Hyland Lake
Use Attainability Analyses

Prepared for
Riley-Purgatory-Bluff Creek Watershed District

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Executive Summary

Overview

This report contains the results of a Use Attainability Analysis (UAA) of Hyland 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 Hyland Lake. The analysis is based upon historical water quality data, results of an intensive lake monitoring program in 2000, 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 Hyland Lake. These goals address recreation, water quality, aquatic communities, water quantity, and wildlife. Wherever possible, Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) goals for Hyland 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 Hyland Lake include the following:

1. The **Recreation Goal** is to provide water quality that: fully supports the lake's MDNR ecological class 40 rating (i.e., a Trophic State Index (TSI_{SD}) of 54.5 or lower). The goal is attainable with the implementation of lake and watershed 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 54.5 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." This goal is attainable with the implementation of lake and watershed management practices listed herein.
4. The **Water Quantity Goal** for Hyland 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 Hyland 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 Hyland Lake from 1971 to 2002 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 basically 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 Hyland Lake as far back as 1951 suggests that the water quality of Hyland Lake has been impaired for a long time. The poor water quality of Hyland Lake is perpetuated by the presence of invasive submersed aquatic vegetation (*Potamogeton crispus*, i.e. curlyleaf pondweed) and phosphorus release from sediments.

Historical Water Quality Trends

Trend analyses from 1971 through 2002 indicate that there has been no significant change in Hyland Lake's water quality. The results of the regression analyses indicate that Secchi disc transparency has remain unchanged; chlorophyll *a* concentration in the surface waters (upper 6 feet) has declined at the rate of 1.1 µg/L per year; total phosphorus concentration in the surface waters has been decreasing at a rate of 0.4 µg/L per year. The changes in Secchi disc, chlorophyll *a,* and total phosphorus are not significantly different from zero. 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 between baseline (i.e., 1971 to 1987) and current (1988 to 2002) trophic state index (TSI) values indicates that Hyland Lake has been unable to fully support fishable use during the baseline and current periods. For the entire 1971 to 2002 period, Hyland Lake was able to meet the MPCA criteria (TSI ≤54.5) for fully supported fishable use only for a few years (1979, 1981, and 1982) following a 1978 restoration effort.

Current Water Quality

The current water quality of Hyland Lake is poor and recreational activities are impaired by invasive aquatic vegetation growth, curlyleaf pondweed (*Potamogeton crispus*), and mid-to late-summer algal blooms that can be characterized as severe. In 2002 Hyland Lake's average summer concentration of total phosphorus, concentration of chlorophyll *a*, and Secchi disc transparency were 80 µg/L, 50 µg/L, and 1.1 m, respectively. This current water quality condition of Hyland Lake is largely the result of historical inputs of sediment and phosphorus and the current influence of invasive and native aquatic plants on the mobilization of phosphorus from lake sediments. As a result, the 2002 total phosphorus, chlorophyll *a*, and Secchi disc data indicate that Hyland Lake ranges from eutrophic to hypereutrophic in the summer and hypereutrophic in the early-fall.

Phosphorus Budget

There are four major sources of phosphorus loading to Hyland Lake: watershed runoff, atmospheric deposition, release of phosphorus from lake sediments, and the release of phosphorus from decaying aquatic plant material. Watershed modeling and in-lake modeling under different climatic conditions and for existing watershed land uses indicates that annual total phosphorus loads to the lake range from 377 pounds for a dry year to 436 pounds for a wet year (Figure EX-1). Watershed modeling for the 495-acre Hyland Lake watershed shows that from 86 (dry year) to 145 (wet year) pounds of phosphorus loading to the lake originates from the surrounding watershed. During an average year watershed loading provides approximately 25.4 percent of the total phosphorus load to the lake, while internal loading (phosphorus loading during the summer from lake sediments and decaying plant material) provides approximately 63.2 percent of the total phosphorus load to the lake (Figure EX-2). The remaining phosphorus load comes from atmospheric deposition (11.4 percent).

The high concentration of phosphorus that is observed in Hyland Lake is largely the result of internal lake processes that mobilize phosphorus from lake sediments by direct release of phosphorus from the sediments and by uptake and subsequent release of phosphorus by submerged aquatic plants. For an average year it is estimated that the direct release of phosphorus from Hyland Lake bottom sediments is responsible for approximately 33 percent of the total phosphorus load to Hyland Lake while aquatic plants are responsible for 30.2 percent of the total phosphorus load to Hyland Lake. Because it is expected that future watershed land use changes will be minimal, total phosphorus loading in the future will be essentially unchanged. The small difference in phosphorus loading between existing and future land uses is largely due to changes in how the Metropolitan Council classifies future land uses. The proportion of phosphorus loading from internal sources is expected to be constant over time.

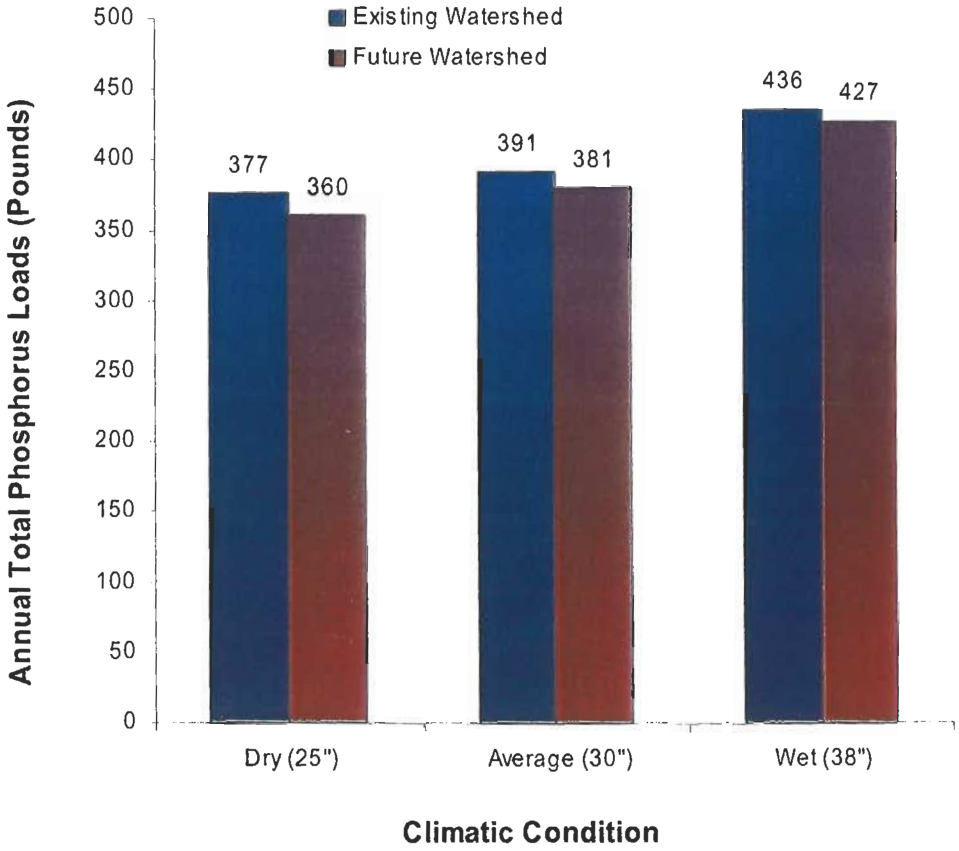

Figure EX-1 Total Phosphorus Loading to Hyland Lake with Varying Climatic Conditions and with Existing and Future Watershed Land Uses

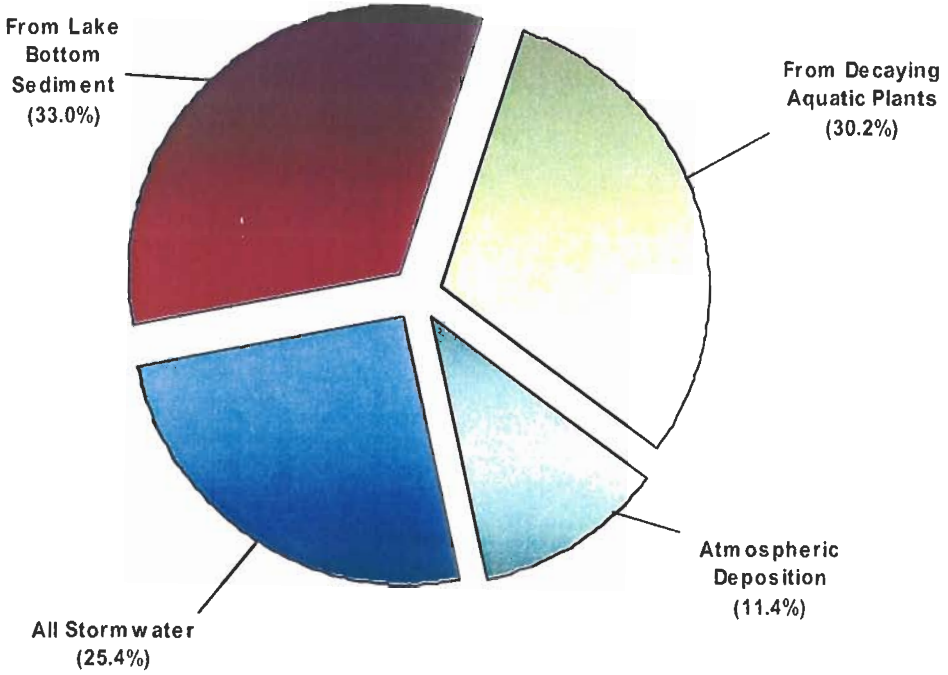

Figure EX-2 Proportion of Phosphorus Loading by Source

Aquatic Plants

Macrophyte surveys were completed in Hyland Lake on June 12 and August 23, 2000. The exotic (nonnative) species, curlyleaf pondweed (*Potamogeton crispus*) was found throughout the lake during June. The annual die-off of this plant in June released phosphorus to the lake, causing increased algal growth for the remainder of the summer. Shading from increased algal growth severely limited macrophyte growth in Hyland Lake. Plants grew to a depth of 10 feet in June and 2 feet in August. Algal shading caused the die-off of three native species of pondweed, floating-leaf pondweed (*Potamogeton natans*), sago pondweed (*Potamogeton pectinatus*), and flat-stem pondweed (*Potamogeton zosteriformis*). They were present in June and absent (decomposed) in August. The pondweed die-off released phosphorus to the lake and further exacerbated the lake's algal blooms. Management of curlyleaf pondweed is recommended to protect the lake's water quality and native plant community and to improve the lake's fishery.

Recommended Goal Achievement Alternatives

Two lake improvement alternatives will achieve or exceed the District goal for Hyland Lake.

The alternatives are:

- **Alternative 1**: Manage aquatic plants by mechanical harvesting for 3 years, herbicide (endothal) treatment for 4 years.
- **Alternative 2**: Manage aquatic plants by mechanical harvesting for 3 years, herbicide (endothal) treatment for 4 years, alum-lime treatment after the 4th year of herbicide treatment.

The expected cost and benefit of each action is presented in Table EX-1 and Figure EX-3. For each alternative to be successful, the prescribed management activities must follow a particular sequence. For **Alternative 1**, mechanical harvesting (by the Three Rivers Park District) will begin in 2004 and will continue through 2006. Herbicide treatment should also begin before harvesting is complete to reap the maximum synergistic benefits from harvesting and treatment. Treatment should continue for 4 years.

For **Alternative 2**, mechanical harvesting will also begin in 2004 and continue through 2006. Herbicide treatment should also begin before harvesting is complete to reap the maximum synergistic benefits from harvesting and treatment. Herbicide treatment should continue for 4 years. Alum-lime should be applied to Hyland Lake only after curlyleaf pondweed is controlled, and it is expected that curlyleaf pondweed will be controlled sometime between the 3rd and 4th year of herbicide treatment.

Table EX-1 Benefits and Costs of Two Management Alternatives

Management Alternative	Trophic State Index (TSI_{SD}) Value				*Cost
	District Goal	Dry Year_2000 (25 inches of precipitation)	Average Year_1998 (30 inches of precipitation)	Wet Year_2002 (38 inches of precipitation)	
Existing Watershed Land Uses					
Aquatic Plant Harvesting (3 years) and Herbicide Treatment (4 years)	≤54.5	55.7	54.5	55.2	$240,000
Aquatic Plant Harvesting (3 years) and Herbicide Treatment (4 years) and Alum-Lime Treatment	≤54.5	53.5	52.4	53.2	$380,000
Future Watershed Land Uses					
Aquatic Plant Harvesting (3 years) and Herbicide Treatment (4 years)	≤54.5	55.0	54.5	54.2	$240,000
Aquatic Plant Harvesting (3 years) and Herbicide Treatment (4 years) and Alum-Lime Treatment	≤54.5	52.7	52.4	53.2	$380,000

*Aquatic plant harvesting annual cost is estimated by the Three Rivers Park District to be $12,500 ($37,500 for 3 years). The Three Rivers Park District intends to start harvesting in 2004. Cost of harvesting not included in this cost estimate.

Selected Implementation Plan

The selected implementation plan is Alternative 2: mechanical harvesting, herbicide (endothal) treatment, and alum-lime treatment. This implementation plan has been selected because experience with past restoration efforts at Hyland Lake have demonstrated that the overall productivity of Hyland Lake needs to be significantly reduced to restore the lake to a more ecologically balanced condition. This means that both significant internal phosphorus sources, the aquatic plant curlyleaf pondweed and phosphorus release from sediments, need to be controlled.

This plan will require monitoring during the various stages of the restoration effort to evaluate effectiveness and determine whether the prescribed components and sequence of management efforts remains appropriate. Aquatic plants and lake water quality should be monitored during the 5 years of treatment and for 3 years following treatment. Water quality monitoring should include total phosphorus, chlorophyll *a*, and Secchi disc monitoring from May through September each year. Sediment monitoring should occur 1 year before and for 3 years after alum-lime treatment. Sediment monitoring should include an evaluation of the location of the treatment layer and collection of mobile phosphorus samples.

Coordination with the Three Rivers Park District

Hyland Lake lies entirely within the borders of the Three Rivers Park District. The Park District will initiate a 3-year aquatic plant harvesting program starting in 2004 to control the growth of curlyleaf pondweed in Hyland Lake. The Park District also intends to draw down the lake to a level such that a new outlet from Hyland Lake can be constructed in 2004. The management alternatives discussed in this study have been developed with consideration of the Three Rivers Park District's 1999 Water Quality Management Plan and the intended efforts by the Three Rivers Park District to improve the water quality of Hyland Lake. This UAA has incorporated some of the intended plans by the Park District. Management recommendations provided in this report include additional efforts that are intended to assist the Park District in reaching their goals for Hyland Lake. We have designed the management alternatives recommended in this study so that there will be time to evaluate the effectiveness of management efforts such as harvesting and herbicide treatment and discuss the appropriate timing for additional management efforts such as an alum-lime treatment.

Hyland Lake
Use Attainability Analyses

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 Surface Water Resources Data

The approved Riley-Purgatory-Bluff Creek Watershed District, *Riley-Purgatory-Bluff Creek Watershed District Water Management Plan*, 1996, (Water Management Plan*)* inventoried and assessed Hyland Lake. The plan articulated five specific goals for Hyland 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 Hyland Lake contained in the approved Water Management Plan.

A use attainability analysis of Hyland 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 Hyland 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 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, historical, current, 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. Historic, current, and proposed future land uses in the Hyland Lake watershed are discussed in the following paragraphs.

The area of the Hyland Lake watershed is 957 acres, however, 462 acres of this watershed does not contribute runoff to the lake. The entire 495 acre watershed that contributes runoff to Hyland Lake is directly tributary to the lake. Much of this watershed (215 acres) is parkland. Runoff from the remainder of the Hyland Lake watershed consists of a golf course and several neighborhoods that are primarily single family residences (low density residential).

The historical land use of a lake can have a significant bearing on the current and future water quality of a lake. Figure 1 shows that the historical land use of Hyland Lake prior to development was a mixture of agriculture and sparsely forested areas. It appears that much of the watershed that is tributary to Hyland Lake today was also tributary to Hyland Lake in 1947 and the lake was connected to agricultural lands via ditches and natural creeks.

Land use data used in the Hyland Lake UAA modeling efforts were derived from the Metropolitan Council Generalized Land Use Maps for the year 2000 (current land use) and 2020 (projected future land use). A detailed description of the current and future land uses of the Hyland Lake watershed are presented in Table 1. Maps of the current and future land uses of the Hyland Lake watershed are presented in Figures 2 and 3.

Table 1 Hyland Lake Land Use for Existing and Proposed Future Land Use Conditions

	Existing Conditions		Future Conditions	
Land Use Type	Non-Contributing	Contributing	Non-Contributing	Contributing
Low Density Residential	214	155	170	120
Medium Density Residential	22	28	18	20
High Density Residential	37	16	33	15
Developed Parkland	--	--	34	92
Natural/Park/Open	163	260	121	57
Institutional	11	13	10	4
Commercial	0	9	1	7
Highway	--	--	60	171
Open Water	15	14	14	9

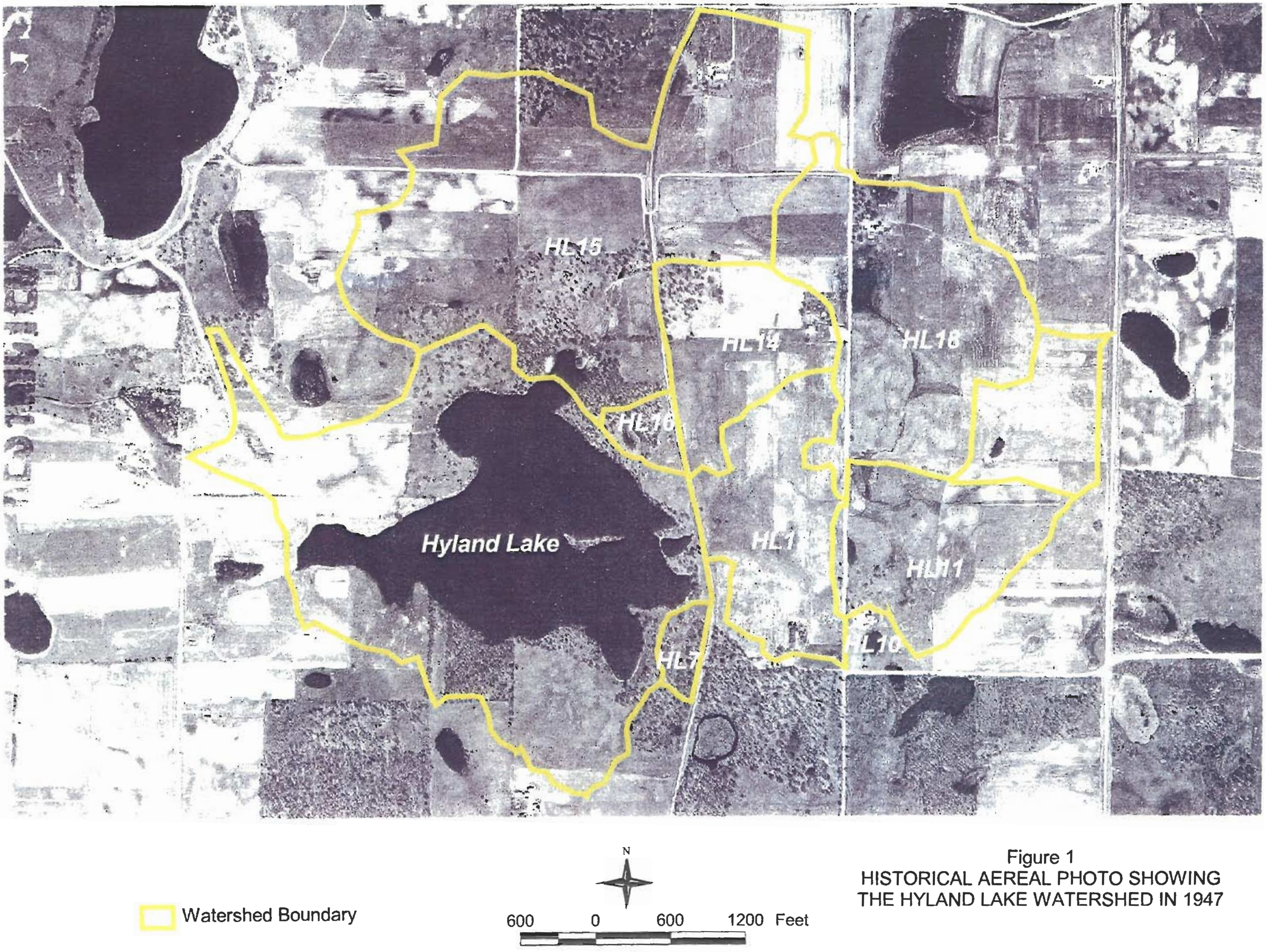

Figure 1
HISTORICAL AEREAL PHOTO SHOWING
THE HYLAND LAKE WATERSHED IN 1947

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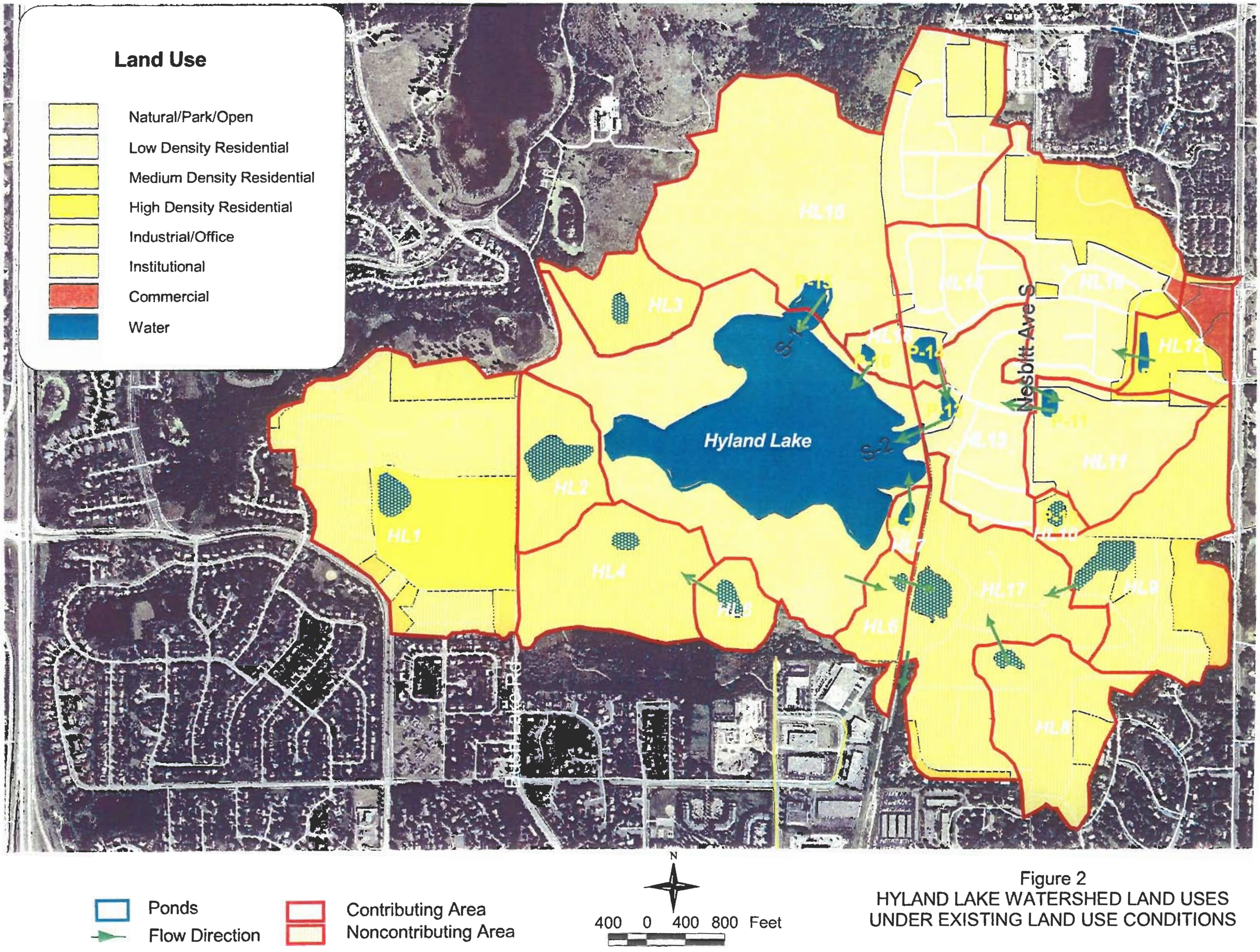

Figure 2
HYLAND LAKE WATERSHED LAND USES
UNDER EXISTING LAND USE CONDITIONS

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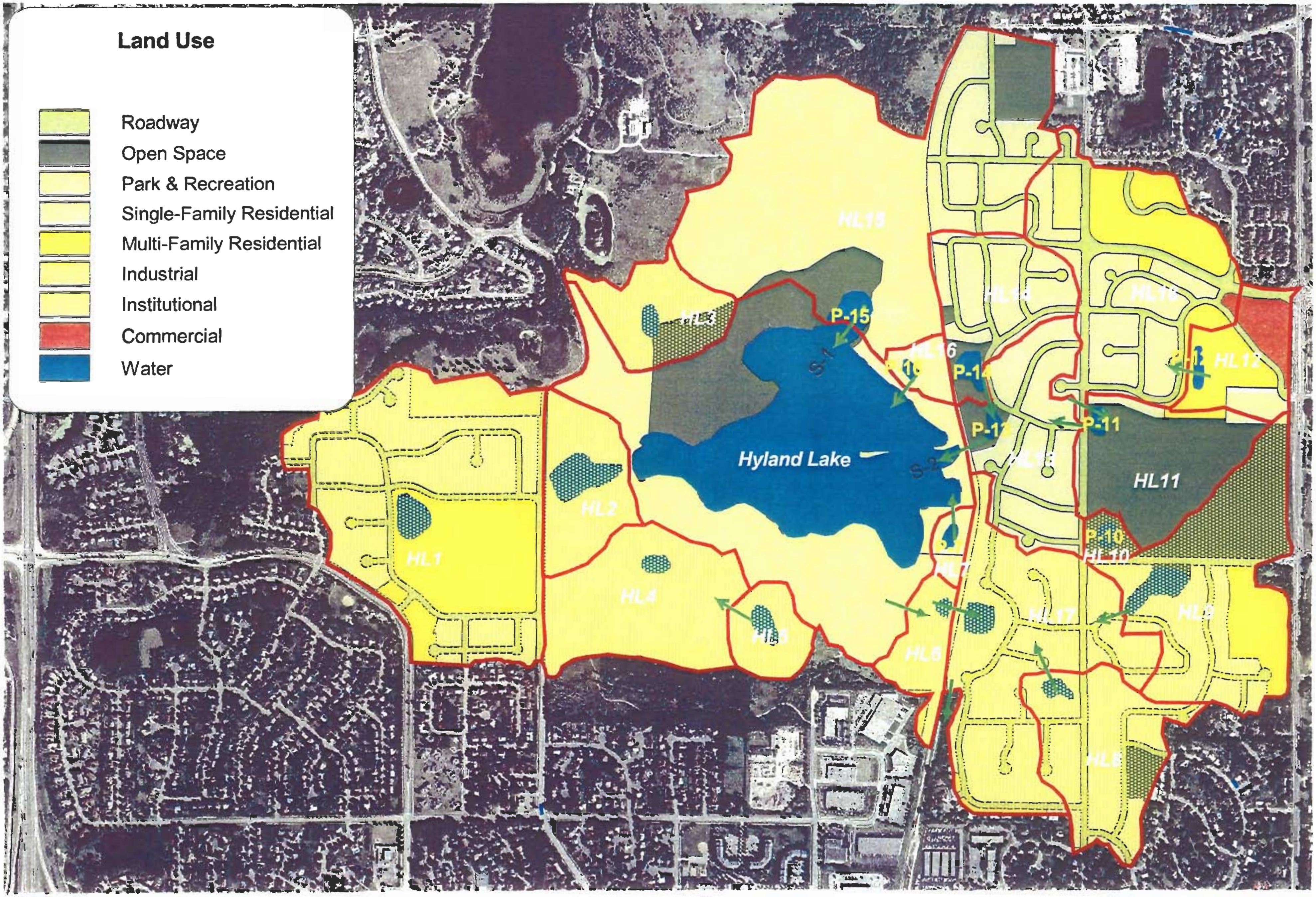

Figure 3
HYLAND LAKE WATERSHED LAND USES
UNDER FUTURE LAND USE CONDITIONS

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1.2 Major Hydrologic Characteristics

At a normal water elevation of 816.3 feet, Hyland Lake has an area of 83 acres and an average depth of 7.5 feet. The entire lake surface is considered littoral, meaning the entire lake is shallow enough to support aquatic plant growth. Water enters the lake by either direct precipitation, runoff from surrounding park land, or storm water conveyances from areas to the east. Water exits the lake by ground water infiltration or through a piped outlet and weir structure at the south end of the lake. The crest of the weir is currently at an elevation of 818.21 feet and hence water discharges from Hyland Lake through this outlet only when the surface elevation of the lake exceeds this elevation. Discharge through the outlet occurs only during very wet conditions. Most of the outflow from the lake is by infiltration to groundwater (Table 2).

