Mitchell Lake Use Attainability Analysis

Prepared for
Riley-Purgatory-Bluff Creek Watershed District

May 2005

Overview

This report contains the results of a Use Attainability Analysis (UAA) of Mitchell Lake. The UAA is a structured scientific assessment of the chemical, physical, and biological conditions in a water body. The analysis includes diagnosis of the causes of observed problems and prescription of alternative remedial measures (such as a diagnostic-feasibility study) that will result in the attainment of the intended beneficial uses of Mitchell Lake. The analysis is based upon historical water quality data, results of an intensive lake monitoring program in 1999, and computer simulations of watershed runoff. Computer simulations were used to estimate watershed runoff (phosphorus and flow) under existing and proposed future land use and under varying climatic conditions.

Riley-Purgatory-Bluff Creek Watershed District Water Quality Goals

The approved *Riley-Purgatory-Bluff Creek Watershed District Water Management Plan,* 1996, articulated five specific goals for Mitchell Lake. These goals address recreation, water quality, aquatic communities, water quantity, and wildlife. Wherever possible, Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) goals for Mitchell Lake have been quantified using a standardized lake rating system termed Carlson's Trophic State Index (Carlson 1977)). This rating system considers the lake's total phosphorus, chlorophyll *a*, and Secchi disc transparency measurements to assign it a water quality index number that reflects its general level of fertility. The resulting index values generally range between 0 and 100, with increasing values indicating more fertile conditions.

Total phosphorus, chlorophyll *a*, and Secchi disc transparency are key water quality parameters upon which Carlson's Trophic State Index (TSI) statistics are computed, for the following reasons:

- **Phosphorus** generally controls the growth of algae in lake systems. Of all the substances needed for biological growth, phosphorus is typically the limiting nutrient.
- **Chlorophyll *a*** is the main pigment in algae. Therefore, the amount of chlorophyll *a* in the water indicates the abundance of algae present in the lake.
- **Secchi disc transparency** is a measure of water clarity and is inversely related to the abundance of algae.

Although any one or all three parameters can be used to compute TSI, water transparency is most often used, since people's perceptions of water clarity are most directly related to recreational use impairment. The TSI rating system is scaled to place a mesotrophic (medium fertility level) lake on the scale between 40 and 50, and high and low fertility lakes (eutrophic and oligotrophic) toward the high and low ends of the TSI range, respectively. Characteristics of lakes in different trophic status categories are listed below with their respective TSI ranges:

1. **Oligotrophic**—[$20 \leq$ TSI ≤ 38] clear, low productivity lakes, with total phosphorus concentrations less than or equal to 10 µg/L, chlorophyll *a* concentrations less than or equal to 2 µg/L, and Secchi disc transparencies greater than or equal to 4.6 meters (15 feet).
2. **Mesotrophic—**[$38 \leq$ TSI ≤ 50] intermediate productivity lakes, with 10 to 25 µg/L total phosphorus, 2 to 8 µg/L chlorophyll *a* concentrations, and Secchi disc measurements of 2 to 4.6 meters (6 to 15 feet).
3. **Eutrophic—**[$50 \leq$ TSI ≤ 62] high productivity lakes, with 25 to 57 µg/L total phosphorus, 8 to 26 µg/L chlorophyll *a* concentrations, and Secchi disc measurements of 0.85 to 2 meters (2.7 to 6 feet).
4. **Hypereutrophic—**[$62 \leq$ TSI] extremely productive lakes, with total phosphorus concentrations greater than 57 µg/L, chlorophyll *a* concentrations greater than 26 µg/L, and Secchi disc measurements less than 0.85 meters (less than 2.7 feet).

The RPBCWD goals for Mitchell Lake include the following:

1. The **Recreation Goal** is to provide water quality that: fully supports the lake's MDNR ecological class 42 rating (i.e., a Trophic State Index (TSI_{SD}) of 62 or lower). The goal is attainable with the implementation of lake management practices as described in this UAA.
2. The **Water Quality Goal** is a trophic state index score that meets or exceeds the necessary level to attain and maintain full support of fishing: A Trophic State Index (TSI_{SD}) of 62 or lower to fully support the lake's fishery. This goal is also attainable with the implementation of lake practices discussed in this UAA.
3. The **Aquatic Communities Goal** is a water quality that fully supports fishing, according to the Minnesota Department of Natural Resources (MDNR) "Ecological Use Classification" (TSI_{SD} of 62 or lower)." This goal is attainable with the implementation of lake management practices listed herein.
4. The **Water Quantity Goal** for Mitchell Lake is to manage surface water runoff from a regional flood, the critical 100-year frequency storm event. This goal has been achieved.
5. The **Wildlife Goal** for Mitchell Lake is to protect existing, beneficial wildlife uses. The wildlife goal has been achieved.

Water Quality Problem Assessment

An evaluation of water quality data for Mitchell Lake from 1972 to 1999 was completed to determine the current status of the lake's water quality. Results of this evaluation indicate that the lake's water quality is poor and has primarily remained in this condition over time. The poor water quality has its origins in historical and current inputs of phosphorus and the accumulation of phosphorus in lake sediments. Early measurement of water quality in Mitchell Lake as far back as 1972 suggests that the water quality of Mitchell Lake has been impaired for a long time. The poor water quality of Mitchell Lake is perpetuated by stormwater runoff from the lake's watershed, phosphorus release from sediments, and the decay of curlyleaf pondweed each summer.

Historical Water Quality Trends

Trend analyses from 1972 through 1999 indicate that there has been no significant change in Mitchell Lake's water quality. Hence, the data indicate the lake's current water quality problems are unlikely to change unless management practices are implemented to improve the lake's water quality.

A comparison of baseline (i.e., 1972 to 1987) and current (1988 to 1999) trophic state index (TSI) values indicates that Mitchell Lake has fully supported fishable use during 40 percent of the baseline period and 67 percent of the current period. For the entire 1972 to 1999 period, Mitchell Lake was able to meet the MDNR criteria ($TSI \leq 62$) for fully supported fishable use during 6 of the 11 monitored years (i.e., 1975, 1984, 1991, 1993, 1995, and 1996).

Current Water Quality

The current water quality of Mitchell Lake is poor and recreation activities are impaired by mid- to late-summer algal blooms that can be characterized as severe. In 1999 Mitchell Lake's average summer concentration of total phosphorus, concentration of chlorophyll *a*, and Secchi disc transparency were 120 μg/L, 37 μg/L, and 0.8 m, respectively. This current water quality condition of Mitchell Lake is the result of inputs of phosphorus from stormwater runoff, the mobilization of phosphorus from lake sediments, and from the decay of curlyleaf pondweed. As a result, the 1999 total phosphorus, chlorophyll *a*, and Secchi disc data indicate that Mitchell Lake ranges from borderline mesotrophic (good) to eutrophic (poor) in the spring and is hypereutrophic (very poor) during summer and fall.

Phosphorus Budget

There are three sources of phosphorus loading to Mitchell Lake: watershed runoff, atmospheric deposition, internal phosphorus loading (e.g., release of phosphorus from lake sediments and decay of curlyleaf pondweed).

Watershed modeling and in-lake modeling under different climatic conditions and for existing watershed land uses indicate that annual total phosphorus loads to the lake range from 354 pounds for a dry year to 626 pounds for a wet year (Figure EX-1). Under future land use conditions, annual phosphorus loads to the lake are expected to range from 399 pounds for a dry year to 691 pounds for a wet year (Figure EX-1). The average rate of watershed loading to the 119-acre lake is 3.7 pounds of phosphorus per acre of lake per year under existing land use conditions and 4.3 pounds of phosphorus per acre of lake per year under future land use conditions. This rate of phosphorus loading is excessive and causes water quality problems (L = 0.418 g/m^2/yr under existing watershed land uses; L = 0.485 g/m^2/yr under future land uses).

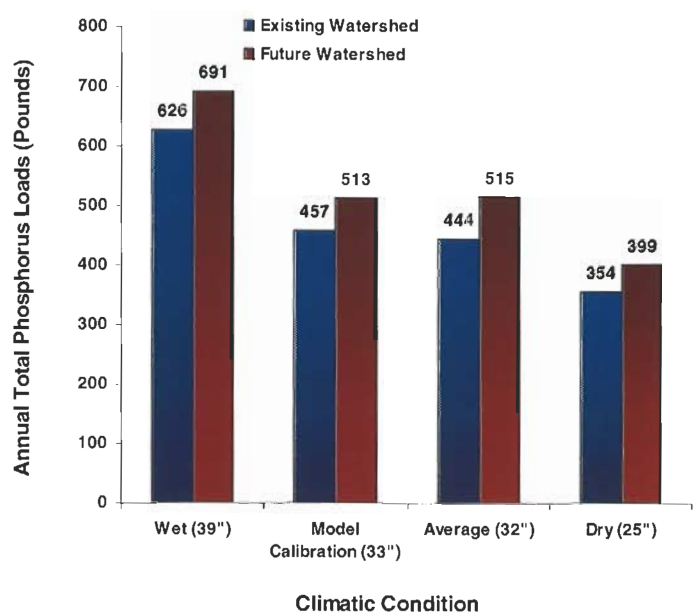

Figure EX-1 Total Phosphorus Loading to Mitchell Lake with Varying Climatic Conditions and with Existing and Future Watershed Land Uses

Watershed modeling for the 980-acre Mitchell Lake watershed (including Mitchell Lake) shows that from 169 (dry year) to 441 (wet year) pounds of phosphorus loading to the lake originates from the surrounding watershed under existing land use conditions. Under existing land use conditions and average precipitation, watershed loading provides approximately 58 percent of the total phosphorus load to the lake, while internal loading provides approximately 29 percent of the total phosphorus load to the lake (Figure EX-2). The remaining phosphorus load comes from atmospheric deposition (13 percent) (Figure EX-2).

The high concentration of phosphorus observed in Mitchell Lake is the result of watershed loading and from internal lake processes including the direct release of phosphorus from the sediments and the decay of curlyleaf pondweed. Under existing watershed land use conditions, internal lake processes are responsible for approximately 20 (wet) to 36 (dry) percent of the total phosphorus load to Mitchell Lake. Changes in future watershed land use are expected to increase the lake's total phosphorus load from stormwater runoff by 9 to 12 percent. Concurrently, the proportion of phosphorus loading from internal sources is expected to be reduced by 2 to 6 percent.

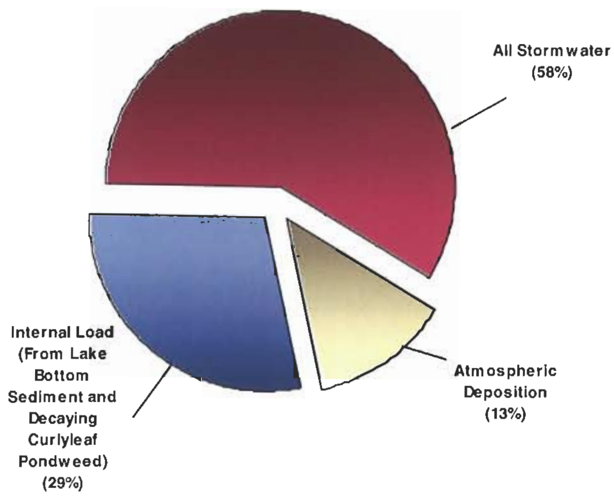

Figure EX-2 Proportion of Phosphorus Loading by Source

Aquatic Plants

District aquatic plant surveys, together with observations by the MDNR, indicate three problematic non-native species currently reside in the lake: curlyleaf pondweed, Eurasian watermilfoil, and purple loosestrife.

District aquatic plant surveys completed in 1999 indicate curlyleaf pondweed (*Potamogeton crispus*), was found throughout the lake in light to moderate density during June. A comparison of current and historical surveys indicates curlyleaf pondweed density is determined by the lake's water clarity. Light plant density occurs when water clarity is poor and heavier density occurs when water clarity improves. This relationship indicates that water quality management to improve the lake's water transparency is likely to result in a denser curlyleaf pondweed growth unless a curlyleaf pondweed management program is completed first.

MDNR and Midwest Aqua Care Inc. staff observed Eurasian watermilfoil in Mitchell Lake during 2002. Although its density was sparse, Eurasian watermilfoil growth was distributed throughout the northern 75 percent of the lake (approximately 20 growth locations). Eurasian watermilfoil has not previously been observed in the lake by MDNR staff or District surveys (1993, 1996, and 1999). Water quality management to improve the lake's water clarity is likely to result in increased Eurasian watermilfoil growth unless a program to manage this plant is completed first.

Purple loosestrife was observed in four locations along the Mitchell Lake shoreline during 1999. Management of purple loosestrife is recommended to protect the quality of vegetation along the lake's shoreline.

Recommended Goal Achievement Alternatives

One lake improvement alternative will achieve or exceed the District goal for Mitchell Lake.

(1) Manage curlyleaf pondweed and Eurasian watermilfoil by herbicide (endothall for curlyleaf pondweed and 2,4-D for Eurasian watermilfoil) until no regrowth is observed and no viable turions are collected (estimate 4 years),

(2) Introduce beetles (*Galerucella pusilla, Galerucella calmariensis*) in purple loosestrife infested areas to control shoreline purple loosestrife, and

(3) Six consecutive years of alum treatment to follow the fourth year of herbicide treatment.

Should current research efforts determine that lime is a better tool for management of curlyleaf pondweed and Eurasian watermilfoil than herbicide treatment, four years of alum-lime treatment followed by two years of alum treatment will replace items (1) and (3).

The expected cost and benefit of this alternative is presented in Table EX-1 and Figure EX-3.

Table EX-1 Benefits and Costs of Management Alternative

Management Alternative	Trophic State Index (TSI_{SD}) Value				Cost
	District Goal	Wet Year_1997 (39 inches of precipitation)	Average Year_1999 (33 inches of precipitation)	Dry Year_2000 (25 inches of precipitation)	
Existing Watershed Land Uses					
Herbicide Treatment (4 years), Alum Treatment (6 years), and Purple Loosestrife Management by Beetles Introduction	≤ 62	61	57	55	$960,000
Future Watershed Land Uses					
Herbicide Treatment (4 years), Alum Treatment (6 years), and Purple Loosestrife Management by Beetles Introduction	≤ 62	62	59	57	$960,000

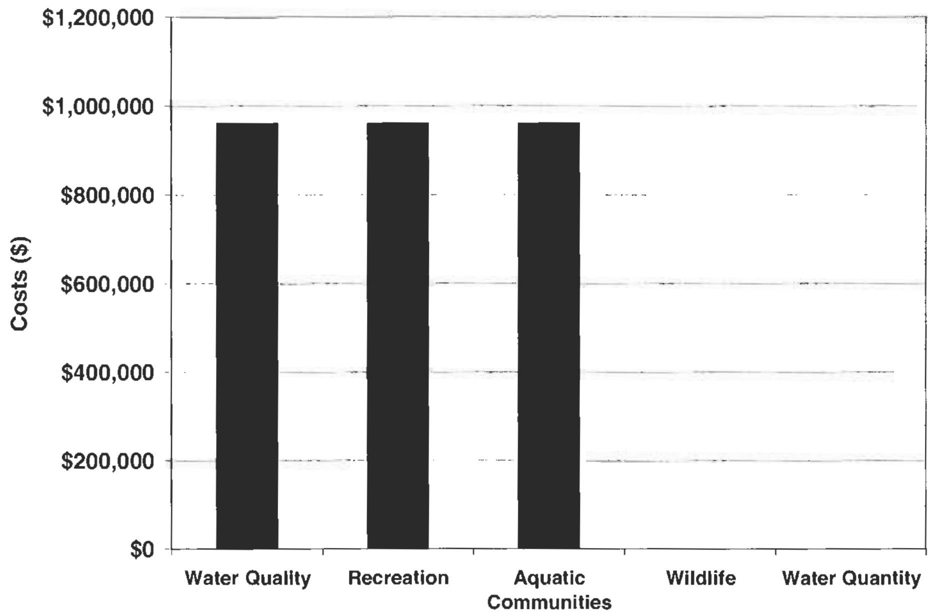

Figure EX-3 Mitchell Lake Costs to Meet or Exceed Goals

Selected Implementation Plan

The selected implementation plan is herbicide treatment of curlyleaf pondweed and Eurasian watermilfoil for four years followed by six consecutive years of alum treatment. This implementation plan has been selected because lake analysis results indicate that the overall productivity of Mitchell Lake needs to be significantly reduced to restore the lake to a more ecologically balanced condition. This means that phosphorus release from sediments and from the decay of curlyleaf pondweed needs to be controlled. In addition, curlyleaf pondweed and Eurasian watermilfoil management is required to avoid additional growth by these nuisance species as water quality improves. Should current research efforts determine that lime is a better tool for management of curlyleaf pondweed and Eurasian watermilfoil than herbicide treatment, four years of alum-lime treatment followed by two years of alum treatment will replace the four herbicide treatments followed by six alum treatments.

Beetles (*Galerucella pusilla, Galerucella calmariensis*) will be introduced in purple loosestrife infested areas to control shoreline purple loosestrife and promote native vegetation.

This plan will require monitoring throughout the restoration effort to evaluate effectiveness and determine whether the prescribed management plan remains appropriate. Aquatic plants, lake water quality, and lake sediments should be monitored. Monitoring data will be used to adjust the implementation plan as warranted.

Proposed 7050 Standards For Lakes

Because of its poor water quality, Mitchell Lake is currently listed on Minnesota's 303(d) impaired waters list. Under proposed 7050 Standards for lakes, Mitchell Lake would remain on the impaired waters list unless the lake's water quality improved such that the Standards were attained. Management of the lake's curlyleaf pondweed community and treatment of Mitchell Lake with alum (i.e., implementation of the recommended water quality improvement plan) is expected to improve the lake's water quality so that the proposed 7050 standards are attained under all but the wet climatic condition under existing watershed land use conditions. However, because additional phosphorus loading is expected to occur under future land use conditions, the lake would only attain the proposed 7050 standards under the dry climatic condition in the future.

Implementation of one additional water quality improvement project would attain the proposed 7050 standards under nearly all conditions. Treatment of pond M-56 inflow waters with alum (80 percent removal of total phosphorus load assumed) would enable Mitchell Lake to attain the proposed 7050 standards under all climatic conditions under existing land use conditions. Despite additional phosphorus loading under future land use conditions, the standard would be attained under all but the wet climatic condition in the future. However an inflow alum treatment facility is both expensive to build and operate. Hence, completion of the recommended implementation plan and evaluation of the resultant lake water quality should precede further consideration of this treatment option.

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1.0 Surface Water Resources Data

The approved *Riley-Purgatory-Bluff Creek Watershed District Water Management Plan*, 1996, (Water Management Plan) inventoried and assessed Mitchell Lake. The plan articulated five specific goals for Mitchell Lake. These goals address recreation, aquatic communities, water quality, water quantity, and wildlife. This report (1) evaluates the existing and potential beneficial uses intended in these goals; (2) contains an analysis of the factors that potentially impair or limit those beneficial uses, particularly problems identified in the inventory and assessment; and (3) expands upon specific aspects of the inventory and assessment of Mitchell Lake contained in the approved Water Management Plan.

A use attainability analysis of Mitchell Lake was completed to provide the scientific foundation for a lake-specific best management plan that will maintain or attain the existing and potential beneficial uses of Mitchell Lake. A use attainability analysis evaluates existing and potential beneficial uses of a water resource. "Use attainment" refers to the designated beneficial uses, such as swimming and fishing. Factors that potentially impair or limit existing beneficial uses, including problems identified in the inventory and assessment, are investigated in the use attainability analysis. Lake analyses rely on previously collected field data and continue with watershed evaluations using water quality modeling.

The main tools used in the technical analysis are an advanced water quality model that predicts the amount of pollutants that reach a lake via stormwater runoff and an in-lake model that is used to better understand in-lake processes. Calibrating a lake model requires an accurate measurement of land use and stormwater inputs. Impacts of upland detention and treatment of stormwater are included in the model.

1.1 Land Use

All land use practices, existing, as well as future practices within a lake's watershed, impact the lake and its water quality. Impacts result from the export of sediment and nutrients, primarily phosphorus, to a lake from its watershed. Each land use contributes a different quantity of phosphorus to the lake, thereby affecting the lake's water quality differently. Existing and proposed future land uses in the Mitchell Lake watershed are discussed in the following paragraphs.

The Mitchell Lake watershed is comprised of:

- Mitchell Lake (119 acres at a water elevation of 870.55 feet)
- Land that drains directly to Mitchell Lake (154 acres). Runoff from the lake's directly tributary watershed is not treated prior to entering the lake.
- Land that drains directly to stormwater treatment ponds (707 acres) and indirectly to Mitchell Lake by a stormwater conveyance system. Stormwater is treated by ponds before entering the lake.
- Round Lake (32 acres) and land that drains to Round Lake (412 acres). Stormwater draining to Round Lake is treated by the lake and conveyed to Mitchell Lake when outflow from Round Lake occurs. Relatively little outflow occurs from Round Lake.

Excluding the land tributary to Round Lake, the Mitchell Lake watershed is 980 acres, including Mitchell Lake (119 acres). Nearly half of the Mitchell Lake watershed is comprised of neighborhoods that are primarily single-family residences (341 acres), but also contain multiple-family residences (114 acres). The remainder of the lake's watershed consists of parks and open areas (233 acres), water (Mitchell Lake 119 acres; stormwater treatment ponds 69 acres), industrial/office areas (67 acres), highway (31 acres), commercial (2 acres), and institutional (4 acres) areas.

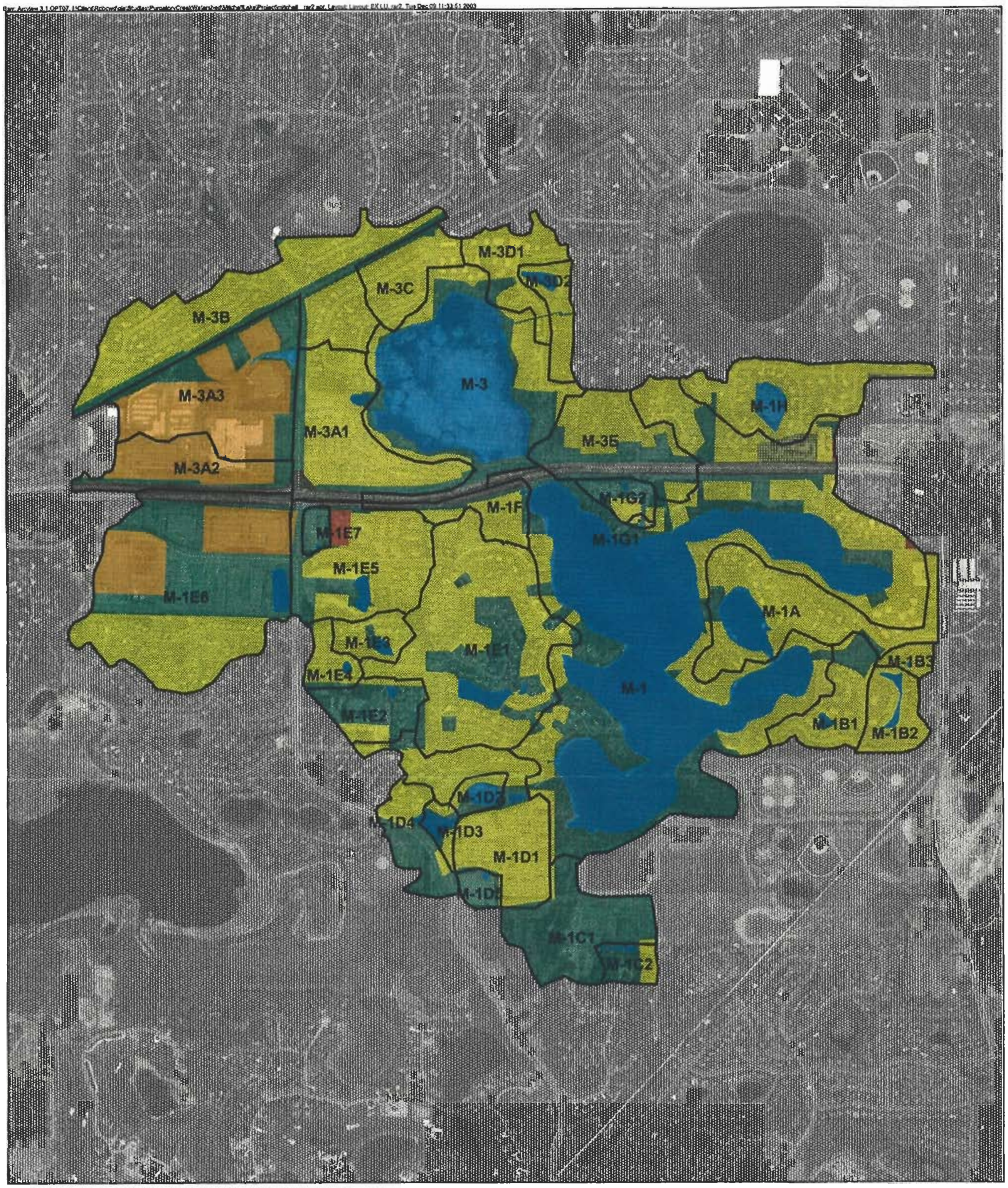
Land use data used in the Mitchell Lake UAA modeling efforts were derived from the Metropolitan Council Generalized Land Use Maps for the year 1997 (existing land use) and 2020 (projected future land use). A detailed description of the existing and future land uses of the Mitchell Lake watershed are presented in Tables 1 and 2, respectively. Maps of the existing and future land uses of the Mitchell Lake watershed are presented in Figures 1, and 2. Mitchell Lake watershed land uses under existing and future conditions are presented in Figure 3.

