Lake for the last four winters. Even though the winters have been mild, the system is expected to help keep the fish community alive in harsher winters as well.

However, an unexpected observation of the winter aeration system is that phosphorus levels are lower in the aerated area compared to the unaerated western arm (Table 29).

It appears winter aeration may have a water quality effect as well. If this is the case, then by adding one or two more aeration systems, there could be an important decrease in winter and spring lake phosphorus concentrations, possibly through the whole lake.

Figure 36. [top] A winter aeration system was installed in Alimagnet Lake in 2000. [bottom] The aeration system maintains about a 1,600 square foot area of open water through the winter months.

However, there is another factor to consider. The watershed area draining to the aeration arm (east side) is only about 150 acres whereas the drainage area to the west arm is about 300 acres. The high phosphorus on the west arm could be a function of watershed phosphorus loading.

Table 29. Secchi disc transparency , total phosphorus, and chlorophyll a data collected in 2003 and 2004.

	Secchi disc		Total Phosphorus (ppb)	Chlorophyll a (ppb)	Iron (mg/l)	Manganese (mg/l)
	feet	meters				
March, 2003			43 - aeration 74 - Burnsville	21 - aeration 66 - Burnsville		
May	3.3	1				
May	3.3	1				
June	1.7	0.5	51 - aeration 138 - Burnsville		213 - aeration 290 - Burnsville	95 - aeration 72 - Burnsville
June	1.7	0.5				
July	1.8	0.6/ 0.5				
July	1.7	0.5				
August	3.0	0.9	85 - aeration 116 - Burnsville	44 - aeration 37 - Burnsville		
August	1.7	0.5				
September	1.0	0.3				
Average	2.0	0.6				
March 8, 2004			40 - aeration 69 - Burnsville			

More testing is needed to evaluate the influence of winter aeration on phosphorus levels. Even if winter aeration does reduce phosphorus, the installation of additional aerators is a reserve project, meaning it would be considered only if other projects were not working. A disadvantage of one or more aerators is the increase of the open water area in Alimagnet in winter.

Expected Benefit: Additional winter aeration is a water quality improvement project with increased confidence that fish will not winterkill as well. Phosphorus reductions associated with aeration are speculative but could range up to 100 pounds per year or more based on lowering the lake phosphorus concentrations 5 to 10 ppb.

Cost Range: An aeration system is composed of an air compressor, airlines, and diffuser stones and is estimated to cost $15,000 per system. Two systems could be installed for a total capital cost of $30,000. Operation and maintenance is about $1,500 per winter per system for a total of $3,000 for two systems per winter.

4. Organic Carbon Amendment

A carbon amendment technique is a new approach to improve lake water clarity.

In eutrophic lakes, blue-green algae blooms represent a significant amount of organic carbon that is unavailable to higher levels in the food chain because it is ungrazable or inedible. Blooms cause significant turbidity and hinder aquatic plant growth. Without a significant phosphorus reduction, a yearly repetitive cycle is set up of algae blooms, die back, phosphorus release and then more algae blooms. It takes extreme phosphorus reductions to break this cycle.

Although projects have attempted to increase the amount of edible algae, in order to get phosphorus up into the higher levels in the food chain, it is difficult to increase the amount of edible algae in a lake. Even if successful it could still result in turbid water. Also fish predation on zooplankton reduces big zooplankton species and limits the ability of the zooplankton community to effectively graze the edible algae. However, if phosphorus could be channeled into heterotrophic production, algae biomass that had been sequestered into the blue-green dead-end would instead be converted to edible or grazable microbial organic carbon. This organic carbon would be available to upper levels in the food chain. Increasing edible bacteria would result in clear water. Because grazing of the edible bacteria can go through other aquatic invertebrates, it does not have to go through zooplankton and thus fish predation effects are minimized. The use of carbon amendments is best suited for cases where external and internal phosphorus loads cannot easily or economically be significantly reduced.

How Organic Carbon Can Improve Water Clarity: Algae are phosphorus limited in lakes. In lakes with high phosphorus concentrations, like Alimagnet, algae growth will be substantial. However, bacteria are carbon limited in lakes and adding carbon to carbon-limited bacteria should increase bacterial growth. Because bacteria outcompete algae for phosphorus when carbon is not limiting bacterial growth, bacteria will reduce the open water phosphorus concentrations and, thus, reduce open water algal growth.