The Three Rivers Park District plans to construct a new outlet from Hyland Lake in 2004 with the intent of lowering the lake elevation by one foot. The effect of this new outlet on outflows through the outlet and by groundwater exfiltration is difficult to predict given the dynamic relationship between ground water outflows/inflows and the normal water elevation of Hyland Lake. It is also difficult to predict by how much the long run normal water elevation will eventually change.

Table 2 Average Lake Volume, Annual Discharge Volume, Annual Infiltration Volume, and Estimated Hydraulic Residence Time of Hyland Lake During a Range of Climatic Conditions (Existing Watershed Landuse)

Climatic Condition (Water Year, Inches of Precipitation)	Average Lake Volume (m^3/ac-ft)	Estimated Annual Lake Outflow through Outlet (m^3/ac-ft)	Estimated Annual Lake Outflow by Infiltration (m^3/ac-ft)	Hydraulic Residence Time (years)
Wet Year (2002, 38 Inches)	826,682/670	29,443/24	218,417/177	3.8
Average Year (1998, 30 Inches)	894,646/725	0/0	181,397/147	4.9
[1]Dry Year (2000, 25 Inches)	826,682/670	0/0	231,991/188	3.4

[1] Model calibration performed for the dry year.

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 Hyland Lake from 1971 to 2000 (for years 1971, 1975, 1981, 1984, 1988, 1990, 1993, 1996, and 2000). Lake monitoring data also used in this study has been provided by the Three Rivers Park District for a number of additional years from 1971 to 2002, and two Secchi disc transparency readings from 1951.

From March through October, 2000, an intensive water quality monitoring program was completed for Hyland 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. Water sampling and analytical methods used in this study are provided in Appendix B.

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 1971 to 2002 monitoring period. Baseline water quality is defined as the average summer water quality for the years 1971 through 1987, while current water quality is defined as the average summer water quality for years 1987 through 2002.

For the baseline and current period, Hyland Lake can be classified as eutrophic to hypereutrophic. Based on the concentration of total phosphorus and chlorophyll *a*, and the Secchi disc transparency of Hyland Lake, it appears that the current water quality of Hyland Lake has slightly worsened since 1987 (Figure 4). This may be due largely because of a period of improved water quality for several years following a lake restoration effort in 1978. This restoration effort involved the draining of the lake to expose the bottom sediments, construction of storm water detention ponds, construction of an outlet, and the construction of an augmentation well and an aeration system. The lake was also restocked with bass.

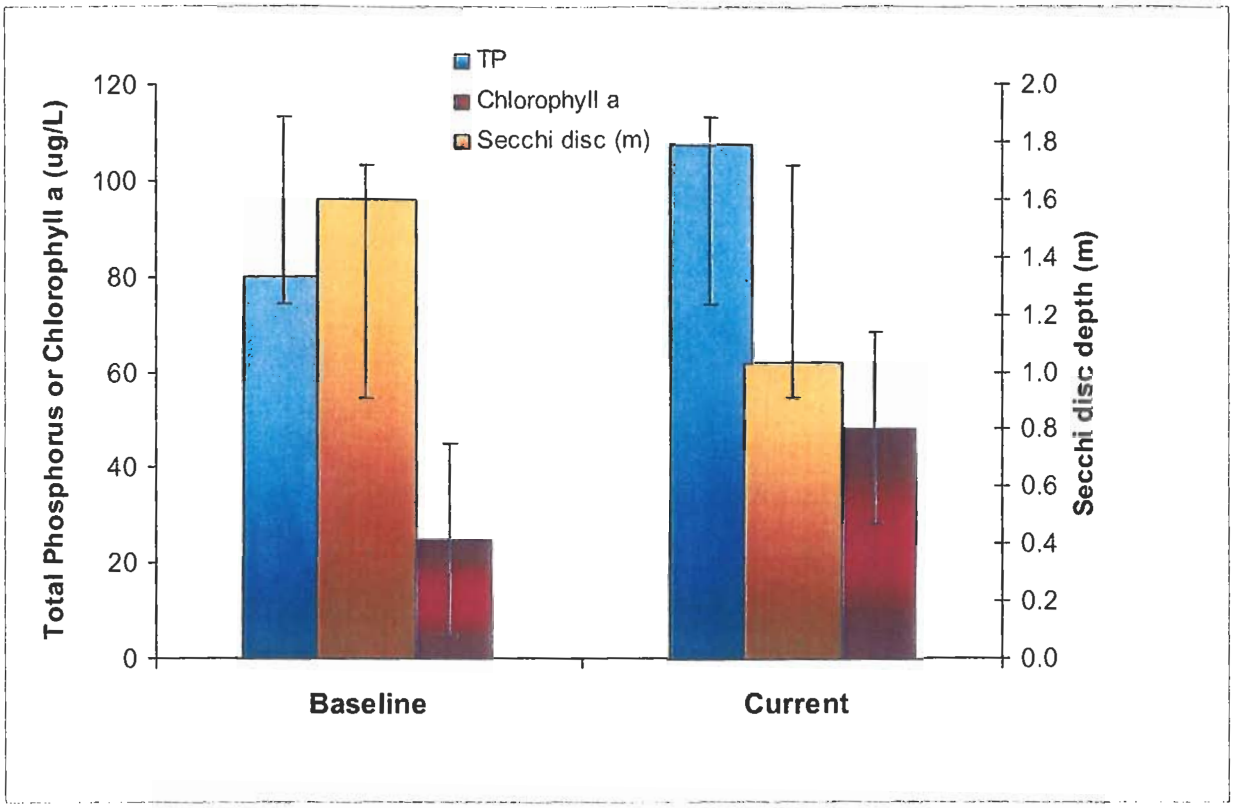


Figure 4 **A Comparison of Baseline Water Quality of Hyland Lake with Current Conditions Based on Summer (June through August) Averages**

The result of the restoration effort was that for a few years following the restoration there were reduced phosphorus levels and significantly reduced chlorophyll *a* levels and improved Secchi disc transparency. The benefits of the restoration began to diminish significantly by 1984. From the water quality data it can be inferred that phosphorus release from the lake sediments was reduced as a result of "aerating" the lake sediments during the lake draw down. However, it appears that the lake sediments became anaerobic sometime after the restoration effort, phosphorus again began to be released from sediments, and phosphorus levels were once again very high in Hyland Lake.

1.3.2.1 Present Water Quality

An evaluation of water quality data for Hyland Lake in 2000 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 5 summarizes the seasonal changes in concentrations of total phosphorus and chlorophyll *a*, and Secchi disc transparencies for Hyland Lake in 2000. The data are compared with a standardized lake rating system.

Water quality in Hyland Lake follows a very distinctive seasonal pattern. In the spring the concentrations of phosphorus and chlorophyll *a* are relatively low. By June the concentration of phosphorus begins to increase somewhat but the concentration of chlorophyll *a* increases dramatically. Phosphorus levels follow a steady rise upward throughout the remainder of the summer and into September. Chlorophyll *a* remains high throughout the summer and water clarity is severely reduced.

Modeling results, sediment sampling, and aquatic plant data (see Section 2.0 and Appendix A) suggest that the annual die-off of aquatic plants and the release of phosphorus from the lake's bottom sediments are responsible for the observed seasonal change in phosphorus concentrations. The dramatic increase in chlorophyll *a* in June that occurred despite only a modest increase in phosphorus is hypothesized to have been related to the upward movement of blue-green algae that were growing on lake sediments.

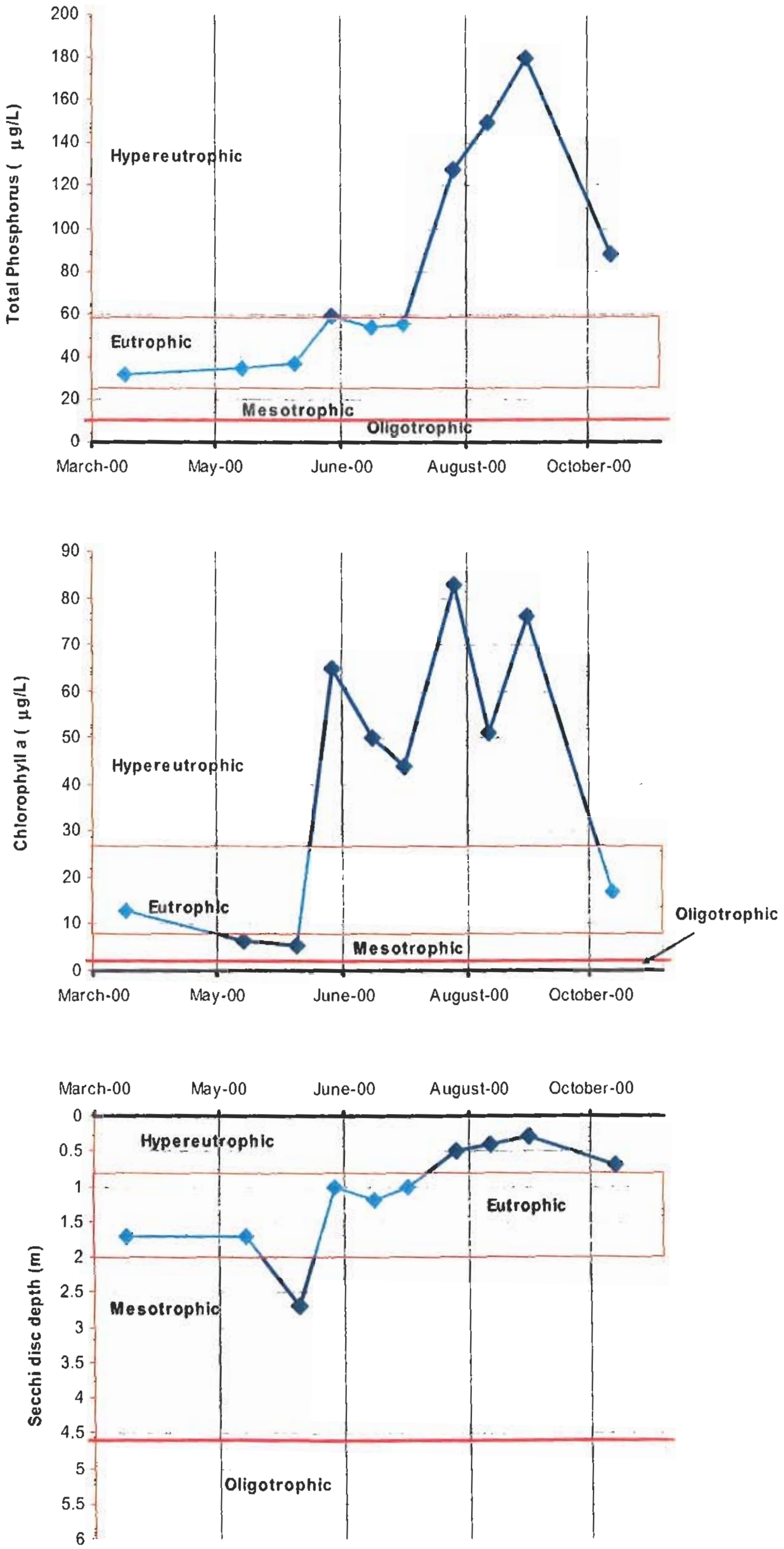


Figure 5 Seasonal Changes in the Concentration of Total Phosphorus and Chlorophyll *a*, and Secchi disc transparency in Hyland Lake for 2000.

1.4 Ecosystem Data

1.4.1 Aquatic Ecosystem

The interactions of the physical, chemical, and biological components of the Hyland Lake aquatic ecosystem have a large effect on the capacity of Hyland 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 Hyland Lake's aquatic ecosystem.

The aquatic ecosystem of Hyland Lake is a good example of how the biological community of a lake (i.e., 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 Hyland Lake.

1.4.2 Phytoplankton

The diverse population of phytoplankton in Hyland Lake goes through a seasonal transformation where green algae and diatoms 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 (Figure 6). Algal blooms are observed in Hyland Lake from late-June through September. 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 Hyland 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, phosphorus levels will need to be reduced to reduce blue-green algae populations in Hyland Lake.

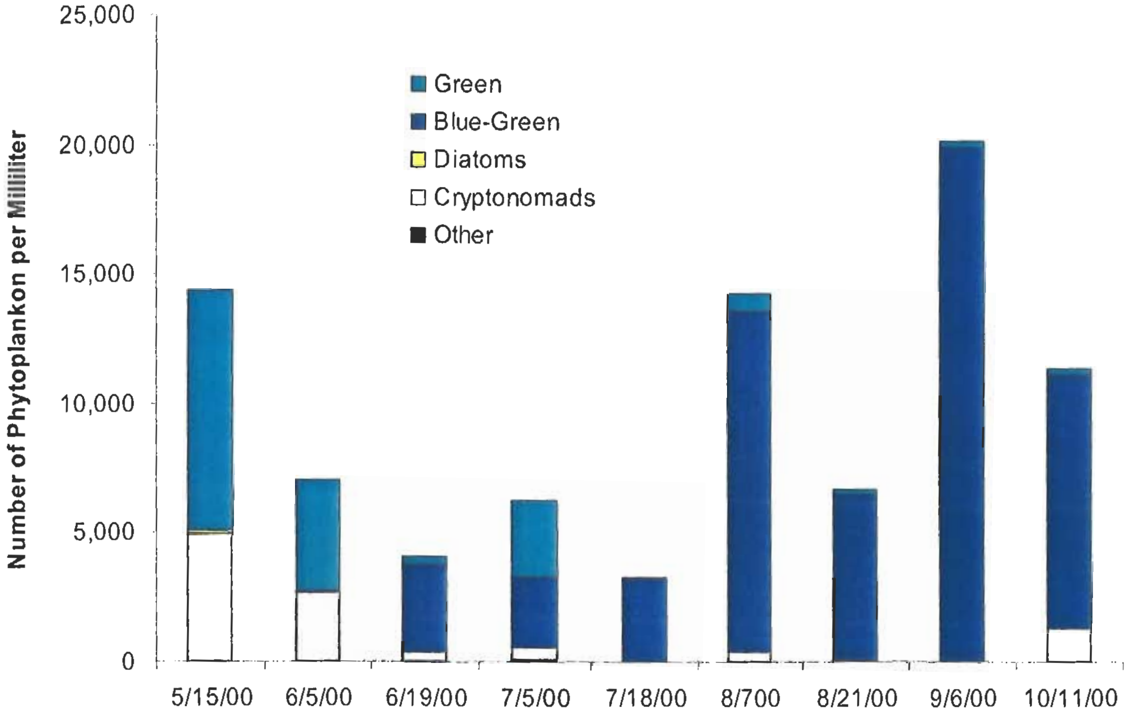


Figure 6 **Phytoplankton Abundance and Diversity in Hyland Lake**

1.4.3 Zooplankton

Zooplankton are an important component of the aquatic ecosystem of Hyland 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 Hyland Lake (Figure 7). In addition to having a large population of rotifers and copepods, there is a large population of Cladocerans, which is good because they have the capacity to biologically control algal growth. It can be seen that the large bodied zooplankton (the Cladocera) decreased significantly in early-June 2000 and did not recover until mid-July. This observed drop in the Cladocera population is typically caused by predation by newly hatched fish, called young-of-the-year. According to a 2002 fish survey by the MDNR (MDNR 2003), the 2000 year-class is large, meaning there was an abundant population of small, newly hatched fish in Hyland Lake in 2000, and to a limited degree this fish population may be affecting the abundance of the Cladocera population in Hyland Lake.

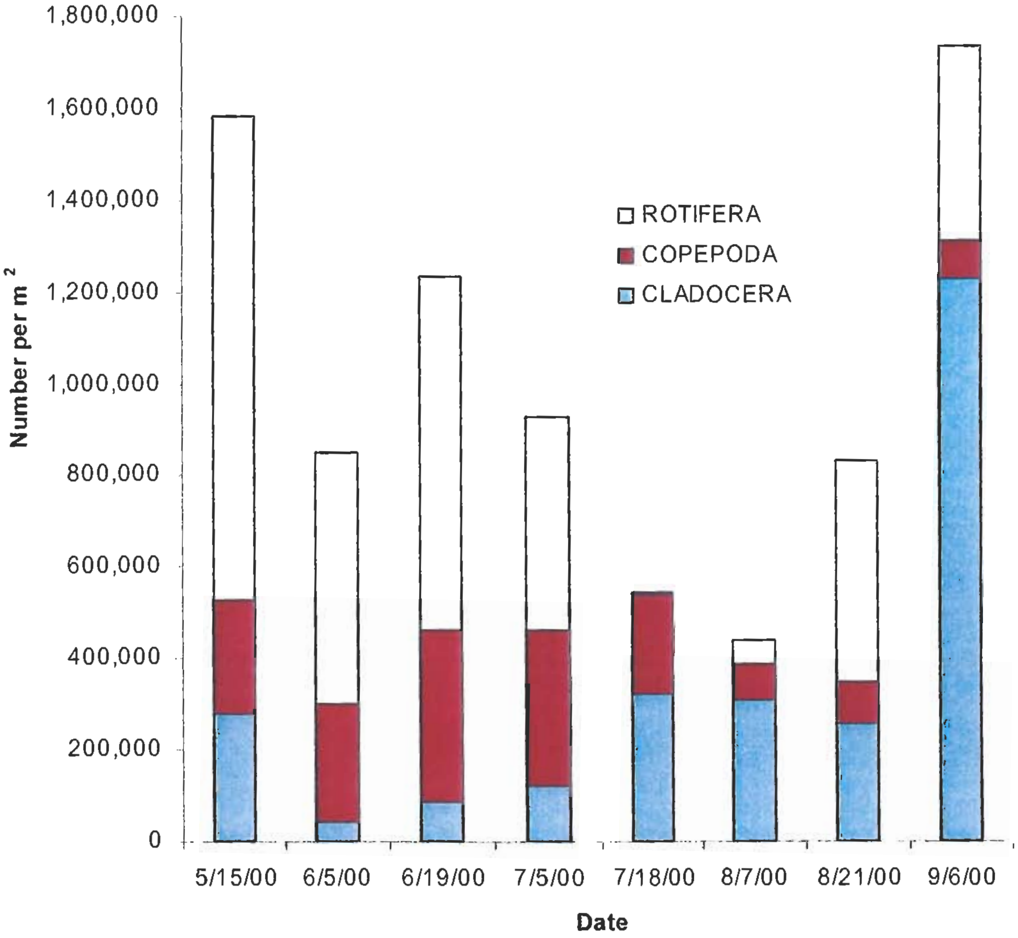


Figure 7 Zooplankton Abundance and Diversity in Hyland Lake

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 by 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 hydroxides contained in the sediment (Drake and Heaney 1987).

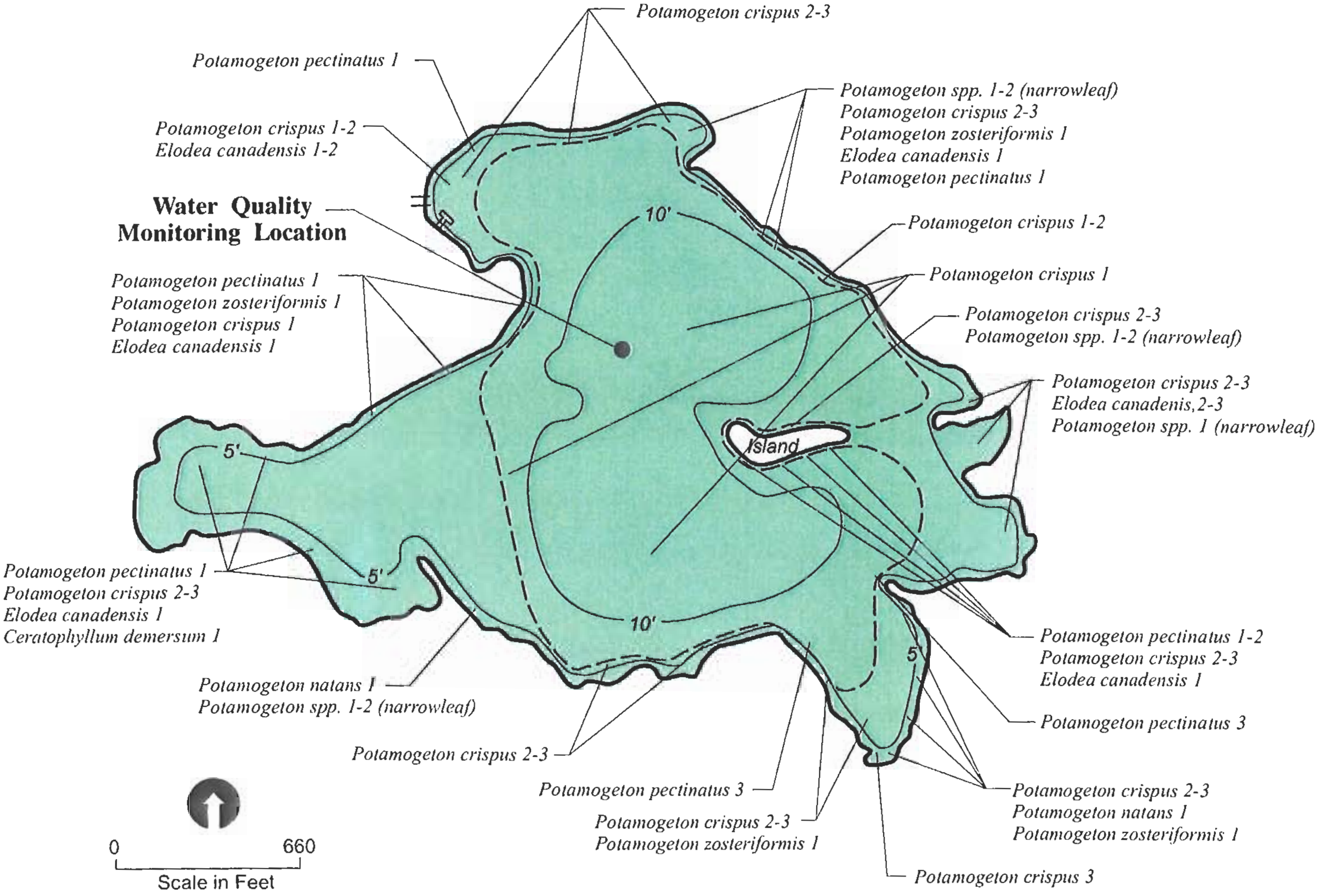
Hyland Lake's macrophytes were surveyed on June 12 (Figure 8) and August 23, 2000 (Figure 9) to identify the conditions of plant growth throughout the lake. In both surveys, the lake's plant community consisted of six individual species. These species are common to Minnesota lakes and most provide good habitat for the fish and aquatic animals living within the lake.

The growth of the exotic (nonnative) species, curlyleaf pondweed (*Potamogeton crispus*), in Hyland Lake is of concern. Curlyleaf pondweed was found throughout the lake during June. Densities of this plant ranged from light to heavy. Heavier growth was found in depths less than 5 feet and lighter growth was found in depths greater than 5 feet.

Once a lake becomes infested with curlyleaf pondweed, this plant typically replaces native vegetation, thereby increasing its coverage and density, and it appears that the coverage of curlyleaf has been expanding since 1993 (Figures 10,11,12,and 13). The curlyleaf pondweed life cycle starts with germination/initial growth in late-August, continued growth throughout the winter at a slow rate, rapid growth in the spring, and die-off 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, thus supporting algal growth for the remainder of the summer.

Shading from increased algal growth severely limited macrophyte growth in Hyland Lake for the remainder of the summer. Hence, a reduction in the lake's maximum depth of plant growth was observed in August. Plants grew to a depth of 10 feet during June and to a depth of 2 feet during August. In June, macrophytes covered the entire lake surface. In August, macrophyte growth was limited to a small near-shore area along the lake's periphery (depths of 2 feet or less). Algal shading caused the die-off of three native species of pondweed, floating-leaf pondweed (*Potamogeton natans*), sago pondweed (*Potamogeton pectinatus*), and flat-stem pondweed (*Potamogeton zosteriformis*). They were present in June and absent (decomposed) in August. The pondweed die-off released phosphorus to the lake and further exacerbated the lake's algal blooms.

Management of curlyleaf pondweed is recommended to protect the lake's water quality and native plant community and to improve the lake's fishery.