Table 1 Existing Land Use in the Mitchell Lake Watershed

Subwatershed Name	Commercial (acres)	Highway (acres)	Medium Density Residential (acres)	Low Density Residential (acres)	Natural/Park/ Open (acres)	Institutional (acres)	Industrial/ Office (acres)	Open Water (acres)	TOTAL (acres)
M-1	0.4	6.6	20.2	47.9	48.9	3.1	0.0	118.5	245.6
M-1A	0.0	0.0	5.0	25.2	1.5	0.0	0.0	6.1	37.9
M-1B1	0.0	0.0	6.1	6.1	2.7	0.0	0.0	0.5	15.4
M-1B2	0.0	0.0	10.5	0.0	0.0	0.0	0.0	1.1	11.6
M-1B3	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.1	3.3
M-1C1	0.0	0.0	0.4	0.2	26.4	0.0	0.0	0.0	26.9
M-1C2	0.0	0.0	0.0	1.7	3.5	0.0	0.0	0.3	5.5
M-1D1	0.0	0.0	18.9	12.2	2.9	0.0	0.0	0.4	34.4
M-1D2	0.0	0.0	0.0	1.6	1.2	0.0	0.0	1.6	4.4
M-1D3	0.0	0.0	0.9	0.7	0.6	0.0	0.0	1.5	3.6
M-1D4	0.0	0.0	0.5	4.2	8.1	0.0	0.0	0.2	13.0
M-1D5	0.0	0.0	0.2	0.0	3.4	0.0	0.0	0.1	3.7
M-1E1	0.0	0.0	0.0	50.9	18.7	0.0	0.0	2.3	71.8
M-1E2	0.0	0.0	0.0	3.2	10.1	0.0	0.0	0.3	13.6
M-1E3	0.0	0.0	0.0	6.7	0.5	0.0	0.0	0.6	7.8
M-1E4	0.0	0.0	0.0	5.3	0.9	0.0	0.0	0.3	6.4
M-1E5	1.8	1.0	13.5	10.5	7.4	0.0	0.4	1.1	35.6
M-1E6	0.0	4.8	0.0	26.2	31.3	0.0	20.0	1.6	83.9
M-1E7	0.0	0.0	0.0	0.0	2.9	0.0	0.0	0.0	3.0
M-1F	0.0	2.6	0.1	6.3	1.9	0.0	0.0	0.1	11.0
M-1G1	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.6
M-1G2	0.0	0.0	1.7	0.1	4.1	0.0	0.0	0.1	5.9
M-1H	0.0	0.0	0.0	24.5	0.3	1.4	0.0	2.7	28.9
M-3	0.0	3.1	4.0	10.2	13.6	0.0	0.0	46.4	77.2
M-3A1	0.0	3.2	21.0	6.9	6.0	0.0	0.0	0.4	37.5
M-3A2	0.0	4.2	0.0	0.0	2.9	0.0	14.2	0.0	21.3
M-3A3	0.0	0.0	0.0	0.0	12.6	0.0	32.7	0.6	45.9
M-3B	0.0	0.0	0.0	49.1	8.3	0.0	0.0	0.0	57.4
M-3C	0.0	0.0	2.1	11.5	1.4	0.0	0.0	0.0	15.0
M-3D1	0.0	0.0	5.6	8.3	1.2	0.0	0.0	0.0	15.2
M-3D2	0.0	0.0	0.0	7.7	0.1	0.0	0.0	1.1	9.0
M-3E	0.0	5.0	0.0	13.7	9.3	0.0	0.0	0.0	28.0
TOTAL	2.2	30.5	114.3	340.6	232.9	4.5	67.3	187.9	980.2

Table 2 Future Land Use in the Mitchell Lake Watershed

Subwatershed Name	Commercial (acres)	Highway (acres)	Medium Density Residential (acres)	Low Density Residential (acres)	Natural/Park/ Open (acres)	Institutional (acres)	Industrial/ Office (acres)	Open Water (acres)	TOTAL (acres)
M-1	0.4	6.6	25.7	66.6	27.4	2.6	0.0	116.4	245.6
M-1A	0.0	0.0	6.2	26.3	0.0	0.0	0.0	5.4	37.9
M-1B1	0.0	0.0	8.9	6.1	0.0	0.0	0.0	0.5	15.4
M-1B2	0.0	0.0	10.5	0.0	0.1	0.0	0.0	1.1	11.6
M-1B3	0.0	0.0	3.2	0.0	0.0	0.0	0.0	0.1	3.3
M-1C1	0.0	17.9	0.2	5.8	3.1	0.0	0.0	0.0	26.9
M-1C2	0.0	0.1	0.0	5.1	0.0	0.0	0.0	0.3	5.5
M-1D1	0.4	0.1	18.9	13.1	1.6	0.0	0.0	0.4	34.4
M-1D2	0.0	0.0	0.0	1.5	1.3	0.0	0.0	1.6	4.4
M-1D3	0.0	0.0	1.0	0.7	0.4	0.0	0.0	1.5	3.6
M-1D4	0.6	0.7	0.5	5.5	5.6	0.0	0.0	0.2	13.0
M-1D5	3.1	0.2	0.4	0.0	0.0	0.0	0.0	0.1	3.7
M-1E1	0.0	0.0	0.0	69.3	0.2	0.0	0.0	2.3	71.8
M-1E2	0.0	0.0	0.0	13.3	0.0	0.0	0.0	0.3	13.6
M-1E3	0.0	0.0	0.0	7.2	0.0	0.0	0.0	0.6	7.8
M-1E4	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.3	6.4
M-1E5	2.9	1.0	16.8	12.5	0.0	0.0	1.4	1.1	35.6
M-1E6	0.0	4.8	0.0	26.0	0.0	0.0	51.4	1.6	83.9
M-1E7	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
M-1F	0.0	2.6	0.3	8.0	0.0	0.0	0.0	0.1	11.0
M-1G1	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.6
M-1G2	0.0	0.0	0.0	5.8	0.0	0.0	0.0	0.1	5.9
M-1H	0.0	0.0	0.0	24.7	1.1	1.2	0.0	1.9	28.9
M-3	0.0	3.1	3.0	19.0	5.6	0.0	0.0	46.6	77.2
M-3A1	0.0	3.2	25.1	7.3	0.3	0.0	1.3	0.4	37.5
M-3A2	0.0	4.2	0.0	0.0	0.0	0.0	17.1	0.0	21.3
M-3A3	0.0	0.0	0.0	0.0	2.7	0.0	42.6	0.6	45.9
M-3B	0.0	0.0	1.4	47.5	8.3	0.0	0.1	0.0	57.4
M-3C	0.0	0.0	0.0	13.7	1.3	0.0	0.0	0.0	15.0
M-3D1	0.0	0.0	1.7	13.4	0.0	0.0	0.0	0.0	15.2
M-3D2	0.0	0.0	0.0	7.7	0.1	0.0	0.0	1.1	9.0
M-3E	0.0	5.0	0.0	20.3	2.3	0.0	0.0	0.4	28.0
TOTAL	10.26	49.29	123.79	433.00	61.36	3.73	113.83	184.90	980.17



Legend

Mitchell Lake Watershed Boundary

Flow Arrows

Existing Land Use

- Natural/Park/Open
- Low Density Residential
- Medium Density Residential
- High Density Residential
- Highway
- Commercial
- Open Water
- Wetland

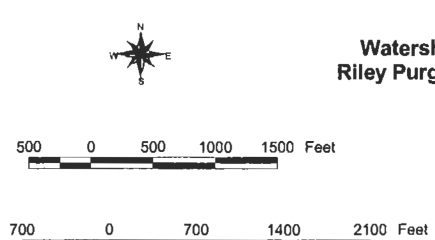
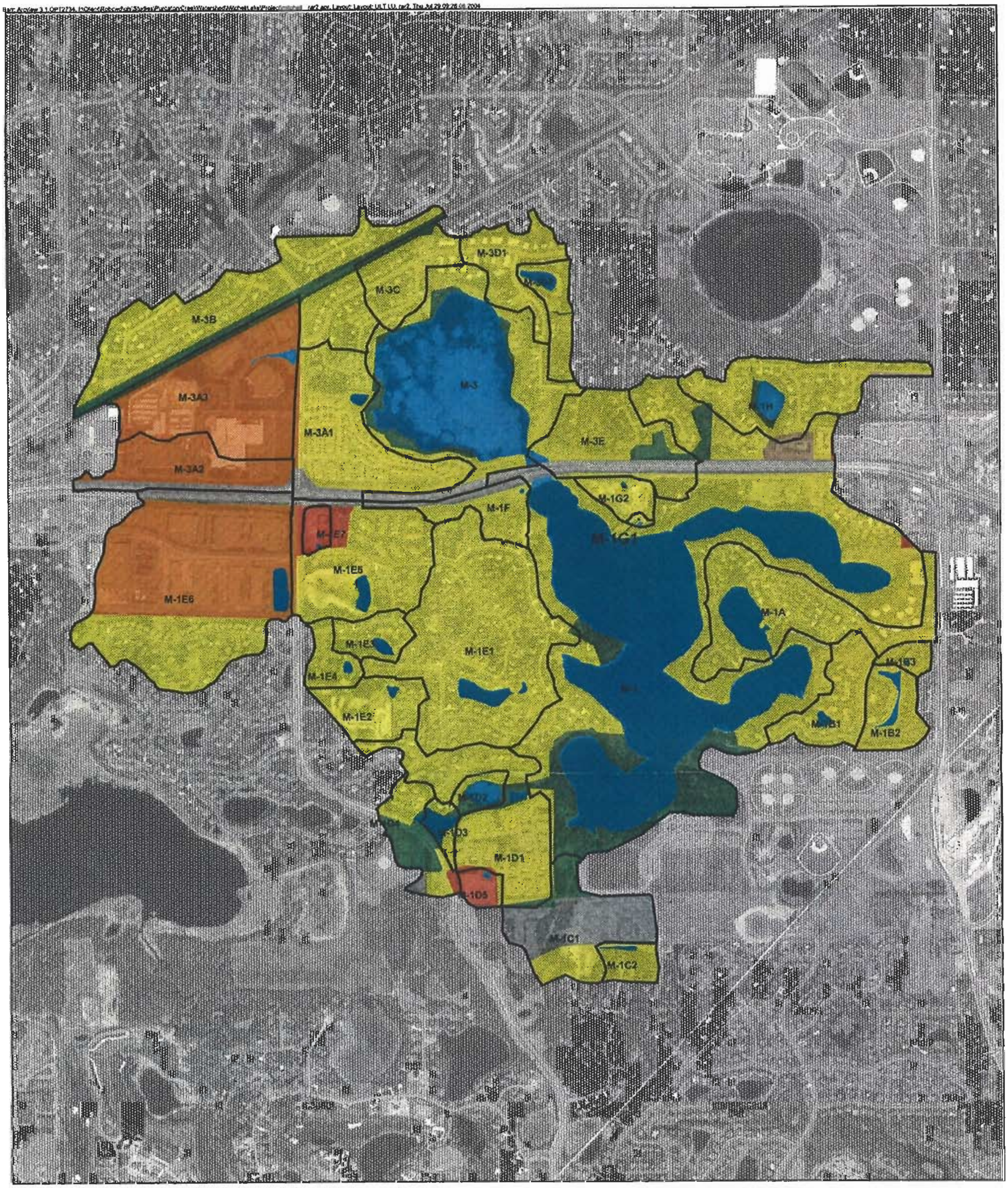


Figure 1

Mitchell Lake UAA
Watersheds and Existing (1997) Land Use
Riley Purgatory Bluff Creek Watershed District



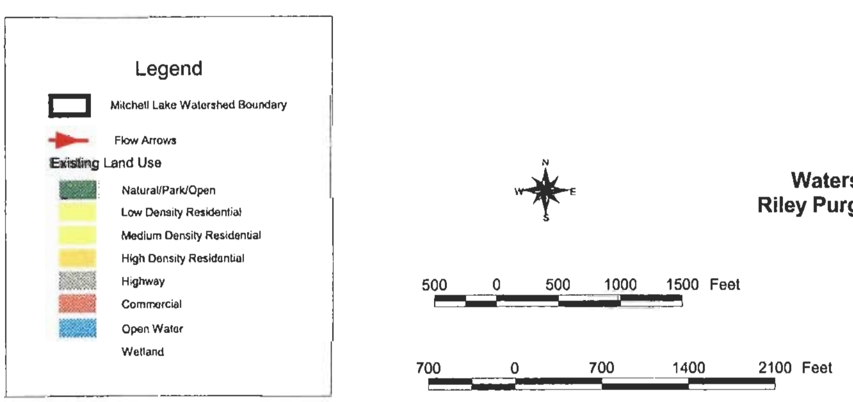
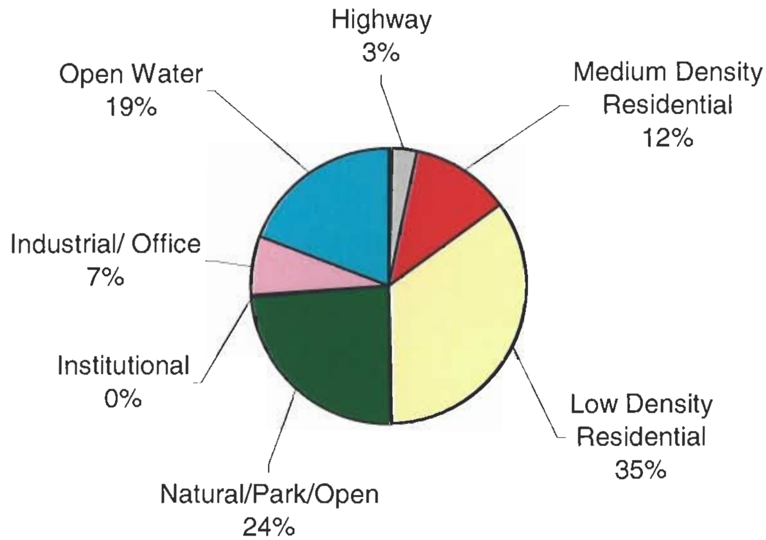


Figure 2

Mitchell Lake UAA
Watersheds and Future(2020) Land Use
Riley Purgatory Bluff Creek Watershed District

Mitchell Lake Watershed Use Attainability
Existing (1997) Land Uses
980 Acres Including Lake Surface Area



Mitchell Lake Watershed Use Attainability
Ultimate Land Uses
980 Acres Including Lake Surface Area

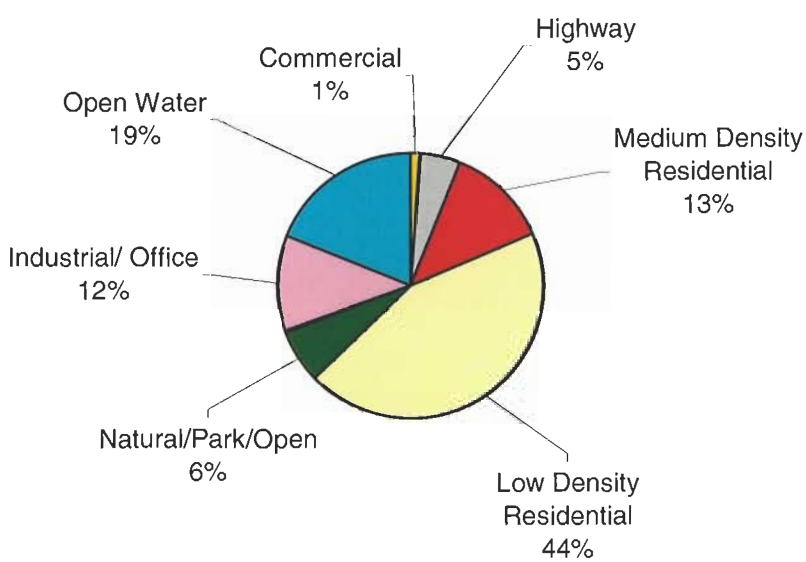


Figure 3
Mitchell Lake Watershed
Land Uses

1.2 Major Hydrologic Characteristics

At a water elevation of 871.5 feet, Mitchell Lake has an area of 123 acres and an average depth of 5.8 feet. Water enters the lake by either direct precipitation, runoff from surrounding land, or storm water conveyances. Water exits the lake by ground water infiltration or through a man-made outlet structure (a manhole with a weir) at the south end of the lake. The outlet is at an elevation of 871.06 feet and hence water discharges from Mitchell Lake through this outlet when the surface elevation of the lake exceeds this elevation. Its outflow volume and hydrologic residence time vary with climatic conditions (Table 3).

Table 3 Average Lake Volume, Annual Discharge Volume, Annual Infiltration Volume, and Estimated Hydraulic Residence Time of Mitchell Lake During a Range of Climatic Conditions (Existing Watershed Land Use)

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume (m^3/ac-ft)	Estimated Annual Lake Ouflow through Outlet* (m^3/ac-ft)	Estimated Annual Lake Ouflow by Infiltration* (m^3/ac-ft)	Hydraulic Residence Time (years)
Wet Year (1997, 39 inches)	840,040/681	875,950/710	225,640/183	0.763
Average Year (1999, 33 inches)	780,120/632	440,650/357	225,640/183	1.170
Calibration Year (Spring 1998-Spring 1999, 32 inches	742,880/602	523,490/425	225,640/183	0.990
Dry Year (2000, 25 inches)	743,500/603	122,210/99	225,640/183	2.138

*Outflows are based on the Mitchell Lake WATBUD model results.

1.3 Water Quality

The water quality of a lake provides an indication of how a lake functions. A standardized lake rating system is often used to classify the ecological condition of a lake. The rating system uses phosphorus, chlorophyll *a*, and Secchi disc transparency values to classify a lake into four categories: Oligotrophic (clear, low productivity lakes with excellent water quality), Mesotrophic (intermediate productivity lakes with good water quality), Eutrophic (high productivity lakes with poor water quality) and Hypereutrophic (extremely productive lakes with poor water quality).

1.3.1 Data Collection

Water quality data were collected by the District for Mitchell Lake from 1972 to 1999 (for years 1972, 1975, 1978, 1981, 1984, 1988, 1991, 1993, 1996, and 1999). Lake monitoring data also used in this study has been provided by the Metropolitan Council for 1995.

From April through October 1999, an intensive water quality monitoring program was completed for Mitchell Lake to calibrate a water quality model for the lake. This data collection effort involved more frequent lake sampling and the collection of samples at additional depths in the lake.

1.3.2 Baseline/Current Water Quality

A comparison of baseline and current water quality (total phosphorus, chlorophyll *a*, and Secchi disc transparency) was completed to determine whether changes in the lake's water quality occurred during the 1972 to 1999 monitoring period. Baseline water quality is defined as the average summer water quality for the years 1972 through 1987, while current water quality is defined as the average summer water quality for years 1988 through 1999.

For the baseline and current period, Mitchell Lake can be classified as eutrophic (poor water quality) to hypereutrophic (very poor water quality). Based on the lake's water transparency, it appears that the lake's water quality has not changed during the period of record. The lake's average Secchi disc water transparency was the same for the baseline and current periods despite decreasing phosphorus and chlorophyll concentrations (See Figure 4).

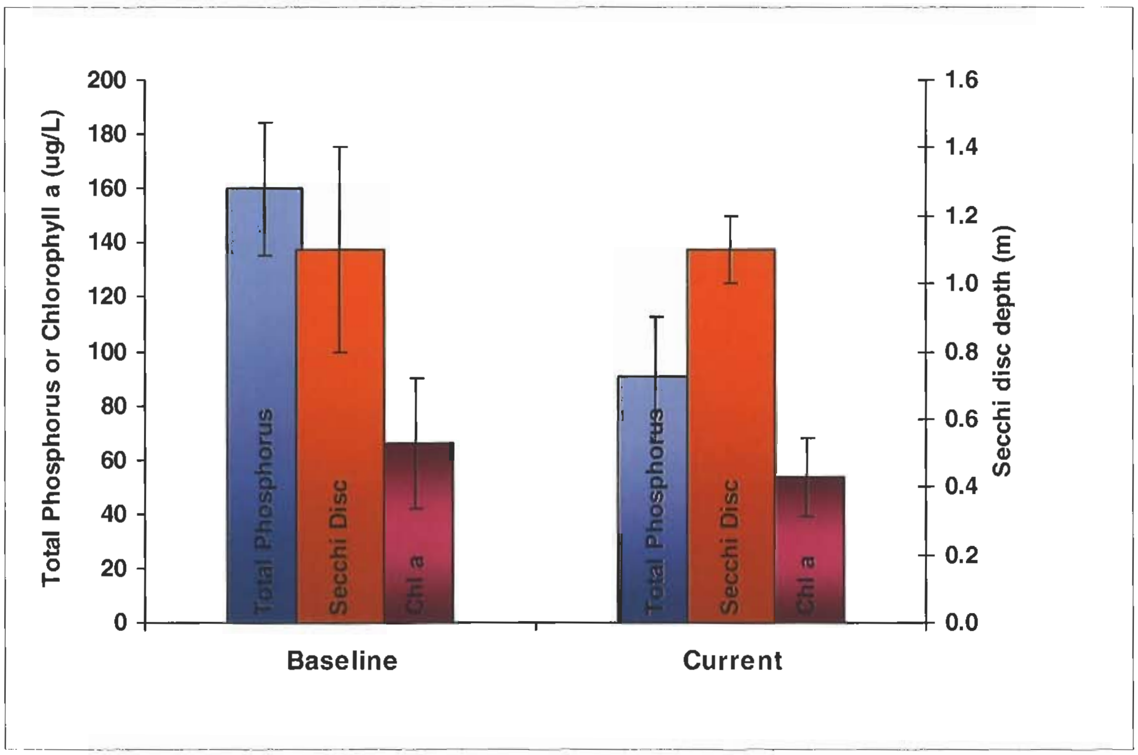


Figure 4 A Comparison of Baseline Water Quality of Mitchell Lake with Current Conditions Based on Summer (June through August) Averages

As shown in Figure 5, the water transparency of lakes with poor water quality tends to be very stable. Hence, large changes in phosphorus concentrations result in little change in water transparency. Mitchell Lake's high phosphorus concentrations throughout the period of record have resulted in a stable water transparency. Fluctuations in average baseline and current summer phosphorus concentrations have not been large enough to cause a change in the lake's average baseline and current summer Secchi disc measurements.