This heterotrophic (microbial) pathway is referred to as the microbial loop (Figure 37). The use of carbon to enhance the microbial loop processes has rarely been considered as a lake management tool although research results in closely-related areas gives support that it has a high potential to be successful (McComas in prep). Manipulating the microbial loop is a new lake improvement strategy but still fits within the broad area of biomanipulation. It's a bottom-up approach compared to the conventional top-down approach.

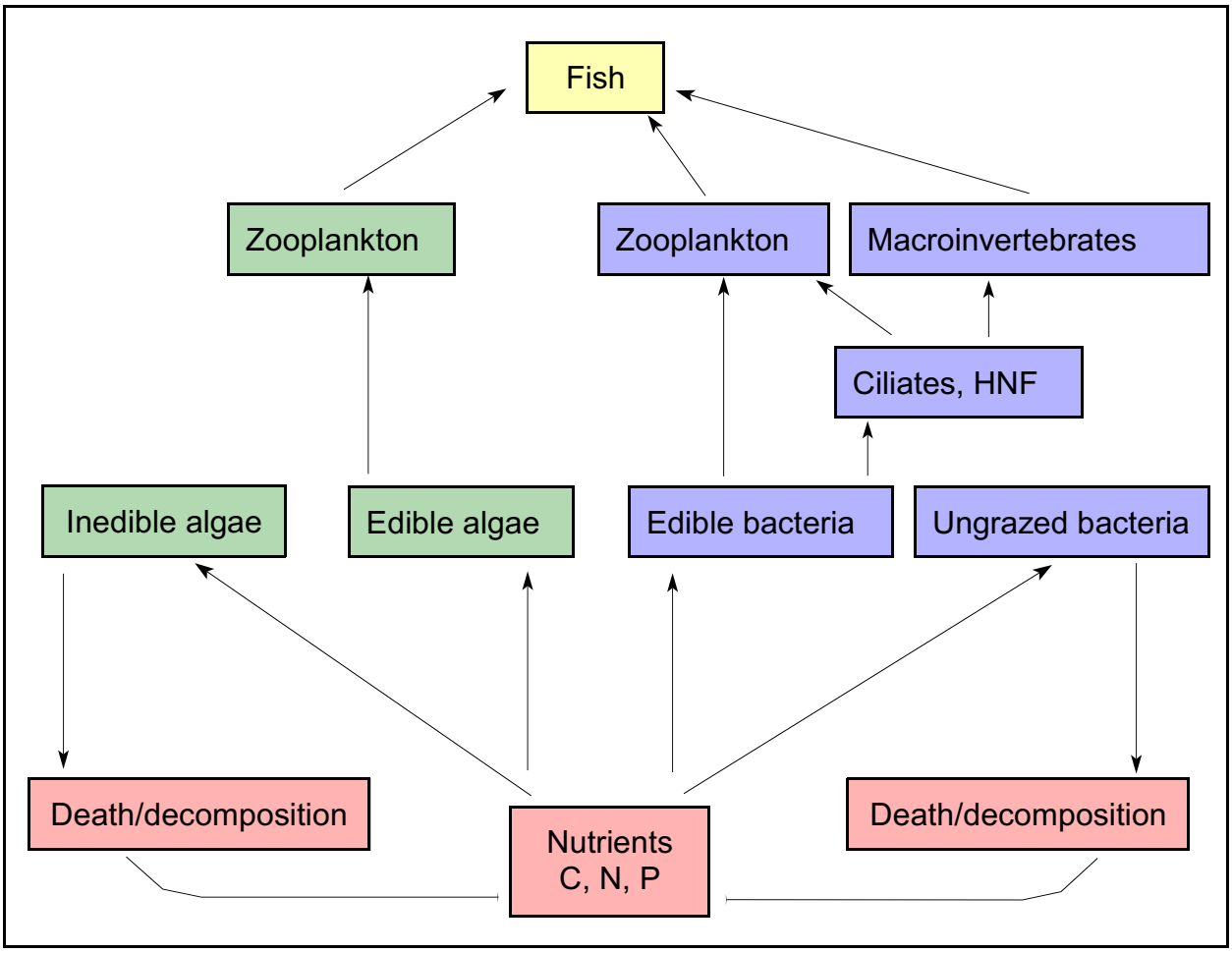


Figure 37. Energy flow through the biota and up to fish in lakes is shown above. Green boxes represent the conventional grazing pathway of algae to zooplankton to fish. The inedible algal box represents colonial blue-greens and it can be a significant carbon sink and an unuseable carbon source to higher trophic levels. Blue boxes represent the microbial loop pathway. If supplied with adequate carbon, bacteria will increase and then organic carbon and phosphorus will go up the food chain through ciliates, heteronanoflagellates (HNF) to zooplankton or macroinvertebrates and into fish. Open water algal growth will be reduced because of a reduction in available open water phosphorus. Barley straw probably serves as a carbon source and the carbon goes into edible bacteria and up the food chain. Algae production is reduced because phosphorus levels go down when bacteria are growing.

Three types of organic carbon amendments that could be used to improve lake clarity are listed below:

Barley Straw: proven that it works, but it takes 200-250 pounds of barley per lake acre. The manual labor of installing the straw can be significant. Cost is about $80/acre.

Microbial Products: these products generally have a significant organic carbon component that aids the bacteria that is being added to the lake. The bacteria included in the product is inconsequential, but the organic carbon helper is essential. The dose should be around 30-50 pounds/lake acre/year of high quality organic carbon. Doses are usually introduced monthly and the cost is high. Costs range $300-$700/lake acre.

Blended Organic Amendments: we should be able to make our own carbon amendment using a mix of organic compounds. The mix should combine easily decomposable organics like sugars or amino acids along with more refractory compounds that are more difficult to break down like cellulose and lignin. Costs are estimated at $150/acre.

Examples of Successful Carbon Amendment Projects: Valley Lake and Twin Lake

Barley straw, which is a carbon amendment, has lowered phosphorus and improved water clarity in eutrophic Valley Lake and eutrophic Twin Lakes (Figure 38). Microbial product additions have anecdotal success stories. But if they work it is because of the carbon additions, not the bacterial additions. Schmidt Lake in Plymouth may be a success story and is an example where microbial products along with organic carbon additions appeared to improve water clarity in 2004. Data are being compiled at this time.