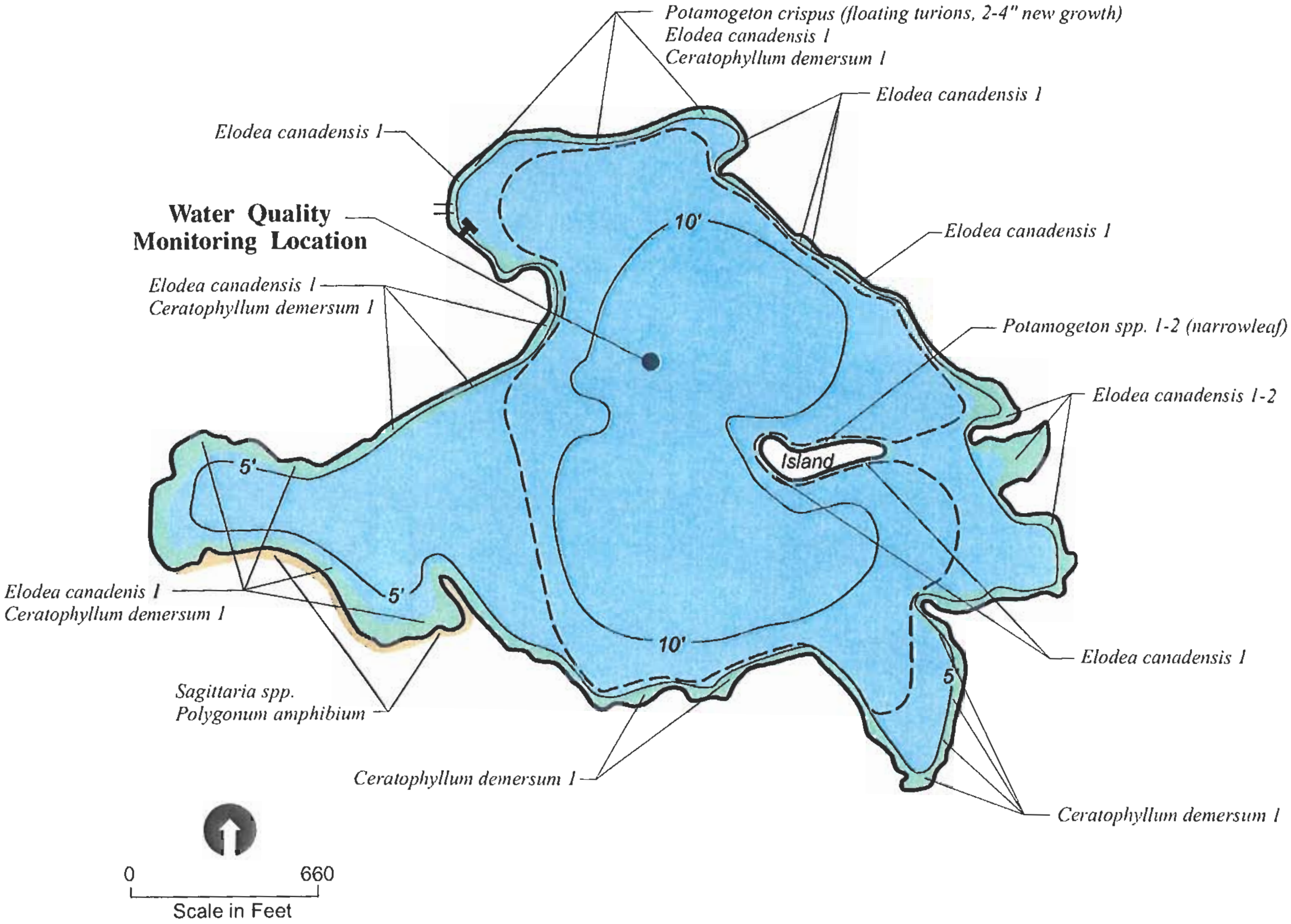


- No Macrophytes Found in Water > 10.0'
- Macrophyte Densities Estimated As Follows: 1 = Light; 2 = Moderate; 3 = Heavy
- Entire Lake has Potamogeton Crispus, Densities are Light Nearer the Center and Heavy Near Shore.

		Common Name	Scientific Name
Submerged Aquatic Plants:	🟩	Narrowleaf pondweed	*Potamogeton spp. (narrowleaf)*
		Curlyleaf pondweed	*Potamogeton crispus*
		Flatstem pondweed	*Potamogeton zosteriformis*
		Sago pondweed	*Potamogeton pectinatus*
		Coontail	*Ceratophyllum demersum*
		Elodea	*Elodea canadensis*
		Floating leaf pondweed	*Potamogeton natans*
Floating Leaf Plants:	🟦		
Emergent Plants:	🟧		
No Aquatic Vegetation Found:	🟦		

Figure 8. HYLAND LAKE
MACROPHYTE SURVEY
JUNE 12, 2000

P:\23\27\053\LAKEMAPS\HYLAND\2000\JUNE2000.CDR RLG 06-03-04

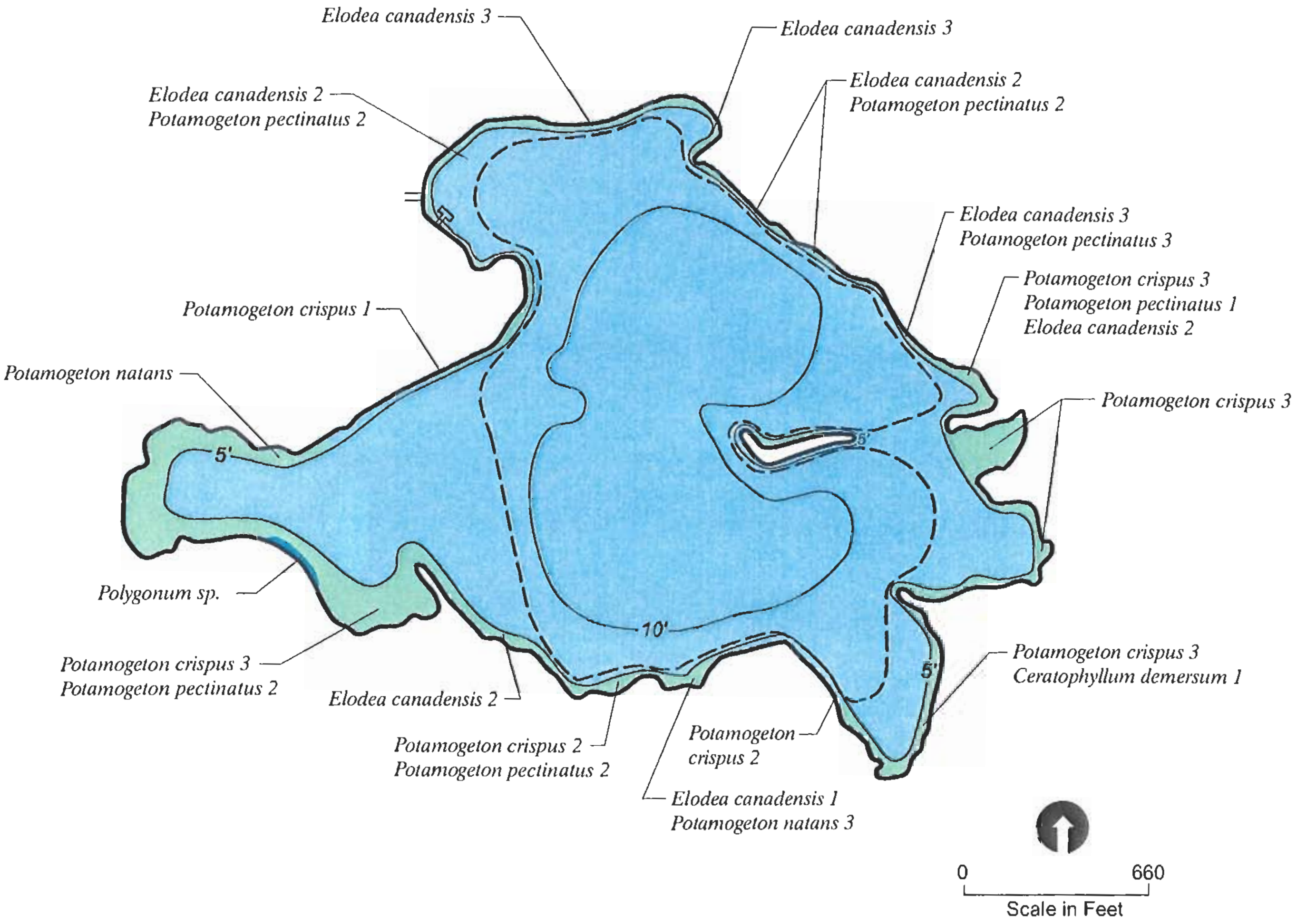


- No Macrophytes Found in Water > 1.0' - 2.0'
- Macrophyte Densities Estimated As Follows: 1 = Light; 2 = Moderate; 3 = Heavy
- June Potamogeton Crispus has Died, Many Turions with 2-4" New Growth Observed Floating on Entire Lake.

		Common Name	Scientific Name
Submerged Aquatic Plants:	🟩	Narrowleaf pondweed Curlyleaf pondweed Coontail Elodea	*Potamogeton spp. (narrowleaf)* *Potamogeton crispus* *Ceratophyllum demersum* *Elodea canadensis*
Floating Leaf Plants:	🟦		
Emergent Plants:	🟧	Arrowhead Water smartweed	*Saggitaria spp.* *Polygonum Amphibium*
No Aquatic Vegetation Found:	🟦		

Figure 9. HYLAND LAKE MACROPHYTE SURVEY AUGUST 23, 2000

P:23\27\053\LAKEMAPS\HYLAND\2000\AUGUST2000.CDR RLG 06-03-04



- No Macrophytes Found in Water >6'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

		Common Name	Scientific Name
Submerged Aquatic Plants:	🟩	Floating leaf pondweed Coontail Curlyleaf pondweed Elodea Sago pondweed	*Potamogeton natans* *Ceratophyllum demersum* *Potamogeton crispus* *Elodea canadensis* *Potamogeton pectinatus*
Floating Leaf Plants:	🟦	Water smartweed	*Polygonum sp.*
Emergent Plants:	🟧		
No Aquatic Vegetation Found:	🟦		

Figure 10. HYLAND LAKE
MACROPHYTE SURVEY
JUNE 29, 1993

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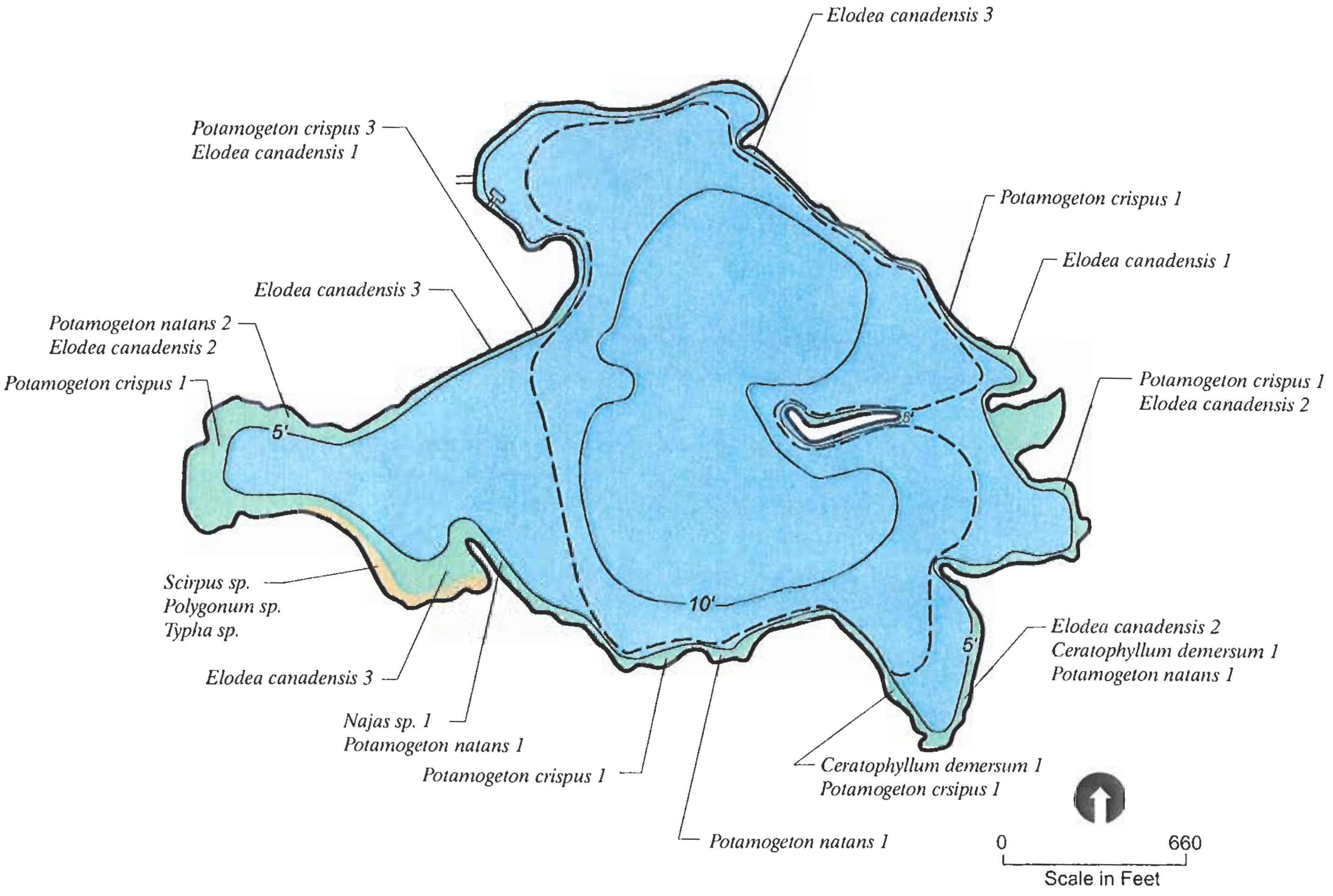

- No Macrophytes Found in Water >6'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

		Common Name	Scientific Name
Submerged Aquatic Plants:	🟩	Coontail	*Ceratophyllum demersum*
		Curlyleaf pondweed	*Potamogeton crispus*
		Elodea	*Elodea canadensis*
		Floating leaf pondweed	*Potamogeton natans*
		Bushy pondweed and naiad	*Najas sp.*
Floating Leaf Plants:	🟦		
Emergent Plants:	🟧	Cattail	*Typha sp.*
		Bullrush	*Scirpus sp.*
		Water smartweed	*Polygonum sp.*
No Aquatic Vegetation Found:	🟦		

Figure 11. HYLAND LAKE MACROPHYTE SURVEY AUGUST 24, 1993

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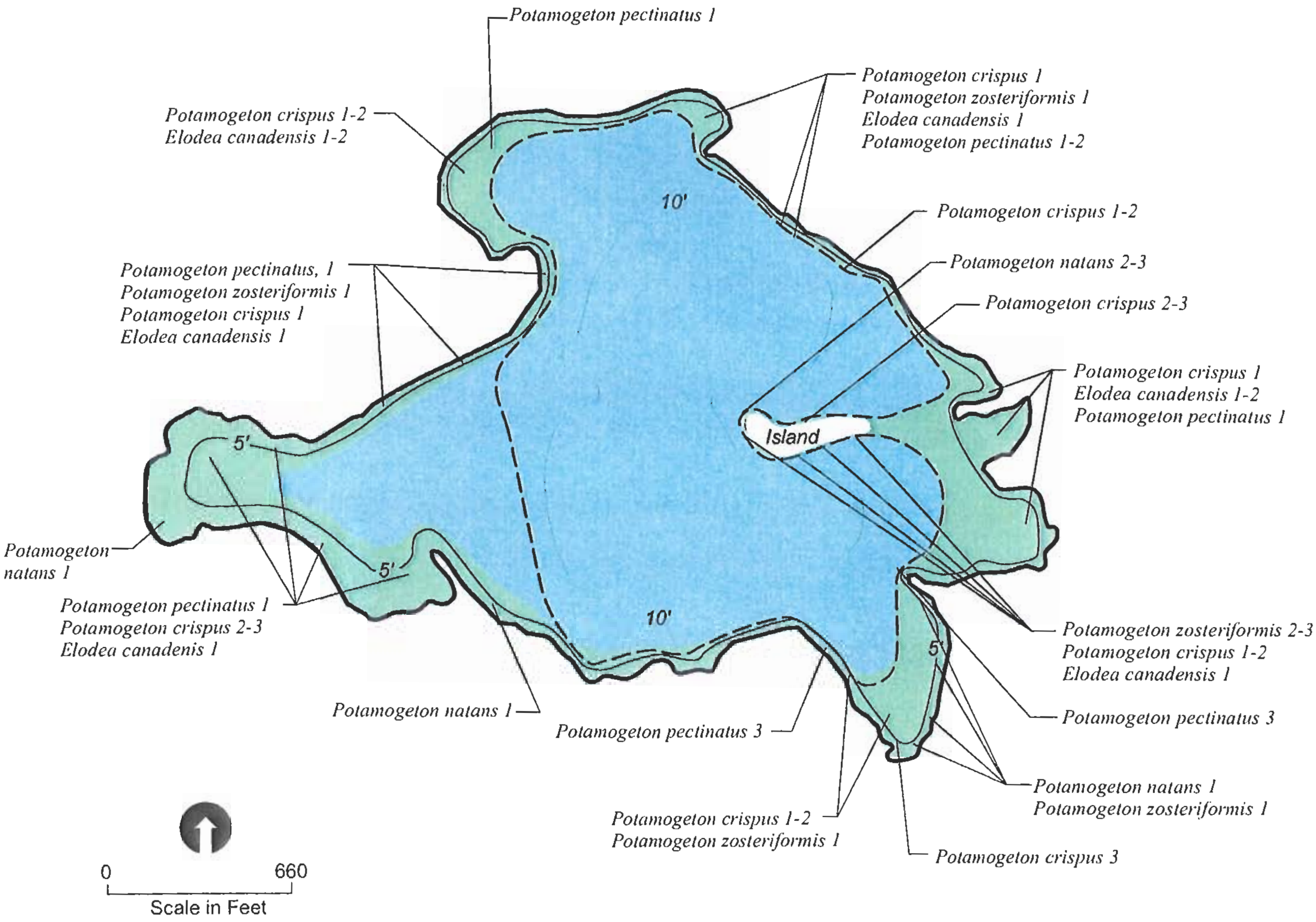
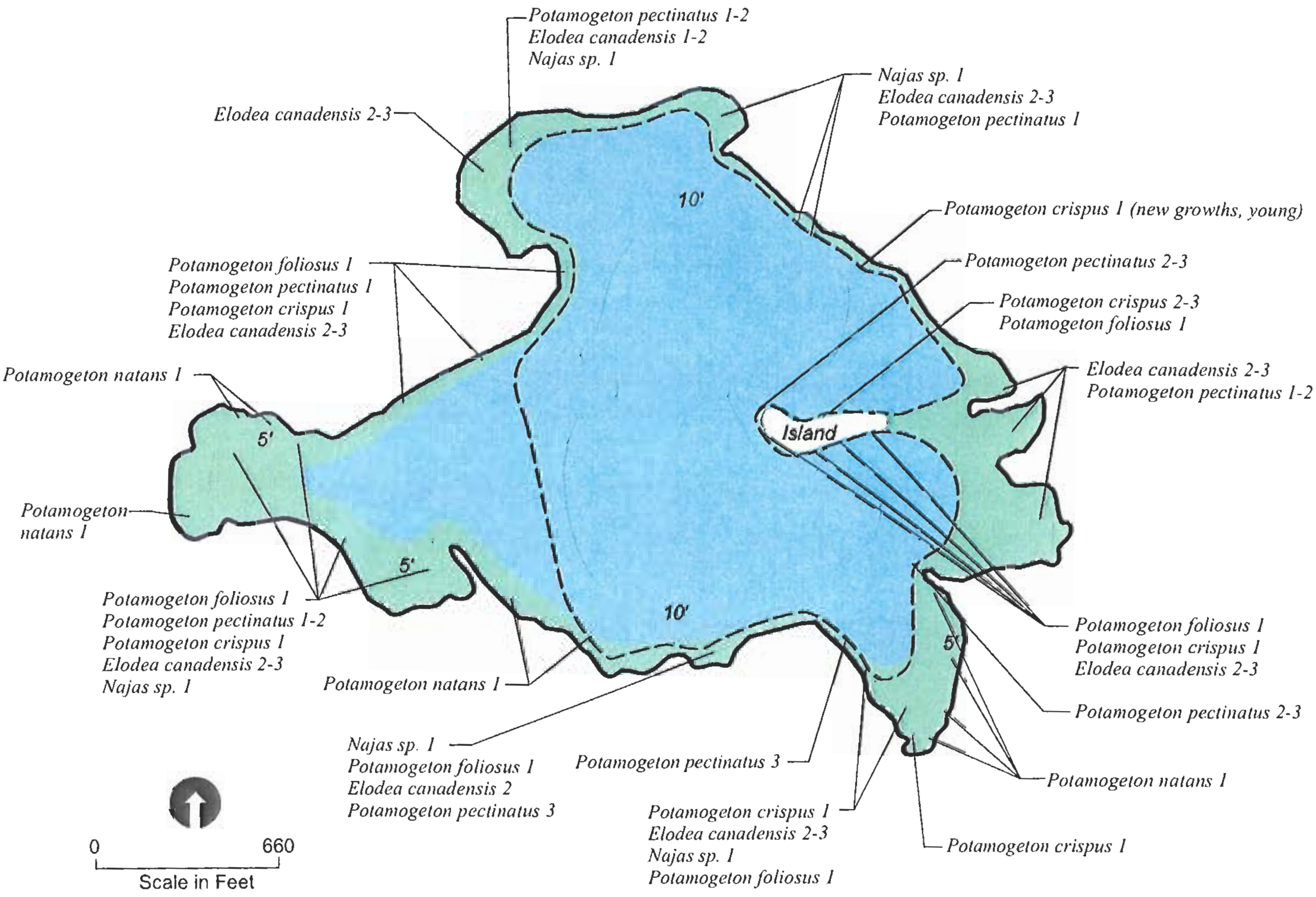


- No Macrophytes Found in Water >5' - 6'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

		Common Name	Scientific Name
Submerged Aquatic Plants:	🟩	Flatstem pondweed	*Potamogeton zosteriformis*
		Curlyleaf pondweed	*Potamogeton crispus*
		Sago pondweed	*Potamogeton pectinatus*
		Floating leaf pondweed	*Potamogeton natans*
		Elodea	*Elodea canadensis*
Floating Leaf Plants:	🟦		
Emergent Plants:	🟧		
No Aquatic Vegetation Found:	🟦		

Figure 12. HYLAND LAKE
MACROPHYTE SURVEY
JUNE 22, 1996

P:23\27\053\LAKEMAPS\HYLAND\1996\JUNE1996.CDR RLG 06-03-04



- No Macrophytes Found in Water >4' - 5'
- Macrophyte Densities Estimated As Follows: 1 = light; 2 = moderate; 3 = heavy

Submerged Aquatic Plants: 🟩

Floating Leaf Plants: 🟦

Emergent Plants: 🟧

No Aquatic Vegetation Found: 🟦

Common Name	Scientific Name
Leafy pondweed	*Potamogeton foliosus*
Curlyleaf pondweed	*Potamogeton crispus*
Sago pondweed	*Potamogeton pectinatus*
Floating leaf pondweed	*Potamogeton natans*
Elodea	*Elodea canadensis*

Figure 13. HYLAND LAKE
MACROPHYTE SURVEY
AUGUST 22, 1996

P:\23\27\053\LAKEMAPS\HYLAND\1996\AUGUST1996.CDR RLG 06-03-04

1.5 Water Based Recreation

Hyland Lake is used for several recreational activities which include fishing, swimming, and boating. There is a swimming beach and fish pier that is owned and operated by the Three Rivers Park District. The Three Rivers Park District has categorized Hyland Lake as a Class II lake (Suburban Hennepin Regional Park District 1999), meaning the primary existing use of the lake is fishing, and swimming is not a desirable use. A creel survey by the MDNR in 1990 (MDNR 1990) indicates that fishing is a popular activity at Highland Lake and fishing pressure is considered to be high.

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, Hyland Lake is a Class 40 lake. Class 40 lakes are typically shallow and productive lakes with fish assemblages that include perch, bluegills, walleye, bullhead, carp, northern pike, and crappie (Schupp, 1992). The MDNR has indicated that the average water quality for the ecological class of Hyland Lake is a TSI_{SD} (Trophic State Index in terms of Secchi disc transparency) of approximately 54.5 or lower (i.e., a summer average Secchi disc transparency of about 4.8 feet or greater). The recommendation is based upon the water quality needs of the fishery found in a Class 40 lake. Hyland Lake's water quality does not meet this recommendation based upon the 2000 data. The lake's current water quality (monitoring year 2000) corresponds to a TSI_{SD} of 58.6 (a summer average Secchi disc of approximately 3.6 feet). Only in a few years (1979, 1981, and 1982) following a lake restoration program in 1978, did Hyland Lake meet the TSI_{SD} goal.

Hyland Lake's fishery currently (2002) consists of panfish, gamefish, rough fish, and other species. The 2002 MDNR fish survey showed that the following species are present in Hyland Lake:

- **Panfish**—black crappie, bluegill, and hybrid sunfish,
- **Gamefish**—largemouth bass, and yellow perch,
- **Rough fish**—black bullhead,
- **Other fish**—golden shiner.

According to the 2002 survey (MDNR 2002), black crappie numbers and median weight per fish were within the normal to high range for lakes of this class and the number of bluegills caught in trap nets (19.9 fish per net) were slightly below the long range goal for Hyland Lake of 23.1 fish per trap net (MDNR 1996). Historically (1982 to 1995), there have been very high numbers of bluegills, ranging from 40 fish per trap net to 403 fish per trap net, while the black crappie population has remained within normal ranges. The number of black bullhead caught in trap nets and gill nets was below the normal range for lakes of this class. The average weight of black bullhead was above the normal range.

The number of predators (largemouth bass and yellow perch) surveyed in 2002 were below normal ranges for lakes of this class, however, the average fish weight was within normal ranges. No walleye or tiger muskellunge were found in the gill net survey in 2002. There has been a history of stocking gamefish in Hyland Lake. Historical fish stocking has included walleye in the late-1970s, occasional largemouth bass stocking from the late-1970s through 1990, and occasional tiger muskellunge stocking from 1988 through 1999. The experimental slot size regulation, meaning fish of a certain size that have been caught must be released, that was established for largemouth bass in Hyland Lake in 1981 expired in 1999.

Hyland Lake provides good habitat for waterfowl such as ducks and geese. There is an island in the middle of the lake that provides potential nesting sites.

1.7 Discharges

1.7.1 Natural Conveyance Systems

The natural inflow to Hyland Lake consists of direct runoff from parkland surrounding the lake and groundwater inflows. All other discharges to the lake are through piped inlets.

1.7.2 Stormwater Conveyance Systems

Stormwater is conveyed primarily from residential neighborhoods directly east of Hyland Lake. This stormwater is routed through five wet detention ponds and a wetland. Details of each storm water detention system are provided in Appendix C. Figure 14 shows the stormwater conveyance systems and the stormwater detention systems of the Hyland Lake watershed. In 2004 the Three Rivers Parks District intends to upgrade the wetland that is located directly north of Hyland Lake.