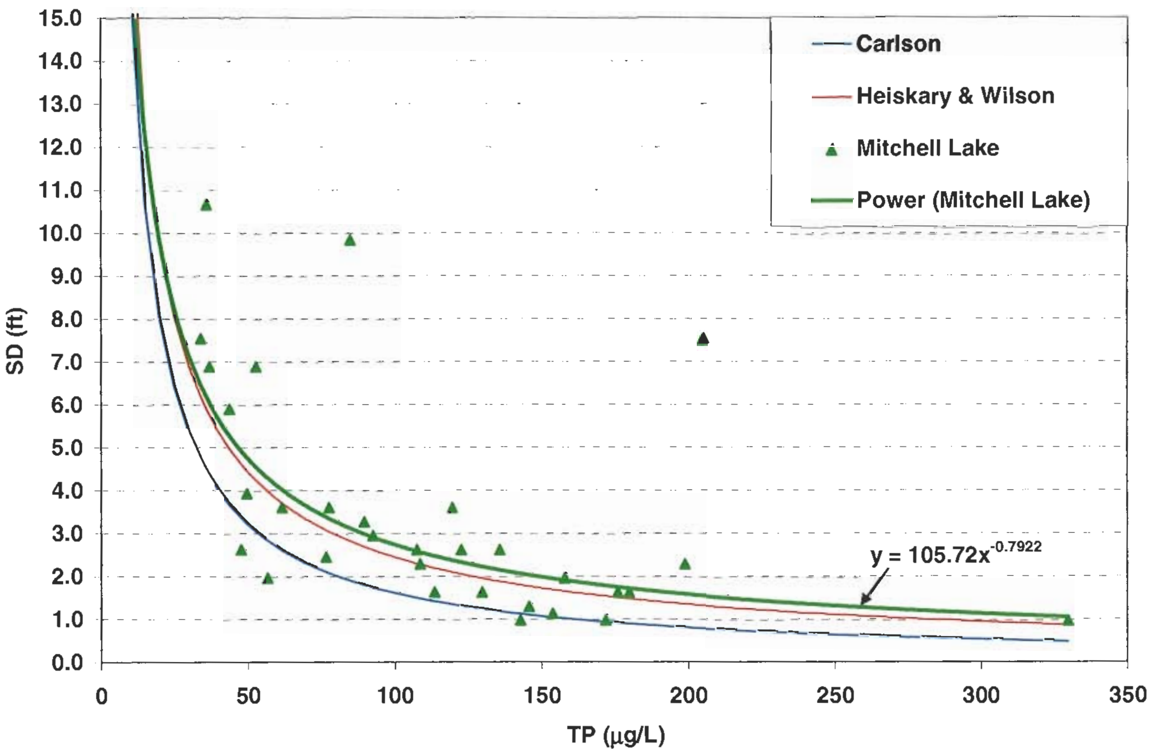


Figure 5 **Total Phosphorus-Secchi Disc Relationship From Mitchell Lake Data and According to Carlson (1977) and Heiskary and Wilson (1990)**

Present Water Quality

An evaluation of water quality data for Mitchell Lake in 1999 was completed to examine the lake's present water quality. The evaluation was based upon a standardized lake rating system. The rating system uses the lake's total phosphorus, chlorophyll *a*, and Secchi disc transparency as the key water quality indicators to determine the lake's present water quality for the following reasons. Phosphorus generally controls the growth of algae in lake systems. Of all the substances needed for biological growth, phosphorus is generally the one present in limited quantity. Consequently, when phosphorus is added to a system, it enhances algal growth. Chlorophyll *a* is the main pigment in algae; therefore, the concentration of chlorophyll *a* in the water indicates the amount of algae present in the lake. Secchi disc transparency is a measure of water clarity, and is inversely related to algal abundance. Water clarity determines recreational use-impairment. Figure 6 summarizes the seasonal changes in concentrations of total phosphorus and chlorophyll *a*, and Secchi disc transparencies for Mitchell Lake in 1999. The data are compared with a standardized lake rating system.

Water quality in Mitchell Lake was poor throughout the monitoring period. Nonetheless, changes in total phosphorus and chlorophyll concentrations and water transparency followed a seasonal pattern. The three parameters concurrently indicated the lake's water quality worsened between the early-and late-summer period. Total phosphorus concentrations were in the eutrophic (nutrient-rich) category during the spring and early-summer, but worsened to the hypereutrophic (extremely nutrient-rich) category by late-summer. Chlorophyll measurements were in the eutrophic (very productive) category during the spring and early-summer periods and worsened to the hypereutrophic (extremely productive) category by late-summer and fall periods. Secchi disc transparency was in the eutrophic (poor) category during April and mesotrophic (good) category during May and early-June. Secchi disc transparency worsened to eutrophic (poor) during late-June and hypereutrophic (very poor) during July through October (See Figure 6).

Modeling results suggest that the decay of curlyleaf pondweed and the release of phosphorus from the lake's bottom sediments are responsible for the observed mid- to late-summer increases in the lake's phosphorus concentrations, which cause increases in chlorophyll *a* concentrations and declining water transparency (See Figure 6).

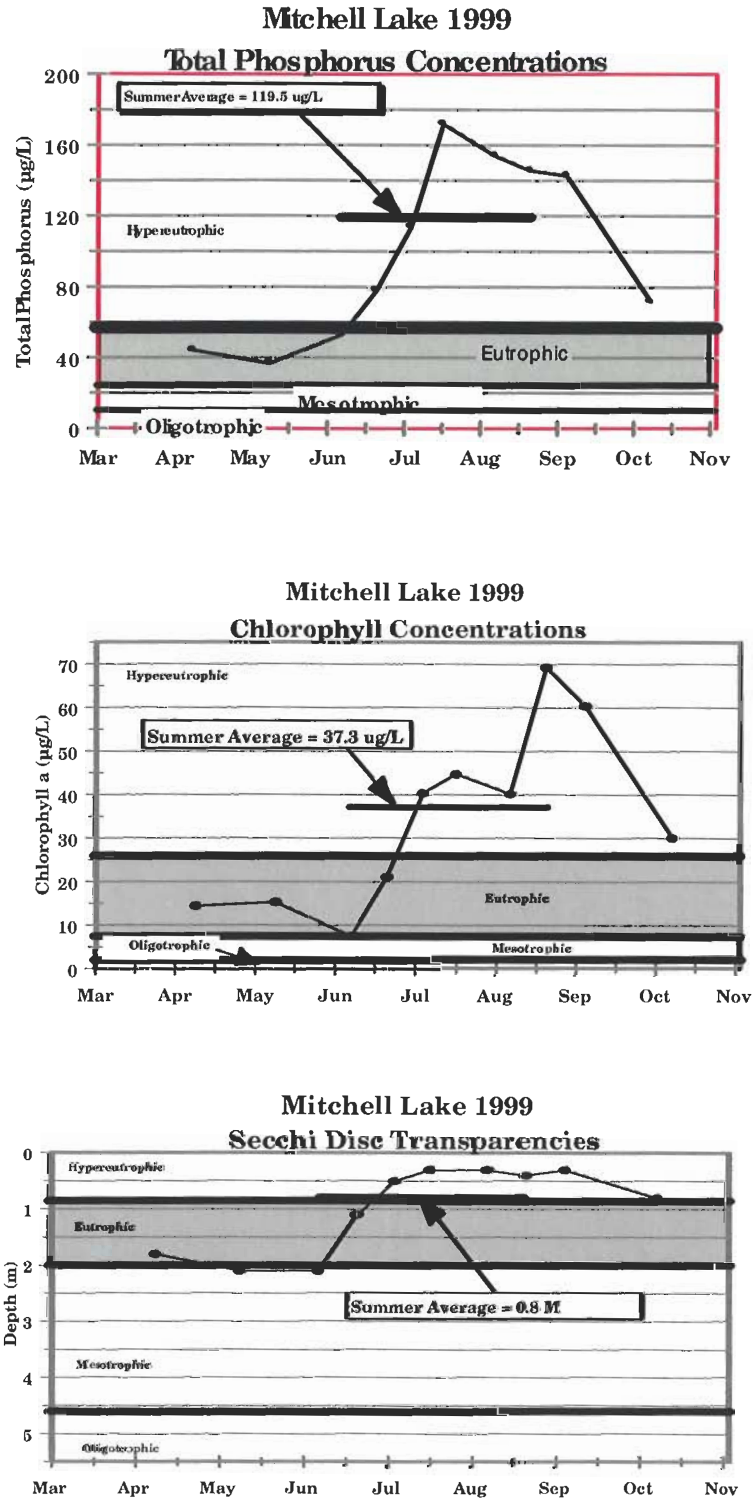


Figure 6 **Seasonal Changes in Concentrations of Total Phosphorus and Chlorophyll *a* and Secchi disc transparencies in Mitchell Lake**

1.4 Ecosystem

1.4.1 Aquatic Ecosystem

The interactions of the physical, chemical, and biological components of the Mitchell Lake aquatic ecosystem have a large effect on the capacity of Mitchell Lake to achieve the recreation, aquatic communities, and water quality goals that have been established for the lake. Hence, this use attainability analysis includes an evaluation of Mitchell Lake's aquatic ecosystem.

The aquatic ecosystem of Mitchell Lake is a good example of how the biological community of a lake, (i.e., the fish, zooplankton, algae, and aquatic plants) can affect the chemical environment of a lake (i.e., pH, phosphorus levels, and dissolved oxygen) which can then also affect the biological community. Data collected for each component of the aquatic ecosystem is reviewed below and then in Section 1.9 a discussion is provided to interpret how these different components function in Mitchell Lake.

1.4.2 Phytoplankton

The diverse population of phytoplankton in Mitchell Lake goes through a seasonal transformation where green algae and Cryptomonads are dominant in the spring but decline in the summer, while blue-green algae populations are low in spring and dominate in the summer and fall (Figures 7 and 8). Algal blooms are observed in Mitchell Lake from late-June through October. The blooms primarily consist of blue-green algae, which are large and visible and are often noted to be floating on the surface during periods of severe blooms.

There are several reasons why dominance of blue-green algae during summer is unfavorable for Mitchell Lake:

- Blue-green algae are not a preferred food source for zooplankton,
- Blue-green algae can float at the lake surface causing highly visible algal blooms,
- Certain blue-green algae can be toxic to animals, and
- Blue-green algae disrupt lake recreation during the summer.

Large populations of blue-green algae are most often associated with high levels of phosphorus. Blue-green algae have a competitive advantage (i.e. grow more quickly) over other algal species when phosphorus levels are high. Hence, reductions in phosphorus levels are needed to reduce blue-green algae populations in Mitchell Lake.

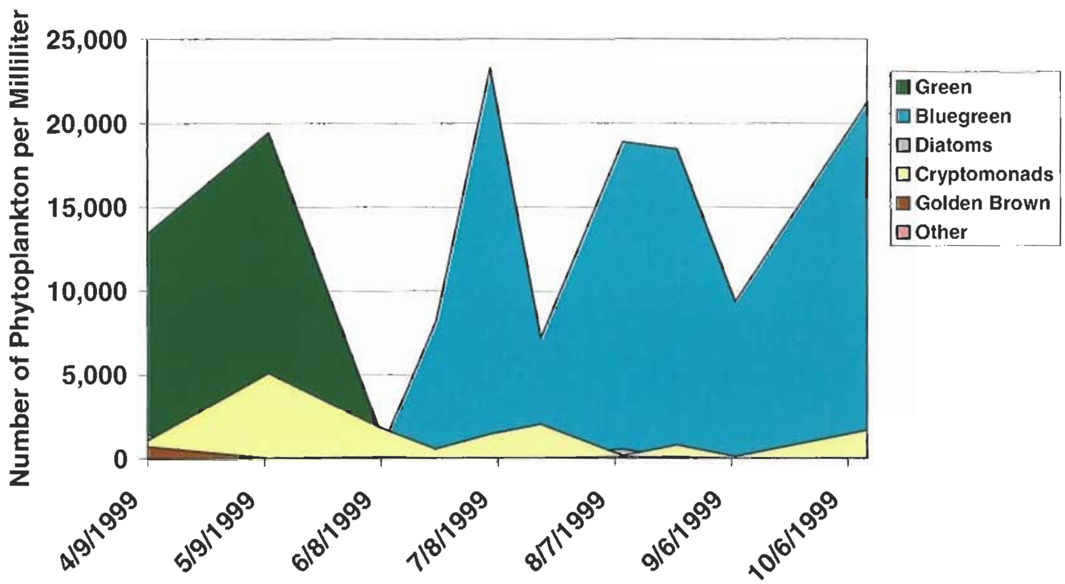


Figure 7 Phytoplankton Abundance and Diversity in Mitchell Lake

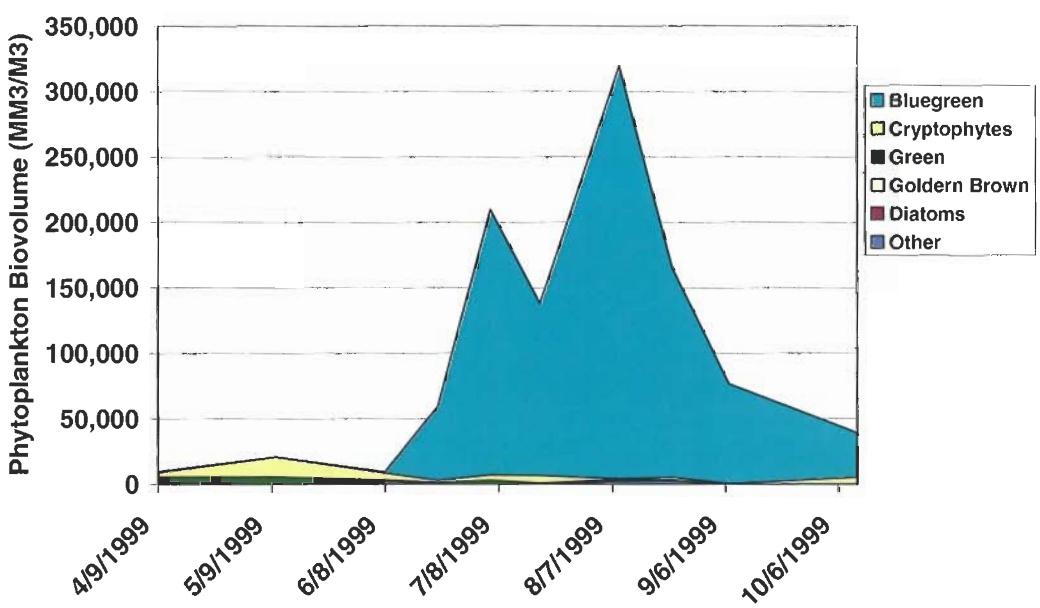


Figure 8 Phytoplankton Biovolume and Diversity in Mitchell Lake

1.4.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Mitchell Lake. They are particularly important for the lake's fishery and for the biological control of algae. Healthy zooplankton communities are characterized by balanced densities (number per meter squared) of the three major groups of zooplankton: Cladocera, Copepods, and Rotifers. Fish predation, however, may alter community structure and reduce the numbers of larger-bodied zooplankters (i.e., larger bodied Cladocera).

All three groups of zooplankton are well represented in Mitchell Lake (Figure 9). A large population of large-bodied cladocerans was observed during May through early-June, which is good because they have the capacity to biologically control algal growth. Daily zooplankton grazing rates of the lake's surface waters (0- to 6-feet) during May through early-June was estimated to range from 40 to 44 percent (See Figure 10). During this period, the phytoplankton (algae) community was comprised of small-bodied algae that are easily eaten by zooplankters. Biological control of the lake's algae resulted in a reduction of the lake's chlorophyll *a* concentration and improved water transparency during early-June, despite an increase in the lake's phosphorus concentration.

Reductions in the numbers of large-bodied cladocera and in the fraction of the algal community comprised of small-bodied, edible algae are the apparent causes of the lack of biological control on the lake's algal growth during late-June through July. Declining grazing rates observed during late-June through July (See Figure 10) corresponded with declining numbers of large-bodied cladocera (See Figure 9) and increasing volumes of blue-green algae (See Figure 8). The algal community was primarily comprised of inedible blue-green algae during late-June through October. Hence, zooplankters were unable to exert biological control during this period.

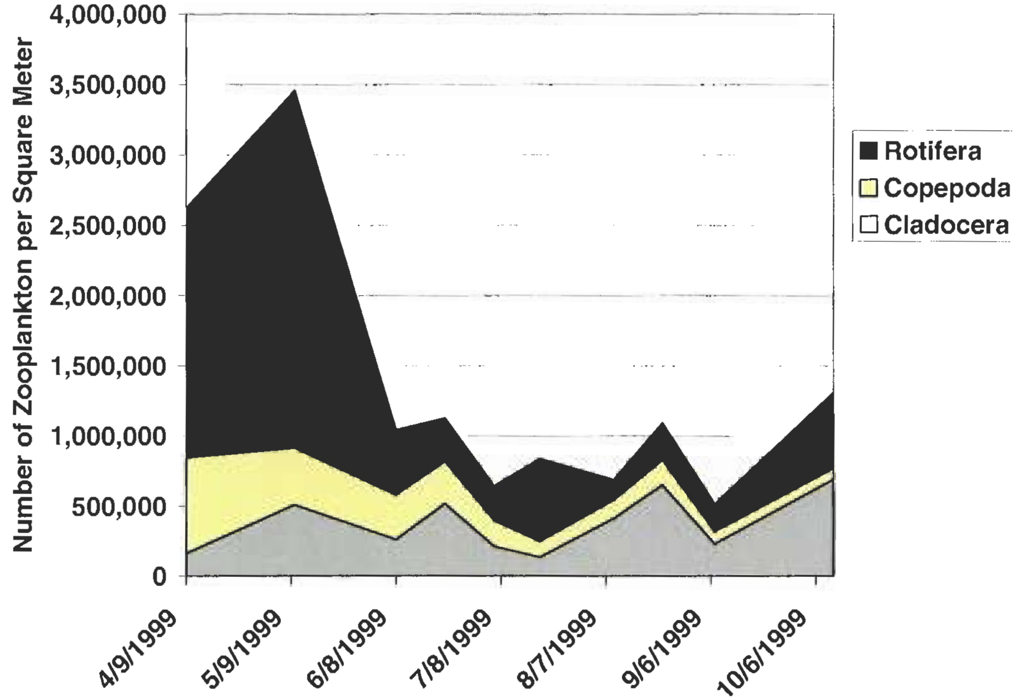


Figure 9 **Zooplankton Abundance and Diversity in Mitchell Lake**

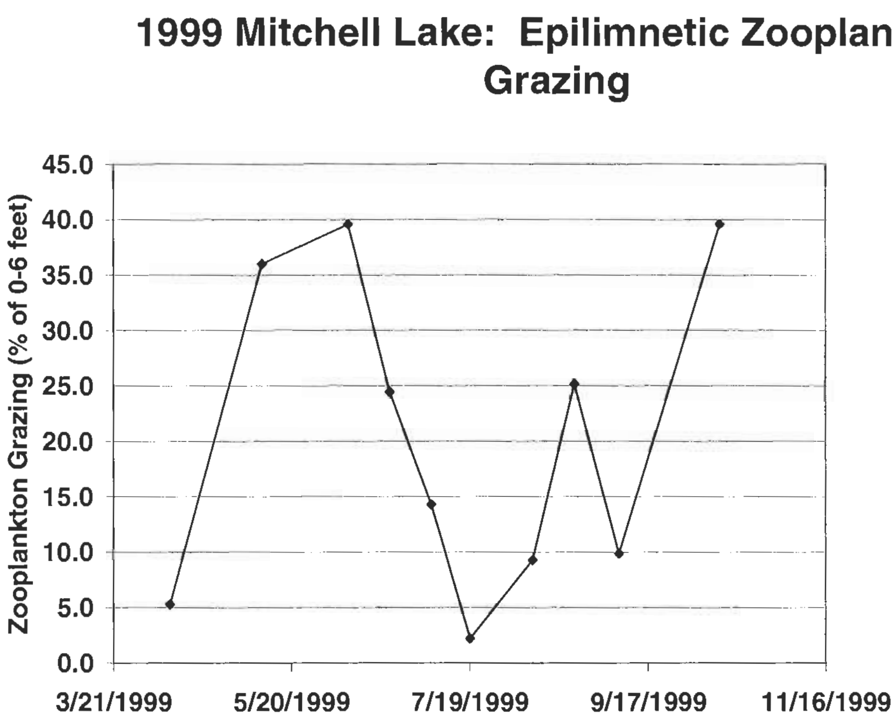


Figure 10 **Percent of Mitchell Lake Surface Waters (0- to 6-feet) Grazed by Zooplankton Each Day**

1.4.4 Macrophytes

Aquatic plants are a natural part of most lake communities and provide many benefits to fish, wildlife, and people. Typical functions of a lake's macrophyte community include:

- Provide habitat for fish, insects, and small invertebrates (Cyr and Downing 1988, Savino and Stein 1989)
- Provide food for waterfowl, fish, and wildlife (Cyr and Downing 1988, Savino and Stein 1989)
- Produce oxygen
- Provide spawning areas for fish in early-spring
- Help stabilize bottom sediments, marshy borders, and protect shorelines from wave erosion (Maceina et al. 1992)
- Provide nesting sites for waterfowl and marsh birds

Macrophytes (aquatic plants) are an important component of the lake ecosystem (Ozimek, Gulati, and va Donk 1990). However, the introduction of exotic (nonnative) aquatic plants into a lake may cause undesirable changes to the plant community and to the lake ecosystem. Dense stands of some mat-forming plant species reduce oxygen exchange, deplete available dissolved oxygen, increase water temperatures, and increase internal loading rates of nutrients (Frodge, Thomas, and Pauley 1991; Frodge et al. 1995; Seki, Takahashi, and Ichimura 1979). Dense canopies formed by some nonnative species (e.g., curlyleaf pondweed) reduce native plant diversity and abundance (Madsen et al. 1991), thereby reducing habitat complexity. This reduction in habitat complexity results in reduced macroinvertebrate diversity and abundance (Krull 1970, Keast 1984) and also reduces growth of fishes (Lillie and Budd 1992). The introduction of a nonnative plant species to a lake is not only deleterious to human use of aquatic systems, but is also detrimental to the native ecosystem.

Submersed aquatic macrophytes can play an important role in the phosphorus budget of a lake. In particular, macrophytes can directly recycle phosphorus from the sediment via root uptake, incorporation into tissue, and subsequent senescence (Barko and Smart 1980; Carpenter 1980; Landers 1982; Smith and Adams 1986; Barko and James 1998). They can also indirectly recycle phosphorus from the sediment via increasing pH in the water column through photosynthetic activities. Phosphorus release from the sediments can be enhanced at high pH as a result of ligand exchange on iron oxides contained in the sediment (Drake and Heaney 1987).

Mitchell Lake's macrophytes were surveyed on June 25 (Figures 11 and 12) and August 27, 1999 (Figures 11 and 13) to identify the conditions of plant growth throughout the lake. Thirteen species were observed in both surveys, and one additional species, curlyleaf pondweed, was observed in June. These species are common to Minnesota lakes and provide good habitat for the fish and aquatic animals living within the lake. Macrophytes were identified to a maximum depth of 4 to 5 feet during the June survey and 3 to 4 feet during the August survey. In general, the lake noted macrophyte densities of light to moderate.