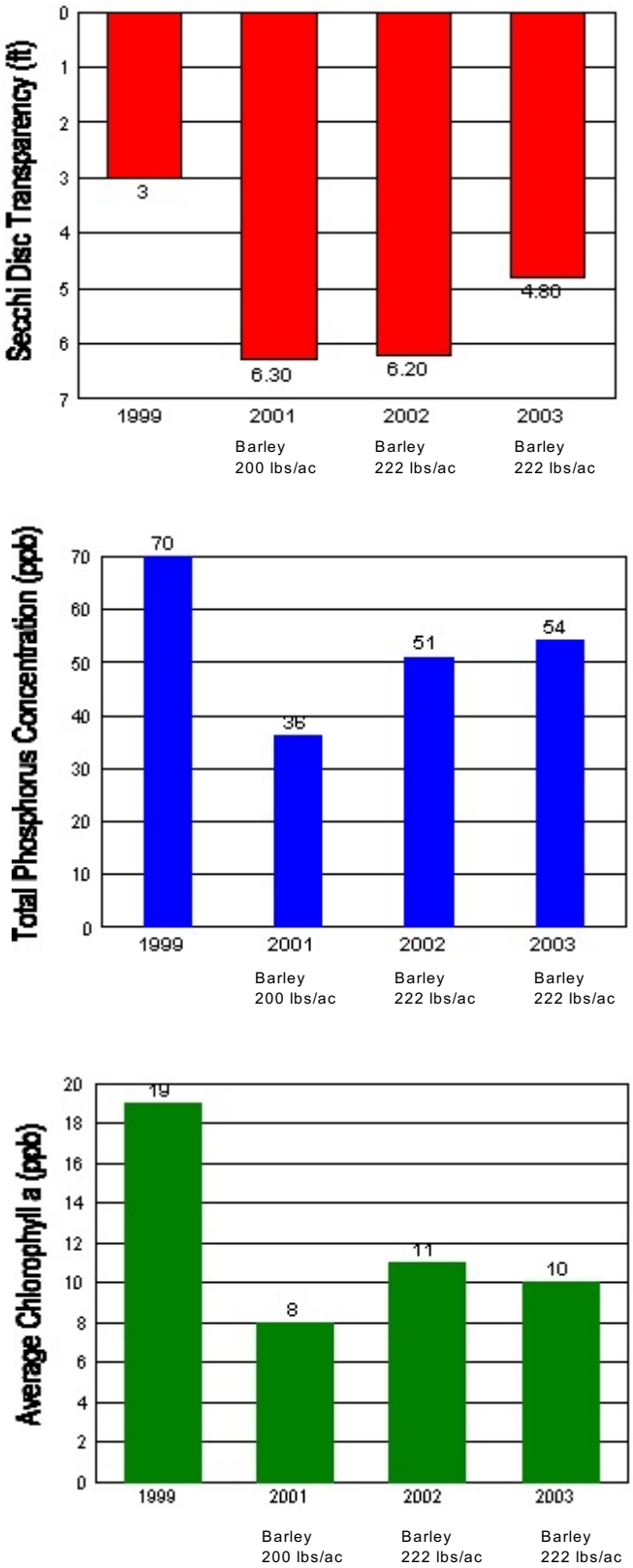


Figure 38. Barley straw successfully increased clarity and reduced the lake phosphorus concentration in South Twin Lake. Growing season average (May-Sept) for Secchi disc, total phosphorus, and chlorophyll from 1999 through 2003 is shown above. Water quality was improved with addition of 200+ pounds of barley per lake acre.

Expected Benefit: Alimagnet Lake has two significant phosphorus sources: watershed inputs and internal loading. Without a significant reduction in external phosphorus loading lake water quality will still be eutrophic. Without a significant reduction in watershed loading, conventional in-lake measures such as alum or iron treatments or aeration probably would not noticeably improve water quality. Another approach is to wait until the spring snowmelt runoff has entered the lake and then use an alum dose to remove phosphorus from the water column. However, the cost is roughly $300/ac or about $30,000 and this would be an annual cost. An alum dosing station that feeds in alum would be even more expensive.

A carbon amendment project may be a practical solution. Carbon amendments will direct phosphorus into heterotrophic growth which will end up in macroinvertebrates and in fish. This is a relatively long-term phosphorus removal mechanism. If the carbon amendment program is run for three to four years, clear water conditions should allow aquatic macrophytes to become reestablished. In the long term, the macrophytes could sustain clear water conditions.

Cost Range: A carbon amendment program using a blended carbon approach would cost approximately $150/ac or $16,000 per year for four or five years. Assume a project cost of $80,000.

5. Lake Sediment Alum Treatment (*reserve project*)