1.7.3 Public Ditch Systems

There are no public ditch systems that affect Hyland Lake.

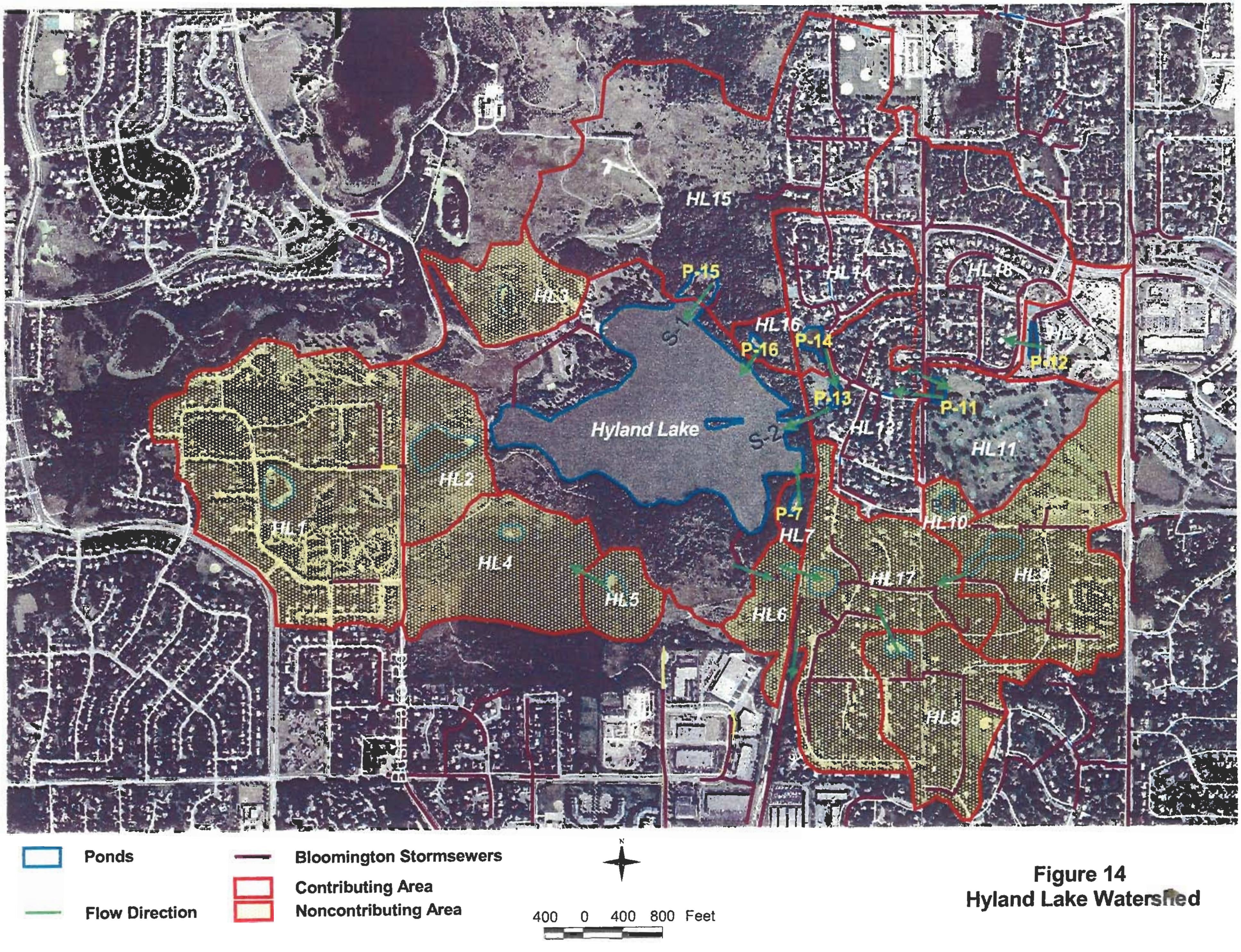


Figure 14
Hyland Lake Watershed

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1.8 Appropriations

There are no known water appropriations from Hyland Lake.

1.9 Summary of Surface Water Resource Data

The current water quality and ecological status of Hyland Lake is largely the result of past activities in the Hyland Lake watershed and management activities in the lake. Because stormwater inputs of phosphorus have been successfully controlled to a large degree and the size of the watershed is small relative to the size of Hyland Lake, the highly eutrophic status of the lake is likely the result of historical sediment loading. A historical aerial photo of the lake (Figure 1) shows that the watershed of the lake in 1947 primarily consisted of agricultural lands that drained to the lake. Agricultural sediment can be high in nutrients. The concentration of phosphorus in the lake sediments that can release into the water column (i.e. mobile phosphorus) of Hyland Lake is relatively high (Figure 15) and corresponds to a potential phosphorus release rate of approximately 3.2 mg per square meter of lake surface per day.

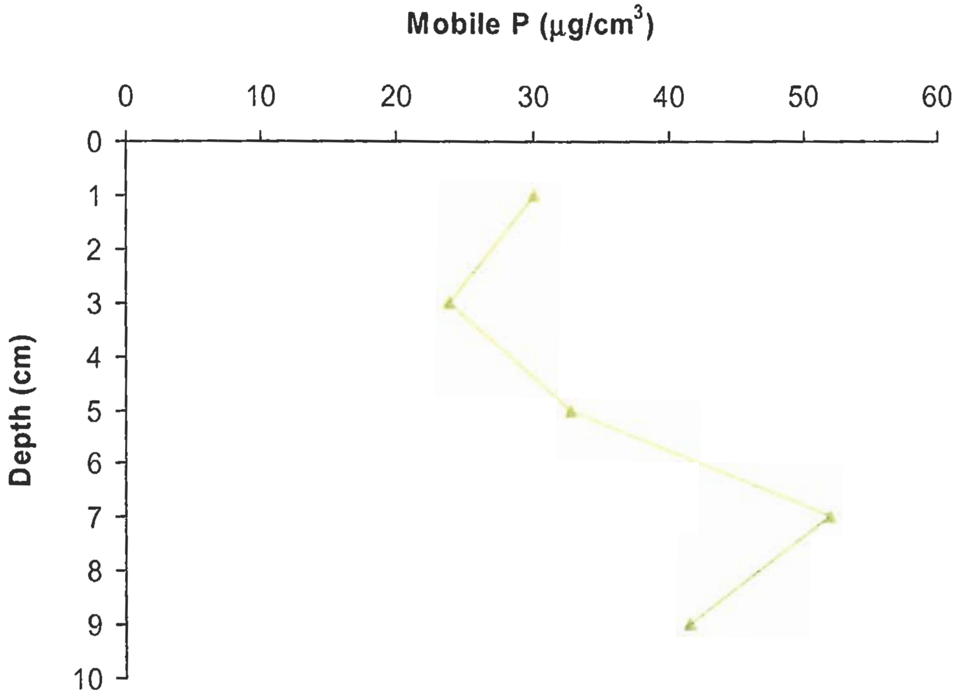


Figure 15 Distribution of Potentially Releasable Phosphorus in Hyland Lake Sediment

Currently, the ecology of Hyland Lake is being driven by the invasive aquatic plant curlyleaf pondweed (*Potamogeton crispus*). This aquatic plant covers the entire surface of the lake in June and then dies off in early-summer. The rapid growth has the effect of increasing the pH of the lake to very high levels. When curlyleaf pond weed dies off it consumes oxygen in the lake water column and releases phosphorus into the lake. The MDNR noted in a 1996 lake management plan (MDNR 1996) that this die-off of curlyleaf pond weed may be causing occasional summer kills (because of low dissolved oxygen) of fish. Low dissolved oxygen and high pH (James 2001) caused by the curlyleaf pond weed growth and die-off, as well as an increase in water temperature, also have the potential to enhance the release of phosphorus that is stored in lake sediments into the lake water column. In mid-to late-summer there is a significant increase in phosphorus in the lake that can be partially attributed to the release of phosphorus from lake sediments. This increase in phosphorus is associated with mid-to late-summer algal blooms (Figure 16).

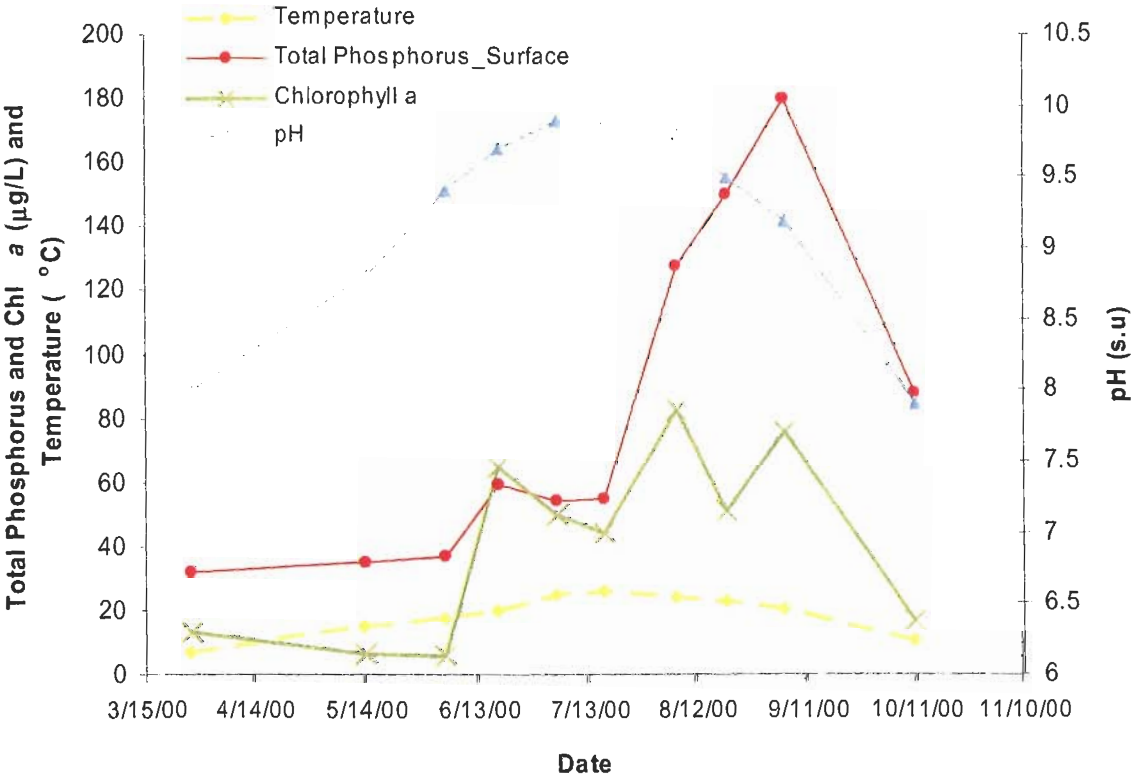


Figure 16 **Seasonal Pattern of pH, Total Phosphorus, Temperature, and Chlorophyll *a* in Hyland Lake**

Monitoring data also suggest that sediment is providing phosphorus to algae that grow on the lake bottom (this algae is typically blue-green algae) in the spring and then float to the lake surface by late-June of each year. For example, in 2000, phosphorus levels were low on June 5 and chlorophyll *a* was also low (<10 μg/L). Two weeks later (June 19), chlorophyll *a* increased dramatically to 65 μg/L although total phosphorus increased only slightly. Monitoring data (Figure 6) show that the algal population in Hyland Lake completely switched to blue-green algae by June 19 even though Hyland Lake was primarily dominated by green algae only 2 weeks prior to June 19. Research has shown that shallow lakes can have significant blue-green algae growth on bottom sediments (Cook 1993). This pattern of sudden increases in chlorophyll *a* without a subsequent increase in total phosphorus was also noted in 1998 (see Appendix E).

According to the 2002 MDNR fish survey, the abundance and weight of most of the fish species in the lake are within the normal range for lakes of the same class as Hyland Lake. Historically, fisheries management of the lake included a restoration effort in 1978. Largemouth bass stocking after completion of the restoration project resulted in high numbers of large mouth bass in the lake during 1980, 1981, and 1982. Bluegills were stocked in the lake in 1979 and 1980. Walleye and tiger muskellunge stocking occurred in the 1970s through the 1990s.

2.0 Assessment of Hyland Lake Problems

2.1 Appropriations

There are no known water appropriations from Hyland Lake.

2.2 Discharges

The model P8 (IEP Inc. 1990) was used to determine the water and phosphorus loading to Hyland Lake from the surrounding park areas and from conveyed stormwater discharges to the lake (parameters used in the P8 model are presented in Appendix D). Although the discharge of stormwater from the Hyland Lake watershed conveys phosphorus to the lake and contributes to the level of phosphorus in the lake, these discharges are not the cause of high phosphorus levels that are observed in Hyland Lake. Details of the phosphorus discharges to the lake are provided below.

2.2.1 Natural Conveyance Systems

Natural conveyance systems contribute stormwater to Hyland Lake from park land that surrounds the lake. There are no other natural conveyances to Hyland Lake such as streams.

2.2.1.1 Direct Watershed

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

- **Wet Year**: annual precipitation of 38 inches, the amount of precipitation that occurred during the 2002 water year.
- **Average Year**: annual precipitation of 30 inches, the amount of precipitation that occurred during the 1998 water year
- **Dry Year**: annual precipitation of 25 inches, the amount of precipitation that occurred during the 2000 water year

Loading from the direct watershed to Hyland Lake is low and is expected to range from 8.4 to 15.6 pounds per year under existing land uses and from 5.8 to 12.8 pounds per year for future land uses (Table 3). Currently loading from the direct watershed represents approximately 2.3 to 3.6 percent of the total phosphorus load to Hyland Lake.

Table 3 **Estimated Annual Total Phosphorus Loads from the Hyland 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 Hyland Lake Total Phosphorus Load
Wet (38")	15.6	3.6
Average (30")	10.0	2.6
Model Calibration/Dry (25")	8.4	2.3

Future Land Uses

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From Direct Watershed (Pounds)	% of Total Annual Hyland Lake Total Phosphorus Load
Wet (38")	12.8	3.0
Average (30")	8.6	2.3
Model Calibration/Dry (25")	5.8	1.6

2.2.2 Stormwater Conveyance Systems

The annual phosphorus load from all stormwater conveyance systems to Hyland Lake (Table 4) under dry, average, and wet conditions (under existing watershed land use) was 21, 23, and 30 percent of all phosphorus loads to lake (all phosphorus loads include both external and internal phosphorus loads). Phosphorus loading to the lake from storm water runoff is primarily coming from the S-2 storm sewer outlet (Table 5). This outlet receives runoff from most of the developed areas of the Hyland Lake watershed (see Figure 2). Before water discharges through the S-2 storm sewer, it has been routed through four stormwater detention basins to remove solids and phosphorus.

Table 4 Estimated Total Phosphorus Loads from All Hyland Lake Stormwater Conveyance Systems Under Varying Climatic Conditions—Existing and Future Land Use

Existing Land Uses

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From All Conveyance Systems (Pounds)	% of Annual Hyland Lake Total Phosphorus Load
Wet (38")	130	30
Average (30")	90	23
Model Calibration/Dry (25")	78	21

Future Land Uses

Climate Condition (inches of precipitation)	Annual Total Phosphorus Load From All Conveyance Systems (Pounds)	% of Annual Hyland Lake Total Phosphorus Load
Wet (38")	123	29
Average (30")	80	21
Model Calibration/Dry (25")	64	18

Table 5 Estimated Total Phosphorus Loading from Each Stormwater conveyance System to Hyland Lake

Existing Land Use

Stormwater Conveyance System	Annual Total Phosphorus Load in Pounds		
	Wet (38")	Average (30")	Dry (25")
S-1	36	22	20
S-2	94	68	58

Future Land Use

Stormwater Conveyance System	Annual Total Phosphorus Load in Pounds		
	Wet (38")	Average (30")	Dry (25")
S-1	29	15	12
S-2	94	65	52

The treatment effectiveness of the detention ponds and wetlands that lie within the Hyland Lake watershed was determined for wet, average, and dry conditions. All of the ponds in the Hyland Lake watershed meet MPCA/NURP criteria. It can be seen that ponds P-15 and P-14 generally had 50 percent total phosphorus removal or greater while for ponds P-11, P-12, and P-13, the annual treatment efficiency of the ponds and wetlands was below 50 percent (Table 6). Pond P-12 removed 37 percent of phosphorus loads to the pond during an average precipitation year. Outflow from P-12 flows overland and is eventually treated by P-13 before entering Hyland Lake. Ponds P-11 and P-13 removed only 21 and 19 percent of phosphorus loads to the ponds during an average precipitation year. Overall removal in these ponds was reduced because the ponds upstream (see Figure 2) had removed most of the phosphorus that could readily settle. Most of the phosphorus that entered these 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 6 Estimated Total Phosphorus Removal Efficiency of Detention Ponds in the Hyland Lake Watershed Under Existing Conditions

Stormwater Conveyance System	Pond Name	Total Phosphorus Removal Efficiency (%)		
		Wet (38")	Average (30")	Dry (25")
S-1	P-15	45	51	57
S-2	P-11	15	21	21
	P-12	29	37	35
	P-13	15	19	21
	P-14	55	55	64

2.2.4 Public Ditch Systems

There are no known ditch systems affecting Hyland Lake.

2.3 Fish and Wildlife Habitat

The MDNR has established criteria for the support of Hyland Lake's fishery, based upon Hyland Lake's classification as a Class 40 lake. The current habitat for Hyland Lake fails to meet the criteria of a TSI_{SD} of 54.5 or lower (a summer average Secchi disc transparency of at least 4.8 feet).

In addition to the impairment of the Hyland Lake fishery resulting from high phosphorus levels and severe summer algal blooms, dissolved oxygen levels can become severely depressed in the summer as a result of curlyleaf pondweed die-off in June each year (Figure 19). However, by August curlyleaf pondweed is typically decomposed and the Hyland Lake system is then dominated by blue-green algal blooms. These blooms have a tendency to float to the surface and block sunlight from reaching lower depths. As an example, dissolved oxygen data from 1990 is displayed in Figure 17. It can be seen in Figure 17 that dissolved oxygen depletion can be more severe in August, likely because the blue-green algae are blocking oxygen transfer into the deeper layers of the lake and blocking sunlight needed for algae to grow below the lake's surface. Clearly the severe dissolved oxygen fluctuations that are observed in Hyland Lake are harmful to the lake's fishery.

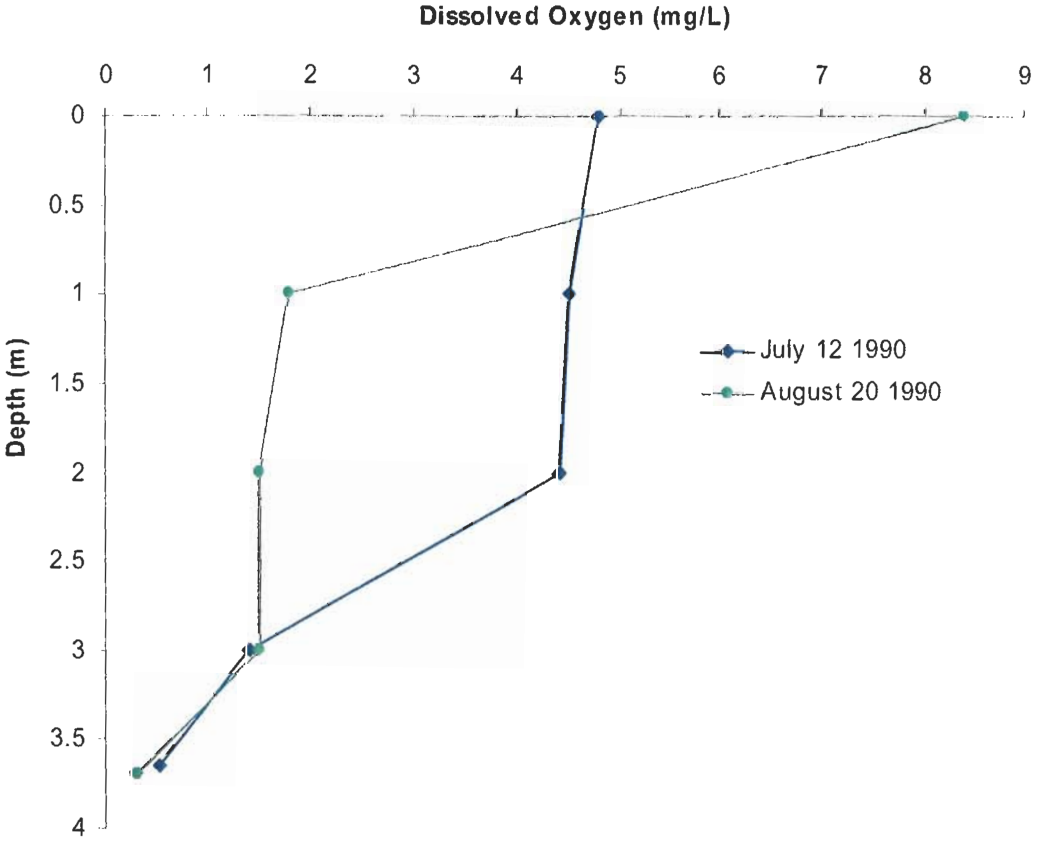


Figure 17 **Dissolved Oxygen in Hyland Lake from the Surface (0 meters) to the Bottom (~3.6 m)**

2.4 Water Based Recreation

The recreational uses of Hyland Lake include swimming, fish, canoeing, paddle boating, and aesthetic viewing. Although there is a beach at Hyland Lake, neither the Riley-Purgatory-Bluff-Creek Watershed District nor the Three Rivers Park District classifies Hyland Lake as a swimming lake. Fishing, boating, and aesthetic viewing are the primary activities at Hyland Lake. These uses are currently being impaired by curlyleaf pondweed growth and die-off, low dissolved oxygen levels in the lake water column, and algal blooms.

2.5 Ecosystem Data

Development of a more balanced ecosystem at Hyland 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 Hyland Lake: (1) problematic growths of curlyleaf pondweed, and (2) high phosphorus levels and severe summer algal blooms.

According to a 2002 MDNR fish survey, the existing fish population at Hyland Lake is generally typical of lakes within the same class. However, it was noted in the 2002 survey that the bluegills were slow growing, suggesting that the very large population of bluegills that had been present in Hyland Lake in prior years may have caused crowding and thus reduced growth rates. It has been shown in past surveys that the bluegill population is much larger than lakes within the same class as Hyland Lake. Also, the largemouth bass population is at the lower range for average weight and number of fish caught per gill net when compared to lakes of similar class.

There was an abundant zooplankton population in Hyland Lake in 2000 despite the large bluegill population. The population declined in June/July of 2000 but recovered by September. It appears that the zooplankton population is generally well balanced by the existing fishery.

2.6 Water Quality

2.6.1 Baseline/Current Analysis

Evaluation of the baseline and current trophic state index (TSI) of Hyland Lake shows that the lake consistently has not met the MDNR-criteria ($TSI_{SD} \leq 54.5$) for the lake's fishery during the baseline and the current periods (Figure 18). The TSI during the baseline period was somewhat lower (less eutrophic) than the current period because of the lake restoration effort that occurred in 1978.

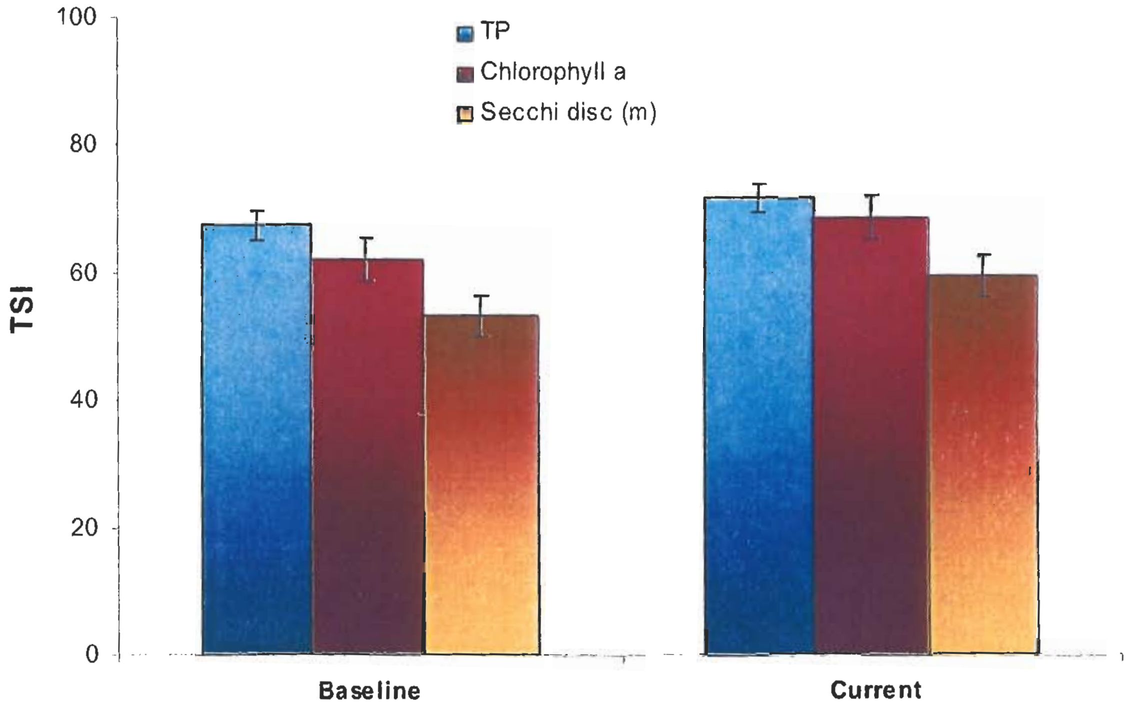


Figure 18 Baseline and Current Trophic State Index (TSI) for Hyland Lake

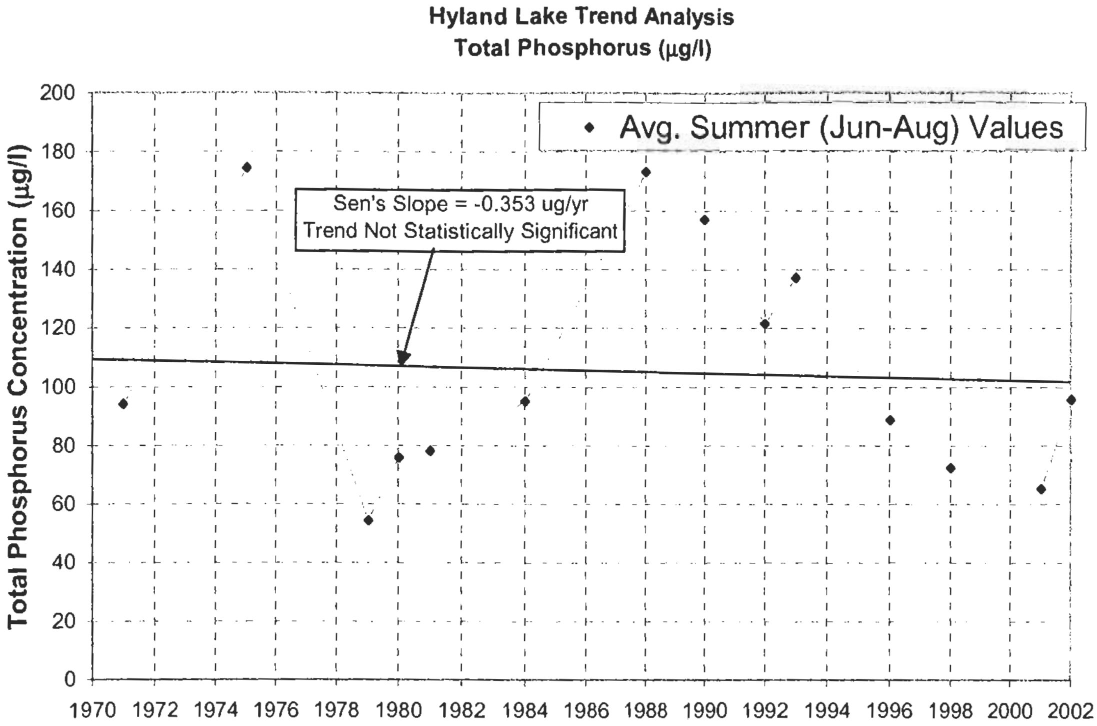
2.6.2 Historical Water Quality-Trend Analysis

A trend analysis for Hyland Lake was completed to identify any significant degradation or improvement during years in which water quality data were available. Prior to the 1978 restoration effort at Hyland Lake, the lake had high levels of phosphorus, a large algal population (high chlorophyll *a*), and very low Secchi disc values (very turbid). From 1979 to 1984, phosphorus and chlorophyll *a* levels were reduced and lake clarity improved. However, phosphorus and chlorophyll *a* levels also began to slowly increase during this time period (see Figures 19, 20, and 21). After a large, approximately 500-year rainfall event occurred in the Hyland Lake watershed in 1987, phosphorus and chlorophyll *a* levels increased substantially because of large stormwater inflows. From 1996 to 2002, it appears that phosphorus and chlorophyll *a* levels and clarity (Secchi disc) have settled back into an equilibrium range of approximately 80 to 100 μg/L total phosphorus, 30 to 50 μg/L chlorophyll *a*, and 1 to 1.5 m Secchi disc transparency. Although there have been large 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 and changes in phosphorus, chlorophyll *a*, and Secchi disc have not been statistically significant (see statistical analysis below in Figures 18, 19, and 20).