Figure 11 1999 Mitchell Lake Aquatic Plants

Figure 11 1999 Mitchell Lake Aquatic Plants			
Common Name	**Scientific Name**	**1999 Density**	**Picture**
Submerged Aquatics			
Curlyleaf pondweed	***P. crispus***	**1-2**	
Flatstem pondweed	***P. zosteriformis***	**1**	
Sago pondweed	***P. pectinatus***	**1-2**	
Narrowleaf pondweed	***P. spp.*** **(Shown: *P. foliosus*)**	**1-2**	

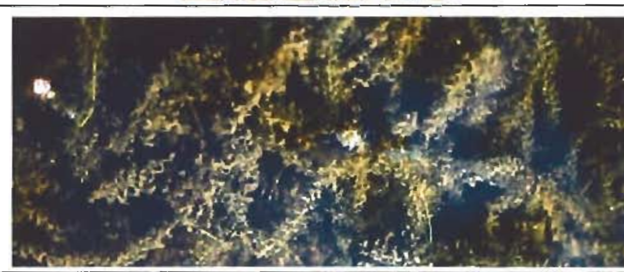
Figure 11 1999 Mitchell Lake Aquatic Plants			
Common Name	**Scientific Name**	**1999 Density**	**Picture**
Submerged Aquatics (continued)			
Northern water milfoil	***Myriophyllum sibericum***	**1-3**	
Water stargrass	***Zosterella dubia***	**1-2**	
Coontail	***Ceratophyllum demersum***	**1-3**	
Elodea	***Elodea Canadensis***	**1**	
Bushy pondweed and naiad	***Najas flexilis***	**1-2**	

Figure 11 1999 Mitchell Lake Aquatic Plants

Common Name	Scientific Name	1999 Density	Picture
Floating Leaf Plants			
White waterlily	***Nymphaea odorata*** **(Shown:** ***subsp. Tuberose*****)**	--	
Water Smartweed	***Polygonum spp.*** **(Shown:** ***Polygonum amphibian*****)**	--	
Emergent Plants			
Bulrush	***Scirpus spp.***	--	
Cattail	***Typha spp.*** ***Left: T. latifolia, broadleaf (native).*** ***Right: T. angustifolia, narrow-leaf (non-native)***	--	
Purple loosestrife	***Lythrum salicaria***		

- No Macrophytes Found in Water >4.0' to 5.0'
- *Potamogeton crispus* (Curyleaf pondweed) has Already Matured and has Begun to Die Off
- Heavy Filamentous Algae Growth Throughout Entire Lake
- Macrophyte Densities Estimated as Follows: 1 = light; 2 = moderate; 3 = heavy
- Some back-water bays have algal growths- floating and covering rooted macrophytes

	Common Name	Scientific Name
Submerged Aquatic Plants:	Narrowleaf pondweed	*Potamogeton spp. (narrowleaf)*
	Curlyleaf pondweed	*Potamogeton crispus*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Northern watermilfoil	*Myriophyllum sibiricum*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
	Bushy pondweed and naiad	*Najas flexilis*
	Water stargrass	*Zosterella dubia*
Floating Leaf Plants:	White waterlily	*Nymphaea tuberosa*
	Water smartweed	*Polygonum spp.*
Emergent Plants:	Bulrush	*Scirpus sp.*
	Cattail	*Typha sp*
	Purple loosestrife	*Lythrum salicaria.*
No Aquatic Vegetation Found:		

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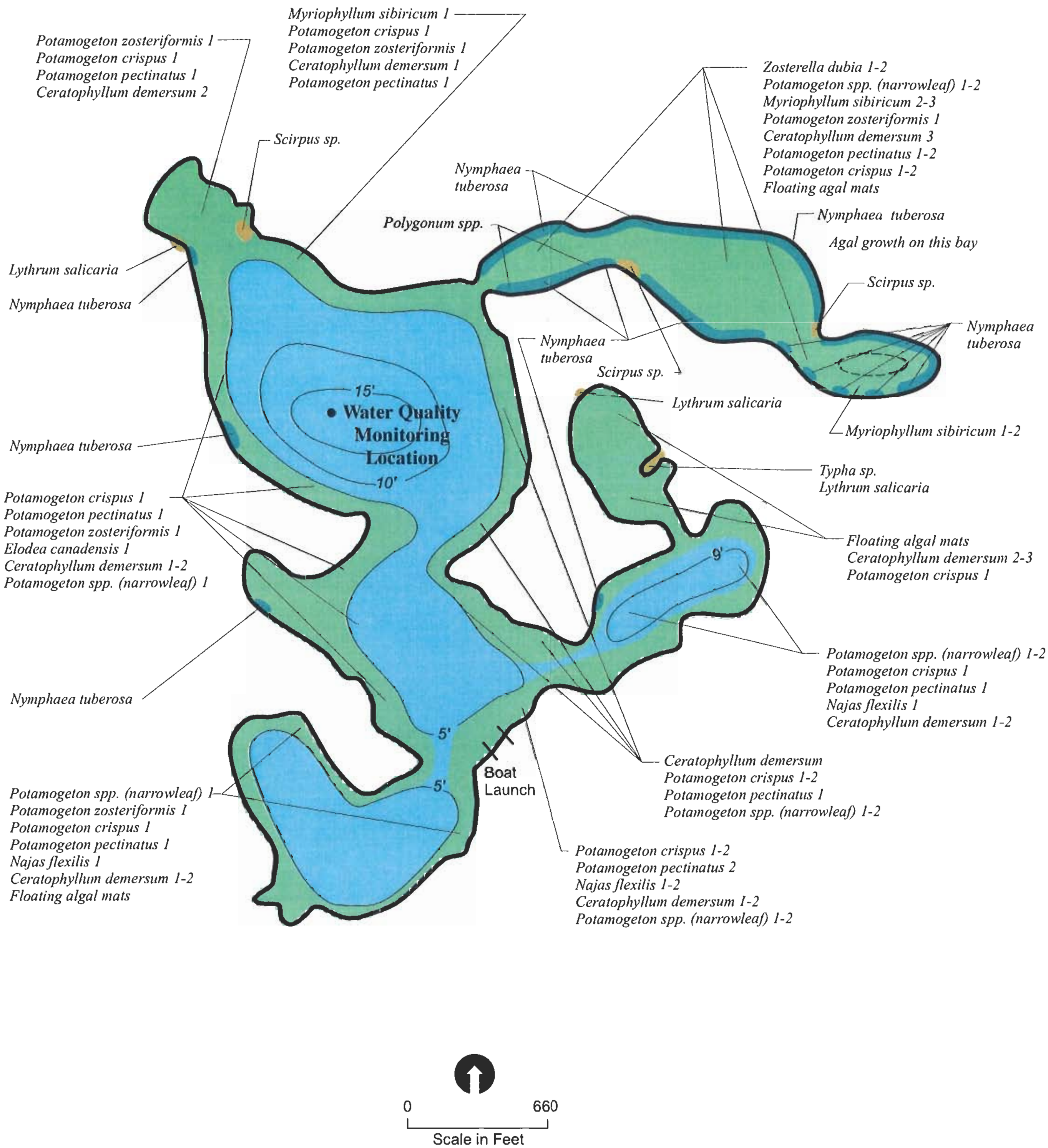

Figure 12

MITCHELL LAKE
MACROPHYTE SURVEY
JUNE 25, 1999

- No Macrophytes Found in Water >3.0' to 4.0'
- Heavy Algal Bloom
- Macrophyte Densities Estimated as Follows: 1 = light; 2 = moderate; 3 = heavy
- Some back-water bays have algal growths- floating and covering rooted macrophytes

	Common Name	Scientific Name
Submerged Aquatic Plants:	Narrowleaf pondweed	*Potamogeton spp. (narrowleaf)*
	Flatstem pondweed	*Potamogeton zosteriformis*
	Sago pondweed	*Potamogeton pectinatus*
	Northern watermilfoil	*Myriophyllum sibiricum*
	Coontail	*Ceratophyllum demersum*
	Elodea	*Elodea canadensis*
	Bushy pondweed and naiad	*Najas flexilis*
	Water Stargrass	*Zosterella dubia*
Floating Leaf Plants:	White waterlily	*Nymphaea tuberosa*
	Water smartweed	*Polygonum spp.*
Emergent Plants:	Bulrush	*Scirpus sp.*
	Cattail	*Typha sp.*
	Purple loosestrife	*Lythrum salicaria*
No Aquatic Vegetation Found:		

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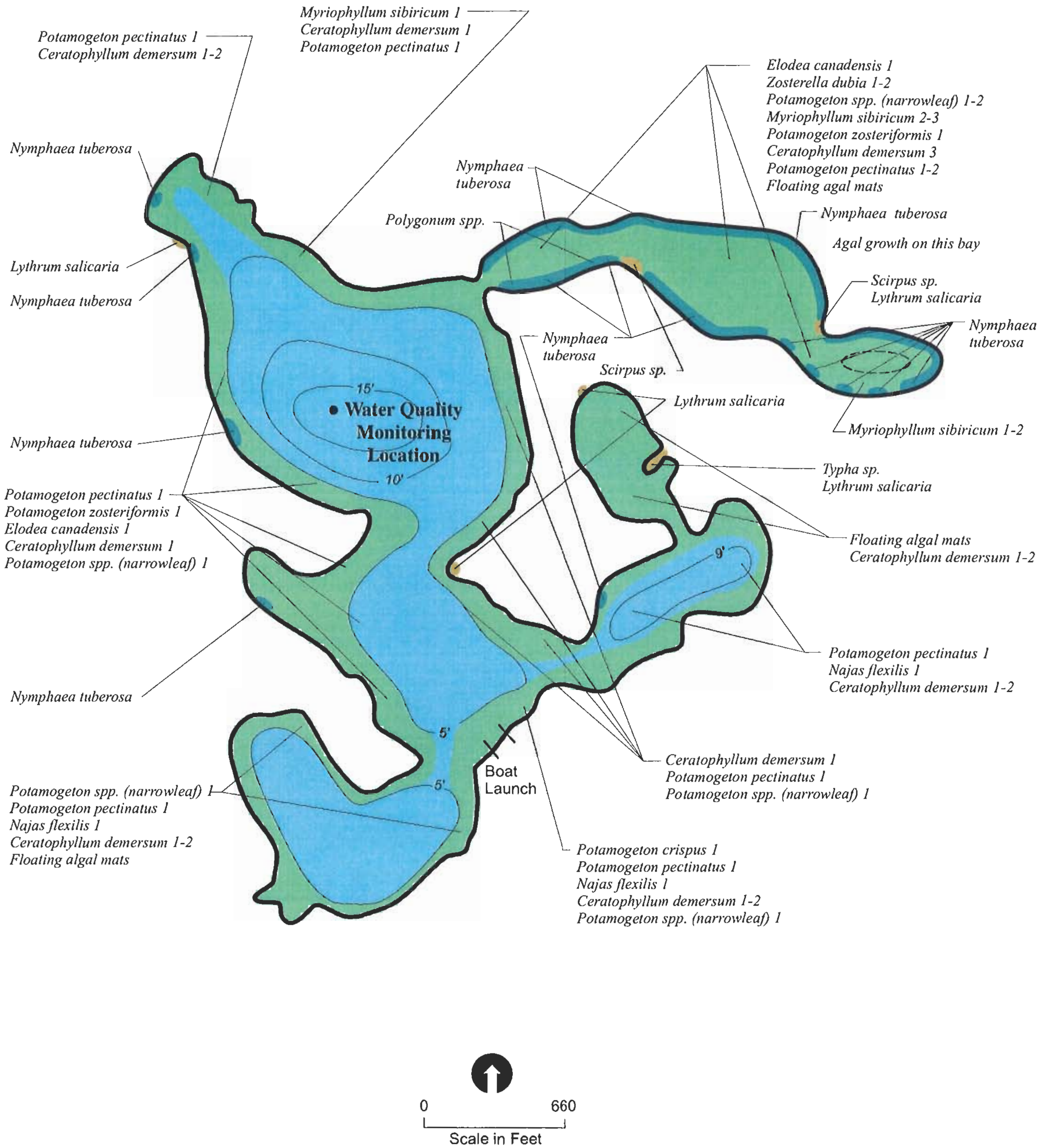


Figure 13

MITCHELL LAKE
MACROPHYTE SURVEY
AUGUST 27, 1999

The growth of the exotic (nonnative) species, curlyleaf pondweed (*Potamogeton crispus*), in Mitchell Lake is of concern (See Figure 14). Curlyleaf pondweed was found throughout the lake during June. Densities of this plant were generally light, but moderate growths were observed east of the boat launch.

Figure 14 ***Potamogeton crispus* (Curlyleaf pondweed)**

Once a lake becomes infested with curlyleaf pondweed, this plant typically replaces native vegetation, thereby increasing its coverage and density. Curlyleaf pondweed begins growing in late-August, grows throughout the winter at a slow rate, grows rapidly in the spring, and dies in early-summer (Madsen et al. 2002). Native plants that grow from seed in the spring are unable to grow in areas already occupied by curlyleaf pondweed, and are displaced by this plant. Curlyleaf pondweed die-off in early-summer releases phosphorus to the lake, causing increased algal growth for the remainder of the summer. It is estimated that approximately 92 pounds of phosphorus were added to Mitchell Lake from curlyleaf pondweed decay during 1999.

Results of water quality and plant surveys during 1993, 1996, and 1999 were evaluated to determine whether lake water transparency influenced the density of curlyleaf pondweed growth in Mitchell Lake. Survey results indicate curlyleaf pondweed grew more densely when the lake's water transparency was better and less densely when the lake's water transparency was poorer. Average summer Secchi disc water transparency in Mitchell Lake was 1.4 meters in 1993, 1.2 meters in 1996, and 0.8 meters in 1999 (See Appendix A) . Curlyleaf pondweed densities were moderate to heavy in June of 1993, light to heavy in June of 1996, and light to moderate in June of 1999 (See Appendix A). The data suggest that shading from increased algal growth in 1999 severely limited curlyleaf pondweed growth in the lake. However, improved water transparency during 1993 and 1996 encouraged heavy curlyleaf pondweed growth. This relationship indicates that water quality management to improve the lake's water transparency is likely to result in heavier curlyleaf pondweed growth unless a curlyleaf pondweed management program is concurrently implemented.

MDNR and Midwest Aqua Care Inc. staff observed Eurasian watermilfoil in Mitchell Lake during 2002 (See Figure 15) (Crowell 2004 and Gertz 2002). Although its density was sparse, Eurasian watermilfoil growth was distributed throughout the northern 75 percent of the lake (approximately 20 growth locations). Eurasian watermilfoil has not previously been observed in the lake by MDNR staff or District surveys (1993, 1996, and 1999). Eurasian watermilfoil is a nuisance non-native species that typically replaces native vegetation. It has a canopy style growth pattern that causes heavy growth near the surface, making it more visible and a greater nuisance for boaters and fishermen. Water quality management to improve the lake's water clarity is likely to result in increased Eurasian watermilfoil growth unless a program to manage this plant is completed first.

Figure 15 ***Myriophyllum spicatum*** **(Eurasian watermilfoil)**

Management of curlyleaf pondweed and Eurasian watermilfoil is recommended to protect the lake's native plant community and to prevent dense plant growths. Management of curlyleaf pondweed will also reduce the lake's phosphorus load and improve its water quality.

In 1999, purple loosestrife was found in four locations along the Mitchell lake shoreline (one on the northwest and three on the east). Purple loosestrife, an emergent plant, is native to Europe and the temperate regions of Asia (see Figure 16). Once introduced into an area, the plant typically replaces native vegetation and rapidly becomes the sole emergent species. Management of purple loosestrife is recommended to protect the quality of vegetation along the lake's shoreline.

Figure 16 ***Lythrum salicaria*** **(Purple loosestrife)**

1.5 Water Based Recreation

Mitchell Lake is used by local residents for canoeing, sailing, fishing, and aesthetic viewing. The lake's primary use is fishing. The Minnesota Department of Natural Resources (MDNR) installed a boat access in 1991 and a fishing pier in 1998 to provide fishing opportunities to the public. Winterkills occurred in 1985 and 1989. An aeration system has been used to prevent winterkill since 1991. Miller Park was built by the city of Eden Prairie in the mid- to late-1980's. The heavily used park is located along the south side of the lake.

1.6 Fish and Wildlife Habitat

The MDNR has developed a classification system for Minnesota lakes relative to the chemical and physical properties of each lake class and the fishery that is supported by each lake (Schupp 1992). According to its ecological classification, Mitchell Lake is a Class 42 lake. Class 42 lakes are typically shallow and productive lakes with fish assemblages that include white sucker, bluegills, and black bullhead (Schupp, 1992). The MDNR has indicated that the average water quality for a Class 42 lake is a TSI_{SD} (Trophic State Index in terms of Secchi disc transparency) of approximately 62 or lower (i.e., a summer average Secchi disc transparency of about 3.0 feet or greater). The recommendation is based upon the water quality needs of the fishery found in a Class 42 lake.

Mitchell Lake's water quality does not meet this recommendation based upon the 1999 data. The lake's current water quality (monitoring year 1999) corresponds to a TSI_{SD} of 63 (a summer average Secchi disc of approximately 2.6 feet). Mitchell Lake has met this goal during approximately half of the monitoring years during the 1972 through 1999 period (1975, 1984, 1991, 1993, 1995, and 1996). Improved water transparency has been observed since MDNR began operation of an aeration system in 1991 to prevent winterkill.

Mitchell Lake's fishery currently (1999) consists of panfish, gamefish, and rough fish. The 1999 MDNR fish survey showed that the following species are present in Mitchell Lake:

- **Panfish**—black crappie, white crappie, bluegill, hybrid sunfish, and pumpkinseed sunfish

Black Crappie

Bluegill

- **Gamefish**—largemouth bass, northern pike

Largemouth Bass

Northern Pike

- **Rough fish**—black bullhead

Black Bullhead

According to the 1999 survey (MDNR 2000), bluegills were the most abundant species in Mitchell Lake. They were small with a mean length of 6.1 inches and a mean weight of one-tenth pound. Black crappies were also abundant, although they were rather small and only averaged between 6 and 7 inches in length and one-tenth pound in weight. Growth for bluegills and black crappie was average. Largemouth bass were present in good numbers and size. Individuals up to 19.8 inches were found. Growth was above average for this species. Age 5 fish were the most abundant sampled. Black bullheads in Mitchell Lake were large and averaged nearly 11 inches in length and three fourths of a pound in weight. White crappies and pumpkinseed sunfish were sampled in low numbers. Neither species has ever been very abundant in Mitchell Lake. Bluegill-pumpkinseed hybrids were also present in the trapnet sample. Three northern pike were sampled in the gillnets. These are the first northern pike sampled from Mitchell Lake. The MDNR believes the northern pike were stocked by a private citizen. Growth was average for this species.

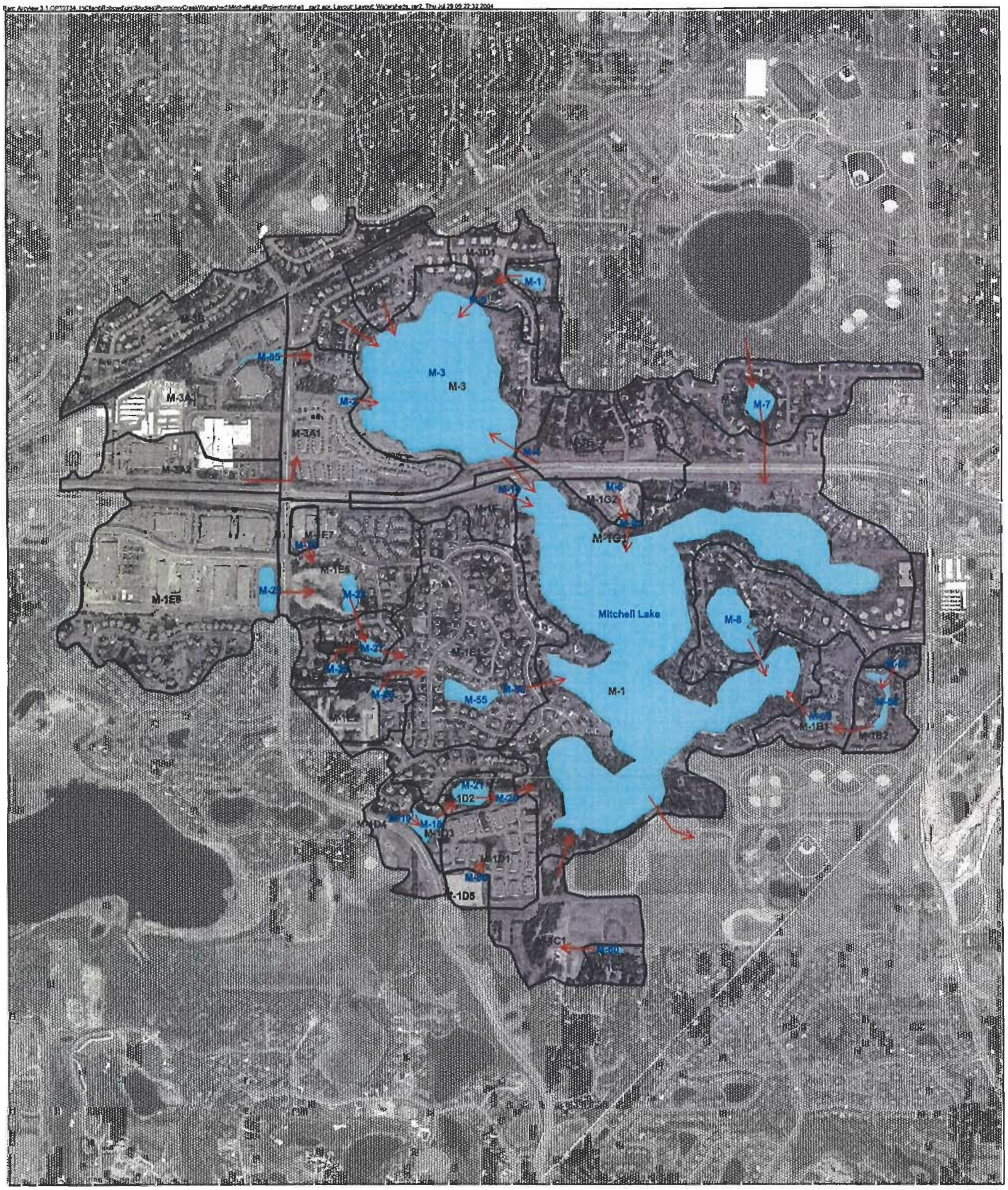
Mitchell Lake is managed by MDNR as a bluegill and largemouth bass fishery. The MDNR operational plan for the lake includes (1) annual winter fish house counts; (2) lake survey in 2005 and population assessment in 2011; (3) monitor oxygen levels in cooperation with the Eden Prairie Parks and Recreation Department; (4) net bluegills for stocking into other lakes and kid's fishing ponds; and (5) continue lake management partnering with the watershed district and Eden Prairie Parks and Recreation Department to improve the lake's water quality and the aquatic plant and fish community. The MDNR mid-range goal for the lake is to maintain the present fishing pressure with a fish community represented by bluegill (summer trapnetting) and largemouth bass (spring electrofishing) that will support 100 angler hours per acre. The MDNR long range goal for Mitchell Lake is to establish quality bass-bluegill fishing that is measured by (1) a largemouth bass electrofishing catch $\geq$20 stock fish per hour with at least 15 of the fish measuring at least 16 inches in length; (2) a bluegill summer trap net catch $\geq$30 fish per set with at least 20 of the fish measuring at least 7.5 inches in length; and (3) a fishery that is capable of supporting 100 angler hours per acre. No stocking is needed for Mitchell Lake.

Mitchell Lake provides good habitat for waterfowl such as ducks and geese.

1.7 Discharges

1.7.1 Natural Conveyance Systems

The natural inflow to Mitchell Lake consists of direct runoff from parkland and single-family homes surrounding the lake and groundwater inflows.



Legend

Mitchell Lake Subwatersheds

Flow Arrows

Mitchell Lake Watershed Ponds

N
W E
S

500 0 500 1000 1500 Feet

700 0 700 1400 2100 Feet

Figure 17

Mitchell Lake Watershed

1.7.2 Stormwater Conveyance Systems

Stormwater, treated by 34 treatment ponds and Round Lake, is conveyed to the lake through nine stormwater conveyance systems. Details of each storm water detention system are provided in Appendix B. Figure 17 shows the stormwater conveyance systems and the stormwater detention systems of the Mitchell Lake watershed.

1.7.3 Public Ditch Systems

There are no public ditch systems that affect Mitchell Lake.

1.8 Appropriations

There are no known water appropriations from Mitchell Lake.

1.9 Summary of Surface Water Resource Data

The current water quality and ecological status of Mitchell Lake is largely the result of phosphorus loading from the lake's watershed and from internal lake processes, including decay of curlyleaf pondweed and the release of phosphorus from the lake's sediments.

The concentration of phosphorus in the lake sediments that can release into the water column (i.e. mobile phosphorus) of Mitchell Lake is very high (Figure 18) and corresponds to a potential phosphorus release rate of approximately 8.9 mg per square meter of lake surface per day.

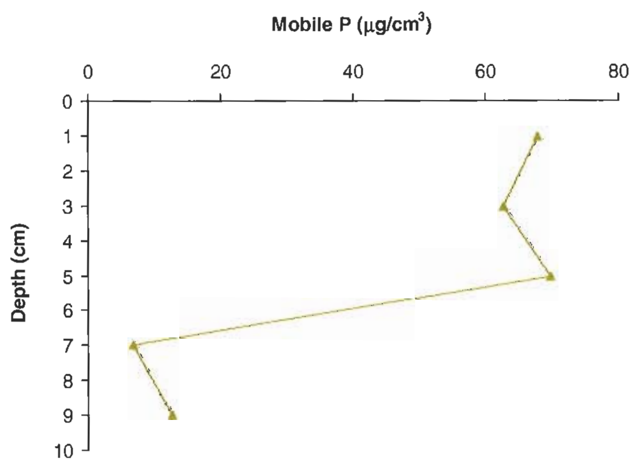


Figure 18 Distribution of Potentially Releasable Phosphorus in Mitchell Lake Sediment

Internal phosphorus loading comprises a significant fraction of the lake's total phosphorus load. Under existing watershed land use and wet, model calibration, average, and dry climatic conditions, the internal phosphorus load comprises 20, 28, 29, and 36 percent of the lake's total annual phosphorus load, respectively. Under future watershed land use conditions, increased volumes of stormwater runoff will slightly reduce the proportion of the internal phosphorus load to 18 (wet), 25 (model calibration), 25 (average), and 32 percent (dry) of the lake's total annual phosphorus load.