A common technique to reduce sediment phosphorus release from lakes when lake sediment phosphorus is a significant phosphorus source is a sediment alum treatment. Using an alum dosing determination methodology of Rydin and Welch (1999), the estimated alum dose required to reduce phosphorus release to 1 mg-P/m^2/day was calculated to be: 85 g-Al/m^2. This is a fairly high dose requirement representing about 1,560 gallons of alum per lake acre treated. A dose of this magnitude would probably be applied with three treatments of 520 gallon of alum/ac over 3 or 6 years.

Expected Benefit: If the alum treatment was effective in reducing the excessive phosphorus release from lake sediments down to 1 mg-P/m^2/day, lake phosphorus concentrations would drop down 5 to 10 ppb in the lake and transparency would increase about 1.6 feet as a seasonal average. However, there is no guarantee the effect would last longer than several years.

It is recommended that an alum treatment should be considered as a reserve project until it can be determined if controlling curlyleaf pondweed in conjunction with an organic carbon amendment can meet water quality goals.

Cost Range: It is assumed that 75 acres of Alimagnet would be treated with alum. The total number of gallons of alum required would be 117,000 gallons. The cost would be approximately $150,000.

Figure 39. An alum application is generally applied from a barge. This was a lake sediment alum application on Lake Susan in Chanhassen.

4.5.4. Estimated Water Quality Benefits of Proposed Lake Projects

A number of lake projects were evaluated for their potential to reduce phosphorus in the lake, improve aesthetics, or improve recreational opportunities.

Watershed modeling indicates that with aggressive watershed improvements, lake water clarity will improve but around 1.2 m (4 ft) based on an estimate in-lake summer phosphorus average of around 80 ppb. Additional lake projects are expected to further lower the lake phosphorus concentrations to around 54 ppb, adding to a slightly improved water clarity.