2.6.3 Water Quality Modeling Analysis

Water quality modeling was performed to better understand the phosphorus dynamics in the Hyland Lake watershed and in Hyland 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 Hyland Lake. Internal loading was divided into two sources: aquatic plants (curlyleaf pondweed die-off) and sediment.

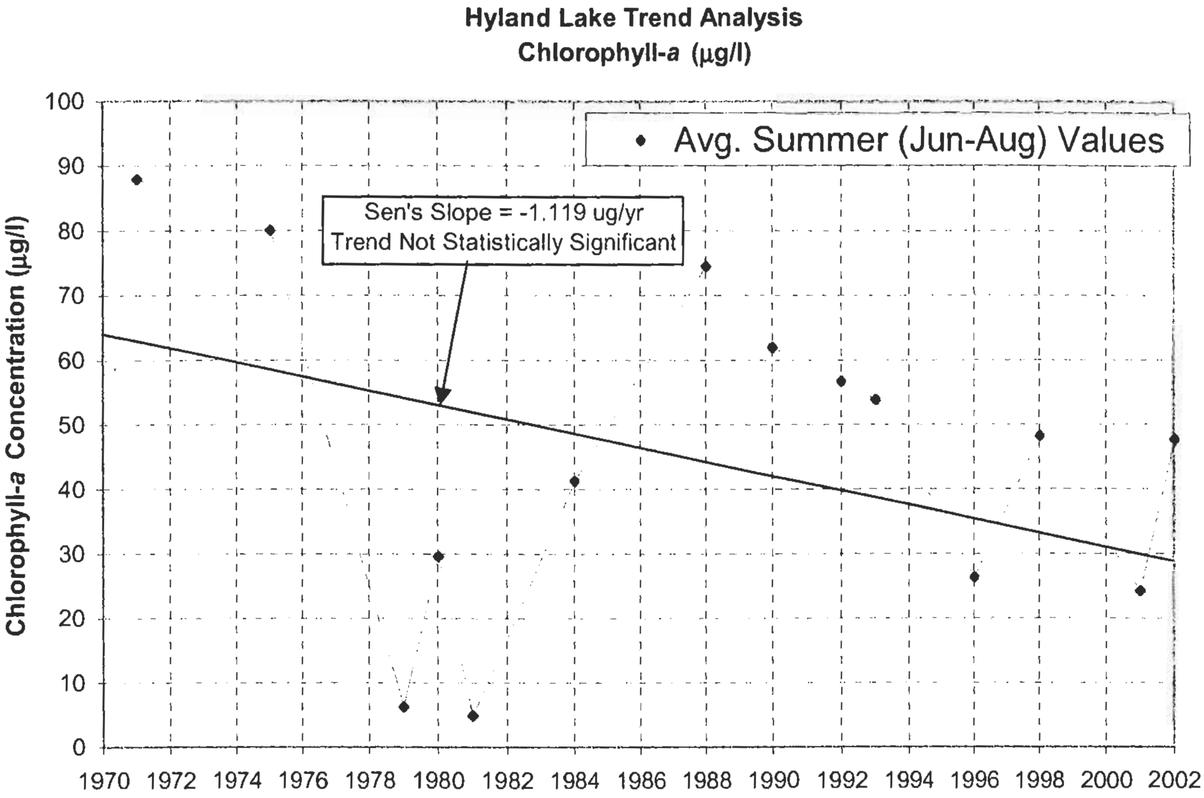
Modeling was performed for three climatic conditions (dry, average, and wet year) and different management efforts to determine the potential effect of these management activities on phosphorus levels in Hyland Lake. A regression between phosphorus levels in Hyland Lake and Secchi disc transparency was developed from historical monitoring data (1971 to 2002) and was used to predict expected lake clarity improvements (Secchi disc transparency) with different management activities. A detailed description of model development, calibration, and validation is provided in Appendix A.



Mann-Kendall/Sen's Slope Trend Test

Confidence Level	Test Statistic = -7	
	Test	Significance
99%	-7 > -48	Not Significant
95%	-7 > -37	Not Significant
90%	-7 > -32	Not Significant
80%	-7 >-25	Not Significant
Sen's Slope	-0.353 µg/year	

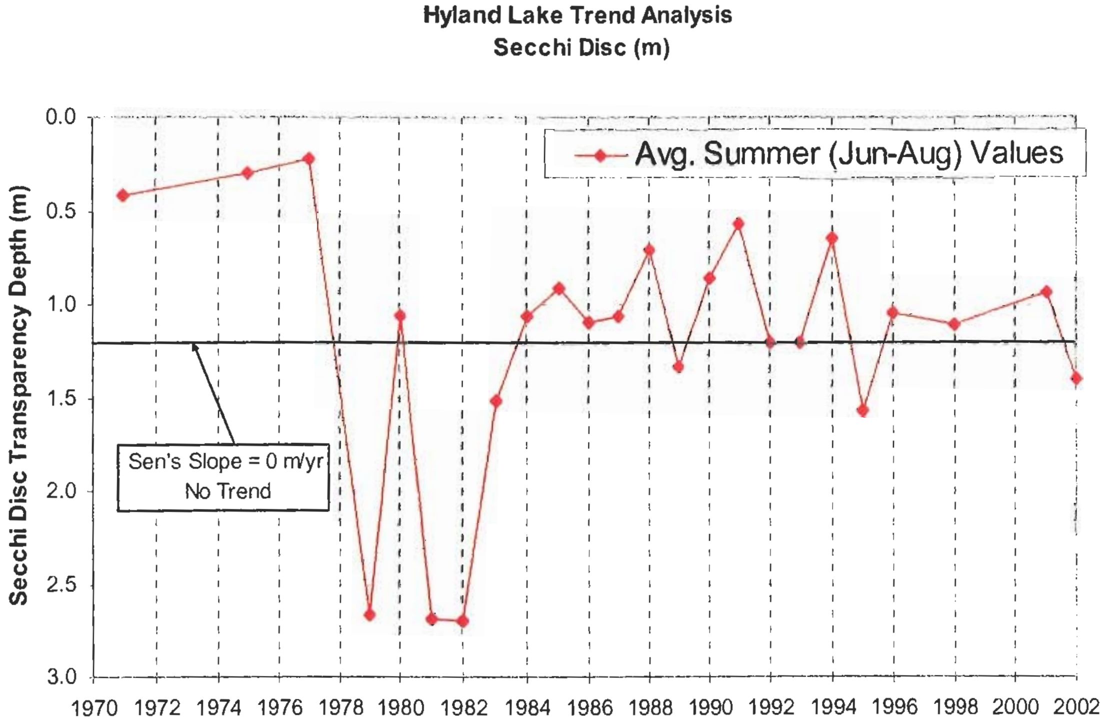
Figure 19 Mann-Kendall Trend Analysis of Total Phosphorus Concentration since 1971 for Hyland Lake



Mann-Kendall/Sen's Slope Trend Test

Confidence Level	Test Statistic = -21	
	Test	Significance
99%	-21 > -48	Not Significant
95%	-21 > -37	Not Significant
90%	-21 > -32	Not Significant
80%	-21 > -25	Not Significant
Sen's Slope	-1.119 µg/year	

Figure 20 Mann-Kendall Trend Analysis of Chlorophyll-*a* Concentration Since 1971 for Hyland Lake



Mann-Kendall/Sen's Slope Trend Test

Confidence Level	Test Statistic = 8	
	Test	Significance
99%	8 < 105	Not Significant
95%	8 < 81	Not Significant
90%	8 < 68	Not Significant
80%	8 < 53	Not Significant
Sen's Slope	0 meters/year	

Figure 21 Mann-Kendall Trend Analysis of Secchi Disc Transparency Depth Since 1971 for Hyland Lake

2.7 Major Hydrologic Characteristics

The major hydrologic characteristics of Hyland Lake have changed as the watershed has changed from primarily agricultural to a mixture of park land and residential neighborhoods. The watershed is nearly fully developed (no change in open space is expected by 2020) and hydrologic loading is not expected to change in the future. However, the outlet from Hyland Lake will be lowered in 2004 and this will have the effect of lowering the lake level, potentially changing the volume of ground water that enters Hyland Lake, and potentially changing the hydraulic residence time of the lake.

2.8 Land Use Assessment

Although the Hyland Lake watershed is nearly fully developed, there is a potential that the remaining open space areas could be developed in the future. Proposed land use changes within the lake's watershed should be evaluated to determine whether increased phosphorus loading to the lake would result from the land use change. Management practices such as detention basins may be required to prevent phosphorus loading increases from future land use changes.

3.0 Hyland Lake Goals

3.1 Water Quantity Goal

The water quantity goal for Hyland 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 Hyland 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 $TSI_{SD} \leq 54.5$. Table 7 shows that the water quality goal is currently not being achieved but with the implementation of the following management practices the water quality goal can be achieved or exceeded:

- WQ-1: Aquatic plant harvesting and herbicide (endothal) treatment,
- WQ-2: Aquatic plant harvesting and herbicide (endothal) treatment, and alum-lime treatment.

The cost of the two alternatives is presented in Figure 22 (the cost of harvesting is not included in the cost estimate because harvesting will be conducted by the Three Rivers Park District). It should be recognized that both of the management alternatives are designed to meet or exceed the TSI_{SD} goal, reduce the fluctuations in dissolved oxygen levels in Hyland Lake that are the result of the invasive curlyleaf pondweed growth and die-off and blue-green algae blooms, and improve the fish habitat in Hyland Lake by promoting native aquatic plant growth.

Table 7 Expected Water Quality with Different Management Alternatives

	Trophic State Index (TSI_{SD}) Value			
Management Approach	**District Goal**	**Dry Year** (25 inches)**	**Average Year (30 inches)**	**Wet Year (38 inches)**
Existing Watershed Land Use Conditions				
No Action-Existing	≤54.5	57.5	56.1	56.7
Harvesting and Herbicide Treatment	≤54.5	55.7	54.5	55.2
Harvesting and Herbicide and *Alum/Lime	≤54.5	53.5	52.4	53.2
Future Watershed Land Use Conditions				
No Action-Expected Future	≤54.5	56.9	56.1	56.7
Harvesting and Herbicide Treatment	≤54.5	55.0	54.5	54.2
Harvesting and Herbicide and *Alum/Lime	≤54.5	52.7	52.4	53.2

*Please see Appendix A for a discussion of the Alum/Lime treatment

**Water quality model calibration performed for the dry year.

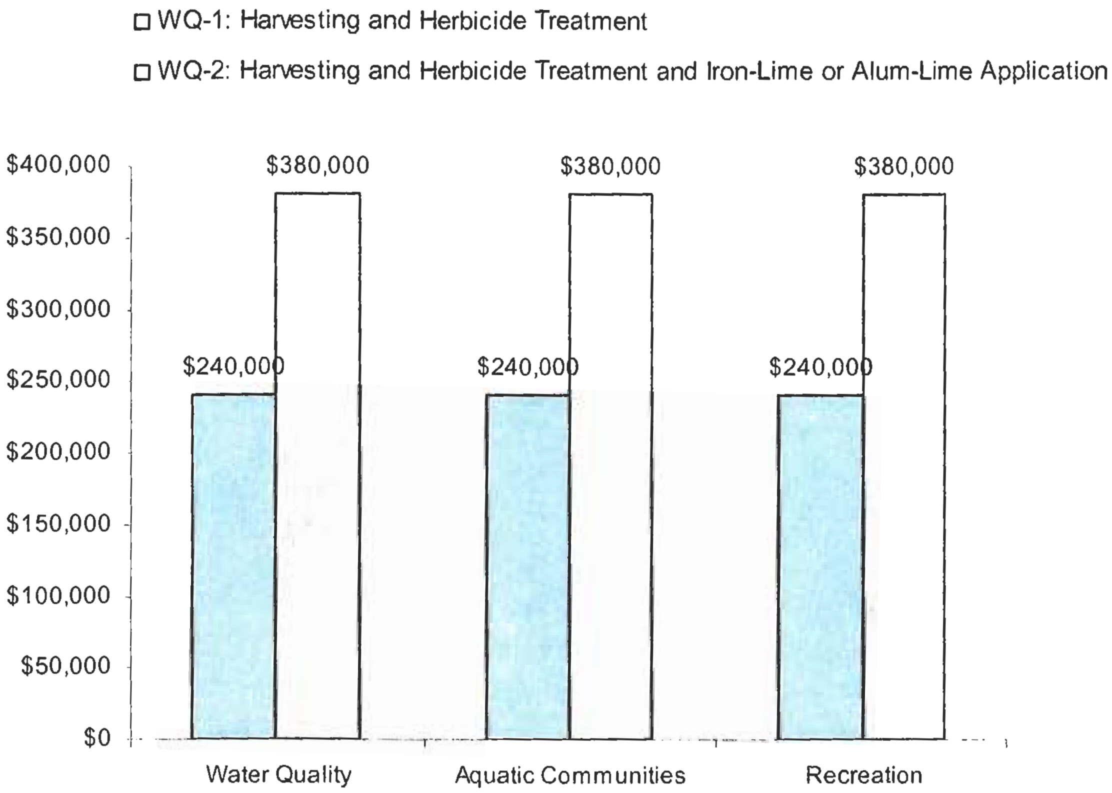


Figure 22 Cost of the Different Management Alternatives

3.3 Aquatic Communities Goal

The aquatic communities goal for Hyland Lake is the achievement and maintenance of water quality that fully supports the lake's fisheries-use classification as determined by the MDNR (Schupp 1992). The goal is to maintain a $TSI_{SD} \leq 54.5$. From the perspective of the TSI_{SD} goal and the problems with dissolved oxygen fluctuations resulting from curlyleaf pondweed growth and die-off and excessive blue-green algae growth, the lake's current water quality does not provide the desired habitat for the lake's fishery. The two alternatives presented in Table 7 will allow Hyland Lake to achieve or exceed the District aquatic communities goal. The costs to implement the management alternatives are presented in Figure 22. It should be noted that the cost of harvesting is not included in the cost estimate because harvesting will be conducted by the Three Rivers Park District.

3.4 Recreation Goal

Because Hyland Lake has not been designated a swimming lake by the Riley-Purgatory-Bluff Creek Watershed District or the Three Rivers Park District, the recreational goal is to fully support the lake's fishery and maintain a TSI_{SD} $\leq$54.5. From the perspective of the TSI_{SD} goal and the problems with dissolved oxygen fluctuations resulting from curlyleaf pondweed growth and die-off and excessive blue-green algae growth, the recreation goal is currently not being achieved. The two alternatives presented in Table 7 will allow Hyland Lake to achieve or exceed the District recreation goal. The cost to implement the management alternatives are presented in Figure 22. The cost of harvesting is not included in the cost estimate because harvesting will be conducted by the Three Rivers Park District.

3.5 Wildlife Goal

The wildlife goal for Hyland 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

Hyland 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 Hyland Lake and to estimate what the consequence may be from different management activities. The root of the imbalances that are observed at Hyland Lake (excessive curlyleaf pondweed growth, blue-green algae blooms, die-off of native pondweed species, 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.

The four primary sources of phosphorus inputs to Hyland Lake are, in order of largest to smallest: release of phosphorus from lake sediments, aquatic plant senescence (curlyleaf and native pondweeds), stormwater inputs, and atmospheric deposition.

Curlyleaf and native pondweeds contribute phosphorus to Hyland Lake. Curlyleaf pondweed contributes phosphorus to Hyland Lake by growing quickly in the spring, extracting phosphorus from the sediments, and dying-off in June, thus releasing phosphorus stored in the plant tissue. The phosphorus released by curlyleaf pondweed results in algal blooms, whose shading causes the die-off of native pondweed species. The pondweed die-off releases additional phosphorus to Hyland Lake.

Phosphorus is released from lake sediments when oxygen becomes depleted at the lake bottom. Monitoring data show that bottom waters can have very low dissolved oxygen concentrations (i.e. <0.5 mg/L) as early as June but monitoring data suggest that phosphorus does not release from sediments until July (see Appendix A).

Stormwater inputs do not appear to be significantly affecting phosphorus levels in Hyland Lake and wet detention ponds are removing a significant fraction of the phosphorus loads (see Table 6) from the adjacent residential neighborhoods. In addition, the Three Rivers Park District intends to upgrade pond P-15 (See Figure 14) to improve phosphorus removal.

Pondweed growth and die-off is having a significant effect on the ecology and the beneficial uses of Hyland Lake. Curlyleaf pondweed grows very quickly in the spring and early-June, causing the pH of Hyland Lake to increase to levels that can promote phosphorus release from sediments (James 2001). When curlyleaf pondweed dies it releases phosphorus but it also consumes oxygen in the water column. The die-off of native pondweed species, caused by algal shading and from curlyleaf pondweed die-off, releases phosphorus and consumes additional oxygen in the water column. The MDNR (MDNR 1991) noted that the die-off of pondweed may be responsible for reported summer fish kills. It also appears that blue-green algae blooms during mid-to late-summer are inhibiting the transfer of dissolved oxygen below the surface of the lake.

The first step in the restoration of Hyland Lake is the management of curlyleaf pondweed. This should involve not just the management of curlyleaf pondweed such that the phosphorus inputs are reduced, but rather to remove it from Hyland Lake such that native plants can replace curlyleaf pondweed. Removal of curlyleaf pondweed should have the added benefit of preserving native pondweed species adversely affected by algal blooms that follow curlyleaf pondweed die-off. The Three Rivers Park District intends to begin aquatic plant harvesting in summer 2004. Experimental research has shown that there are significant synergistic benefits to pondweed control when harvesting and herbicides are used together (Filizadeh 2002). Research has also shown that the appropriate herbicide for curlyleaf pondweed control is endothal, and that this herbicide should be applied in the spring (when water is approximately 55-60°F) and at a dose of 1 mg/L (Poovey et al. 2002, Skogerboe - personal communication). Preliminary results from studies in Eagan, MN by John Skogerboe of the US Army Corps of Engineers have shown that four subsequent years of endothal 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 4 years.

Phosphorus that is directly released from sediment is the largest source of phosphorus to the water column of Hyland Lake. Although it is difficult to separate loading due to curlyleaf pondweed die-off from loading due to sediment phosphorus release, differences in release time may be used to estimate loading from each source. James 2001 showed that curlyleaf pondweed decomposition and phosphorus release were complete 30 days after plant death. Since curlyleaf pondweed die-off occurs during June, much of the loading from curlyleaf pondweed is complete by late-July. Because there is evidence that phosphorus continues to significantly increase in the water column from late-July through early-September (see years 1998, 2001, 2002 in Appendix E), and that the levels of releasable phosphorus (mobile phosphorus) are relatively high in Hyland Lake (see Figure 15), sediment has been identified as a significant source of phosphorus loading from July through September.

Monitoring data also suggest that sediment is providing phosphorus to algae that grow on the lake bottom (this algae is typically blue-green algae) in the spring and then float to the lake surface by late-June of each year. For example, in 2000, phosphorus levels were low on June 5 and chlorophyll *a* was also low (<10 µg/L). Two weeks later (June 19), chlorophyll *a* increased dramatically to 65 µg/L although total phosphorus increased only slightly. Monitoring data (Figure 6) show that the algal population in Hyland Lake completely switched to blue-green algae by June 19 even though Hyland Lake was primarily dominated by green algae only 2 weeks prior to June 19. Research has shown that shallow lakes can have significant blue-green algae growth on bottom sediments (Cook 1993). This pattern of sudden increases in chlorophyll *a* without a subsequent increase in total phosphorus was also noted in 1998 (see Appendix E).

Because of significant blue-green algal growth on Hyland Lake sediments, it is expected that even with extensive curlyleaf pondweed control there will be significant blue-green algae blooms in the summer. For this reason, phosphorus in Hyland Lake sediments needs to be bound by treatment with alum and lime to inhibit the supply of phosphorus to benthic blue-green algae and to the overlying water column.

Sediment treatment should not be performed until curlyleaf pondweed is completely controlled. Sediment treatment prior to curlyleaf pondweed control could possibly increase the light availability to this plant and stimulate curlyleaf pondweed growth.

4.2 Expected Implementation Sequence of Plan

Below is the expected sequence of the lake management activities.

Year 1 (2004)	Three Rivers Park District begins aquatic plant harvesting. The Three Rivers Park District constructs a new outlet for Hyland Lake and the lake is drawn down, partially exposing lake sediments.
Year 2 (2005)	Continued plant harvesting. Herbicide (endothal) treatment begins in the spring.
Year 3 (2006)	Continued plant harvesting and endothal treatment.
Year 4 (2007)	Plant harvesting complete. Continued endothal treatment.
Year 5 (2008)	Final endothal treatment. Alum-lime treatment in the fall.

4.3 Monitoring and Evaluation

An important part of this plan is monitoring and evaluation. Water quality parameters (total phosphorus, chlorophyll *a*, Secchi disc transparency, dissolved oxygen, and pH) should be monitored every 2 weeks from April through September for each year of the plan implementation and for 3 years following plan implementation. Water quality monitoring will be coordinated with the Three Rivers Park District. Monitoring should be designed to answer the following questions: (1) are harvesting and endothal treatments having the effect of reducing phosphorus and algae to desirable levels, improving Secchi disc transparency to desired levels (i.e. $TSI_{SD} \leq 54.5$)?; and (2) is sediment treatment required in the 5th year of the implementation plan in order to control summer blue-green algal blooms and reach the TSI_{SD} goal?

Macrophytes should also be monitored annually for each year of the plan implementation and for 3 years following plan implementation. The data will be used to evaluate curlyleaf pondweed and native plant growth. These evaluations will be used to monitor the expected improvement in native aquatic plant growth and determine whether a 5th year of endothal treatment is warranted.

Sediment monitoring should occur before alum-lime 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-lime layer. If the layer is below the sediments' surface, the distance from the surface will be measured.

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Appendices

Appendix A

Lake Modeling

Appendix A Lake Modeling

A-1 Modeling Approach

The purpose of developing a watershed and in-lake model for Hyland Lake was to determine how different phosphorus sources contribute to the observed levels of phosphorus in the lake. Modeling was performed for a range of climatic conditions (dry, average, and wet years). The in-lake model was calibrated using lake monitoring data from 2000 (dry year) and validated using data from 2002 (wet year). The calibrated in-lake model was then run for an average year (1998) to determine the expected average summer total phosphorus concentration for years with average precipitation levels.

One of the first steps in developing the in-lake model was the determination of water and phosphorus loads from different potential sources. The four phosphorus sources evaluated in this modeling study include: the Hyland Lake watershed, aquatic plant senescence, phosphorus release and migration from sediment, and atmospheric deposition.

The in-lake model was run under varying climatic conditions (dry, average, and wet year) to determine expected average summer phosphorus levels under a range of precipitation conditions. The model was also run under different management approaches to assess their benefits. From the predicted total phosphorus levels, average expected Secchi disc transparency was predicted from a relationship between total phosphorus and Secchi disc transparency. Data used to develop this relationship were from historical Hyland Lake monitoring data.

A-2 Watershed Modeling

Phosphorus loading from the Hyland Lake watershed was determined using the P8 model (IEP, Inc. 1990). Water and phosphorus loading were estimated using input from land use maps, soils maps, aerial photos with elevation contours, and storm sewer maps (see Appendix D). Phosphorus removal by detention basins was also calculated with the P8 model. Daily phosphorus and water loading outputs from this model were used as inputs to an in-lake model.

A-3 Lake Modeling

The first step in lake modeling was the identification and evaluation of different phosphorus sources. Both external phosphorus sources, i.e. watershed inputs and direct atmospheric deposition on the lake, and internal phosphorus sources were considered for this model. Because of the significant increases in phosphorus that are observed in the Hyland Lake water column from late-June through mid-September, and the fact that this increase was not associated with storm water inputs, internal phosphorus loading was identified early in this study as a significant source of phosphorus loading (see Figure A-1).