Currently, the ecology of Mitchell Lake is being driven by phosphorus loading from the lake's watershed and internal phosphorus loading. In mid- to late-summer there is a significant increase in phosphorus in the lake that is due to curlyleaf pondweed decay and the release of phosphorus from lake sediments. This increase in phosphorus is associated with mid- to late-summer algal blooms (Figure 19).

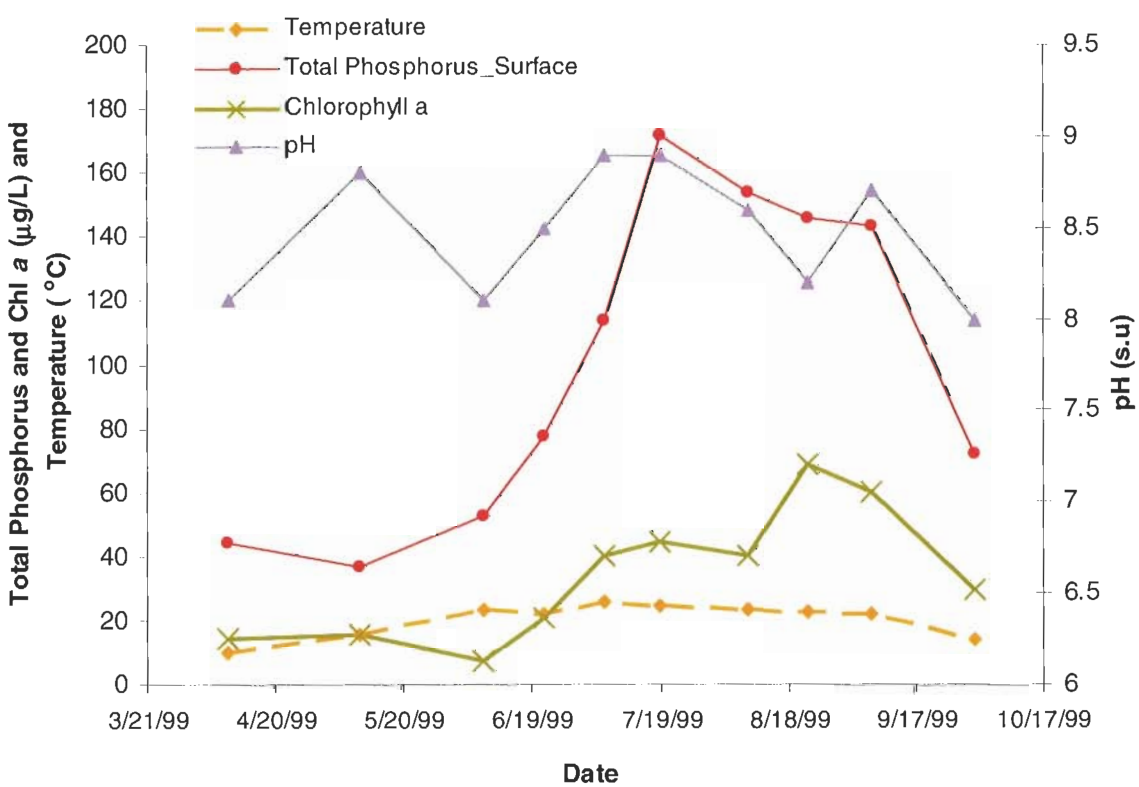


Figure 19 **Seasonal Pattern of pH, Total Phosphorus, Temperature, and Chlorophyll a in Mitchell Lake**

Figure 20 depicts the sources of the lake's phosphorus concentrations measured during 1999 (calibration year) as determined from in-lake modeling of Mitchell Lake. Stormwater runoff apparently was the source of more than three quarters of the lake's phosphorus concentration during early June. Internal processes began contributing phosphorus to the lake during June and apparently were the source of more than two thirds of the lake's phosphorus concentration during mid- through late-summer. Most of the lake's internal phosphorus load during mid-June through early July resulted from curlyleaf pondweed decay. This source of phosphorus apparently caused the lake's total phosphorus concentration to double in early July. Sediment phosphorus release was an important source of phosphorus during late July through September. The increase in lake phosphorus concentration from sediment phosphorus release in late July was similar in magnitude to the increase from curlyleaf pondweed observed in early July. Hence, from late July through September, the lake's phosphorus concentration originated from watershed loading, curlyleaf pondweed decay, and sediment phosphorus release in nearly equal proportions.

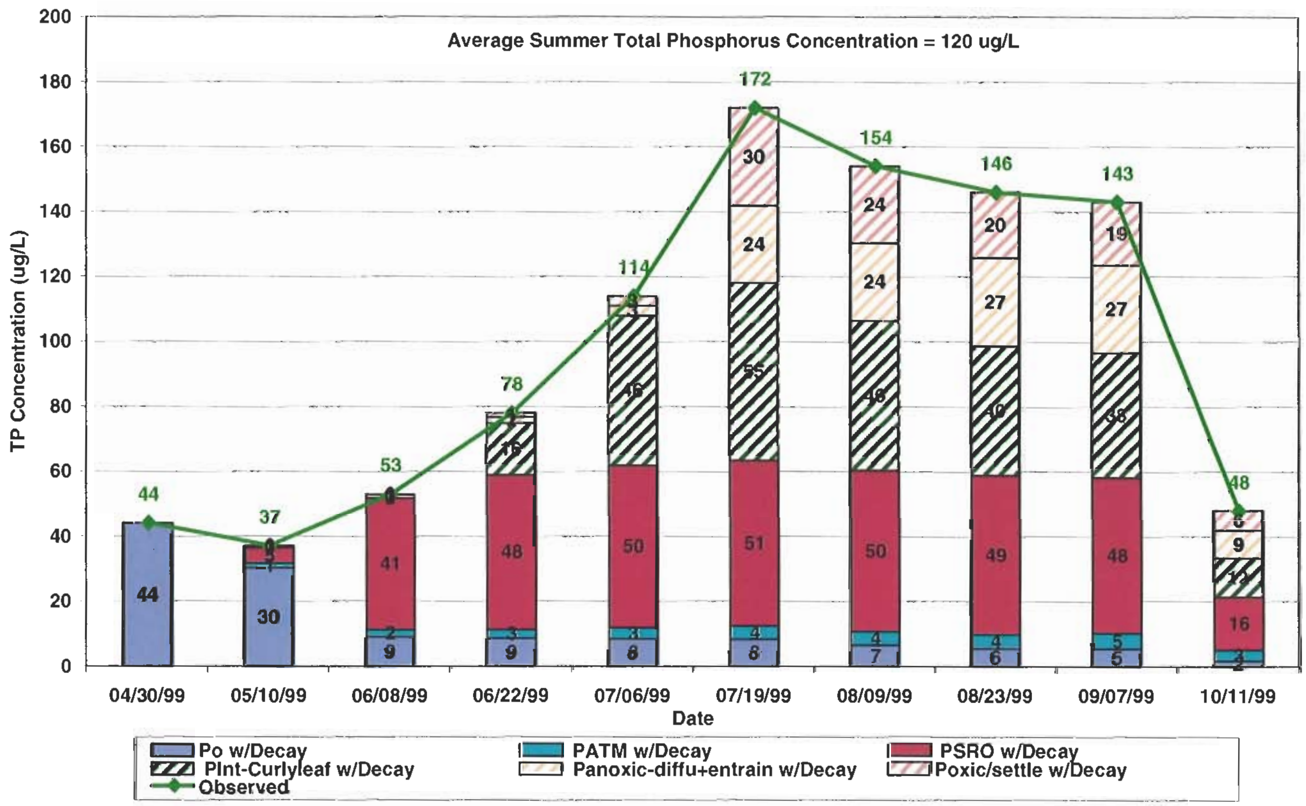


Figure 20 1999 Mitchell Lake Epilimnetic Total Phosphorus Sources

Key to Figure Legend:

P_0 w/decay = The lake's epilimnetic phosphorus concentration following ice-out in April is the starting phosphorus concentration. Most of the phosphorus present in April left the lake through its outlet during the growing season (meaning of w/decay).

Pint-Curlyleaf w/Decay = The fraction of the lake's epilimnetic phosphorus concentration resulting from decay of curlyleaf pondweed. A portion of this phosphorus load left the lake through its outlet during the growing season (w/decay).

Observed = epilimnetic total phosphorus concentrations measured during 1999

PATM w/Decay = The fraction of the lake's epilimnetic phosphorus concentration resulting from atmospheric deposition. A portion of this phosphorus load left the lake through its outlet during the growing season (w/decay)

Panoxic-diffu+entrain w/Decay = The fraction of the lake's epilimnetic phosphorus concentration resulting from sediment release of phosphorus that either diffused from the hypolimnion to the epilimnion (diffu) or was mixed into the epilimnion from the hypolimnion due to a strong wind (occurred between July 6 and July 19). A portion of this phosphorus load left the lake through its outlet during the growing season (w/decay).

PSRO w/Decay = The fraction of the lake's epilimnetic phosphorus concentration resulting from stormwater runoff. A portion of this phosphorus load left the lake through its outlet during the growing season (w/decay).

Poxic/settle/w/Decay = The fraction of the lake's epilimnetic phosphorus concentration resulting from sediment phosphorus release under oxic conditions. A portion of this load left the lake through its outlet during the growing season (w/decay).

2.0 Assessment of Mitchell Lake Problems

2.1 Appropriations

There are no known water appropriations from Mitchell Lake.

2.2 Discharges

The model P8 (IEP Inc. 1990) was used to determine the water and phosphorus loading to Mitchell Lake from the surrounding park and residential areas and from conveyed stormwater discharges to the lake. The discharge of stormwater from the Mitchell Lake watershed conveys phosphorus to the lake. These discharges, together with internal phosphorus loading, are the cause of high phosphorus levels that are observed in Mitchell Lake. Details of the phosphorus discharges to the lake are provided below.

2.2.1 Natural Conveyance Systems

Natural conveyance systems contribute stormwater to Mitchell Lake from parkland and residences that surround the lake. There are no other natural conveyances to Mitchell Lake such as streams.

2.2.1.1 Direct Watershed

The Mitchell Lake direct watershed is the land that surrounds the lake. There is no treatment of this runoff. Phosphorus loading from this watershed area was modeled using four climatic conditions:

- **Wet Year**: annual precipitation of 39 inches, the amount of precipitation that occurred during the 1997 water year.
- **Average Year**: annual precipitation of 33 inches, the amount of precipitation that occurred during the 1999 water year.
- **Calibration**: annual precipitation of 32 inches, the amount of precipitation that occurred during the period May 1998 through April 1999.
- **Dry Year**: annual precipitation of 25 inches, the amount of precipitation that occurred during the 2000 water year.

Loading from the direct watershed to Mitchell Lake is estimated to range from 71 to 137 pounds per year under existing land uses and from 99 to 176 pounds per year for future land uses (Table 4). Currently loading from the direct watershed represents approximately 18 to 22 percent of the total phosphorus load to Mitchell Lake. Under future land use conditions, loading from the direct watershed will represent approximately 22 to 25 percent of the lake's total phosphorus load.

Table 4 Estimated Annual Total Phosphorus Loads from the Mitchell Lake Direct Watershed For Existing and Future Land Uses

Existing Land Uses

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From Direct Watershed (Pounds)	% of Total Annual Mitchell Lake Total Phosphorus Load
Wet (39")	137	22
Average (33")	78	18
Model Calibration (32")	84	18
Dry (25")	71	20

Future Land Uses

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From Direct Watershed (Pounds)	% of Total Annual Mitchell Lake Total Phosphorus Load
Wet (39")	176	25
Average (33")	112	23
Model Calibration (32")	117	22
Dry (25")	99	25

2.2.2 Stormwater Conveyance Systems

The annual phosphorus load from all stormwater conveyance systems to Mitchell Lake (Table 5) is estimated to range from 98 to 304 pounds under existing land uses and from 115 to 330 pounds for future land uses. Currently loading from all stormwater conveyance systems represents approximately 28 to 49 percent of the total phosphorus load to Mitchell Lake. Under future land use conditions, loading from all stormwater conveyance systems will change little and represent approximately 29 to 48 percent of the lake's total phosphorus load (the lake's total phosphorus load includes both external and internal phosphorus loads).

Table 5 Estimated Total Phosphorus Loads from All Mitchell Lake Stormwater Conveyance Systems Under Varying Climatic Conditions-Existing and Future Land Use

Existing Land Use

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From All Stormwater Conveyance Systems (Pounds)	% of Annual Mitchell Lake Total Phosphorus Loads
Wet (39")	304	49
Average (33")	181	41
Model Calibration (32")	188	41
Dry (25")	98	28

Future Land Use

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From All Stormwater Conveyance Systems (Pounds)	% of Annual Mitchell Lake Total Phosphorus Loads
Wet (39")	330	48
Average (33")	218	41
Model Calibration (32")	211	42
Dry (25")	115	29

Phosphorus loading to the lake from stormwater runoff is primarily coming from stormwater outlets M3, M7, and M56 (Table 6, locations shown on Figure 17). Currently, these outlets are each estimated to contribute from 18 to 32 percent of the annual total phosphorus load from storm water conveyance systems. Collectively, the three outlets contribute approximately 79 to 84 percent of the current annual conveyance system phosphorus load. Hence, the remaining six conveyance systems collectively contribute only 16 to 21 percent of the current conveyance system phosphorus load. Under future land use conditions, stormwater outlets M3, M7, and M56 collectively are estimated to contribute approximately 81 to 85 percent of the conveyance system phosphorus load.

Table 6 Estimated Total Phosphorus Loading from Each Storm Water Conveyance System

Existing Land Use

Stormwater Conveyance System	Annual Total Phosphorus Load in Pounds			
	Wet (39")	Average (33")	Model Calibration (32")	Dry (25")
M3	123	77	80	55
M6	3	2	2	2
M7	115	83	80	31
M8	12	7	7	5
M10	9	5	6	5
M20	36	18	20	15
M56	126	58	67	49
M59	15	9	9	7
M60	2	1	1	1

Future Land Use

Stormwater Conveyance System	Annual Total Phosphorus Load in Pounds			
	Wet (39")	Average (33")	Model Calibration (32")	Dry (25")
M3	134	87	90	63
M6	4	2	2	2
M7	124	109	92	40
M8	13	7	8	5
M10	10	6	6	5
M20	41	22	24	19
M56	160	86	94	71
M59	16	10	10	8
M60	2	1	1	1

The treatment effectiveness of the detention ponds and wetlands that lie within the Mitchell Lake watershed was determined for wet, model calibration, average, and dry conditions. It can be seen that approximately two thirds of the ponds and wetlands in the Mitchell Lake watershed have an annual treatment efficiency near or above 50 percent total phosphorus removal (Tables 7 and 8). Overall, removal in downstream ponds was reduced because the ponds upstream (See Figure 17) had removed most of the phosphorus that could readily settle. For example, phosphorus removal in Pond M22, an upstream pond, ranged from 50 to 62 percent under varying climatic conditions and existing watershed land use. Pond M56, the most downstream pond in an eight pond conveyance system, removed only 1 percent of its phosphorus load under the same conditions. Most of the phosphorus that entered these downstream ponds was associated with very small particles or was considered to be dissolved. An increase in the dead storage volume of these ponds would not lead to measurable improvements in phosphorus removal.

Table 7 Estimated Total Phosphorus Removal Efficiency of Detention Ponds in the Mitchell Lake Watershed Under Existing Conditions

Stormwater Conveyance System	Pond Name	Total Phosphorus Removal Efficiency (%)			
		Wet (39")	Average (33")	Model Calibration (32")	Dry (25")
M3	M1	59	62	62	70
	M85	29	18	16	17
	M2	14	38	35	38
	M3	60	54	56	61
M6	M6	32	47	43	46
M7	R-M	40	56	51	55
	R-P	69	79	78	85
	R-AG1	38	57	53	59
	R-AG2	39	53	50	56
	R-RLP	7	13	10	13
	R-RLE	43	71	62	62
	R-B	80	90	89	93
	R-A	83	96	94	97
	R-C	69	77	77	91
	M-7	8	8	8	10
M8	M8	64	64	65	73
M10	M10	19	30	26	27

Stormwater Conveyance System	Pond Name	Total Phosphorus Removal Efficiency (%)			
		Wet (39")	Average (33")	Model Calibration (32")	Dry (25")
M20 (cont.)	M19	22	40	32	34
	M18	54	40	49	61
	M21	29	20	26	35
	M20	28	41	37	41
	M80	60	55	58	70
M56	M22	50	59	57	62
	M70	38	47	44	50
	M23	25	30	29	33
	M25	43	53	50	54
	M27	5	7	7	8
	M26	52	52	55	63
	M55	26	28	28	34
	M56	1	1	1	1
M59	M57	34	45	41	43
	M58	56	61	60	66
	M59	33	40	38	44
M60	M60	54	56	56	65

Table 8 Estimated Total Phosphorus Removal Efficiency of Detention Ponds in the Mitchell Lake Watershed Under Proposed Future Conditions

Stormwater Conveyance System	Pond Name	Total Phosphorus Removal Efficiency (%)			
		Wet (39")	Average (33")	Model Calibration (32")	Dry (25")
M3	M1	59	62	62	70
	M85	13	15	14	15
	M2	28	36	33	35
	M3	60	55	57	61
M6	M6	31	46	41	45
M7	R-M	40	56	51	55
	R-P	69	79	78	85
	R-AG1	38	57	53	59
	R-AG2	39	53	50	56
	R-RLP	7	13	10	13
	R-RLE	43	71	62	62
	R-B	80	90	89	93

Stormwater Conveyance System	Pond Name	Total Phosphorus Removal Efficiency (%) Wet (39")	Average (33")	Model Calibration (32")	Dry (25")
M7 (cont.)	R-A	83	96	94	97
	R-C	69	77	77	91
	M-7	8	8	8	10
M8	M8	64	65	65	73
M10	M10	19	25	25	26
M20	M19	23	33	33	34
	M18	53	50	50	60
	M21	27	23	23	31
	M20	26	33	33	37
	M80	57	62	62	65
M56	M22	48	55	55	58
	M70	36	39	39	40
	M23	22	26	26	29
	M25	43	50	50	54
	M27	5	6	6	7
	M26	52	57	57	63
	M55	24	26	26	31
	M56	1	1	1	1
M59	M57	34	41	41	43
	M58	56	60	60	66
	M59	34	40	40	45
M60	M60	54	59	59	65

Some of the ponds in the lake's direct watershed were constructed prior to the establishment of current MPCA- and NURP-criteria. Approximately one third of the ponds in the Mitchell Lake watershed do not meet MPCA- and NURP- criteria. Upgrading eight ponds by removing a total of approximately 10,000 cubic yards of material to increase their storage volume is expected to improve their treatment efficiency. The upgrade is expected to result in the removal of an additional 34 to 47 pounds of phosphorus (8 to 10 percent of the lake's annual total phosphorus load) under existing land use conditions and 43 to 54 pounds of phosphorus (from 8 to 11 percent of the lake's annual total phosphorus load) under future land use conditions (See Table 9).

Table 9 Estimated Total Phosphorus Loading Reduction From Upgrade of Ponds M57, M20, M19, M25, M70, M10, M85 and M4 to Meet MPCA/NURP Criteria

Existing Land Use

Climatic Condition	Additional Pounds of Phosphorus Removed
Wet (39")	47
Average (33")	39
Model Calibration (32")	37
Dry (25")	34

Future Land Use

Climatic Condition	Additional Pounds of Phosphorus Removed
Wet (39")	54
Average (33")	49
Model Calibration (32")	47
Dry (25")	43

The upgrade of eight ponds is expected to have a negligible effect on the lake's water quality. Hence, the District's recreation, water quality, and aquatic communities goals would not be attained by upgrading ponds M57, M20, M19, M25, M70, M10, M85, and M4 to meet MPCA and NURP criteria (See Table 10).

Table 10 Expected Water Quality From Upgrade of Ponds M57, M20, M19, M25, M70, M10, M85, and M4 to Meet MPCA/NURP Criteria

Existing Land Use

Management Approach	Trophic State Index (TSI_{SD}) Value				
	District Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
No Action	≤ 62	68	66	66	65
Upgrade Ponds M57, M20, M19, M25, M70, M10, M85, and M4 to Meet MPCA/NURP Criteria	≤ 62	68	66	66	65

Future Land Use

Management Approach	Trophic State Index (TSI_{SD}) Value				
	District Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
No Action	≤ 62	69	67	67	66
Upgrade Ponds M57, M20, M19, M25, M70, M10, M85, and M4 to Meet MPCA/NURP	≤ 62	68	67	67	66

Increased infiltration of stormwater runoff was considered as a treatment alternative to reduce phosphorus loading from the lake's watershed. Feasible sites for planting rainwater gardens (the planting of attractive plants to increase infiltration) were identified in the watershed and the increased storage from the rainwater gardens estimated. Under existing watershed land use conditions, storage of an additional 9 to 44 acre-feet of watershed runoff in rainwater gardens would decrease phosphorus loading to Mitchell Lake by 32 to 41 pounds (6 to 9 percent of the lake's annual total phosphorus load) under varying climatic conditions. Under future watershed land use conditions, storage of an additional 13 to 46 acre-feet of watershed runoff in rainwater gardens would decrease phosphorus loading by 29 to 51 pounds (7 to 12 percent of the lake's annual total phosphorus load) under varying climatic conditions (See Table 11).

Table 11 Estimated Total Phosphorus Loading Reduction From Planting Rainwater Gardens in Feasible Watershed Locations

Existing Land Use

Climatic Condition	Additional Pounds of Phosphorus Removed
Wet (39")	36
Average (33")	41
Model Calibration (32")	36
Dry (25")	32

Future Land Use

Climatic Condition	Additional Pounds of Phosphorus Removed
Wet (39")	51
Average (33")	59
Model Calibration (32")	42
Dry (25")	29

The phosphorus load reduction from rainwater garden treatment of stormwater runoff would have a negligible effect on the lake's water quality. Hence the District's recreation, water quality, and aquatic communities goals would not be attained by planting rainwater gardens in feasible watershed locations (See Table 12).

Table 12 Expected Water Quality From Planting Rainwater Gardens in Feasible Watershed Locations

Existing Land Use

	Trophic State Index (TSI_{SD}) Value				
Management Approach	**District Goal**	**Wet Year (39")**	**Average Year (33")**	**Model Calibration Year (32")**	**Dry Year (25")**
No Action	≤ 62	68	66	66	65
Planting Rainwater Gardens in Feasible Locations	≤ 62	68	66	66	65

Future Land Use

Management Approach	**Trophic State Index (TSI_{SD}) Value**				
	District Goal	**Wet Year (39")**	**Average Year (33")**	**Model Calibration Year (32")**	**Dry Year (25")**
No Action	≤ 62	69	67	67	66
Planting Rainwater Gardens in Feasible Locations	≤ 62	68	67	67	66

2.2.3 Public Ditch Systems

There are no known ditch systems affecting Mitchell Lake.

2.3 Fish and Wildlife Habitat

The MDNR has established criteria for the support of Mitchell Lake's fishery, based upon Mitchell Lake's classification as a Class 42 lake. The current habitat for Mitchell Lake fails to meet the criteria of a TSI_{SD} of 62 or lower (a summer average Secchi disc transparency of at least 3 feet). The lake's poor water transparency is caused by algal blooms, which result from excessive phosphorus.