Phosphorus reductions and lake benefits associated with the recommended lake improvement projects are shown in Table 30.

Table 30. Lake improvement benefits associated with lake projects.

Priority Lake Projects	Description	TP Load Reduction (lbs-P/yr)	Other Benefits
1	Shoreland projects	4	Wildlife enhancement, aesthetics
2a	Continue to control curlyleaf pondweed	90	Improved recreational use
2b	Harvesting nuisance aquatic plant growth	15	Improved recreational use
3a	Black bullhead removal	0 - 60	Improves fishing
3b	Stock catfish and bass	0	Improves fishing, controls roughfish
4	Organic carbon amendment	150*	No herbicides used, improved fishing

* An estimated 150 pounds of phosphorus per year would be directed into the microbial community rather than into the algal community. This type of phosphorus redirection has been documented in lakes that have used barley straw.

In addition to the priority lake projects, additional projects have been identified that could be implemented if the priority projects are not meeting lake goals. These reserve projects have the potential to further reduce lake phosphorus concentrations but are not proposed for implementation unless needed based on future assessment of the lake condition. The three reserve projects are listed in Table 31.

Table 31. Reserve projects.

Reserve Projects	Description	TP Load Reduction (lbs/yr)
2c	Lake sediment iron treatment for curlyleaf control	150
3c	Install one or two additional winter aeration systems	100
5	Lake sediment alum treatment	150

* technique is still experimental. If successful this would be the estimated phosphorus reduction.

4.5.5. Watershed and Lake Programs

1. Ongoing Education Program

Both Cities, Apple Valley and Burnsville, have ongoing water quality information and education (I & E) programs. In some cases, that material can be customized for the residents in the Alimagnet Lake watershed. Listed below are examples of I & E programs that can be promoted. Additional I & E materials can be produced in the future.

1a. Adopt-A-Pond Program

Burnsville has an Adopt-A-Pond program in place and is an example of a hands-on education program. Below is the brochure that outlines the program (source: City of Burnsville)

What is Adopt-A-Pond?
Does your backyard pond look green and slimy?
Is your shoreline eroding?
Do you see fewer birds and other wildlife there?
You CAN do something about it!
Team up with neighbors to improve water quality— join the City of Burnsville's Adopt A-Pond program!

How Does It Work?
With guidance from City staff, your group will develop and implement a plan to restore your pond. A commitment of at least one year is desired and two years is preferred.

What Are The Requirements?
At a minimum, your group must clean up debris along the pond's shoreline twice a year. Additional restoration projects may include:

1. Installing storm water treatments to reduce and/or treat runoff from rooftops, driveways and roads. Impervious surfaces allow more pollutants and storm water to travel through the watershed.

2. Creating and/or maintaining a naturally vegetated buffer along the water's edge. By using native plants, you can filter a significant amount of storm water flowing into the pond and provide quality habitat for wildlife.

3. Controlling aquatic weeds through harvesting or other treatments. Many ponds are overgrown with algae, which make them green, slimy and smelly, as well as suffocate aquatic life.

Who May Participate?
This program is geared towards residents who live on property adjacent to ponds, but anyone may participate. For more information on the Adopt-A-Pond program, please contact Daryl Jacobson, Natural Resources Technician, at 952-895-4574 or daryl.jacobson@ci.burnsville.mn.us.

What Else Should I Know?
Your Adopt-A-Pond group may apply for a Water Resources Enhancement Grant (up to $1,000) from the City to fund shoreline restoration projects and storm water runoff treatments, or pay for disposal of trash cleanups. For more information on the Water Resources Enhancement Grant, please contact Leslie Yetka, Water Resources Specialist, at 952-895-4518 or leslie.yetka@ci.burnsville.mn.us.

1b. Newsletters and Other Media

Lake residents get an important amount of lake protection information from lake newsletters. Each issue should offer tips on lake protection techniques. There is abundant material available. An example of an informational piece is shown below.

Reduce Waste *If not you, who?*

YOUR LAWN AND THE ENVIRONMENT

New phosphorus lawn fertilizer law aims to protect Minnesota lakes and rivers

Minnesota has recently passed a law that restricts the use of lawn fertilizers containing phosphorus, the primary nutrient that turns lakes green with algae.