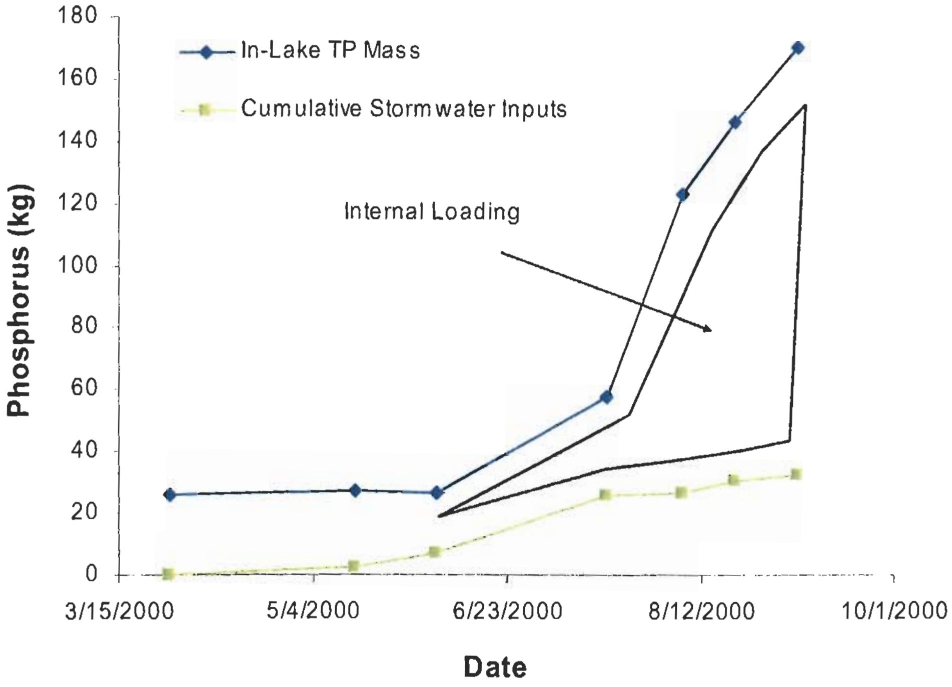


Figure A-1 In Lake Phosphorus Mass Compared to Cumulative Storm Water Inputs

Two types of internal loading were evaluated, aquatic plants and sediments. A macrophyte survey in 2000 showed that a significant population of curlyleaf pondweed, together with three native species (*Potamogeton natans, Potamogeton pectinatus, and Potamogeton zosteriformis*), existed at Hyland Lake in June. All four pondweed species were absent (decomposed) by August and were identified as a potentially significant source of internal loading. Sediment cores were collected in 2003 and analyzed for total and potentially releasable (mobile) phosphorus. Results of the sediment analysis indicated that sediment was also a potentially significant source of phosphorus loading to Hyland Lake.

Macrophytes

Because pondweed decomposition was identified as a potentially significant source of internal loading, the total phosphorus mass contributed to the Hyland Lake water column by the die-off of curlyleaf pondweed and three native species was estimated. 2000 macrophyte densities were semi-quantitatively determined for Hyland Lake. At several sampling locations in the lake (see Figure 8), macrophyte species were identified as light (1), typical (2), or heavy (3). Light approximately corresponds to 30 stems per square foot, typical to 41 stems per square foot, and heavy to 59 stems per square foot (Barr 2001). For the entire lake, it was determined that, on average, the density of pondweed at Hyland Lake corresponds to the light category.

Data from a macrophyte study performed in Wisconsin was used to estimate the mass and phosphorus content of pondweed in Hyland Lake (Barr 2000). This study determined that the mass of each stem was 0.35 grams and the phosphorus content per gram of pondweed material was 2 mg. This corresponds to 226.8 mg of phosphorus per square meter or approximately 0.92 kg phosphorus per acre. Because this value represents the maximum potential phosphorus load by the pondweed this loading estimate was viewed as a starting point from which to calibrate the contribution of phosphorus loading by pondweed. Also, it should be noted that this estimate of phosphorus mass per square meter is comparable to a study on Half Moon Lake, Wisconsin (James et al. 2001) where a dense population of pondweed was estimated to contain between 103 to 216 mg of phosphorus per square meter of lake surface. A literature review by Bolduan et al. 1994 presented phosphorus content for pondweed that ranged from 1.15 mg to 8.0 mg per gram of plant material (0.115 to 0.8 percent). The density of pondweed (stems per square meter) was not presented in this study.

The contribution of phosphorus to the water column by pondweed is a two step process with die-off followed by decomposition and then release of phosphorus. James et al. 2001 estimated that this is a non-linear process with most of the phosphorus release occurring within 30 days of die-off. Because all of the pond weed at Hyland Lake does not die-off at the same time, a mathematical model, which was derived from the chemical kinetics literature (Brezonik 1994), was used to estimate die-off then phosphorus release. This kinetic equation consists of two first order equations called a two-set first order sequence. Figure A-2 shows how pondweed die-off and phosphorus inputs were modeled. It was assumed that phosphorus input from pondweed die-off begins in July of each year.

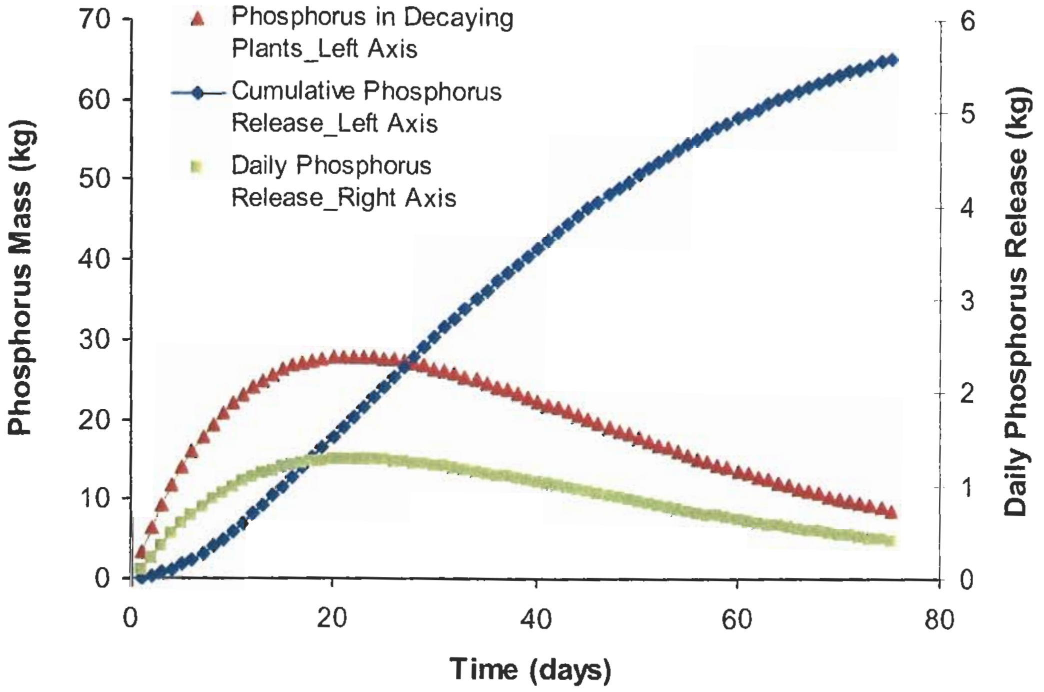


Figure A-2. Phosphorus Release to the Hyland Lake Water Column by Pondweed

Sediment

Total phosphorus monitoring data for Hyland Lake shows that the concentration of phosphorus in the water column can increase significantly in August through early-September. Since pondweed died-off is primarily complete by August and most of the phosphorus release from the decaying pondweed is complete by this time, it appears that the phosphorus release from the lake sediments is contributing to observed phosphorus levels. Hyland Lake sediment is relatively high in phosphorus that can release into the lake column (see Figure 17). From the sediment phosphorus data it was estimated that the phosphorus release rate was 3.2 mg per square meter per day from July through August (Pilgrim 2002).

Calibration

Two parameters were used to calibrate the lake model: (1) phosphorus settling velocity, and (2) the rate of phosphorus release from pondweed. The phosphorus settling velocity was calculated using an equation from Dillon and Rigler (1974) and lake characteristics such as lake volume and mean depth, watershed phosphorus and water loading from the spring of one year to the spring of the next year (1 year of phosphorus loading), outflow discharge volume, and outflow concentration. The phosphorus settling velocity was calculated such that the model-predicted a phosphorus concentration was equal to the concentration of phosphorus monitored in the spring (calibrated with 2000 monitoring data). The rate of phosphorus release from pondweed was used as an input to a second mass balance model (adapted from Thomann and Mueller 1987) to develop a calibrated model. The phosphorus release rate from pondweed was adjusted to minimize the difference between model-predicted and monitored phosphorus concentrations.

The equations used in this study are presented below.

Pondweed Die-Off

For the process: pondweed (A) $\xrightarrow{k_1}$ decaying pondweed (B) $\xrightarrow{k_2}$ released phosphorus (C), two equations apply,

$$[B] = \frac{k_1[A_o]}{k_2 - k_1}\{\exp(-k_1 t) - \exp(-k_2 t)\}$$

$$[C] = \frac{[A_o]}{k_2 - k_1}\{k_2(1 - \exp(-k_1 t)) - (1 - \exp(-k_2 t))\}$$

where t is time in days.

Dillon and Rigler

There are two equations for the Dillon and Rigler model.

$$R_{\exp} = \frac{Vp}{q_a + Vp}$$

and

$$C = L\frac{(1 - R_{\exp})}{Zp}$$

where $R_{\exp}$ = retention coefficient, q_a = overflow rate, Vp = net apparent settling rate, C = lake concentration, L = phosphorus loading, z = average lake depth, and p = the fraction of the lake that is lost by discharge. The first equation was solved for net apparent settling rate variable, Vp. This variable was then input in the equation below. The second equation was used to estimate the concentration of phosphorus that will occur in the spring.

Adapted from Thomann and Mueller

$$\frac{\Delta C}{\Delta t} \equiv \frac{Q_{in} * C_{in} - Q_{out} * C_{lake} - C_{lake} * A * Vp + SedPond}{V}$$

where: C = concentration of total phosphorus in the lake, t = time, Q_{in} = water flow into lake, Q_{out} = water flow out of lake, A = lake area, Vp = net total phosphorus settling "removal" rate, *SedPond* = sediment and pondweed loading, and V = lake volume. This model was used with a daily time step.

Management Estimates

The effect of different management actions on phosphorus loading to Hyland Lake was estimated for pondweed harvesting, lime treatment, herbicide treatment, and alum-lime treatment.

It is estimated that pondweed harvesting can remove 43 percent of the pondweed. This was estimated using a minimum cutting depth of 2 feet (this is based upon how close the cutting machine can get to the shore without running aground) and a depth of cut of 6 feet.

It was estimated that herbicide (endothal) treatment with harvesting can increase pondweed removal to 80 percent. This estimate was approximated from published literature (Poovey et al 2002). Lime treatment has resulted in pondweed growth inhibition from 50 to 80 percent (Reedyk et al. 2001). For modeling purposes lime treatment was assumed to have the same effectiveness as endothal.

The magnitude of phosphorus release inhibition from Hyland Lake sediments is based upon the alum-lime dose that is used. Alum-lime dose can be applied that will reduce the sediment phosphorus release rate to 0.5 mg per square meter per day. This release rate was used as a model input to simulate the effect of sediment treatment on phosphorus levels in Hyland Lake.

A-4 Results

Graphical presentations of the model calibration and validation results are shown below in Figure A-3 and A-4. The lake model was calibrated by changing the time-distributed input of phosphorus by pondweed die off (see Figure A-2 for the time-distributed input of pondweed phosphorus). For validation, the calibrated model was used with 2002 hydrology (e.g. water inputs, lake level, outflows) and watershed phosphorus loading inputs to see how closely the model-predicted in-lake total phosphorus concentration matched the monitored total phosphorus concentration. The validation results (Figure A-4) show good agreement between the model-predicted total phosphorus concentration and the monitored concentration.

The expected outcome of several alternative management actions was modeled using the calibrated model for dry, average, and wet years. The expected outcome of each management activity is presented as the average summer total phosphorus concentration, the expected Secchi disc transparency given the average total phosphorus concentration, and the TSI that corresponds to the Secchi disc transparency (Table A-1). The expected Secchi disc transparency presented in Table A-1 was calculated using a logarithmic relationship between measured summer phosphorus levels in Hyland Lake and corresponding Secchi disc transparency (Figure A-5).

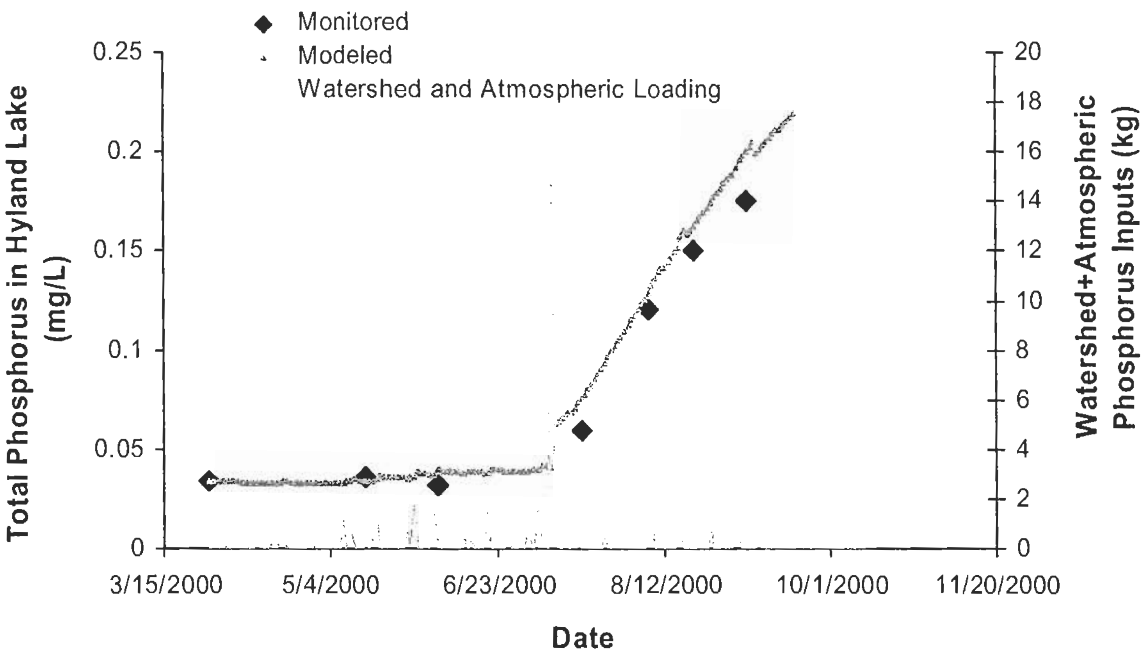


Figure A-3 **Calibrated Lake Model.**

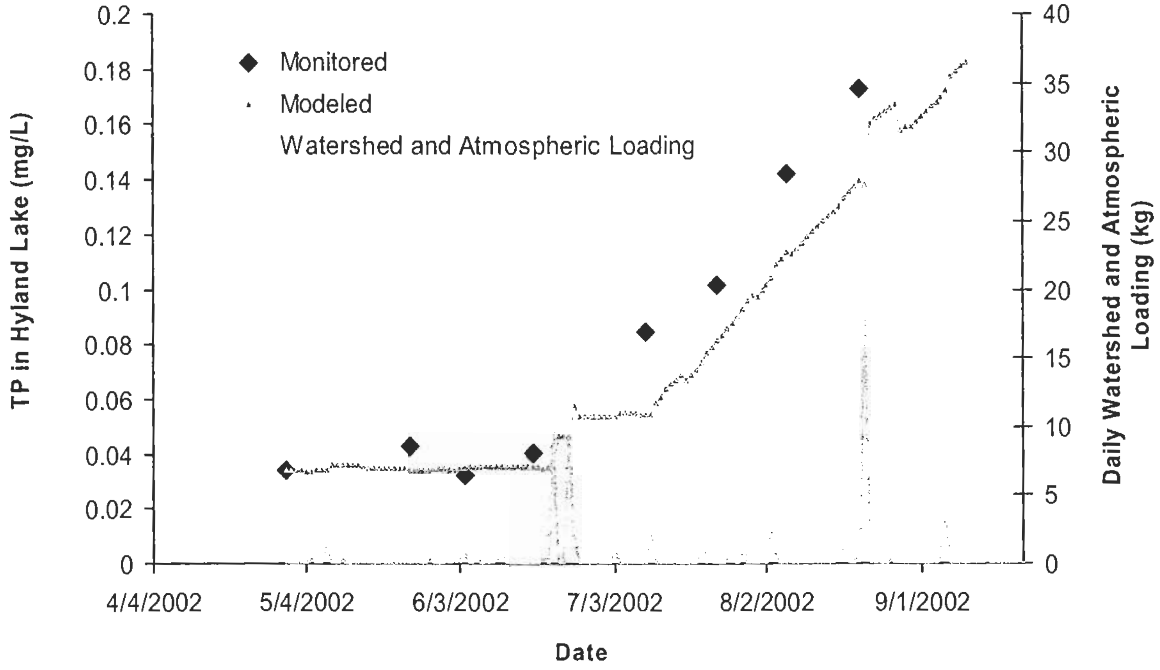


Figure A-4 **Validation of the Calibrated Lake Model.**

Table A-1 **Expected Trophic State Index Values Under Varying Climatic Conditions and Management Approaches**

Management Approach	Trophic State Index (TSI_{SD}) Value District Goal	Dry Year (25 inches)	Average Year (30 inches)	Wet Year (38 inches)
Existing Watershed Land Use Conditions				
No Action	≤54.5	57.5	56.1	56.7
Aquatic Vegetation Harvesting	≤54.5	56.5	55.2	55.9
Harvesting + Herbicide Treatment	≤54.5	55.7	54.5	55.2
Harvesting + Lime Treatment	≤54.5	55.7	54.5	55.2
Harvesting + Herbicide + Lime-Alum	≤54.5	53.5	52.4	53.2
Future Watershed Land Use Conditions				
No Action	≤54.5	56.9	56.1	56.7
Aquatic Vegetation Harvesting	≤54.5	55.9	55.3	55.9
Harvesting + Herbicide Treatment	≤54.5	55.0	54.5	55.2
Harvesting + Lime Treatment	≤54.5	55.0	54.5	55.2
Harvesting + Herbicide + Lime-Alum	≤54.5	52.7	52.4	53.2

Management Approach	Mean Summer Secchi Disc (m) Dry Year (25 inches)	Average Year (30 inches)	Wet Year (38 inches)
Existing Watershed Land Use Conditions			
No Action	1.19	1.31	1.26
Aquatic Vegetation Harvesting	1.27	1.40	1.33
Harvesting + Herbicide Treatment	1.34	1.47	1.40
Harvesting + Lime Treatment	1.34	1.47	1.40
Harvesting + Herbicide + Lime-Alum	1.57	1.69	1.60
Future Watershed Land Use Conditions			
No Action	1.24	1.31	1.26
Aquatic Vegetation Harvesting	1.33	1.38	1.33
Harvesting + Herbicide Treatment	1.41	1.47	1.40
Harvesting + Lime Treatment	1.41	1.47	1.40
Harvesting + Herbicide + Lime-Alum	1.66	1.69	1.60

Management Approach	Mean TP Concentration (μg/L)		
	Dry Year (25 inches)	Average Year (30 inches)	Wet Year (38 inches)
Existing Watershed Land Use Conditions			
No Action	89	79	83
Aquatic Vegetation Harvesting	82	72	77
Harvesting + Herbicide Treatment	76	67	72
Harvesting + Lime Treatment	76	67	72
Harvesting + Herbicide + Lime-Alum	60	53	58
Future Watershed Land Use Conditions			
No Action	85	79	83
Aquatic Vegetation Harvesting	77	73	77
Harvesting + Herbicide Treatment	71	67	72
Harvesting + Lime Treatment	71	67	72
Harvesting + Herbicide + Lime-Alum	55	53	58

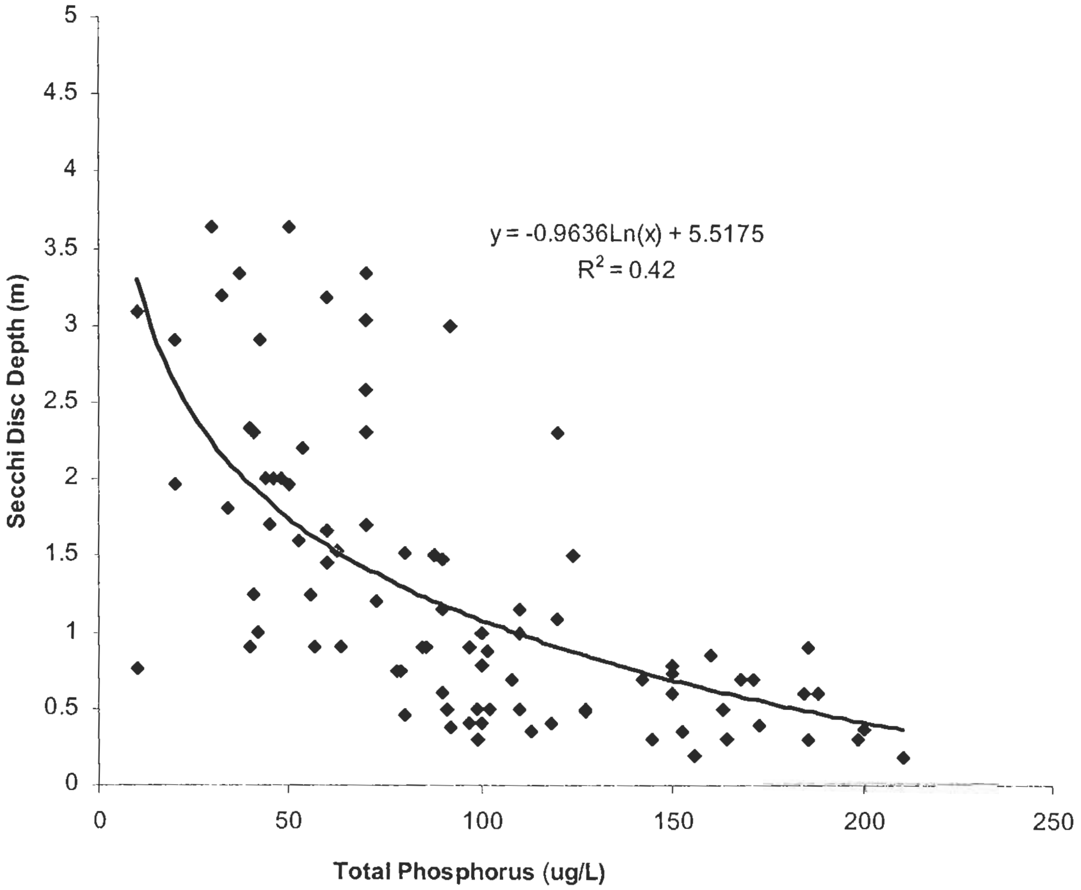


Figure A-5 Historical Relationship Between Total Phosphorus and Secchi Disc Transparency for Hyland Lake

A-5 Conclusions

This lake model was used to estimate the relative phosphorus loading from watershed inputs, pondweed, and lake sediment, and how management of these different sources would affect phosphorus levels in Hyland Lake. An important part of this modeling study was the identification of the relative contribution of pondweed and lake sediment to internal phosphorus loading. The phosphorus contribution by pondweed was estimated from a semi-quantitative survey of Hyland Lake and studies on the phosphorus content of pondweed. The total pondweed loading was not altered from initial estimates (i.e. 0.92 kg phosphorus per acre) for the calibration of this model; only the time-sequence of phosphorus loading was changed such that the model-predicted total phosphorus concentration closely matched the measured concentration. Internal loading from lake sediment was based upon the releasable phosphorus content of the top 6 centimeters of Hyland Lake sediment and a relationship between the phosphorus content and the expected release rate (Pilgrim 2002).

The prescribed management activities should be completed according to the management plan presented in Section 4.2. By following this management plan the relative contribution by the lake sediment to phosphorus levels in Hyland Lake can be confirmed because harvesting and herbicide treatment should eliminate phosphorus contributed by pondweed. Once the pondweed is adequately controlled, the potential need for alum-lime treatment to reduce the dense blue-green algal blooms at Hyland Lake in the summer will become evident. In addition, alum-lime treatment should not be performed before the pondweed is under control because of the potential for these treatments to stimulate pondweed growth by improving light availability.

Appendix B

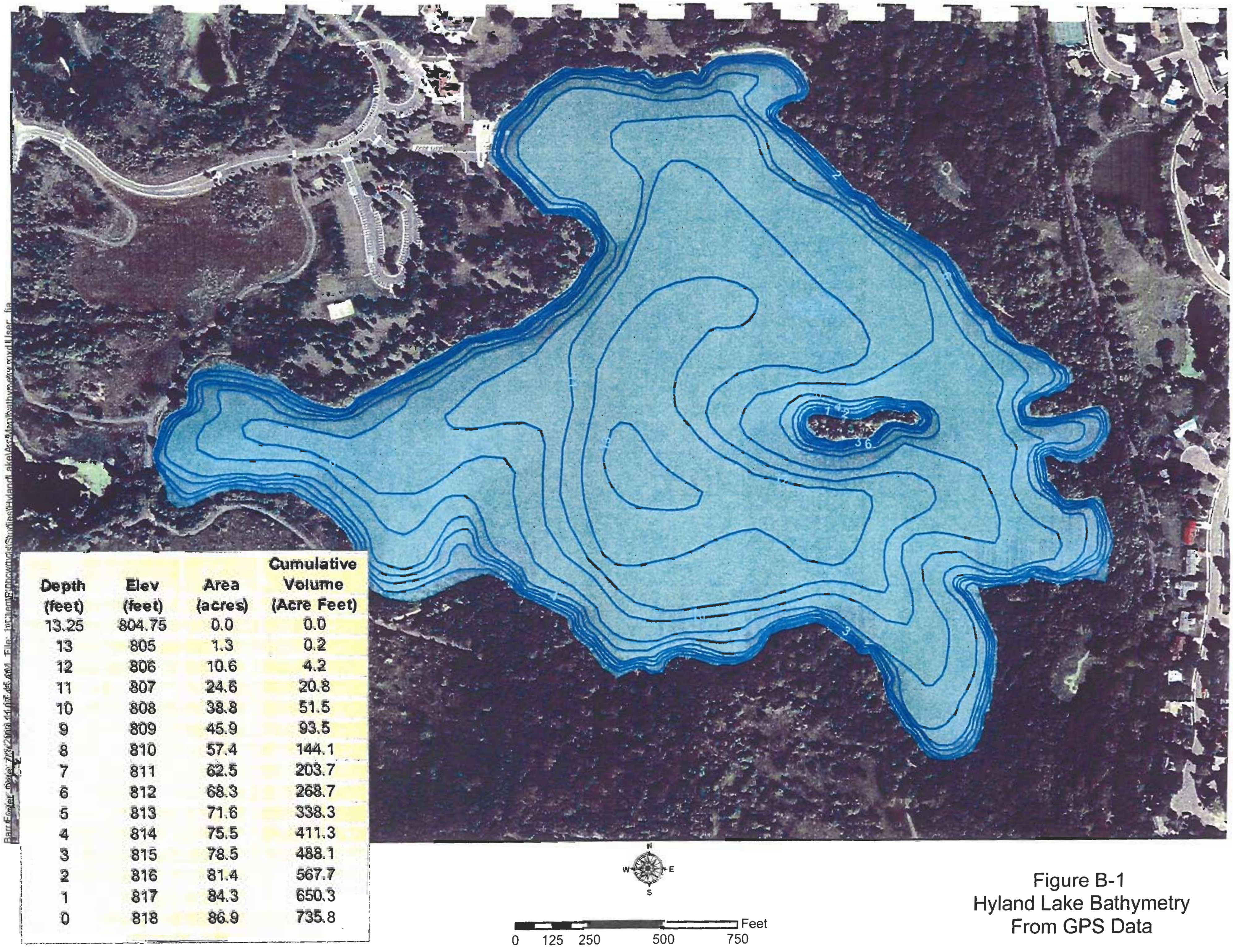
Monitoring and Analysis Methods

Appendix B Monitoring and Analysis Methods

The Hyland Lake UAA included the collection of lake water quality data and ecosystem data.