In addition to the impairment of the Mitchell Lake fishery caused by high phosphorus levels and severe summer algal blooms, dissolved oxygen levels can become severely depressed in the summer as a result of algal senescence. Oxygen is depleted or consumed when dead algae decay. In May of 1999, the lake's upper 4 meters contained sufficient oxygen (>5 mg/L) to support the lake's gamefish. Oxygen depletion caused by algal senescence reduced the area habitable by gamefish to the upper 2 meters by June. It can be seen in Figure 21 that severe oxygen depletion during the summer caused stressful conditions for the lake's gamefish. The oxygen content of the lake's upper 2 meters in August was below 5 mg/L and the lake was void of oxygen below the 2 meter depth.

Clearly the severe dissolved oxygen depletion that is observed in Mitchell Lake is harmful to the lake's fishery.

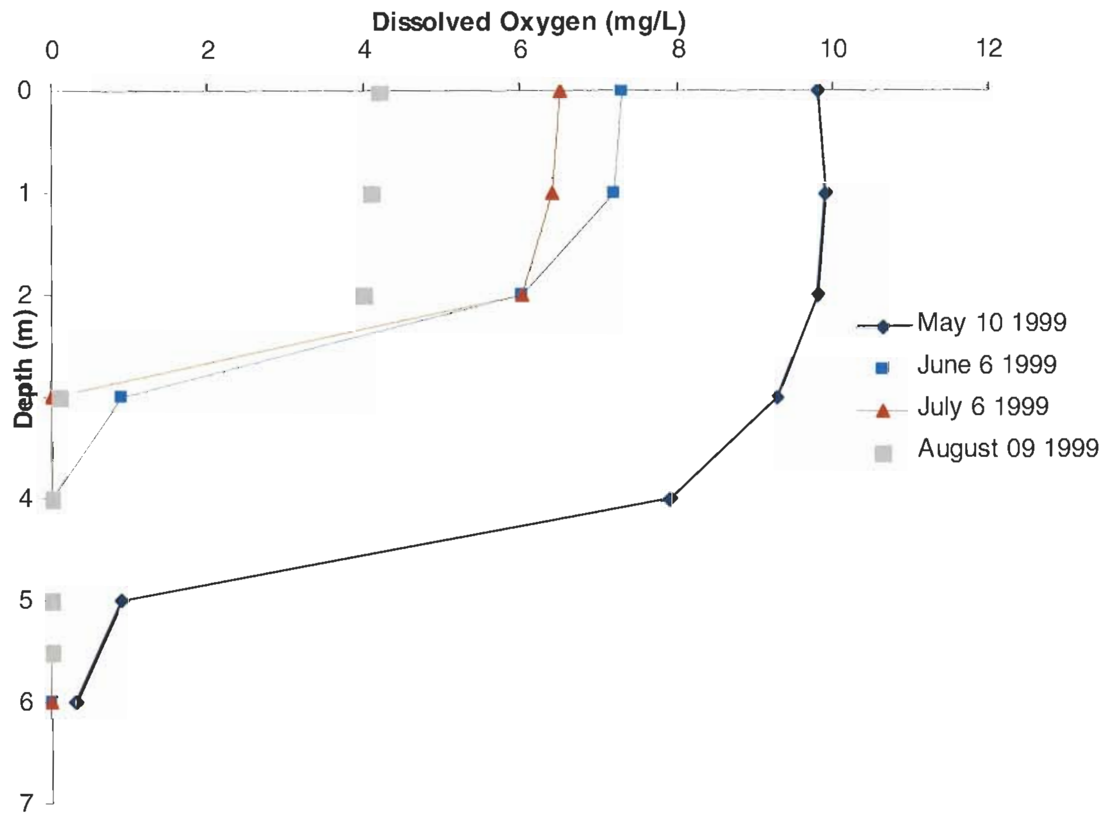


Figure 21 **Dissolved Oxygen in Mitchell Lake from the Surface (0 meters) to the Bottom (~6 m)**

2.4 Water Based Recreation

The recreational uses of Mitchell Lake include fishing, canoeing, sailing, and aesthetic viewing. Fishing is the primary activity at Mitchell Lake. This use is currently impaired by severe algal blooms and low dissolved oxygen levels in the lake water column.

2.5 Ecosystem Data

Development of a more balanced ecosystem at Mitchell Lake is needed for the lake to achieve the recreation, aquatic communities, and water quality goals that have been set for the lake. There are two primary imbalances in Mitchell Lake: (1) high phosphorus levels and severe summer algal blooms; (2) growths of non-native species including curlyleaf pondweed, Eurasian watermilfoil, and purple loosestrife.

It appears that Mitchell Lake's zooplankton population is generally well balanced by the existing fishery. However, a short-term imbalance occurs each summer when disappearance of the lake's zooplankton refuge results in reduced numbers of large-bodied zooplankton. A refuge is the deepest spot in a lake with sufficient oxygen for zooplankton (1 to 3 mg/L) but insufficient oxygen for predatory fish (at least 3 mg/L). Zooplankton hide in a refuge when one is available to them, thus avoiding predation by fish. When a lake's refuge thins to a meter or less, its protection to large-bodied zooplankton is inadequate. Senescence from summer algal blooms depleted Mitchell Lake's oxygen and destroyed the lake's zooplankton refuge. With no place to hide, large-bodied zooplankton were easily eaten by fish and their numbers were reduced. Reduction of phosphorus is necessary to minimize oxygen depletion and preserve the lake's zooplankton refuge during the summer period. Attaining a balanced zooplankton community during the summer period will help attain the lake's water quality, recreation, and aquatic communities goals.

According to a 1999 MDNR fish survey, the existing fish population at Mitchell Lake is generally typical of lakes within the same class. However, it was noted in the 1999 survey that bluegills were abundant but small (mean length of 6.1 inches). The MDNR long range goal for Mitchell Lake includes attaining a blue-gill summer trap net catch $\geq$30 fish per set with at least 20 of the fish measuring at least 7.5 inches in length. Attainment of the MDNR long range goal will result in a more balanced fishery.

2.6 Water Quality

2.6.1 Baseline/Current Analysis

Evaluation of the baseline and current trophic state index (TSI) of Mitchell Lake shows that the lake consistently has not met the MDNR-criteria ($TSI_{SD} \leq 62$) for the lake's fishery during the baseline and the current periods (Figure 22). The TSI during the current period, however, was somewhat lower (less eutrophic) than the baseline period. Mitchell Lake fully supported fishable use during 40 percent of the baseline period and 67 percent of the current period. For the entire 1972 to 1999 period, Mitchell Lake was able to meet the MDNR- criteria for fully supported fishable use during 6 of the 11 monitored years (i.e., 1975, 1984, 1991, 1993, 1995, and 1996).

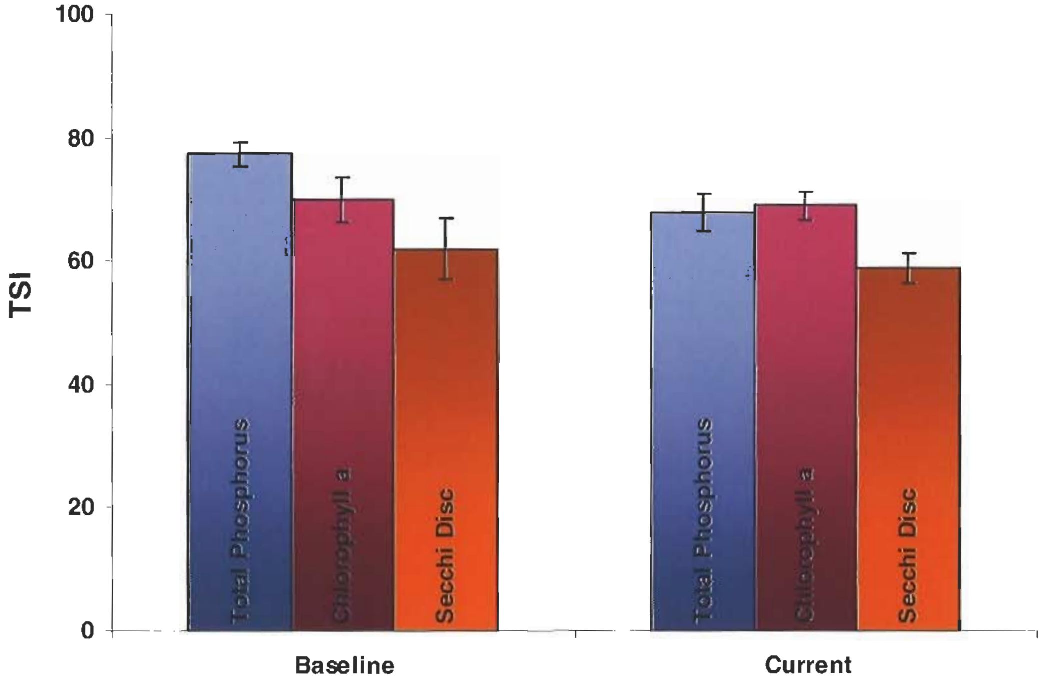


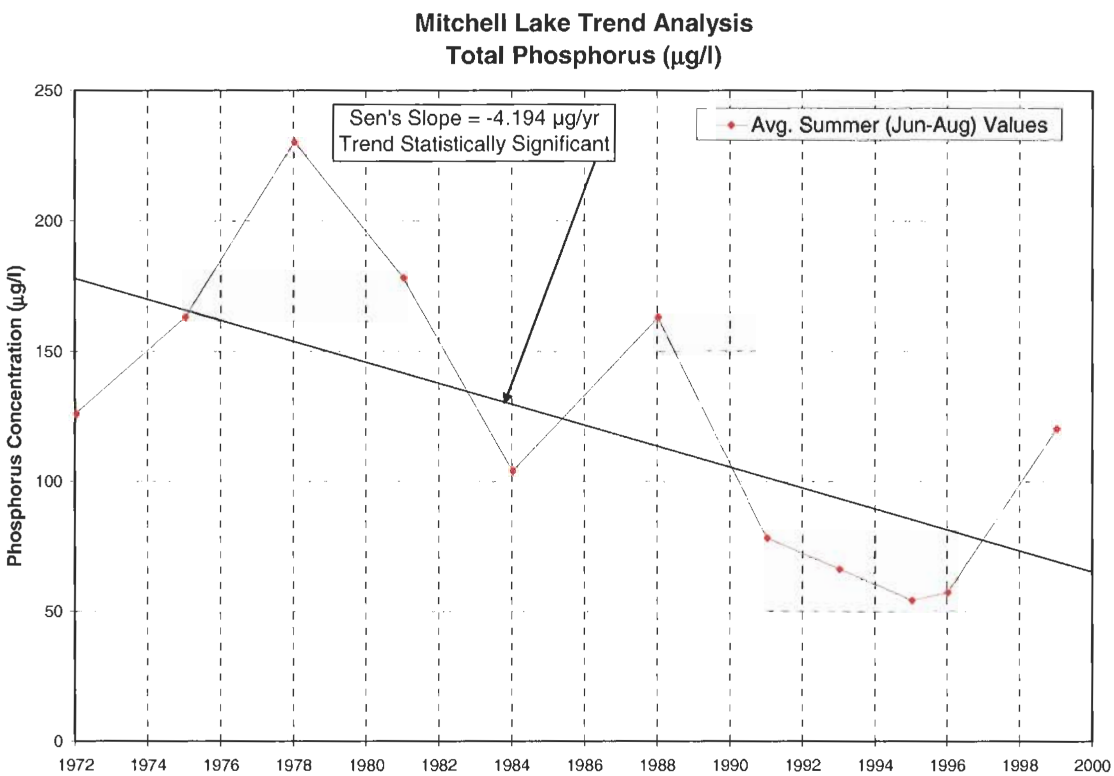
Figure 22 Baseline and Current Trophic State Index (TSI) for Mitchell Lake

2.6.2 Historical Water Quality-Trend Analysis

A trend analysis for Mitchell Lake was completed to identify any significant degradation or improvement during years in which water quality data were available. Although there have been fluctuations in phosphorus levels, chlorophyll *a* levels, and in lake clarity, it appears that over time the water quality of the lake has remained within a consistent range.

Trend analyses from 1972 through 1999 indicate that there has been no significant change in Mitchell Lake's water quality (see statistical analyses in Figures 23, 24, and 25). The results of the regression analyses indicate that Secchi disc transparency has declined at the rate of 0.01 meters per year; chlorophyll *a* concentration in the surface waters (upper 6 feet) has increased at a rate of 0.3 μg/L per year; total phosphorus concentration in the surface waters has been decreasing at a rate of 4 μg/L per year. The changes in Secchi disc and chlorophyll *a* are not significantly different from zero at the 95 percent confidence level. The decline in phosphorus was significantly different from zero at the 95 percent confidence level. Concurrent decreases in total phosphorus and chlorophyll *a* concentrations in the presence of increasing transparencies, all statistically significant at the

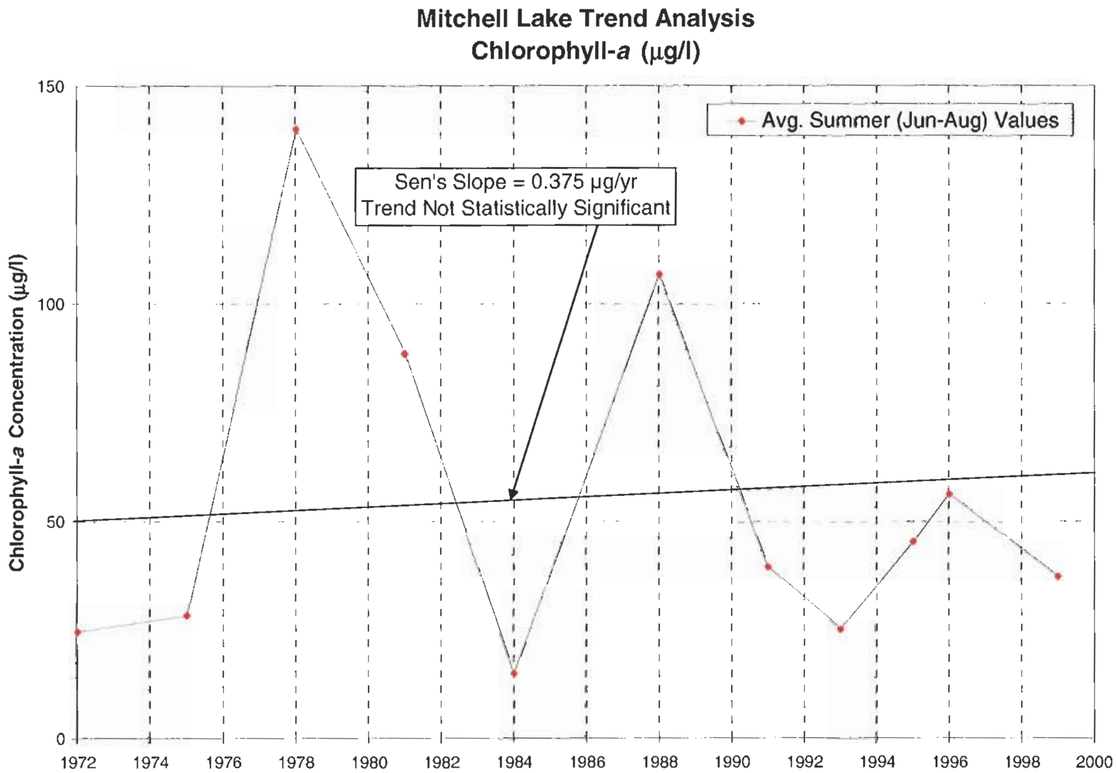
95 percent confidence level, is considered to be a consistent improvement in lake water quality. Hence the data indicate the lake's current water quality problems are unlikely to change unless management practices are implemented to improve the lake's water quality.



Mann-Kendall/Sen's Slope Trend Test

Confidence Level	Test Statistic = -28	
	Test	Significance
99%	-28 >-34	Not Significant
95%	-28 < -27	Significant Decrease
90%	-28 < -23	Significant Decrease
80%	-28 < -18	Significant Decrease
Sen's Slope	-4.194 µg/year	

Figure 23 Mann-Kendall Trend Analysis of Total Phosphorus Concentration since 1972 for Mitchell Lake

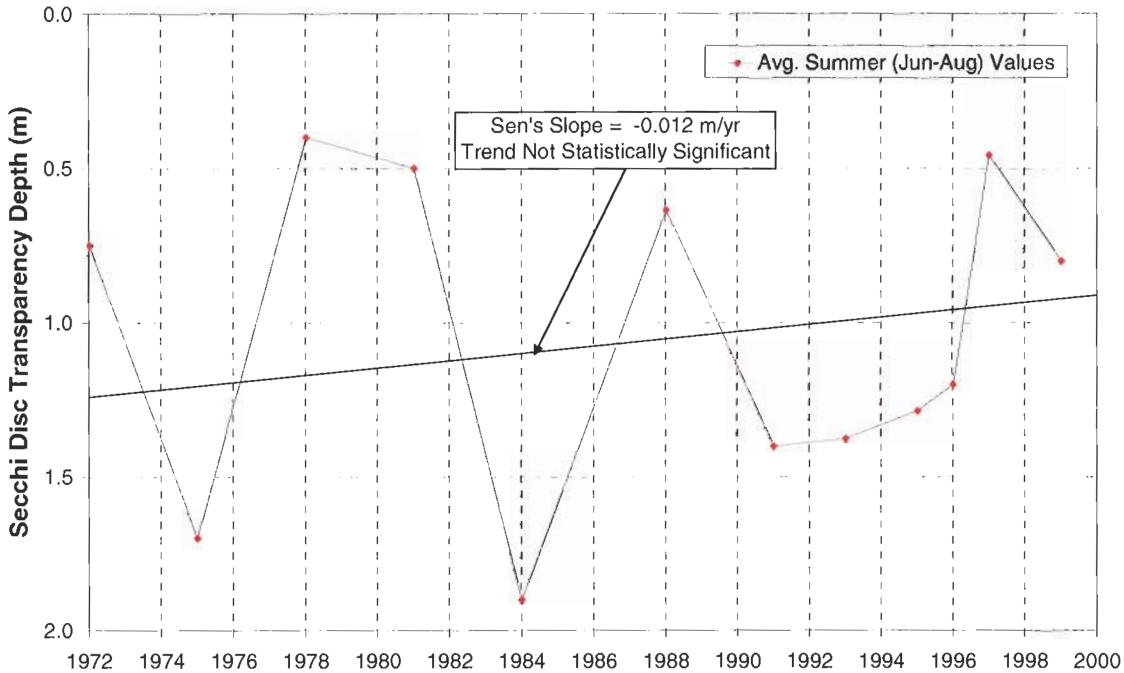


Mann-Kendall/Sen's Slope Trend Test

Confidence Level	Test Statistic = 3	
	Test	Significance
99%	3 < 34	Not Significant
95%	3 < 27	Not Significant
90%	3 < 23	Not Significant
80%	3 < 18	Not Significant
Sen's Slope	0.375 µg/year	

Figure 24 **Mann-Kendall Trend Analysis of Chlorophyll-a Concentration Since 1972 for Mitchell Lake**

Mitchell Lake Trend Analysis
Secchi Disc (m)



Mann-Kendall/Sen's Slope Trend Test

Confidence Level	Test Statistic = -4	
	Test	Significance
99%	-5 >-38	Not Significant
95%	-5 >-30	Not Significant
90%	-5 >-26	Not Significant
80%	-5 >-20	Not Significant
Sen's Slope	-0.012 meters/year	

Figure 25 Mann-Kendall Trend Analysis of Secchi Disc Transparency Depth Since 1972 for Mitchell Lake

2.6.3 Water Quality Modeling Analysis

Water quality modeling was performed to better understand the phosphorus dynamics in the Mitchell Lake watershed and in Mitchell Lake, and to understand how phosphorus loading is affecting algal growth in the lake. Watershed modeling, which includes both hydrologic and phosphorus loading, was performed using the P8 (IEP, Inc. 1990) model. In-lake models (Dillon and Rigler 1974, and Thomann and Mueller 1987) were used to determine how external and internal phosphorus loading (loading within the lake) lead to the observed levels of phosphorus in Mitchell Lake. Internal loading was from curlyleaf pondweed decay and sediment phosphorus loading.

Modeling was performed for four climatic conditions (dry, average, model calibration, and wet year) and different management efforts to determine the potential effect of these management activities on phosphorus levels in Mitchell Lake. A regression between phosphorus levels and Secchi disc transparency was developed by the Minnesota Pollution Control Agency from Minnesota lake monitoring data and was used to predict expected lake clarity improvements (Secchi disc transparency) with different management activities (Heiskary and Wilson, 1990; See Figure 5). A detailed description of model development, calibration, and validation is provided in Appendix B.

2.7 Major Hydrologic Characteristics

The major hydrologic characteristics of Mitchell Lake have changed as the watershed has changed from primarily agricultural to urban. Although the watershed is nearly developed, some additional development will occur in the future. Park and open space areas will decline and residential, commercial, and industrial/office areas will increase. Following these land use changes, the lake's annual water load is expected to increase by about 15 to 29 percent. Hence, the lake's hydrologic residence time is expected to decrease by about 13 to 24 percent upon attainment of future (2020) watershed land use conditions.

2.8 Land Use Assessment

Land use in the watershed has changed from the predevelopment period. The watershed's land use changed from wooded to agriculture to urbanized. Watershed urbanization is nearly complete. However, future redevelopment within the watershed could result in density increases and increased phosphorus loading to the lake. Increased density in residential development and increased commercial development are both possible in the future. Proposed land use changes within the lake's watershed should be analyzed to determine whether increased phosphorus loading to the lake would result from the land use changes. Management practices such as detention basins may be required to prevent phosphorus loading increases from future land use changes.

3.0 Mitchell Lake Goals

3.1 Water Quantity Goal

The water quantity goal for Mitchell Lake is to provide sufficient water storage during a regional flood. The water quantity goal has been achieved and no action is required.

3.2 Water Quality Goal

The water quality goal of Mitchell Lake is predicated on the lake's recreational goal. The goal is to achieve a water quality that will fully support the lake's use as a fishery. The District goal is a TSI_{SD} ≤ 62. Table 13 shows that the water quality goal is currently not being achieved, but with the implementation of the following management practice the water quality goal can be achieved or exceeded:

- WQ-1: Herbicide Treatment of Curlyleaf Pondweed and Alum treatment of Mitchell Lake

The cost of the alternative is presented in Figure 26. It should be recognized that the management alternative is designed to meet or exceed the TSI_{SD} goal and reduce the fluctuations in dissolved oxygen levels in Mitchell Lake that are the result of the summer algal blooms.