New Phosphorus Law

Starting January 1, 2004, **fertilizers containing phosphorus cannot be used on lawns in the Twin Cities metro area** (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott and Washington counties). Greater Minnesota is restricted to lawn fertilizers with 3 percent or less phosphate content (with fertilizer, phosphorus is measured as *phosphate*). Look for the middle number on a bag of fertilizer. For the metro area, it should be zero (0) and in Greater Minnesota it should be three (3).

Keep fertilizer off paved surfaces: It's illegal to spread any fertilizer on hard surfaces such as streets, sidewalks, and driveways. Rain can wash the fertilizer into nearby storm drains or road ditches, eventually getting into a lake or river near you. If you accidentally spill or spread fertilizer on a hard surface, clean it up immediately.

Exemptions

Fertilizers containing phosphorus may be used on lawns if a soil test indicates that it is needed or if you are establishing a new lawn.

These restrictions do not apply to fertilizers used for agricultural crops, flower and vegetable gardening, or on golf courses by trained staff.

Do the green thing: fertilize responsibly Many garden centers and hardware stores now carry phosphorus-free lawn fertilizers.

Will phosphorus-free fertilizer keep my lawn healthy?

While phosphorus is necessary to grow healthy lawns, soils in many parts of Minnesota already have an adequate amount. In these instances, adding more phosphorus in fertilizer is not needed and will not benefit your lawn. Healthy lawns can be maintained with phosphorus-free fertilizers.

THE PROBLEM: TOO GREEN

Green and mucky Excess algae and weed growth is a major problem in many Minnesota lakes and waterways.

More phosphorus, less fish Too much algae lowers oxygen levels and darkens the water. This can have a devastating effect on fish populations.

What to look for

On any bag or box of fertilizer, there is a string of three numbers. The middle number indicates phosphorus content and should read "0" in the Twin Cities seven-county metropolitan area, and "3" or less in Greater Minnesota.

What can you do to protect water quality?

Fertilizers, leaves, grass clippings, eroded soil, and animal waste are all sources of phosphorus. When they are swept or washed into the nearest street or storm drain, they end up in your local lake or river. You can do your part to protect water quality by doing the following:

- Follow Minnesota's new phosphorus lawn fertilizer law.
- Keep leaves and lawn clippings out of your gutters, streets, and ditches.
- Clean lawn and garden equipment on the grass, not on hard surfaces. Never wash or blow soil or grass clippings into the street.
- Pick up pet waste promptly. Pet waste can contain harmful bacteria as well as nutrients. Never drop pet waste in the street or ditches.

- Control soil erosion around your house. When left bare, soil is easily washed away with rain, carrying phosphorus with it. Soil erosion can be prevented by keeping soil covered with vegetation or mulch.

Sweep it up Grass clippings and leaves left on streets and sidewalks are a major source of phosphorus.

Find out what you need: Test your soil

A soil test is a good idea, especially if you are concerned that your lawn may need phosphorus.

Instructions on soil testing are available through the University of Minnesota Extension Service's INFO-U by calling 612-624-2200 (metro) or 1-800-525-8636 and requesting message 468.

Soil testing information can also be obtained through the Internet by visiting **www.extension.umn.edu** and searching for "Lawn Soil Testing."

A list of laboratories certified for soil testing by the Minnesota Department of Agriculture can be found at **www.mda.state.mn.us/appd/soilabs.htm**.

Visit **www.reduce.org** for lots of ideas about reducing waste and toxic chemicals in your day-to-day life.

reduce.org

To obtain additional copies of this fact sheet

contact Office of Environmental Assistance's **Education Clearinghouse** at 1-800-877-6300, 651-215-0232 or e-mail: clearinghouse@moea.state.mn.us.

For more information on lawn care

- The **Yard & Garden Line** is the University of Minnesota Extension Service's one-stop telephone link to information about plants and insects in the home landscape. Call 612-624-4771, or (toll free) 1-888-624-4771 in Greater Minnesota.
- University of Minnesota **Extension Service's web site**: www.extension.umn.edu. From the home page click on "Garden" then on "Lawns."
- University of Minnesota Extension Service - **Sustainable Urban Landscape Information Series** (SULIS): www.sustland.umn.edu. From the home page, click on "Maintenance" then on "Lawn care."
- **Minnesota Department of Agriculture**: www.mda.state.mn.us. From the home page, click on "Water & Land," then on "Lawn Care & Water Quality."