B.1 Lake Water Quality Data Collection

In 1997, a representative Hyland Lake sampling station was selected (i.e., located at the deepest location in the lake basin, see Figure B-1). Samples were collected from March through the beginning of October 2000. A total of eleven water quality parameters were measured at the Hyland Lake sampling station. Table B-1 lists the water quality parameters and specifies at what depths the samples or measurements were collected. Dissolved oxygen, temperature, specific conductance, and Secchi disc transparency were measured in the field, water samples were analyzed in the laboratory for total phosphorus, soluble reactive phosphorus, total nitrogen, chlorophyll *a*, and pH. The procedures for chemical analyses of the water samples are shown in Table B-2. Generally, the methods can be found in Standard Methods for Water and Wastewater Analysis.



Depth (feet)	Elev (feet)	Area (acres)	Cumulative Volume (Acre Feet)
13.25	804.75	0.0	0.0
13	805	1.3	0.2
12	806	10.6	4.2
11	807	24.6	20.8
10	808	38.8	51.5
9	809	45.9	93.5
8	810	57.4	144.1
7	811	62.5	203.7
6	812	68.3	268.7
5	813	71.6	338.3
4	814	75.5	411.3
3	815	78.5	488.1
2	816	81.4	567.7
1	817	84.3	650.3
0	818	86.9	735.8

Figure B-1
Hyland Lake Bathymetry
From GPS Data

Table B-1 Hyland Lake Water Quality Parameters

Parameters	Depth (Meters)	Sampled or Measured During Each Sample Event
Dissolved Oxygen	Surface to bottom profile	X
Temperature	Surface to bottom profile	X
Specific Conductance	Surface to bottom profile	X
Secchi Disc	—	X
Total Phosphorus	0 2 Meter Composite Sample	X
Total Phosphorus	Profile at 1 meter intervals from 3 meters to 0.5 meters above the bottom	X
Soluble Reactive Phosphorus	0-2 Meter Composite Sample	X
Total Nitrogen, Total Kjeldahl Nitrogen, Nitrate + Nitrite	0-2 Meter Composite Sample	X
pH	0-2 Meter Composite Sample	X
pH	Profile at 1 meter intervals from 3 meters to 0.5 meters above the bottom	X
Chlorophyll *a*	0-2 Meter Composite Sample	X
Turbidity	0-2 Meter Composite Sample	X

Table B-2 Procedures for Chemical Analyses Performed on Water Samples

Analysis	Procedure	Reference
Total Phosphorus	Persulfate digestion, manual ascorbic acid	Standard Methods, 18th Edition (1992) modified per Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Soluble Reactive Phosphorus	Manual ascorbic acid	Standard Methods, 18th Edition modified per Eisenreich, et al., Environmental Letters 9(1), 43-53 (1975)
Total Nitrogen	Persulfate digestion, scanning spectrophotometric	Bachman, Roger W. and Daniel E. Canfield, Jr., 1991. A Comparability Study of a New Method for Measuring Total Nitrogen in Florida Waters. Report submitted to the Florida Department of Environmental Regulation.
Total Kjeldahl Nitrogen	Digestion, treatment with sodium hypochlorite and sodium phenolate, run of Technicon Autoanalyzer II	USEPA Methods of Chemical Analysis of Water and Wastes, 351.1
Nitrate + Nitrite Nitrogen	Copperized reduction column and Lachat Flow Injection Ion Analyzer	USEPA Methods of Chemical Analysis of Water and Wastes, 353.2
Chlorophyll *a*	Spectrophotometric	Standard Methods, 18th Edition, 1992, 10200 H
pH	Potentiometric measurement, glass electrode	Standard Methods, 16th Edition, 1985, 423
Specific Conductance	Wheatstone bridge	Standard Methods, 16th Edition, 1985, 205
Temperature	Thermometric	Standard Methods, 16th Edition, 1985, 212
Dissolved Oxygen	Electrode	Standard Methods, 16th Edition, 1985, 421F
Phytoplankton Identification and Enumeration	Inverted Microscope	Standard Methods, 16th Edition, 1985, 1002F (2-d), 1002H (2)
Zooplankton Identification and Enumeration	Sedgewick Rafter	Standard Methods, 16th Edition, 1985, 1002F (2-d), 1002H
Transparency	Secchi disc	

B.2 Ecosystem Data Collection

Ecosystem data collected from April to October 2000 included:

- **Phytoplankton**—A composite 0-2 meter sample was collected during each water quality sampling event during the period April 2000 thorough October 2000.
- **Zooplankton**—A zooplankton sample was collected (i.e., bottom to surface tow) during each water quality sample event during the period April 2000 thorough October 2000.
- **Macrophytes**—Macrophyte surveys were completed during June and August 2000.

Phytoplankton and zooplankton samples were identified and enumerated to provide information on species diversity and abundance. The macrophyte community was surveyed to determine species locations, composition, and abundance.

B.3 Watershed Pond Survey

During the winter of 2002, four ponds in the Hyland Lake watershed were surveyed. The ponds' bathymetry was determined in the survey. This work was completed to help establish the current conditions of water bodies that affect the flow of storm water runoff from the Hyland Lake watershed. The wet detention pond surveys began by recording the type and size of the outlet and estimating the height to the low overflow point. A grid was then marked off on the pond with points approximately 20 feet apart. An ice auger was used to drill through the ice and a depth gage was dropped to the bottom to get the water depth. The grid points and associated water depths were then recorded on a map of the pond. The maps were then placed in the Geographical Information System (GIS) and pond volumes, both dead and live storage, were determined. Pond data are summarized in Appendix C. The information was used for water quality modeling of the Hyland Lake watershed.

Appendix C

Hyland Lake Watershed Pond Data

Appendix C: Hyland Lake Watershed Pond Data

Pond	Pond Bottom Surface Area (ac)	Permanent Pool Surface Area (ac)	Permanent Pool Storage Volumes (ac-ft)	Flood Pool Surface Area (ac)	Flood Pool Storage Volume (ac-ft)	Normal Outlet Orifice Diameter (in)	Weir Length (ft)
P-7	0	1.3	0.3	1.6	1.3	--	6
P-16	0	0.8	0.2	1.16	1.9	--	6
P-11	0	0.7	1.5	1.51	7.7	42	--
P-12	0	0.5	1.5	1.051	6.1	18	--
P-13	0	1.0	2.1	1.68	5.5	30 and 42	--
P-14	0	2.1	4.1	2.28	4.1	12	--
P-15	0	2.0	10.5	2.005	0.0	--	6

Appendix D

P8 Model Parameter Section

Appendix D: P8 Model Parameter Selection

P8 version 2.4 was used for Hyland Lake watershed modeling. The parameters selected for the Hyland Lake P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting.

Time Step, Snowmelt, and Runoff Parameters (Case-Edit-Other)

- **Time Steps Per Hour (Integer)—2.** Selection was based upon the number of time steps required to eliminate continuity errors greater than 2 percent.
- **Minimum Inter-Event Time (Hours)—12.** The selection of this parameter was based upon an evaluation of storm hydrographs to determine which storms should be combined and which storms should be separated to accurately depict runoff from the lake's watershed.
- **Snowmelt Factors—Melt Coef (Inches/Day-Deg-F)—0.06.** The selection was based upon the snowmelt rate that provided the best match between the observed and predicted snowmelt.
- **Snowmelt Factors—Scale Factor For Max Abstraction—1.** This factor controls the quantity of snowmelt runoff (i.e., controls losses due to infiltration). Selection was based upon the factor that resulted in the closest fit between modeled and observed runoff volumes.
- **Growing Season/Non-Growing Season AMC-II = 0.5 and AMC-III = 1.1 (growing season), 1.2 (non-growing season).** This indicates that AMC-II is used if the 5-day antecedent moisture is 0.5 inches or greater and AMC-III is used if antecedent moisture is 1.1 (growing season) or 1.2 (non-growing season) inches or greater.

Particle Scale Factor (Case-Edit-Components)

- **Scale Fac.—tp—1.0** The particle scale factor adjusts phosphorus loading for site specific factors. A factor of 1.0 indicates no adjustment.

Particle File Selection (Case—Read—Particles)

- **NURP50PAR.** The NURP 50 particle file was used to predict phosphorus loading and settling in wet detention ponds.

Precipitation File Selection (Case—Edit—First—Prec. Data File

- **MS4999bc.PCP.** The precipitation file MS4999bc.PCP is comprised of hourly precipitation. The precipitation data in this file consists of hourly data from the Eden Prairie that has been adjusted by daily precipitation values from a gage located near Bloomington, MN and the Chanhassen gage located at the National Weather Service in Chanhassen.

Air Temperature File Selection (Case—Edit—First—Air Temp. File)

- **2MSP4998.TMP**. The temperature file was comprised of temperature data from the Minneapolis—St. Paul International airport during the period 1949 through 1998.

Devices Parameter Selection (Case—Edit—Devices—Data—Select Device)

- **Pond Bottom**—The surface area of the pond bottom of each detention pond was determined and entered here.
- **Detention Pond—Permanent Pool—Area and Volume**—The surface area and dead storage volume of each detention pond was determined and entered here.
- **Detention Pond—Flood Pool—Area and Volume**—The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) was determined and entered here.
- **Detention Pond—Orifice Diameter and Weir Length**—The orifice diameter or weir length was determined for each detention pond and entered here.
- **Detention Pond or Generalized Device—Particle Removal Scale Factor**—0.3 for ponds less than 2 feet deep, 0.6 for ponds from 2 to 3 feet deep, and 1 for all ponds 3 feet deep or greater. The particle removal factor for watershed devices determines particle removal by devices.
- **Detention Pond or Generalized Device—Outflow Device No's**—The number of the downstream device receiving water from the detention pond outflow was entered for infiltration, normal, and spillway.
- **Generalized Device**—Infiltration Outflow Rates (cfs)—0 for all ponds.
- **Detention Pond—Infiltration Rate (in/hr)**—0 for all ponds.
- **Pipe/Manhole—Time of Concentration**—The time of concentration for each pipe/manhole device was determined and entered here. A "dummy" pipe/manhole device was placed immediately upstream of each pond and a time of concentration of 0 hours per "dummy" pipe was selected. Because the timing of stormwater runoff was not an issue in this watershed, no lag time was needed. A "dummy" pipe called Hyland Lake was used to combine all of the inflow pipes into one source. The Hyland Lake pipe in each model received all water and phosphorus loads that enter Hyland Lake. A time of concentration of 0 was used for the Hyland Lake pipe in each model. Use of the pipe forced each model to total the water and phosphorus loads entering the lake, thus avoiding hand tabulation.

Watersheds Parameter Selection (Case—Edit—Watersheds—Data—Select Watershed)

- **Outflow Device Number**—The device number of the device receiving runoff from the watersheds was selected.

- **Pervious Curve Number**—A weighted SCS curve number was used as outlined in the following procedure. The P8 Pre-Processor (GIS algorithm) was used to compute a SCS curve number for each watershed. The computation was based upon soil types in the watershed, land use, and hydrologic conditions. The computation also weighted the pervious curve number with indirect (i.e., disconnected) impervious areas in each sub watershed as follows:

WCN = {[(Indirect Impervious Area) * (98)] + [(Pervious Area) * (Pervious Curve Number)]}/(Total Area)

The assumptions for direct, indirect, and total impervious areas were based upon measurements from representative areas within the Hyland Lake watershed.

- **Swept/Not Swept**—An "unswept" assumption was made for the entire impervious watershed area. A sweeping frequency of 0 was selected for swept. Hence, selected parameters were placed in the unswept category, including impervious fraction, depression storage, impervious runoff coeff, and scale factor for particle loads.

- **Impervious Fraction**—The direct or connected impervious fraction for each subwatershed was determined and entered here. The direct or connected impervious fraction includes driveways and parking areas that are directly connected to the storm sewer system. The P8 pre-processor performed the computations to determine impervious fractions for the subwatersheds. The direct impervious fraction for each subwatershed was based upon measurements from representative areas within the Hyland Lake watershed. The direct impervious fraction for each land use type was weighted with the acres of each land use to obtain a weighted average for each subwatershed.

- **Depression Storage**—0.03

- **Impervious Runoff Coef.**—1

Passes Through the Storm File (Case—Edit—First—Passes Thru Storm File)

- **Passes Thru Storm File—5**. The number of passes through the storm file was determined after the model had been set up and a preliminary run completed. The selection of the number of passes through the storm file was based upon the number required to achieve model stability. Multiple passes through the storm file were required because the model assumes that dead storage waters contain no phosphorus. Consequently, the first pass through the storm file results in lower phosphorus loading than occurs with subsequent passes. Stability occurs when subsequent passes do not result in a change in phosphorus concentration in the pond waters. It was determined that all three P8 models (i.e., wet, dry, average) achieved stability at 5 passes.

Appendix E

Monitoring Data

Appendix E: Monitoring Data

Table E-1. Water Quality Monitoring Data for 2000 Collected by Barr Engineering

Date	Max Depth (m)	Sample Depth (m)	Secchi Depth (m)	Chl-*a* (mg/L)	Turbidity (NTU's)	D. O. (mg/L)	Temp (°C)	Sp. Cond. (µmho/cm @ 25°C)	Total P (mg/L)	Ortho P (mg/L)	Total N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite Nitrogen (mg/L)	pH (S.U.)
3/28/2000	3.5	0-2	1.7	0.0129	3.5	--	--	--	0.032	<0.002	0.80	--	--	8.0
		0.0				6.7	6.6	283						
		1.0				7.2	6.7	283						
		2.0				7.4	6.7	282						
		3.0				7.6	6.7	282	0.036					8.0
5/15/2000	3.0	0-2	1.7	0.0063	3.0	--	--	--	0.035	<0.006	--	0.81	<0.02	8.8
		0.0				7.8	15.2	262						
		1.0				7.8	15.2	262						
		2.0				7.8	15.2	262						
		2.5				7.8	15.2	262	0.037					8.8
6/5/2000	3.0	0-2	2.7	0.0055	1.9	--	--	--	0.037	<0.006	--	0.37	<0.02	9.4
		0.0				8.3	17.2	237						
		1.0				8.2	17.2	237						
		2.0				8.3	17.1	237						
		2.5				8.3	17.1	237	0.027					9.4
6/19/2000	3.0	0-2	1.0	0.065	13.5	--	--	--	0.059	<0.006	--	1.1	0.03	9.7
		0.0				11.0	20.2	240						
		1.0				11.0	20.2	239						
		2.0				8.3	19.8	239						
		2.5				6.9	19.6	241	0.059					9.6

Table E-1. Water Quality Monitoring Data for 2000 Collected by Barr Engineering

Date	Max Depth (m)	Sample Depth (m)	Secchi Depth (m)	Chl-*a* (mg/L)	Turbidity (NTU's)	D. O. (mg/L)	Temp (°C)	Sp. Cond. (µmho/cm @ 25°C)	Total P (mg/L)	Ortho P (mg/L)	Total N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite Nitrogen (mg/L)	pH (S.U.)
7/5/2000	3.2	0-2	1.2	0.05	15.0	--	--	--	0.054	<0.006	--	1.4	<0.02	9.9
		0.0				11.0	24.9	243						
		1.0				11.3	24.9	244						
		2.0				7.3	24.5	242						
		2.7				6.5	21.2	290	0.065					9.9
7/18/2000	3.0	0-2	1.0	0.044	12.0	--	--	--	0.055	<0.006	--	1.4	<0.02	9.9
		0.0				9.5	26.0	240						
		1.0				9.5	26.1	241						
		2.0				9.5	26.2	240						
		2.5				9.4	26.2	246	0.064					9.9
8/7/2000	3.0	0-2	0.5	0.083	35.0	--	--	--	0.128	0.009	--	1.5	0.02	9.8
		0.0				8.0	24.5	236	--					
		1.0				7.1	24.5	235	--					
		2.0				6.8	24.3	235	--					
		2.5				5.2	24.2	235	0.114					9.8
8/21/2000	3.2	0-2	0.4	0.051	35.0	--	--	--	0.150	<0.006	--	1.4	<0.02	9.5
		0.0				6.6	22.8	228	--					
		1.0				6.1	22.8	228	--					
		2.0				6.0	22.8	228	--					
		2.5				5.8	22.8	228	0.150					9.5
9/6/2000	3.0	0-2	0.3	0.076	45.0	--	--	--	0.180	<0.006	--	1.8	<0.02	9.2
		0.0				7.2	20.6	231	--					

Table E-1. Water Quality Monitoring Data for 2000 Collected by Barr Engineering

Date	Max Depth (m)	Sample Depth (m)	Secchi Depth (m)	Chl-*a* (mg/L)	Turbidity (NTU's)	D. O. (mg/L)	Temp (°C)	Sp. Cond. (µmho/cm @ 25°C)	Total P (mg/L)	Ortho P (mg/L)	Total N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite Nitrogen (mg/L)	pH (S.U.)
		1.0				7.1	20.7	231	--					
		2.0				7.0	20.6	231	--					
		2.5				7.0	20.6	231	0.170					9.2
10/11/2000	3.0	0-2	0.7	0.017	20.0	--	--	--	0.088	<0.006	--	1.8	0.05	7.9
		0.0				6.9	10.5	260	--					
		1.0				6.8	10.5	260	--					
		2.0				6.5	10.2	261	--					
		2.5				6.5	10.2	260	0.089					--

Table E-2. Historical Monitoring Data Collected by Barr Engineering

Date	Epilimnetic Chlorophyll *a* (mg/L)	Epilimnetic Total Phosphorus (mg/L)	Secchi Disc (m)
06/23/71	0.056	0.091	0.5
08/13/71	0.121	0.097	0.4
06/17/75	0.033	0.185	0.3
08/22/75	0.127	0.164	0.3
06/05/81	0.004	0.120	2.3
08/13/81	0.005	0.092	3
06/19/84	0.010	0.088	1.5
08/03/84	0.072	0.102	0.5
06/27/88	0.051	0.185	0.9
07/18/88	0.098	0.163	0.5
08/22/88	0.074	0.171	0.7
06/19/90	0.016	0.124	1.5
07/10/90	0.045	0.150	0.6
08/01/90	0.121	0.156	0.2
08/21/90	0.066	0.198	0.3
06/29/93	0.061	0.086	0.9
07/12/93	0.061	0.110	1
08/03/93	0.048	0.168	0.7
08/24/93	0.045	0.184	0.6
04/30/96	0.056	0.097	0.9
06/18/96	0.007	0.054	2.2
07/15/96	0.023	0.064	0.9
08/05/96	0.041	0.127	0.5
08/19/96	0.034	0.110	0.5
09/03/96	0.108	0.100	0.4

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
8/6/1951	0									6	0.30
8/15/1951	0									6	0.27
6/23/1971	0						54.6				0.48
8/13/1971	0						121.2				0.36
10/17/1971	0			200			210				0.36
9/8/1972	0			210	15		364				0.18
9/8/1972	0			194	0						
9/22/1972	0			210	35		336.5				0.18
9/22/1972	0			212	35						
10/30/1972	0			155	0		149				
10/30/1972	0			187	15						
7/20/1977	0										0.23
9/21/1978	0			370	100		200	9.2	0.170		0.27
9/21/1978	0			360	100		200	9	0.170		0.27
10/19/1978	0			250	50		10	7.4	0.220		0.52
10/19/1978	0			180	50		31	7.6	0.220		0.52
3/7/1979	0			180	100		6		0.420		
3/8/1979	0			254	45			7.6	0.420	4	
3/8/1979	0			189	55			7.7	0.410	4	
3/8/1979	0			132	53			7.5	0.380	3	
3/8/1979	0			127	110			7.4	0.390	3	
6/12/1979	0			47	10		3.2	8.3	0.350	14	3.76
6/12/1979	0			37	20		3.2	8.3	0.360	13	3.33
6/12/1979	0			54	30			7.9	0.370	13	
7/3/1979	0	25	8.3	70	130		2	8.1	0.390	13	
7/3/1979	0			20	1		2	7.4	0.370	14	2.91
7/3/1979	1	25	8.4								
7/3/1979	2	27	8.3								
7/3/1979	3	25	13.4								
7/3/1979	3.5	25	11.2								

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
7/9/1979	0	27	11	40	4		14	8.4	0.325	12	
7/9/1979	0			50	3		15	8.5	0.350	14	1.97
7/9/1979	1	25	11.5								
7/9/1979	1.5	25	12.3								
7/9/1979	2	24	14.7								
7/9/1979	2.5	24	14.4								
7/9/1979	3	23	11.2								
7/9/1979	3.5	22	7								
7/16/1979	0										2.67
7/23/1979	0	27	8.6	90	23		11	8.5	0.375	13	
7/23/1979	0			60	17		9	8.7	0.350	13	1.67
7/23/1979	1	26	8.6								
7/23/1979	2	26	8								
7/23/1979	3	25	5.2								
7/23/1979	3.5	24	1.4								
8/9/1979	0	26	6.7	80	3		2	8.7	0.350	130	
8/9/1979	0			30	3		1	8.7	0.350	130	
8/9/1979	1	26	6.6								
8/9/1979	2	26	6.1								
8/9/1979	2.5	26	6								
8/9/1979	3	26	3.6								
8/22/1979	0	23	5.5	70	11		4	7.7	0.375	13	3.03
8/22/1979	0			50	14		5	7.6	0.350	12	
8/22/1979	1	22	5.4								3.03
8/22/1979	2	22	5.2								3.03
8/22/1979	3	21.5	4.9								3.03
8/22/1979	3.2	21	2.2								3.03
9/10/1979	0	21	6.5	40	5		14	7.2	0.340	14	2.33
9/10/1979	0			40	4		12	7.6	0.345	15	
9/10/1979	1	21	6.2								2.33
9/10/1979	2	21	6.2								2.33

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
9/10/1979	3	21	6								2.33
9/10/1979	3.5	21	6								2.33
9/25/1979	0	18	8.4	70	3		11	7.5	0.390	14	2.58
9/25/1979	0			60	5		11	7.7	0.355	15	
9/25/1979	1	18	8.4								2.58
9/25/1979	2	18	7.9								2.58
9/25/1979	3	18	8								2.58
9/25/1979	4	18	6.2								2.58
4/29/1980	0	10.5	12.2	80	52		40	8.6	0.275	15	
4/29/1980	0			50	42		33	8.6	0.270	16	
4/29/1980	1	10.5	12.2								
4/29/1980	2	10	11.9								
4/29/1980	3	10	11.9								
4/29/1980	4	8.5	0.8								
5/20/1980	0	13	10.8	100	43		24	8	0.210	11	1.00
5/20/1980	0			130	53		29	8	0.285	90	
5/20/1980	1	12.5	10.3								1.00
5/20/1980	2	10	10.2								1.00
5/20/1980	3	9	9.8								1.00
5/20/1980	3.2	8	2.1								1.00
6/3/1980	0	15	13.3	40	24		9	9	0.245	11	0.91
6/3/1980	0			40	16		9	8.2	0.250	10	
6/3/1980	1	12	14.5								0.91
6/3/1980	2	11.5	10.6								0.91
6/3/1980	3	7.5	2.1								0.91
6/3/1980	4	6	1.2								0.91
6/16/1980	0	11	13.8	450	450		58	9	0.260	11	0.55
6/16/1980	0			1240	520		39	7.2	0.295	12	
6/16/1980	1	10	12.6								0.55
6/16/1980	2	10	10.8								0.55
6/16/1980	3	8	1								0.55

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
6/26/1980	0	12	9.6	60	30		21	8.1	0.170	1	1.45
6/26/1980	0			70	50		25	7.4	0.200	2	
6/26/1980	1	12	9.1								1.45
6/26/1980	2	10	5.8								1.45
6/26/1980	3	8	0.5								1.45
6/26/1980	3.2	9	0.4								1.45
7/8/1980	0	30	15	80	30		82	8.8	0.200	12	0.45
7/8/1980	0			70	40		22	7.9	0.300	11	
7/8/1980	1	29	14.2								0.45
7/8/1980	2	24	0								0.45
7/8/1980	3	22	0								0.45
7/8/1980	3.2	21	0								0.45
7/28/1980	0	27	11.4	90	10		59	8.6	0.200	12	0.61
7/28/1980	0			230	30		36	8.5	0.200	13	
7/28/1980	1	25	11.2								0.61
7/28/1980	2	25	7.4								0.61
7/28/1980	3	25	2.3								0.61
7/28/1980	3.2	22	0.2								0.61
8/12/1980	0	24	3.5	20	20		13	8	0.190	10	1.97
8/12/1980	0			80			11	7.8	0.185	11	
8/12/1980	1	24	3.3								1.97
8/12/1980	2	24	3.1								1.97
8/12/1980	3	24	2.9								1.97
8/12/1980	3.2	23	0.4								1.97
8/29/1980	0	23	6.7	80	60		14	8.2	0.270	13	1.52
8/29/1980	0			50	20		13	8.2	0.270	12	
8/29/1980	1	23	6.5								1.52
8/29/1980	2	22	6.2								1.52
8/29/1980	3	22	5.5								1.52
8/29/1980	3.2	22	3								1.52
9/9/1980	0	23	10.1	260	20			8.1	0.270	11	0.76

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
9/9/1980	0			180	10			8.1	0.275	10	
9/9/1980	1	23	10								0.76
9/9/1980	2	22.5	6.5								0.76
9/9/1980	3	22	0.7								0.76
9/9/1980	3.2	22	0.2								0.76
9/25/1980	0	16	9.1	90	20			8.1	0.270	11	1.15
9/25/1980	0			50	10			8	0.275	12	
9/25/1980	1	16	9.4								1.15
9/25/1980	2	16	9.2								1.15
9/25/1980	3	16	9								1.15
4/1/1981	0	20	7.3								
4/1/1981	1	20	7.2								
4/1/1981	2	20	7.2								
4/1/1981	3	20	7.2								
4/2/1981	0	9.5	10.8	10	10		3	8.1	0.270	12	3.09
4/2/1981	1	9	10.9								3.09
4/2/1981	2	9	11.2								3.09
4/2/1981	3	9	11.1								3.09
4/2/1981	3.5	9	11.1								3.09
6/10/1981	0			30	10		0.6	8	0.270	13	3.64
7/10/1981	0										3.03
7/29/1981	0										0.76
8/7/1981	0	21.5	8.3	70	40		10	9.3	0.200	11	3.33
8/7/1981	1	21.5	8.1								3.33
8/7/1981	2	21	7.3								3.33
8/7/1981	3	18	0.1								3.33
8/22/1981	0										3.03
3/5/1982	0	1	8.9	20	20			8.2	0.290	13	
3/5/1982	0.5	2.5	9								
3/5/1982	1	4.5	6.7								
3/5/1982	1.5	5	4.4								