Table 13 Expected Water Quality with Water Quality Management Alternative

Existing Land Use

Management Approach	Trophic State Index (TSI_{SD}) Value				
	District Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
No Action	≤ 62	68	66	66	65
Herbicide Treatment of Curlyleaf Pondweed and Lake Alum Treatment	≤ 62	61	57	57	55

Future Land Use

Management Approach	Trophic State Index (TSI_{SD}) Value				
	District Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
No Action	≤ 62	68	67	67	66
Lake Alum Treatment	≤ 62	62	59	59	57

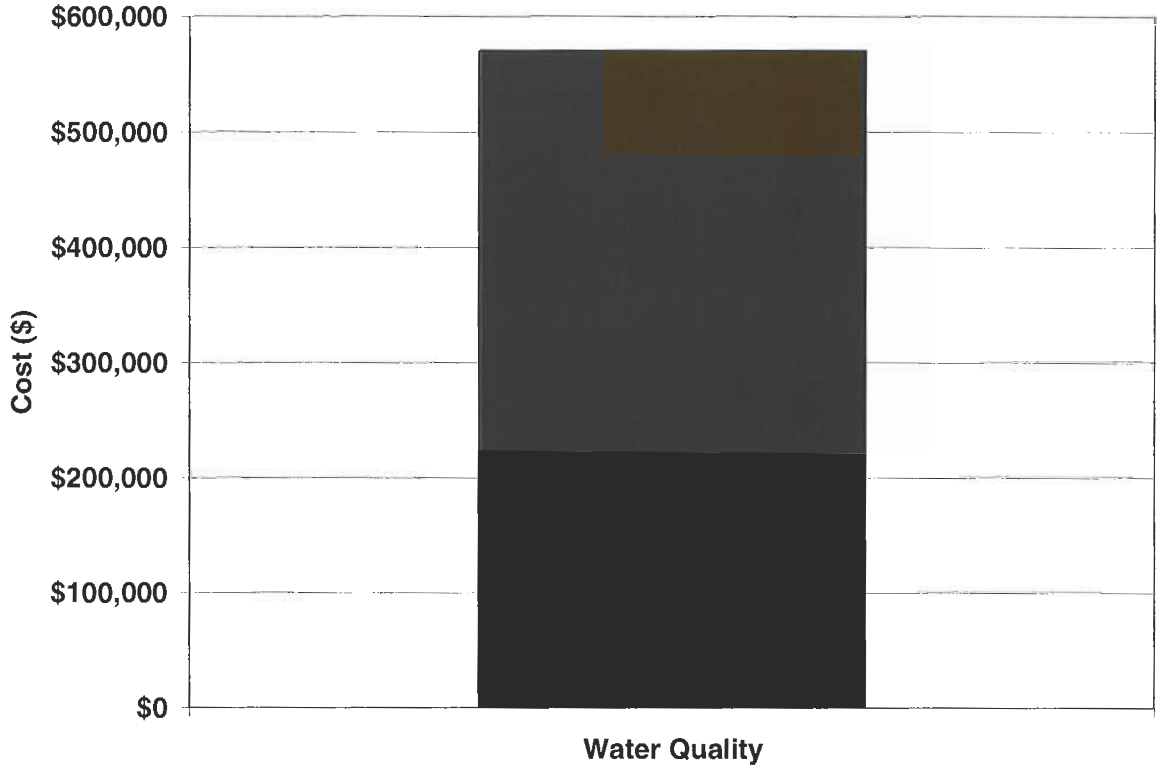


Figure 26 **Cost of the Water Quality Management Alternative**

3.3 Aquatic Communities Goal

The aquatic communities goal for Mitchell Lake is the achievement and maintenance of a water quality and habitat that fully supports the lake's fisheries-use classification as determined by the MDNR (Schupp 1992). The goal is to maintain a $TSI_{SD} \leq 62$, reduce the fluctuations in dissolved oxygen levels in Mitchell Lake that are the result of the summer algal blooms, and manage invasive non-native plant species, including curlyleaf pondweed, Eurasian watermilfoil, and purple loosestrife. The lake's current water quality and oxygen fluctuations do not provide the desired habitat for the lake's fishery. The lake's non-native species threaten further habitat degradation by problematic growths and displacement of native species. The alternative presented in Table 14 will allow Mitchell Lake to achieve or exceed the District aquatic communities goal. The costs to implement the management alternative are presented in Figure 27.

Table 14 Expected Water Quality with Aquatic Communities Management Alternative

Existing Land Use

Management Approach	Trophic State Index (TSI_{SD}) Value District Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
No Action	≤ 62	68	66	66	65
Lake Alum Treatment, Herbicide Treatment of Curlyleaf Pondweed and Eurasian Watermilfoil, Beetle Treatment of Purple Loosestrife	≤ 62	61	57	57	55

Future Land Use

Management Approach	Trophic State Index (TSI_{SD}) Value District Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
No Action	≤ 62	68	67	67	66
Lake Alum Treatment, Herbicide Treatment of Curlyleaf Pondweed and Eurasian Watermilfoil, Beetle Treatment of Purple Loosestrife	≤ 62	62	59	59	57

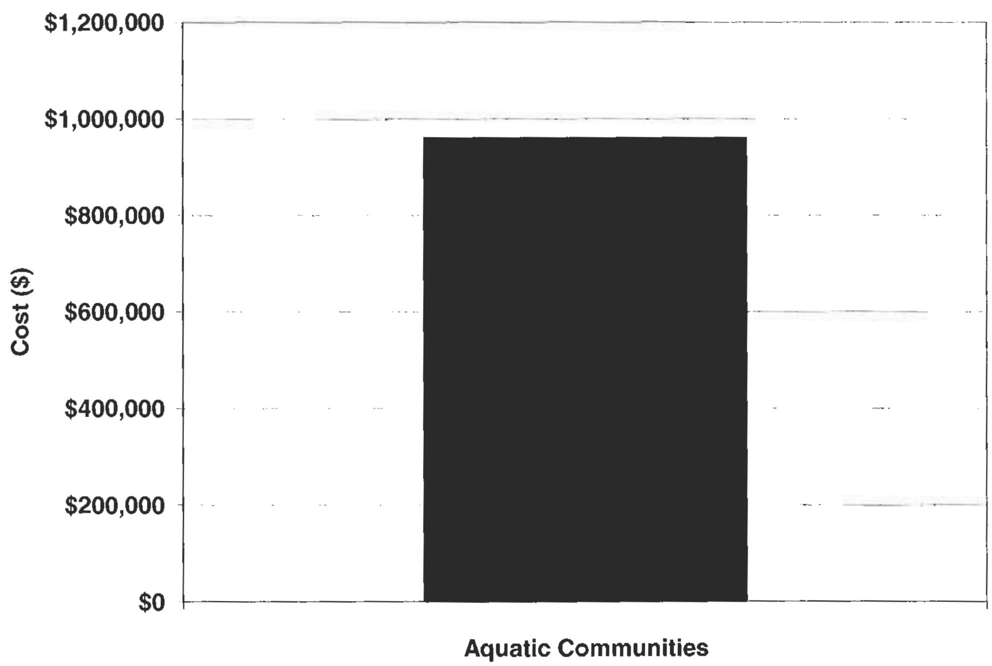


Figure 27 Cost of the Aquatic Communities Management Alternative

3.4 Recreation Goal

Because Mitchell Lake has not been designated a swimming lake by the Riley-Purgatory-Bluff Creek Watershed District, the recreational goal is to fully support the lake's fishery and maintain a $TSI_{SD} \leq 62$ (Schupp 1992). From the perspective of the TSI_{SD} goal and the problems with dissolved oxygen fluctuations resulting from excessive blue-green algae growth, the recreation goal is currently not being achieved. In addition, the lake's non-native species may cause problematic growths to further impair recreational use of Mitchell Lake. The alternative presented in Table 15 will allow Mitchell Lake to achieve or exceed the District recreation goal. The cost to implement the management alternative is presented in Figure 28.

Table 15 Expected Water Quality with Recreation Management Alternative

Existing Land Use

	Trophic State Index (TSI_{SD}) Value				
Management Approach	**District Goal**	**Wet Year (39")**	**Average Year (33")**	**Model Calibration Year (32")**	**Dry Year (25")**
No Action	≤ 62	68	66	66	65
Lake Alum Treatment, Herbicide Treatment of curlyleaf pondweed and Eurasian watermilfoil, Beetle Treatment of Purple Loosestrife	≤ 62	61	57	57	55

Future Land Use

	Trophic State Index (TSI_{SD}) Value				
Management Approach	**District Goal**	**Wet Year (39")**	**Average Year (33")**	**Model Calibration Year (32")**	**Dry Year (25")**
No Action	≤ 62	68	67	67	66
Lake Alum Treatment, Herbicide Treatment of curlyleaf pondweed and Eurasian watermilfoil, Beetle Treatment of Purple Loosestrife	≤ 62	62	59	59	57

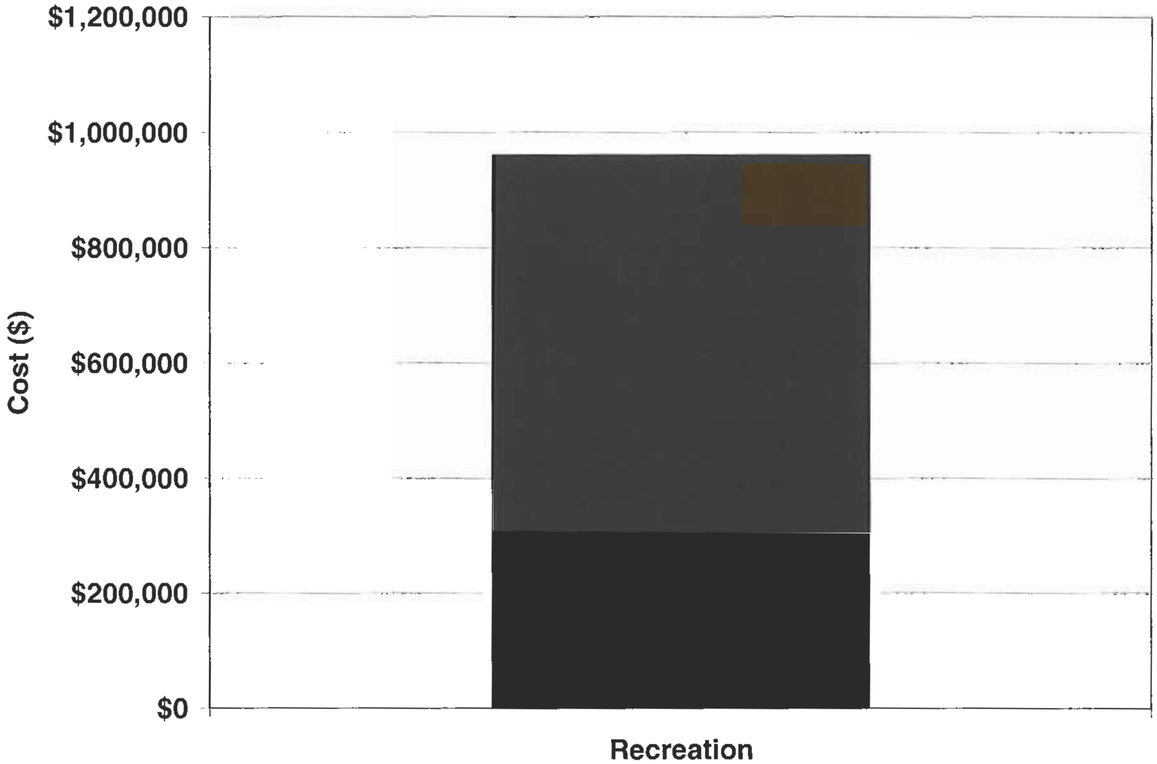


Figure 28 Cost of the Recreation Management Alternative

3.5 Wildlife Goal

The wildlife goal for Mitchell Lake is to protect existing, beneficial wildlife uses. The wildlife goal has been achieved.

3.6 Public Participation

The public participation goal is to encourage public participation as part of the use attainability analysis. This goal will be achieved through a public meeting to obtain comments on the use attainability analysis.

4.0 Selected Implementation Plan

4.1 Basis for Selected Implementation Plan

Mitchell Lake is a complex aquatic system. Any management action must be taken with consideration of how the different components of the ecosystem fit together. Monitoring data and modeling results have been used to better understand the ecology of Mitchell Lake and to estimate what the result may be from different management activities. The root of the imbalances that are observed at Mitchell Lake (blue-green algae blooms and low dissolved oxygen in the summer) is a high level of phosphorus. Although it may appear that the solution is to immediately reduce phosphorus levels, simply reducing phosphorus in a non-systematic manner may not lead to expected improvements and may have some unintended consequences.

Curlyleaf pondweed and Eurasian watermilfoil, two nuisance non-native species, are presently found in Mitchell Lake. Improvement in the lake's water clarity is expected to increase light availability to the plants and promote additional growth of both species. Failure to effectively manage these plant species before improving the lake's water clarity could result in the unintended consequence of problematic growths of both species. Additional curlyleaf pondweed growth could hamper lake improvement efforts. Decaying curlyleaf pondweed currently contributes approximately 92 pounds of phosphorus to Mitchell Lake annually. Increased coverage or density of curlyleaf pondweed would contribute additional phosphorus to the lake. This plant grows quickly in the spring, extracts phosphorus from the sediments, and dies off in June, thus releasing phosphorus stored in plant tissue. Consideration of curlyleaf pondweed and Eurasian watermilfoil indicate management of these plants should occur before completion of a lake alum treatment to manage phosphorus loads from the lake's sediments. Failure to follow this order during the implementation program could have the unintended consequences of problematic plant growths and a failure to attain water quality improvement goals. Management of curlyleaf pondweed and Eurasian watermilfoil should involve removing the species from Mitchell Lake so that native plants can replace them.

Because curlyleaf pondweed decay comprises about half of the lake's internal phosphorus load, management of curlyleaf pondweed is expected to attain approximately half of the water quality improvement estimated in Tables 13 through 15. Under model calibration (1999) climatic conditions, the lake's epilimnetic total phosphorus concentration is expected to be reduced from 120 µg/L (Figure 20) to 86 µg/L (Figure 29) following completion of the curlyleaf pondweed management program.

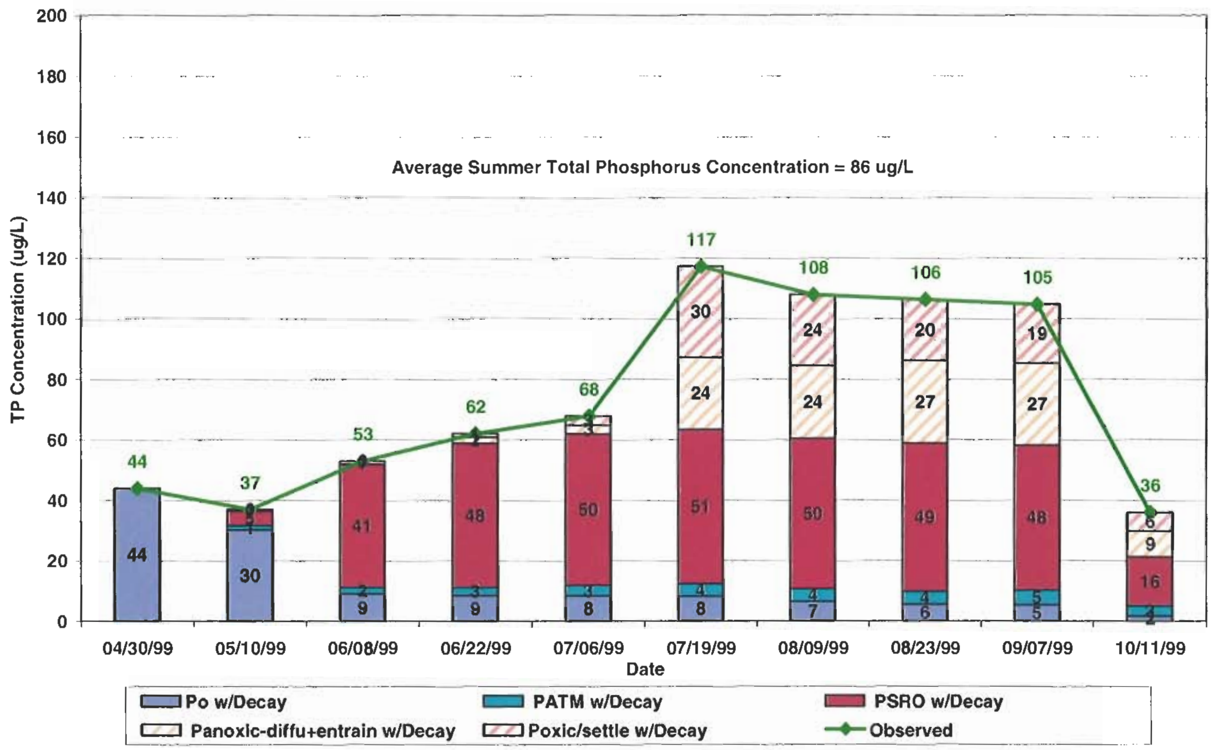


Figure 29. Estimated Total Phosphorus Concentration Following Implementation of Curlyleaf Pondweed Management Program in Mitchell Lake – Model Calibration Climatic Condition (1999)

Research has shown that the appropriate herbicide for curlyleaf pondweed control is endothall, and that this herbicide should be applied in the spring (when the water temperature is approximately 55 to 60°F) and at a dose of 1 to 1.5 mg/L (Poovey et al. 2002, Skogerboe – personal communication). Preliminary results from studies in Eagan, Minnesota by John Skogerboe of the U.S. Army Corps of Engineers have shown that four subsequent years of endothall treatment have essentially eliminated curlyleaf pondweed from two of the study lakes and that after the 4th year of treatment no viable turions (pondweed seeds) remained in the sediment (John Skogerboe, personal communication). To remove curlyleaf pondweed, treatment will need to continue until no viable turions remain after treatment is completed. Treatment is expected to continue for four years.

Current research is evaluating the effectiveness of lime to control curlyleaf pondweed. In a pilot study at Big Lake, Wisconsin, curlyleaf pondweed did not grow in 1-acre plots treated with lime, even though the plant continued to grow throughout the lake (Barr 2001). In whole lake studies, curlyleaf pondweed was not observed where lime had been applied in Clifford Lake and Faille Lake, located near Osakis in central Minnesota. The U.S. Army Corps of Engineers is currently conducting a lime slurry research project at the Eau Galle Aquatic Ecology Laboratory near Spring Valley, Wisconsin. Should the project results indicate lime would be the most effective tool to control curlyleaf pondweed in Mitchell Lake, lime will be used rather than endothall to manage this plant.

Current research has shown that the appropriate herbicide for Eurasian watermilfoil control is 2,4-D, and that this herbicide should be applied in the spring as soon as Eurasian watermilfoil starts rapidly growing (April or May). Preliminary results from a study in Bloomington, Minnesota by John Skogerboe of the U.S. Army Corps of Engineers have shown that 2,4-D was effective in controlling Eurasian watermilfoil. Study results further indicate a synergistic benefit to Eurasian watermilfoil control when endothall and 2,4-D are used together (Skogerboe – personal communication). To remove Eurasian watermilfoil, treatment will need to continue until this plant species is no longer observed in the lake. The lake's Eurasian watermilfoil infestation is recent and only a sparse growth was observed. Its removal is expected to occur within four years.

Annual herbicide treatment (endothall for curlyleaf pondweed and 2,4-D for Eurasian watermilfoil) should occur until curlyleaf pondweed and Eurasian watermilfoil are no longer observed in Mitchell Lake and no viable curlyleaf turions are found (estimate 4 years of treatment).

Purple loosestrife along the lake's shoreline threatens to displace native vegetation and reduce the habitat quality of the lake's shoreline area. Introducing a natural predator will control purple loosestrife growth along the shore. Two beetle species, *Galerucella pusilla* and *Galerucella calmariensis*, effectively prey upon purple loosestrife, inhibit purple loosestrife growth, and greatly reduce flowering seed output. Introducing the beetles to infested areas of Mitchell Lake will control purple loosestrife growth and promote the growth of native species.

Stormwater runoff comprises about half of the annual phosphorus load to Mitchell Lake. However, wet detention ponds are removing a significant fraction of the phosphorus loads (see Table 7) from the adjacent watershed. Few opportunities for additional removal of phosphorus from stormwater runoff are apparent. Upgrading eight ponds in the lake's watershed to meet MPCA/NURP criteria would have a negligible effect on the lake's water quality. Increasing infiltration of stormwater runoff by the planting of rainwater gardens in feasible locations would have a negligible effect on the lake's water quality. Treatment of phosphorus inflow to Mitchell Lake from major inlets (i.e., M3, M56, and M7) would significantly improve the lake's water quality. However, an inflow alum treatment facility is both expensive to build and expensive to operate.

Phosphorus stored in sediment, together with phosphorus from decaying curlyleaf pondweed plants, are the most treatable sources of phosphorus to the water column of Mitchell Lake. The concentration of phosphorus in Mitchell Lake sediments that can release into the water column (i.e., mobile phosphorus) is very high (Figure 18) and corresponds to a potential phosphorus release rate of approximately 8.9 mg per square meter of lake surface per day. Phosphorus released from the lake's sediments comprise approximately half of the lake's internal phosphorus load. This internal load comprises 20 to 36 percent of the lake's annual total phosphorus load under existing watershed land use conditions and varying climatic conditions. Treatment of the lake's sediments with alum will reduce phosphorus loading to the lake and improve its water quality. Alum treatment of the lake and management of the lake's curlyleaf pondweed are the most cost effective methods of improving the lake's water quality. Under model calibration (1999) climatic conditions, the lake's epilimnetic total phosphorus concentration is expected to be reduced from 120 μg/L (Figure 20) to 57 μg/L (Figure 30) following completion of the curlyleaf pondweed management program and alum treatment of the lake.

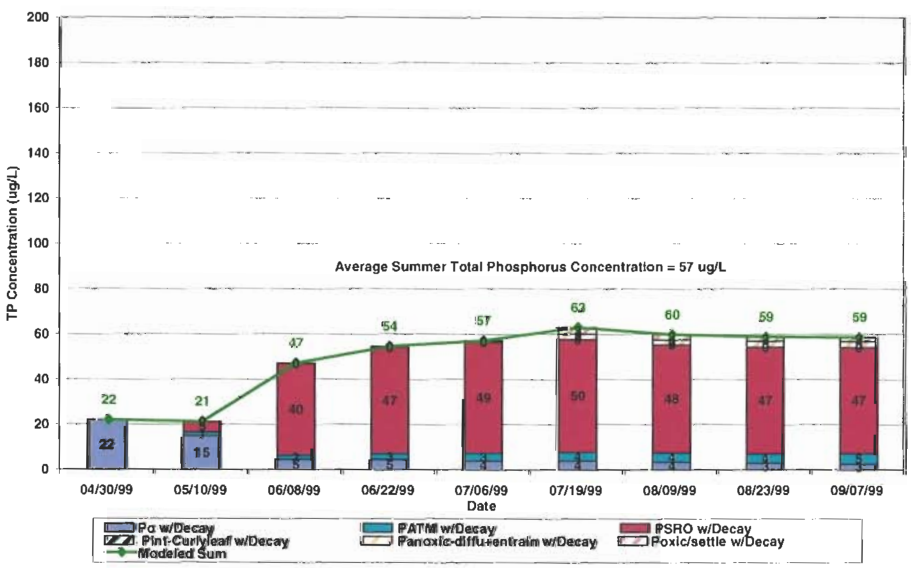


Figure 30 **Estimated Total Phosphorus Concentration Following Implementation of Curlyleaf Pondweed Management Program and an Alum Treatment of Mitchell Lake – Model Calibration Climatic Condition (1999)**

If applied in one treatment, the large dose of alum that is required to treat Mitchell Lake's sediments may be too heavy for the sediments to bear. The sediments have a limited weight bearing capacity because the water content of the upper 6 centimeters of the lake's sediments is 94 to 97 percent. Hence, the weight of the alum may cause it to sink far below the sediment's surface.

Splitting the large dose into smaller doses applied annually for 6 consecutive years is recommended. The smaller annual doses are expected to remain in the upper 6 centimeters of lake sediment and effectively treat the sediment's mobile phosphorus. Treatment effectiveness is dependent upon the alum treating the upper 6 centimeters of the lake's sediments. If the alum sinks below the 6 centimeter depth, the treatment will have the unintended consequence of not treating the upper 6 centimeters of sediments that are releasing phosphorus into the lake's water column.

4.2 Manage Curlyleaf Pondweed and Eurasian Watermilfoil

The recommended treatment program for curlyleaf pondweed and Eurasian watermilfoil consists of annual spring herbicide treatment until they are removed from the lake. Treatment will occur in late-April or early-May when the water temperature is approximately 55 to 60°F. Curlyleaf pondweed will be treated with the herbicide endothall at a dose of approximately 1 to 1.5 mg/L. Eurasian watermilfoil will be treated with the herbicide 2,4-D. To remove both species from Mitchell Lake, treatment will need to continue annually until no curlyleaf pondweed, no viable turions, and no Eurasian watermilfoil remain. Treatment is expected to continue for four years.

Mitchell Lake has been classified by the MDNR as a natural environment lake (MN Rule 6120.300). MN Rule 6280 prohibits the use of pesticides in all natural environment lakes, including Mitchell Lake. Pesticide has the meaning given by Minnesota Statutes, Section 18B.01, and includes herbicides used for aquatic plant control. MN Rule 6280 also has a variance provision:

> *6280.1000 Variance*
>
> > *Subpart 1. Variance. Provisions of this chapter may be waived under special circumstances when deemed necessary by the commissioner for the protection and preservation of the natural resources of the state.*
> >
> > *Subpart 2. Lake vegetation management plan (LVMP). This chapter may be modified or waived in accordance with a lake vegetation management plan approved by the commissioner.*

The District will need a variance to implement the recommended non-native plant management program. Hence, the District should submit the Mitchell Lake UAA to MDNR as a Lake Vegetation Management Plan and request MDNR approval. Assuming approval of the Mitchell Lake Vegetation Management Plan is granted, the District should apply for a variance from the prohibition on the use of pesticides in Mitchell Lake. Assuming the variance is obtained, the District should apply for an aquatic plant management permit (APM) from the MDNR (MN Rule 6280.0250).