Minnesota Department of Agriculture — From the Farm to Your Family

Metro WaterShed Partners

University of Minnesota Extension Service

Minnesota Office of Environmental Assistance

2. Watershed and Lake Monitoring Program

Watershed water quality monitoring will be important in order to track effectiveness of watershed projects. The main emphasis will be to evaluate conditions in the three critical stormwater ponds (1A, 6C, and 7A). Pond monitoring is incorporated into watershed project 1.

A lake monitoring program is outlined in Table 32. It is basically continuation of the CAMP program combined with winter dissolved oxygen monitoring.

Table 32. Alimagnet Lake water quality monitoring program outline.

Category	Level	Alternative	Labor Needed	Cost/Year
A. Dissolved oxygen	1	Check dissolved oxygen in Alimagnet Lake every two weeks in January, February, and March depending on winter conditions.	Moderate	$0
	2	Check dissolved oxygen in Alimagnet Lake every one to two weeks in December, January, February, and March, depending on winter conditions and collect phosphorus samples.	Moderate	$0
B. Water clarity	1	Secchi disc taken at spring and fall turnover.	Low	$0
	2	Secchi disc monitoring once per month May - October.	Low-moderate	$0
	3	Secchi disc monitoring twice per month, May - October.	Moderate	$0
C. Water chemistry	1	Spring and fall turnover samples are collected. Selected parameters for analysis include: TP and chlorophyll.	Low	$200
	2	Spring and fall turnover samples are collected. Expanded list of parameters is analyzed.	Low	$600
	3	Sample for phosphorus and chlorophyll once per month from May - September (surface water only).	Low-moderate	$300
	4	Sample for phosphorus and chlorophyll twice per month from May - October (CAMP program).	Moderate	$600
	5	Sample for phosphorus, chlorophyll, Kjeldahl-N, nitrate-nitrite-N, and ammonia-N once per month (May-October)	Moderate	$960
	6	Sample for phosphorus, chlorophyll, Kjeldahl-N, nitrate-nitrite-N, and ammonia-N twice per month (May-October).	Moderate	$1,920
D. Special samples or surveys	1	Special samples: suspended solids, BOD, chloride, sampling bottom water, and other parameters as appropriate. Aquatic plant surveys, etc.	--	$100-$3,000

A recommended program consists of Level A1, Level B3 and Level C4 annually. An aquatic plant survey (Level D1) should be conducted every year until projects are implemented and the lake condition is stable.

5. Recommended Lake Management Projects

Watershed Projects

1. Stormwater pond improvements.
   - 1a. Carbon amendments for three ponds.
   - 1b. Excavation of pond 1A.
   - 1c. Excavation of pond 7A.
2. Fertilizer management and control.

Lake Projects

1. Shoreland buffers.
2. Aquatic plant projects.
   - 2a. Continue curlyleaf control program.
   - 2b. Harvest nuisance plant growth if water clarity improves.
3. Fish management
   - 3a. Black bullhead survey/removal.
   - 3b. Predator stocking.
4. Whole lake organic carbon amendment.

Watershed and Lake Programs

1. Information and education
2. Watershed and lake monitoring

Reserve Projects

Street sweeping
Infiltration and rain gardens
Use iron addition to control curlyleaf pondweed
Installation of additional winter aeration sytems
Whole lake alum project

Project Costs

Estimated project costs for the Alimagnet Lake improvement program are summarized in Table 33.

Table 33. Summary of recommended projects and costs.