Current research to determine the effectiveness of lime to manage aquatic plants, including non-native species, could potentially conclude that lime is a better management tool than herbicide for control of curlyleaf pondweed and/or Eurasian watermilfoil. Should lime prove to be a better tool, lime treatment will replace herbicide treatment for curlyleaf pondweed and/or Eurasian watermilfoil. Should the MDNR deny the District's request for a variance from pesticide prohibition for Mitchell Lake, lime treatment will be used for control of the lake's curlyleaf pondweed and Eurasian watermilfoil. A letter of support from the MPCA and MDNR must be obtained prior to treating the lake with lime.

4.3 Manage Purple Loosestrife

The recommended purple loosestrife treatment program includes introduction of beetles, natural predators, into shoreline areas infested with purple loosestrife. The MDNR will provide beetles to the District at no cost. However, introducing the beetles into purple loosestrife infested areas is the District's responsibility. Management of purple loosestrife generally spans several years (four years estimated). During the treatment period, annual field surveys will measure beetle population establishment and persistence. Survey results will determine whether the collection and release of additional beetles are warranted.

4.4 Alum Treatment of Mitchell Lake

The recommended treatment program to reduce the lake's phosphorus concentrations is management of the lake's curlyleaf pondweed and a lake alum treatment. The recommended alum dose is 22.6 mg/m^2 by 1 centimeter deep or 2,474 gallons per acre to treat the top 6 centimeters of sediment in Mitchell Lake. The dose will be administered in increments of one sixth the total dose. A dose of approximately 412 gallons per acre will be administered annually in the fall for six consecutive years to attain the recommended treatment dose of 2,474 gallons per acre. Annual monitoring of the lake and sediments will measure treatment effectiveness and the mobile phosphorus remaining in the lake's sediments. Dose adjustments will be made as warranted.

A letter of support must be obtained from the MPCA and MDNR prior to treating the lake with alum.

4.5 Expected Sequence of Implementation Plan

Below is the expected sequence of the lake management activities.

Year 1-3 Herbicide (endothall and 2,4-D) treatment of curlyleaf pondweed and Eurasian watermilfoil in the spring; beetle treatment of purple loosestrife in the spring; monitoring and evaluation of aquatic plants (transect surveys), including purple loosestrife; monitoring and evaluation will determine warranted changes in herbicide treatment and whether additional beetles need to be introduced into purple loosestrife infested areas.

Year 4 Continued herbicide treatment; monitoring and evaluation of sediments, lake water quality, and aquatic plants (transect surveys), including purple loosestrife (qualitative mapping); monitoring and evaluation will determine warranted changes in herbicide treatment and whether this is the final year of treatment; monitoring and evaluation will determine whether purple loosestrife control is complete or whether additional beetles need to be introduced to complete purple loosestrife control.

Years 5-7 Alum treatment in the fall; monitoring and evaluation of lake water quality, sediments, and aquatic plants (transect surveys), including purple loosestrife (qualitative mapping); monitoring and evaluation of lake water quality and sediments will determine warranted changes in alum dose.

Year 8-10 Continued alum treatment in the fall; monitoring and evaluation of lake water quality, sediments, and aquatic plants (qualitative mapping), including purple loosestrife (qualitative mapping); monitoring and evaluation of water quality and sediments will determine warranted changes in alum dose and when the final alum treatment occurs.

Years 11-13 Monitoring and evaluation of lake water quality, sediments, and aquatic plants (qualitative mapping), including purple loosestrife (qualitative mapping); completion of a final report which summarizes the treatment program and monitoring results.

The annual costs of the lake management activities for the 13 year period are shown in Figure 31.

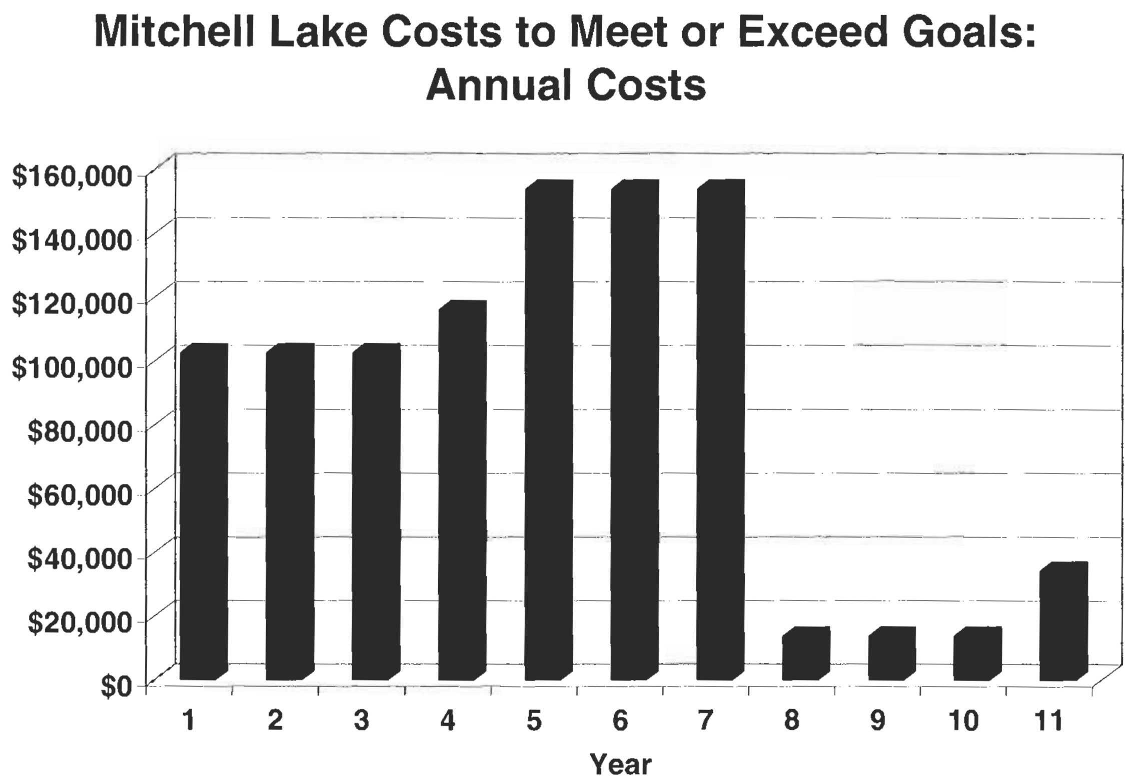


Figure 31 **Annual Cost of Mitchell Lake Management Alternative to Meet or Exceed Goals**

4.6 Monitoring and Evaluation

An important part of this plan is monitoring and evaluation, including aquatic plant monitoring, purple loosestrife and beetle monitoring, water quality monitoring, and sediment monitoring.

4.6.1 Aquatic Plant Monitoring

During each treatment year and for 3 years following treatment, aquatic plant surveys should be completed on three occasions: pre-treatment survey, late-spring survey, and late-summer survey. The three surveys will determine the locations and density of plants in Mitchell Lake, including curlyleaf pondweed and Eurasian watermilfoil. Because treatment is expected to occur in late-April or early-May, the pre-treatment survey should be completed in either April or May, but before treatment occurs. The late-spring survey should be completed by late-June. The late-summer survey should be completed by late-August. During the late-spring survey, turions (curlyleaf pondweed "seeds") should be collected from 10 percent of sample locations.

Annual monitoring will be used to assess plant community changes and to determine treatment changes. It is anticipated that reduced curlyleaf pondweed (and turions) and Eurasian watermilfoil will occur annually during the treatment period. The treatment area is expected to decrease with decreased coverage. The treatment program will be adjusted annually based upon monitoring results and will be terminated when no curlyleaf pondweed or Eurasian watermilfoil plants are observed in Mitchell Lake and no viable turions are collected.

4.6.2 Purple Loosestrife/Beetle Monitoring

Annual field surveys should determine purple loosestrife coverage and measure beetle population establishment and persistence.

4.6.3 Water Quality Monitoring

Water quality parameters (total phosphorus, chlorophyll *a*, Secchi disc transparency, dissolved oxygen, and pH) should be monitored every 2 weeks from April through September one year prior to the lake's alum treatment, during each year of alum treatment, and for 3 years following the final alum treatment.

4.6.4 Sediment Monitoring

Sediment monitoring should occur before alum treatment, during each of the six years of treatment, and for 3 years following treatment. The monitoring will evaluate changes in the mobile phosphorus content of the lake's sediments. The monitoring following sediment treatment will also evaluate the location of the alum layer. If the layer is below the sediment's surface, the distance from the surface will be measured.

5.0 Proposed 7050 Rules For Lakes

The 1972 amendments to the federal Clean Water Act require the MPCA to assess the water quality of rivers, streams, and lakes in Minnesota (Code of Federal Regulations, title 40, part 130). Waters determined to be not meeting water quality standards and not supporting assigned beneficial uses are defined as "impaired." Impaired waters are listed and reported to the citizens of Minnesota and to the Environmental Protection Agency (EPA) in the 305(b) report and the 303(d) list. Both listings are named after the relevant sections of the Clean Water Act. The beneficial uses assessed in this context are aquatic life and recreation (swimming) and aesthetics.

Impaired water or impaired condition is defined in Minn. R. pt. 7050.0150 as follows:

> *... a water body that does not meet applicable water quality standards or fully support applicable beneficial uses, due in whole or in part to water pollution from point or nonpoint sources, or any combination thereof.*

The listing of a waterbody on the 303(d) list triggers a regulatory response on the part of the MPCA to address the causes and sources of the impairment. This process is called a Total Maximum Daily Load (TMDL) analysis. The purpose of the TMDL analysis is to focus attention and resources on impaired waters and ultimately bring them back into compliance with water quality standards. Current rules require that a TMDL analysis be completed after a water body is listed on the 303(d) impaired waters list to determine a water quality improvement program to bring the water body in compliance with MPCA standards. The rules also require implementation of the water quality improvement program to bring the water body in compliance with MPCA standards.

The MPCA has developed lake criteria to determine impaired waters. The criteria are found in *Guidance Manual for Assessing the Quality of Minnesota Surface Waters For Determination of Impairment. 305(b) Report and 303(d) List* (MPCA 2004). The MPCA used these criteria to assess Mitchell Lake. Because the lake failed to meet these criteria (See Table 16), Mitchell Lake was listed on the 303(d) List as an impaired waters of the State.

Table 16 Eutrophication Criteria Used to List Lakes on the 303(d) List for 2004: Lakes in the North Central Hardwood Forests (NCHF) Ecoregion, including Mitchell Lake

Parameter	Criteria*
Total Phosphorus (µg/L)	<40
Chlorophyll *a* (µg/L)	<15
Secchi Disc (m)	>1.2

*Lakes meeting the criteria are not listed on the 303(d) list.

The criteria found in Table 16 were modified during the 2004 revision of Minnesota's 7050 Water Quality Standards. The 7050 Standards' revisions include the addition of eutrophication standards for lakes (i.e., total phosphorus, chlorophyll *a*, and Secchi disc standards) on a regional basis. Within each region, separate criteria were established for deeper lakes (depths greater than 15 feet) and shallow lakes (depth of 15 feet or less and/or 80 percent or more of the lake is littoral). Mitchell Lake is located within the North Central Hardwood forests region and, because 93 percent of the lake is littoral, it is a shallow lake. The proposed 7050 standards for Mitchell Lake are shown in Table 17.

Table 17 Proposed 7050 Standards Under Consideration for North Central Hardwood Forests (NCHF) Shallow Lakes, including Mitchell Lake

Parameter	Criteria*
Total Phosphorus (µg/L)	≤60
Chlorophyll *a* (µg/L)	≤20
Secchi Disc (m)	≥1.0

*Lakes meeting the proposed criteria will not be listed on the 303(d) list.

The proposed changes to the 7050 Standards are expected to be finalized during 2005. Once finalized, the 7050 standards will be used to assess lakes to determine lake impairment. Lakes not meeting the standards will be placed on Minnesota's 303(d) Impaired Waters List (List). Lakes currently on the List must attain the water quality of the 7050 standards to be removed from the List.

Mitchell Lake's historical water quality has generally failed to meet the proposed 7050 Standards (Standards). During the 1972 through 1999 monitoring period, the lake's water quality failed to meet the proposed Standards for total phosphorus, chlorophyll *a*, and Secchi disc at a frequency of 82, 91, and 50 percent, respectively.

Following implementation of the recommended lake improvement plan, Mitchell Lake's **water transparency** is expected to meet the proposed Standards (See Table 18) during all existing land use conditions and all but the wet condition under future land use. Under existing land use, the lake's **phosphorus** concentrations are expected to meet the proposed standards under average and dry climatic conditions, but not under wet conditions. Under future land use conditions, the lake's **phosphorus** concentrations are expected to meet the standard under dry conditions, but not under average or wet conditions.

Table 18 Comparison of Proposed 7050 Standards for Mitchell Lake With Expected Water Quality Following Implementation of Recommended Plan

Existing Land Use

Parameter	Proposed 7050 Standard Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
Total Phosphorus (µg/L)	≤ 60	76	58	57	46
Secchi Disc (m)	≥1.0	1.0	1.2	1.2	1.5

Future Land Use

Parameter	Proposed 7050 Standard Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
Total Phosphorus (µg/L)	≤ 60	83	68	66	57
Secchi Disc (m)	≥1.0	0.9	1.0	1.1	1.2

Implementation of one additional water quality improvement project would enable Mitchell Lake to meet the proposed 7050 standards during nearly all conditions. Treatment of inflow waters to watershed ponds M-3, M-56, or M-7 provides the greatest opportunity for water quality improvement since they each contribute from 18 to 22 percent of the annual total phosphorus load from stormwater conveyance systems. Collectively, these three outlets contribute approximately 79 to 84 percent of the current annual conveyance system phosphorus load to Mitchell Lake. Treatment of watershed pond M-56 inflows (Location Shown on Figure 17) with alum (80 percent removal rate) is expected to attain the proposed Standards under all conditions except the wet climatic condition under future land use (See Table 19). An alum treatment plant, however, is expensive to construct and operate.

Design and construction of an alum treatment facility may cost one million dollars. Operational costs of an alum treatment facility include the cost of alum and the disposal cost of alum floc (contains the phosphorus removed from stormwater runoff). Phosphorus removal costs by inflow alum treatment are estimated to be approximately $300 for each pound of phosphorus removed (Barr, 2003). Assuming a range of 35 to 120 pounds of phosphorus would be removed annually by alum treatment of pond M-56 inflows, the annual phosphorus removal cost would range from approximately $11,000 to $35,000.

Table 19 Comparison of Proposed 7050 Standards for Mitchell Lake With Expected Water Quality Following Implementation of Recommended Plan and Treatment of Pond M-56 Lake Inflows With Alum

Existing Land Use

Parameter	Proposed 7050 Standard Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
Total Phosphorus (µg/L)	≤ 60	49	49	48	36
Secchi Disc (m)	≥1.0	1.4	1.4	1.4	1.8

Future Land Use

Parameter	Proposed 7050 Standard Goal	Wet Year (39")	Average Year (33")	Model Calibration Year (32")	Dry Year (25")
Total Phosphorus (µg/L)	≤ 60	65	54	53	43
Secchi Disc (m)	≥1.0	1.1	1.3	1.3	1.5

Barko, J. W., and Smart, R. M. 1980. *Mobilization of Sediment Phosphorus by Submersed Freshwater Macrophytes.* Freshwat. Biol. 10, 229-238.

Barko, J. W., and James, W. F. 1998. *Effects of Submerged Aquatic Macrophytes on Nutrient Dynamics, Sedimentation, and Resuspension.* In: *The Structuring Role of Submerged Macrophytes in Lakes.* E. Jeppesen, M. Sondergaard, M. Sondergaard, K. Christoffersen, Eds., Springer Verlag.

Barr Engineering Company. 1973a. *1971-1972 Water Quality Inventory.* Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1973b. *1972 Engineer's Annual Report.* Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1976. *1975 Engineer's Annual Report.* Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1979. *1978 Lake Quality Inventory.* Prepared for Riley-Purgatory Creek Watershed District.

Barr Engineering Company. 1982. *1981 Lake Quality Inventory.* Prepared for Riley-Purgatory Creek Watershed District

Barr Engineering Company. 1985. *1984 Lake Quality Inventory.* Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1989. *1988 Lake Water Quality Inventory: Lakes Ann, Duck, Hyland, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, Staring and Susan.* Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1993. *1990 and 1991 Lake Water Quality Inventory and Historical Water Quality Trend Analyses.* Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 1996. *1993 and 1994 Lake Water Quality Inventory, Trend Analysis, and Mass Balance Modeling.* Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering Company. 2000. *1996-1999 Lake Water Quality Inventory and Assessment—Lakes: Ann, Lotus, Lucy, Mitchell, Red Rock, Rice Marsh, Riley, Round, and Susan.* Prepared for Riley-Purgatory-Bluff Creek Watershed District.

Barr Engineering. 2001. *Big Lake Protection Grant LPT-67: Big Lake Macrophyte Management Plant Implementation. Volume I: Report.* Prepared for Church Pine, Round, and Big Lake Protection and Rehabilitation District.

Barr Engineering Company. 2003. *Tanner's Lake CIP Performance Evaluation.* Prepared for Ramsey Washington Metro Watershed District.

Bolduan, B.R., Van Eeckhout, G.C, and Quade, J.E. 1994. *Potamogeton crispus-The Other Invader.* Lake and Reserv. Manage. 10(2):113-125.

Burns, C.W., 1969. *Relation Between Filtering Rate, Temperature, and Body Size in Four Species of Daphnia.* Limnology and Oceanography, 14:696-700.

Carlson, R.E. 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography 22 (2): 361-369.

Carpenter, S. R. 1980. *Enrichment of Lake Wingra, Wisconsin, by Submersed Macrophyte Decay.* Ecology 61, 1145-1155.

Chapra, S.C. and K.H. Reckhow. 1983. *Engineering Approaches for Lake Management, Volume 2: Mechanistic Modeling.* Butterworth Publishers, Stoneham, MA.

Cook, G.D., Welch, E.B, Peterson, S.A., and Newroth, P.R. 1993. *Lake and Reservoir Management.*

Crowell, W. 2004. Personal Communication

Dillon, P.J. and F.H. Rigler. 1974. *A Test of a Simple Nutrient Budget Model Predicting the Phosphorus Concentrations in Lake Water.* J. Fish. Res. Be. Can. 31: 1771-1778.

Drake, J. C., and Heaney, S. I. 1987. *The Occurrence of Phosphorus and Its Potential Remobilization in the Littoral Sediments of a Productive English Lake.* Freshwat. Biol. 17, 513-523.

Frodge, J.D., Marino, D. A., Pauley, G. B., and Thomas, G. L. 1995. *Mortality of Largemouth Bass (Micropterus salmoides) and Steelhead Trout (Oncorhynchus mykiss) in Densely Vegetated Littoral Areas Tested Using an In Situ Bioassay.* Lake and Reserv. Manage. 11, 343-58.

Frodge, J. D., Thomas, G. L., and Pauley, G. B. 1991. *Sediment Phosphorus Loading Beneath Dense Canopies of Aquatic Macrophytes.* Lake and Reserv. Manage. 7, 61-71.

Gertz, T.J. 2002. Letter to Leslie Stovring, City of Eden Prairie and Map Showing Eurasian Watermilfoil locations in Mitchell Lake During 2002.

Heiskary, S.A. and W.W. Walker. 1988. *Developing Phosphorus Criteria for Minnesota Lakes.* Lake and Reservoir Management. 4:1-9.

Heiskary, S.A. and C.B. Wilson. 1990. *Minnesota Lake Water Quality Assessment Report—Second Edition—A Practical Guide for Lake Managers.* Minnesota Pollution Control Agency.

IEP, Inc. 1990. *P8 Urban Catchment Model.* Version 2.1. Prepared for the Narragansett Bay Project. Providence, Rhode Island.

James, W.F., Barko, J.W., and Eakin, H.L. 2001. *Direct and Indirect Impacts of Submersed Aquatic Vegetation on the Nutrient Budget of an Urban Oxbow Lake.* APCRP Technical Notes Collection (ERDV TN-APCRP-EA-02), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Keast, A. 1984. *The Introduced Macrophyte, Myriophyllum spicatum, as a Habitat for Fish and Their Invertebrate Prey.* Can. J. Zool. 62, 1289-1303.

Krull, J. N. 1970. *Aquatic Plant-Invertebrate Associations and Waterfowl.* J. Wildl. Manage. 34, 707-18.

Landers, D. H. 1982. *Effects of Naturally Senescing Aquatic Macrophytes on Nutrient Chemistry and Chlorophyll a of Surrounding Waters.* Limnol. Oceanogr. 27, 428-439.

Lillie, R. A., and Budd, J. 1992. *Habitat Architecture of Myriophyllum spicatum as an Index to Habitat Quality for Fish and Macroinvertebrates.* J. Freshwat. Ecol. 7, 113-25.

Melmer, David. 2004. Personal Communication.

Madsen, J.D., J.W. Sutherland, J.A. Bloomfield, L.W. Eichler, and C.W. Boylen. 1991. *The Decline of Native Vegetation Under Dense Eurasian Watermilfoil Canopies.* Journal of Aquatic Plant Management 29: 94-99.

Madsen, J. D., Dick, G. O., Honnell, O., Shearer, J., and Smart, R. M. 1994. *Ecological Assessment of Kirk Pond.* Miscellaneous Paper A-94-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Madsen, J. D. and Crowell, W. 2002. *Curlyleaf Pondweed (Potamogeton crispus L.).* Lakeline. Spring 2002, 31-32.

MDNR. 2003. *Minnesota Department of Natural Resources Section of Fisheries Lake Survey Report: Mitchell Lake, 1999. Division of Waters Inventory Number 27-0070-00.*

MDNR. 2000. *Lake Management Plan for Mitchell Lake.*

Minnesota Pollution Control Agency. 1989. *Protecting Water Quality in Urban Areas.*

Minnesota Pollution Control Agency. 1998. *Minnesota Lake Water Quality Assessment Data: 1997—An Update to Data Presented in the Minnesota Lake Water Quality Assessment Report: 1990.* Water Quality Division. Prepared for the Environmental Protection Agency.

Nurnberg, G.K. 1984. *The Prediction of Internal Phosphorus Loads in Lakes with Anoxic Hypolimnia.* Limnology and Oceanography 299(1): 111-124.

Osgood, R.A. 1989. *Assessment of Lake Use—Impairment in the Twin Cities Metropolitan Area.* Prepared for the Minnesota Pollution Control Agency. Metropolitan Council Publication 590-89-130. 12pp.

Pilgrim, K.M. 2002. *Evaluation of the Potential Benefits and Adverse effects of Alum Treatment to Remove Phosphorus from Lake Inflows.* Ph.D. Thesis. University of Minnesota.

Poovey, A.G., Skogerboe, J.G., and Owens, C.S. *Spring Treatments of Diquat and Endothall for Curlyleaf Pondweed Control*. J. Aquat. Plant Manage. 40: 63-67.

Rattei, M. R. 2004. *Lime Slurry—An Innovative Management Tool for Aquatic Plants.* Ecological Restoration 22(2):147-148.

Reedy K, S., Prepas, E.E., Chambers P.A. 2001. *Effects of Single $Ca(OH)_2$ Doses on Phosphorus Concentration and Macrophyte Biomass of Two Boreal Eutrophic Lakes Over 2 Years*. Freshwat. Biol. 46:1075-1087.

Rydin, E. and Welch, E.B. 1998. *Aluminum Dose Required to Inactivate Phosphate in Lake Sediments.* Water Res. 32(10): 2969-2976.

Schupp, D.H. 1992. *An Ecological Classification of Minnesota Lakes With Associated Fish Communities.* Investigational Report 417, Minnesota Department of Natural Resources.

Smith, C. S., and Adams, M. S. 1986. *Phosphorus Transfer From Sediments by* *Myriophyllum spicatum.* Limnol. Oceanogr. 31, 1312-1321.

Thomann, R.V, and Mueller, J.A. 1987. *Principles of Surface Water Quality Modeling and Control.* Harper Collins Publishers, Inc.

Walker, W.W. 1987. *Phosphorus Removal by Urban Runoff Detention Basins.* Lake and Reservoir Management: Volume III. North American Lake Management Society.