	Estimated Phosphorus Reduction (pounds/year)	Capital Cost	Average Annual O & M (5 yr)	5 Year Cost
Watershed Projects				
1. Stormwater pond improvements.				
1a. Barley straw for three ponds.	123	0	4,000	20,000
1b. Excavation of pond 7A.	16	65,000	0	65,000
1c. Excavation of pond 1A.	37	150,000	0	150,000
1d. Construction of pre-treatment pond for 1A.	19	240,000	0	240,000
2. Fertilizer management and control.	13	0	2,000	10,000
Subtotal	***208***	***455,000***	***6,000***	***485,000***
Lake Projects				
1. Shoreland buffers.	4	0	3,000	15,000
2. Aquatic plant projects.				
2a. Continue curlyleaf control program	90	5,000	1,000	10,000
2b. Harvest nuisance plant growth.	--	0	3,000	15,000
3. Fish management				
3a. Black bullhead removal.	30	0	4,200	21,000
3b. Predator stocking.	--	0	800	4,000
4. Organic carbon amendment.	150	0	16,000	80,000
Subtotal	***274***	***5,000***	***28,000***	***145,000***
Watershed and Lake Programs				
1. Information and education	10	0	3,000	15,000
2. Watershed and lake monitoring	--	0	2,500	12,500
Subtotal	***10***	***0***	***5,500***	***27,500***
TOTAL	***492***	***460,000***	***39,500***	***657,500***
Margin of Safety Projects (see page 61 for explanation)				
Street sweeping	9	0	4,500	22,500
Infiltration and rain gardens	22	300,000	0	300,000
Reserve Projects (see page 84 for explanation)				
Lake sediment iron treatment for curlyleaf pondweed	150	30,000	0	30,000
Install winter aeration in two additional locations	100	30,000	3,000	45,000
Lake sediment alum project	150	100,000	0	150,000

Table 34. Alimagnet Lake improvement project sequence, annual costs, and total project cost for a 5-year program.

	Year 1	Year 2	Year 3	Year 4	Year 5	5 Year Cost
Watershed Projects						
1. Stormwater pond improvements.						
1a. Barley straw for 3 ponds.	4,000	4,000	4,000	4,000	4,000	20,000
1b. Excavation of pond 7A.	--	65,000	--	--	--	65,000
1c. Excavation of pond 1A.	--	60,000	90,000	--	--	150,000
1d. Construction of pre-treatment pond for 1A.	--	40,000	120,000	80,000	--	240,000
2. Fertilizer management and control.	2,000	2,000	2,000	2,000	2,000	10,000
Subtotal	***6,000***	***171,000***	***216,000***	***86,000***	***6,000***	***485,000***
Lake Projects						
1. Shoreland buffers.	3,000	3,000	3,000	3,000	3,000	15,000
2. Aquatic plant projects.						
2a. Continue curlyleaf control program	6,000	1,000	1,000	1,000	1,000	10,000
2b. Harvest nuisance plant growth.	--	--	5,000	5,000	5,000	15,000
3. Fish management						
3a. Black bullhead removal.	7,000	7,000	7,000	--	--	21,000
3b. Predator stocking.	1,500	900	800	800	--	4,000
4. Organic carbon amendment.	16,000	16,000	16,000	16,000	16,000	80,000
Subtotal	***33,500***	***27,900***	***32,800***	***25,800***	***25,000***	***145,000***
Watershed and Lake Programs						
1. Information and education	3,000	3,000	3,000	3,000	3,000	15,000
2. Watershed and lake monitoring	2,500	2,500	2,500	2,500	2,500	12,500
Subtotal	***5,500***	***5,500***	***5,500***	***5,500***	***5,500***	***27,500***
TOTAL	***45,000***	***204,400***	***254,300***	***117,700***	***36,500***	***657,500***

6. References

Claytor, R. 1999. New Developments in Street Sweeper Technology. Center for Watershed Protection. Ellicott City, MD. Watershed Protection Techniques. 3(1).

Connecticut Department of Environmental Protection. Accessed on May 20, 2004 from Internet site http://wethersfieldct.com/physical/grass.htm.

Fagerness, Matthew J. *Recycling Grass Clippings*, Kansas State University, January 2001.

Lake Access. Accessed on May 20, 2004 from Internet site http://lakeaccess.org/lakedata/lawnfertilizer/recentresults.htm

Minnesota Pollution Control Agency (MPCA). 2002. Protecting Water Quality in Urban Areas. St. Paul, Minnesota.

Runoff Report. A Clean Sweep Now Possible. The Terrene Institute, Alexandria, VA. 6(4). July/August 1998.

Rydin, E. and E.B. Welch. 1999. Dosing alum to Wisconsin lake sediments based on in vitro formation of aluminum bound phosphate. Journal Lake and Reservoir Management 15:324-331

United States Environmental Protection Agency (US EPA). 1999. Technical Note 56. State-of-the-art Street Sweeper Could Reduce Suspended Solids in Receiving Waters.

Wisconsin Department of Transportation. Report Number WI-11-01. Pollutant Loadings to Stormwater Run-off From Highways: The Impact of a Freeway Sweeping Program. June, 2002.