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
3/5/1982	2	5	3.1								
3/5/1982	2.5	5	2.6								
3/5/1982	3	5	1.5								
3/5/1982	3.5	6.5	0.5								
3/11/1982	0		13.2								
3/11/1982	0.5		13.1								
3/11/1982	0.5	1.9	8.2								
3/11/1982	0.8	1.8	11.8								
3/11/1982	0.8	3.5	8.4								
3/11/1982	1		7.8								
3/11/1982	1.2	1.9	8								
3/11/1982	1.2	2.1	7.9								
3/11/1982	1.5		7								
3/11/1982	1.5	2	6.9								
3/11/1982	1.8	2.1	6.1								
3/11/1982	1.8	2.1	7.9								
3/11/1982	1.8	3.9	3.8								
3/11/1982	2		4.5								
3/11/1982	2.1	2.3	5.9								
3/11/1982	2.5		1.7								
3/11/1982	2.7	2.7	2.6								
3/11/1982	3		0.1								
3/11/1982	3	4	1.2								
3/11/1982	3.25		0.1								
5/28/1982	0										2.73
6/14/1982	0										3.79
7/5/1982	0										3.03
7/20/1982	0										2.73
8/15/1982	0										1.97
8/17/1982	0										1.97
9/10/1982	0										1.06

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
6/5/1983	0										2.42
7/2/1983	0										0.91
7/20/1983	0										1.06
8/10/1983	0										1.67
9/1/1983	0										0.61
3/9/1984	0.7	3.7	7.5								
3/9/1984	0.76	3.7	7.5								
3/9/1984	0.9	3.1	2.9								
3/9/1984	0.9	3.1	2.9								
3/9/1984	1.2	4	2.5								
3/9/1984	1.2	4	2.5								
3/9/1984	1.5	3.5	2.2								
3/9/1984	1.5	3.5	2.2								
3/9/1984	2.4	4.1	1.5								
3/9/1984	2.4	4.1	1.3								
3/9/1984	3	4.5	0.9								
3/9/1984	3	4.5	0.9								
3/9/1984	3.4										
3/9/1984	3.4										
6/12/1984	0										1.52
7/4/1984	0										1.82
7/24/1984	0										0.45
8/12/1984	0										0.61
9/5/1984	0										1.30
3/8/1985	0.7	1.9	3								
3/8/1985	0.7	1.8	3.2								
3/8/1985	0.9	3	2.7								
3/8/1985	0.9	2.7	2.7								
3/8/1985	1.2	4	2.1								
3/8/1985	1.2	3.2	2.3								
3/8/1985	1.5	4.1	1.9								

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
3/8/1985	1.5	3.8	2.1								
3/8/1985	2.1	4.3	1.5								
3/8/1985	2.1	3.9	1.9								
3/8/1985	2.7	4.9	0.9								
3/8/1985	3		0.2								
3/8/1985	3	4.2	1.7								
3/8/1985	3.7										
3/13/1985	0.7	2	3								
3/13/1985	0.9	3.1	2.7								
3/13/1985	1.2	3.5	2.3								
3/13/1985	1.8	4.3	1.2								
3/13/1985	2.4	4.9	1								
3/13/1985	3										
5/22/1985	0										2.88
6/13/1985	0										1.36
7/2/1985	0										1.06
7/22/1985	0										0.45
8/14/1985	0										0.76
9/4/1985	0										1.06
3/7/1986	1	2.1	4.7								
3/7/1986	1.5	2.9	3.1								
3/7/1986	2.1	3.8	1.4								
3/7/1986	2.7	4	0.9								
3/7/1986	3										
3/14/1986	0.9		4.6								
3/14/1986	0.9		4.7								
3/14/1986	1.2		2.4								
3/14/1986	1.5		1.7								
3/14/1986	1.5		3.7								
3/14/1986	1.8		1.2								
3/14/1986	1.8		1.9								

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
3/14/1986	2.1		1.1								
3/14/1986	2.1		1.6								
3/14/1986	2.4		0.8								
3/14/1986	2.4		1.2								
3/14/1986	2.7		0.7								
5/27/1986	0										3.03
6/19/1986	0										1.52
7/9/1986	0										1.67
7/28/1986	0										0.61
8/19/1986	0										0.61
9/9/1986	0										0.76
5/25/1987	0										1.52
6/16/1987	0										0.91
7/7/1987	0										1.21
7/27/1987	0										1.06
8/17/1987	0										1.06
9/9/1987	0										0.76
3/7/1988	0		4.2								
3/7/1988	0.6		2.4								
3/7/1988	1.2		2.2								
3/7/1988	1.8		1.7								
3/7/1988	2.4		1.2								
3/7/1988	2.9		0.4								
5/25/1988	0										2.73
6/14/1988	0										0.76
7/3/1988	0.3		3.6								
7/3/1988	0.6		2.7								
7/3/1988	0.6		3.6								
7/3/1988	0.7		3.6								
7/3/1988	1.2		2.6								
7/3/1988	1.8		2.4								

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
7/3/1988	2.4		2.2								
7/3/1988	3		1.4								
7/6/1988	0										0.61
7/27/1988	0										0.61
8/15/1988	0										0.91
9/6/1988	0										0.61
6/7/1989	0										1.94
6/28/1989	0										2.58
7/24/1989	0										0.45
8/31/1989	0										0.36
1/17/1990	0	0	4.7								
1/17/1990	1	4	5								
1/17/1990	2	4	6.5								
5/3/1990	0										2.52
6/8/1990	0										2.06
6/14/1990	0	23.9	9.1					10.16	0.227		2.18
6/14/1990	1	23.6	9.1						0.227		2.18
6/14/1990	2	20.3	9.8						0.230		2.18
6/14/1990	3	15.9	4.4						0.235		2.18
6/14/1990	3.65	14.3	1.4						0.254		2.18
7/2/1990	0										0.52
7/12/1990	0	22.9	4.8					9.81	0.225		
7/12/1990	1	23	4.5						0.225		
7/12/1990	2	2.31	4.4						0.225		
7/12/1990	3	21.4	1.4						0.265		
7/12/1990	3.65	16.5	0.5						0.355		
7/21/1990	0							9.81	0.225		0.79
7/25/1990	0										0.45
8/1/1990	0	24.9	13.8					10.1	0.227		0.30
8/1/1990	1	24.6	13.8						0.228		0.30
8/1/1990	2	24.2	12.8						0.229		0.30

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
8/1/1990	3	21.8	0.5						0.272		0.30
8/1/1990	3.65	18.6	0.2						0.384		0.30
8/16/1990	0										0.36
8/20/1990	0	21.4	8.4					8.71	0.247		0.45
8/20/1990	1	21.5	1.8						0.247		0.45
8/20/1990	2	21.6	1.5						0.246		0.45
8/20/1990	3	21.6	1.5						0.246		0.45
8/20/1990	3.7	19.5	0.3						0.415		0.45
9/5/1990	0										0.33
9/11/1990	0		7.6					9.32	0.241		0.30
9/11/1990	1		7.6						0.241		0.30
9/11/1990	2		6.3						0.242		0.30
9/11/1990	3		0.6						0.325		0.30
9/11/1990	3.3										0.30
9/25/1990	0										0.36
5/9/1991	0										1.16
5/28/1991	0										1.16
6/24/1991	0										0.94
7/8/1991	0										0.55
7/29/1991	0										0.27
8/29/1991	0										0.21
3/6/1992	0.6		10								
3/6/1992	0.6		10								
3/6/1992	1.2		8.3								
3/6/1992	1.2		9.8								
3/6/1992	1.8		2.7								
3/6/1992	1.8		5.6								
5/4/1992	0										1.91
5/21/1992	0	22.5	10.5					7.81	0.257		
5/21/1992	1	22.2	10.4						0.257		
5/21/1992	2	22.1	10.4						0.257		

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
5/21/1992	3	19.9	5.2						0.264		
6/4/1992	0	23.8	8.3	0.07		1.2	4.5	8.22	0.249		2.30
6/4/1992	1	23.1	8.3						0.251		2.30
6/4/1992	2	21.3	4.8						0.256		2.30
6/4/1992	3	19.1	0.8						0.258		2.30
6/17/1992	0	21.7	6.4	0.09		1.2	11	7.45	0.253		1.48
6/17/1992	1	21.9	5.9						0.252		1.48
6/17/1992	2	21.9	5.6						0.251		1.48
6/17/1992	3	22	5.7						0.251		1.48
7/2/1992	0	21.3	7.7	0.12		1.6	56	7.92	0.250		1.09
7/2/1992	1	21.4	7.3						0.250		1.09
7/2/1992	2	21.3	5.7						0.253		1.09
7/2/1992	3	21	5.1						0.229		1.09
7/16/1992	0	22.6	7	0.11		1.9	35	8.2	0.239		1.15
7/16/1992	1	22.6	7						0.239		1.15
7/16/1992	2	22.1	4.4						0.244		1.15
7/16/1992	3	21.7	0.6						0.249		1.15
7/16/1992	3.6	20.7	0.05						0.297		1.15
7/30/1992	0	23.2	14.6	0.16		2.4	98	8.68	0.229		0.85
7/30/1992	1	23.2	14.2						0.230		0.85
7/30/1992	2	22.6	9.1						0.238		0.85
7/30/1992	3	21.3	0.65						0.255		0.85
7/30/1992	4	20.8	0.2						0.278		0.85
8/13/1992	0	22.8	8.8	0.15		2.9	100	8.29	0.216		0.79
8/13/1992	1	22.9	8.8						0.216		0.79
8/13/1992	2	22.8	6.1						0.217		0.79
8/13/1992	3	22.4	5.7						0.218		0.79
8/13/1992	3.3	21.9	2.2						0.236		0.79
8/27/1992	0	20.9	4.6	0.15		2.3	92	7.68	0.218		0.73
8/27/1992	1	20.9	4.3						0.218		0.73
8/27/1992	2	21	3.3						0.218		0.73

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
8/27/1992	3	20.8	2.2						0.220		0.73
8/27/1992	3.3	20.8	2.1						0.261		0.73
9/4/1992	0	16.9	8.5	0.1		1.8	38	8.1	0.222		0.79
9/4/1992	1	16.8	7.7						0.223		0.79
9/4/1992	2	16.8	5.6						0.223		0.79
9/4/1992	3	16.7	2.5						0.223		0.79
9/4/1992	3.6	16.7	0.2						0.234		0.79
9/10/1992	0	17.5	8.3	0.01		0.33	7.6	8.01	0.225		0.76
9/10/1992	1	17.6	8.2						0.225		0.76
9/10/1992	2	17.6	7.8						0.225		0.76
9/10/1992	3	17.6	7.7						0.225		0.76
9/10/1992	3.3	17.6	0.3						0.249		0.76
10/20/1992	0										1.15
3/12/1993	0	0.6	6.6								
3/12/1993	0	-0.2	6.6								
3/12/1993	1	2.2	4.6								
3/12/1993	1	2.8	5.2								
3/12/1993	2	3.2	2.6								
3/12/1993	2	3.2	3.7								
3/12/1993	3	3.2	1.5								
3/12/1993	3	3.6	2.4								
3/12/1993	3.6	3.4	0.15								
6/2/1993	0										2.30
6/18/1993	0										2.82
7/1/1993	0										0.61
8/5/1993	0										0.82
8/13/1993	0										1.06
9/8/1993	0										0.48
10/4/1993	0										1.06
6/21/1994	0										0.76
7/8/1994	0										0.61

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
7/20/1994	0										0.61
8/5/1994	0										0.61
9/2/1994	0										0.45
5/15/1995	0										3.64
6/8/1995	0										2.45
7/14/1995	0										2.88
7/15/1995	0										0.48
8/4/1995	0										0.45
10/19/1995	0										1.21
10/27/1995	0	0.2	11								
10/27/1995	1	3	11								
10/27/1995	2	4	8.6								
10/27/1995	3	4.2	8.7								
4/1/1996	0	0.2	9								
4/1/1996	1	4.8	18.8								
4/1/1996	2	4.8	15.4								
4/1/1996	3	4.8	4.1								
4/1/1996	4	5.2	0.3								
5/30/1996	0										3.33
7/5/1996	0										1.52
7/20/1996	0										1.06
8/30/1996	0										0.61
4/21/1998	0	12	8.8	44		0.55	6	8.08			2.00
4/21/1998	1	12	8.7								2.00
4/21/1998	2	12	8.7								2.00
4/21/1998	3	12	8.4								2.00
4/21/1998	4	11.8	1								2.00
5/11/1998	0.1	20.13	10.17	34		0.61	3	8.57	0.283		
5/11/1998	1	20.05	10.13					8.6	0.282		
5/11/1998	2	19.85	10.14					8.5	0.284		
5/11/1998	3	18.93	6.76					7.47	0.286		

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
5/11/1998	3.6	18.54	0.28					7.09	0.305		
5/27/1998	0.2	22.61	10.94	46		0.97	27	8.99	0.270		2.00
5/27/1998	1	22.19	10.86					8.95	0.270		2.00
5/27/1998	2	20.71	8.78					8.68	0.270		2.00
5/27/1998	3	20.05	7.49					8.34	0.271		2.00
5/27/1998	3.5	19.92	1.18					7.67	0.280		2.00
6/10/1998	0.3	18.18	8.19	72.5		1.02		8.71	0.276		1.20
6/10/1998	1	17.72	8.27					8.84	0.274		1.20
6/10/1998	2	17.56	8.34					8.87	0.278		1.20
6/10/1998	3	17.53	8.18					8.8	0.275		1.20
6/10/1998	3.5	17.54	0.64					7.85	0.283		1.20
6/24/1998	0.3	23.9	10	45		0.91	10	9.42	0.245		1.70
6/24/1998	1	23.86	9.96					9.44	0.245		1.70
6/24/1998	2	22.41	7.99					9.12	0.256		1.70
6/24/1998	3	18.21	0.86					8.08	0.297		1.70
6/24/1998	3.5	17.76	0.62					7.79	0.356		1.70
7/8/1998	0.4	25.95	9.5	48		0.78	10	8.77	0.231		2.00
7/8/1998	1	25.67	9.46					8.76	0.230		2.00
7/8/1998	2	25.1	7.01					8.59	0.232		2.00
7/8/1998	3	21.22	2.03					7.68	0.290		2.00
7/8/1998	3.6	19.3	1.4					7.09	0.363		2.00
7/22/1998	0	27.2	8.6	57		1.32	45		0.251		0.90
7/22/1998	1	27.2	8.5						0.251		0.90
7/22/1998	2	27.1	8.5						0.251		0.90
7/22/1998	3	23	0.4						0.355		0.90
8/5/1998	0	22.8	5.12	98.9		2.03	58	8.21	0.255		0.50
8/5/1998	1	22.8	4.71					8.15	0.255		0.50
8/5/1998	2	22.79	4.57					8.13	0.252		0.50
8/5/1998	3	22.78	4.46					8.12	0.254		0.50
8/5/1998	3.3	22.33	0.79					7.13	0.351		0.50
8/18/1998	0.2	23.95	6.91	113		2.37	118	9.42	0.239		0.35

Table E-3. Historical Monitoring Data Provided by the Three Rivers Park District

Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
8/18/1998	1	23.95	6.84					9.42	0.239		0.35
8/18/1998	2	23.92	6.45					9.34	0.240		0.35
8/18/1998	3	21.85	0.48					7.63	0.281		0.35
8/18/1998	3.6	21.25	0.42					7.41	0.320		0.35
9/2/1998	0.1	23.38	8.3	145		2.28	97	9.07	0.230		0.30
9/2/1998	1	23.14	7.22					8.99	0.229		0.30
9/2/1998	2	23.1	6.56					8.93	0.231		0.30
9/2/1998	3	22.94	6.34					8.94	0.227		0.30
9/2/1998	3.7	21.84	0.88					7.36	0.355		0.30
9/16/1998	0.1	23.45	14.35	118			78	9.32	0.228		0.40
9/16/1998	1.1	23.16	14.49					9.35	0.227		0.40
9/16/1998	2	22.49	4.85					8.35	0.228		0.40
9/16/1998	3	21.8	0.53					7.86	0.242		0.40
10/6/1998	0.2	14.26	9.41	107.9		1.89	36	7.67	0.238		0.70
10/6/1998	1	14.26	9.3					7.72	0.237		0.70
10/6/1998	2	14.26	9.22					7.74	0.235		0.70
10/6/1998	3	14.23	9.13					7.74	0.235		0.70
10/6/1998	3.5	14.76	0.75					7.26	0.341		0.70
4/25/2001	0	12.2	10.4	56		0.9	7.5		0.200		1.25
4/25/2001	1	10.4	10.4						0.190		1.25
4/25/2001	2	10	10.4						0.190		1.25
4/25/2001	3	9.6	9.5						0.190		1.25
4/25/2001	4	9.2	5						0.190		1.25
5/16/2001	0	22.1	10.4	36		0.61	5.7	8.5	0.293		
5/16/2001	1.04	21.7	8.6					8.1	0.292		
5/16/2001	2.02	18.9	8.7					8.1	0.292		
5/16/2001	3.02	16.4	5.3					7.9	0.298		
5/16/2001	3.42	15.9	0.7					7.5	0.303		
5/29/2001	0			63		0.9	21.5				1.53
6/11/2001	0.1	23.8	13.5	41		0.9	20.3	8.5	0.257		1.25
6/11/2001	1.01	23.4	13.5					8.4	0.258		1.25

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Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
6/11/2001	2.01	18.8	14.1					8.4	0.263		1.25
6/11/2001	3.01	17.1	2.9					8	0.298		1.25
6/11/2001	3.74	16.2	0.5					7.4	0.388		1.25
6/26/2001	0.25	25.3	10.4	53		1.1	14.9	8.7	0.219		1.60
6/26/2001	1.01	25.3	10.5					8.8	0.220		1.60
6/26/2001	2.01	25.3	10.4					8.8	0.220		1.60
6/26/2001	3.01	21.1	1.3					8.5	0.242		1.60
6/26/2001	3.93	17.8	0.7					7.9	0.303		1.60
7/9/2001	0.14	28	12.2	42		0.9	13.6	9.1	0.199		1.00
7/9/2001	1.02	27.8	12.2					9	0.198		1.00
7/9/2001	2.02	25.2	11.8					9.1	0.202		1.00
7/9/2001	3.01	22	0.9					8	0.233		1.00
7/9/2001	3.78	19.4	0.6					7.5	0.297		1.00
7/24/2001	0.26	28.7	10.6	79		1.5	30.9	9	0.190		0.74
7/24/2001	1.02	28.6	10.4					9.2	0.190		0.74
7/24/2001	2.02	27.4	1.5					8.4	0.199		0.74
7/24/2001	3.01	23.4	0.6					7.7	0.245		0.74
7/24/2001	3.68	21.5	0.4					7.3	0.286		0.74
8/6/2001	0.08	32	12.9	78		1.5	41.1	9.3	0.247		0.75
8/6/2001	1.03	30.2	12.8					9	0.245		0.75
8/6/2001	2.02	27.6	1.6					8	0.258		0.75
8/6/2001	3.02	23.5	1					7.2	0.314		0.75
8/6/2001	3.52	22.6	0.7					6.8	0.361		0.75
8/22/2001	0			99		1.97					0.30
9/12/2001	0.1	21.5	9.3	92		1.85	57.2		0.245		0.38
9/12/2001	1.03	21.4	8.2						0.245		0.38
9/12/2001	2.04	20.8	4.6						0.247		0.38
9/12/2001	3.06	20.7	3.3						0.249		0.38
9/12/2001	3.57	20.6	1.4						0.264		0.38
10/3/2001	0.18	16.6	9.8	188		2.74	49.3	8.4	0.261		0.60
10/3/2001	1.01	16.6	9.8					8.4	0.260		0.60

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Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
10/3/2001	2.03	16.5	7.3					8.1	0.262		0.60
10/3/2001	3.03	16.2	2.8					7.7	0.268		0.60
10/3/2001	3.59	16.2	0.8					7.5	0.275		0.60
10/23/2001	0.11	10.7	10.4	70	7	2.05	35.5	8.1	0.247		1.70
10/23/2001	1	10.6	8.3					7.9	0.246		1.70
10/23/2001	2.02	10.5	7.8					7.9	0.245		1.70
10/23/2001	3.04	10.5	7.6					7.8	0.246		1.70
10/23/2001	3.4	10.5	3.5					7.4	0.246		1.70
4/30/2002	0.17	10.75	11.66	34		1.0	1	8.41	0.267		1.80
4/30/2002	1.037	10.49	11.5					8.43	0.266		1.80
4/30/2002	2.037	10.08	11.43					8.44	0.266		1.80
4/30/2002	3.018	10.01	11.32					8.41	0.266		1.80
4/30/2002	3.467	10.05	1.34					7.85	0.270		1.80
5/24/2002	0.136	16.39	12.92	43		0.0	2	9.36	0.224		2.90
5/24/2002	1.132	15.96	13.11					9.38	0.225		2.90
5/24/2002	2.084	15.75	13.06					9.41	0.226		2.90
5/24/2002	3.045	15.56	12.66					9.32	0.229		2.90
6/4/2002	0.123	18.2	11.12	32		0.7	7	9.56	0.219		3.20
6/4/2002	1.104	18.23	10.84					9.63	0.219		3.20
6/4/2002	2.088	18.22	10.6					9.62	0.218		3.20
6/4/2002	3.034	16.92	3.98					8.62	0.268		3.20
6/4/2002	3.36	16.65	0.53					8.04	0.269		3.20
6/17/2002	0.282	22.21	10.77	41		0.7	11	9.44	0.238		2.30
6/17/2002	1.035	22.22	10.61					9.53	0.238		2.30
6/17/2002	2.012	21.36	10.73					9.44	0.243		2.30
6/17/2002	3.012	18.35	2.43					8.65	0.265		2.30
6/17/2002	3.563	17.66	0.37					7.78	0.326		2.30
7/9/2002	0.228	29.19	12.85	85	16	1.6	56	9.7	0.232		0.90
7/9/2002	1.018	28.61	11.9					9.83	0.227		0.90
7/9/2002	2.016	26.84	0.89					9.07	0.212		0.90
7/9/2002	3.031	20.67	0.79					8.47	0.260		0.90

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Date	Depth m	Temp ° C	DO mg/L	TP µg/L	SRP µg/L	TN mg/L	Chl-*a* µg/L	pH	SpCond mS/cm	CL mg/L	Secchi m
7/9/2002	3.66	18.86	0.72					8.11	0.292		0.90
7/23/2002	0.272	27.14	10.39	102	38	1.2	36	9.41	0.232		0.88
7/23/2002	1.029	26.86	10.36					9.6	0.232		0.88
7/23/2002	2.035	26.46	8.73					9.56	0.230		0.88
7/23/2002	3.017	22.22	0.91					8.28	0.273		0.88
7/23/2002	3.8	20.38	0.65					7.8	0.333		0.88
8/6/2002	0.234	24.1	6.3	142		1.4	50	8.07	0.225		0.70
8/6/2002	1.056	24.13	5.73					8.49	0.226		0.70
8/6/2002	2.062	24.13	5.66					8.55	0.226		0.70
8/6/2002	3.03	24.13	5.53					8.59	0.226		0.70
8/6/2002	3.94	21.82	0.25					7.26	0.367		0.70
8/20/2002	0.176	22.9	18.86	173	5	2.0	126	8.8	0.202		0.39
8/20/2002	1.066	22.83	19.7					9.14	0.201		0.39
8/20/2002	2.02	22.64	18.86					9.25	0.201		0.39
8/20/2002	3.013	21.92	4.21					8.55	0.203		0.39
8/20/2002	3.974	21.63	0.36					7.87	0.233		0.39
9/10/2002	0	25	10.2	153	2	2.0	114		0.221		0.35
9/10/2002	1	25	9.5						0.219		0.35
9/10/2002	2	23.8	0.1						0.222		0.35
9/10/2002	3	22.5	0.1						0.226		0.35
9/10/2002	4	22	0.1						0.270		0.35
9/30/2002	0.261	16.62	8.54	127	2	2.1	66	7.57	0.226		0.48
9/30/2002	1.039	16.5	7.97					7.55	0.226		0.48
9/30/2002	2.056	16.32	7.34					7.55	0.226		0.48
9/30/2002	3.024	16.21	6.9					7.48	0.226		0.48
9/30/2002	3.894	16.19	1.7					6.85	0.265		0.48

Table E-4. Phytoplankton in the Top 2 Meters of Hyland Lake

		Units of Phytoplankton/mL								
DIVISION	**TAXON**	**5/15/00**	**6/5/00**	**6/19/00**	**7/5/00**	**7/18/00**	**8/7/00**	**8/21/00**	**9/6/00**	**10/11/00**
CHLOROPHYTA (GREEN ALGAE)	*Ankistrodesmus falcatus*	234	84	0	0	0	0	0	0	0
	Chlamydomonas globosa	8706	4088	312	1484	0	429	195	117	234
	Cosmarium sp.	0	0	0	39	0	0	0	0	0
	Oocystis parva	39	0	0	39	42	0	0	39	0
	Schroederia Judayi	0	0	0	1405	0	39	0	78	0
	Scenedesmus quadricauda	78	84	0	0	0	0	0	0	0
	Scenedesmus sp.	78	0	0	0	0	234	0	0	0
	Selenastrum minutum	78	42	0	0	0	0	0	0	0
	CHLOROPHYTA TOTAL	9213	4298	312	2967	42	703	195	234	234
CHRYSOPHYTA (YELLOW-BROWN ALGAE)	**CHRYSOPHYTA TOTAL**	0	0	0	0	0	0	0	0	0
CYANOPHYTA (BLUE-GREEN ALGAE)	*Anabaena affinis*	0	0	39	117	0	0	195	117	0
	Anabaena flos-aquae	0	0	2694	1288	0	0	0	0	0
	Anabaena spiroides v. crassa	0	42	0	0	0	78	78	0	0
	Anabaenopsis raciborski	0	42	0	0	0	0	3162	16826	8979
	Aphanizomenon flos-aquae	0	0	625	820	1728	10775	39	390	234
	Merismopedia tenuissima	0	0	0	0	0	39	0	39	0
	Microcystis aeruginosa	0	0	0	508	1433	2264	2616	781	625
	Microcystis incerta	0	0	0	0	42	0	0	0	0
	Oscillatoria limnetica	0	0	0	0	0	0	351	1718	0
	Phormidium mucicola	0	0	0	0	801	1054	273	0	0
	CYANOPHYTA TOTAL	0	84	3357	2733	3203	13156	6442	19871	9838

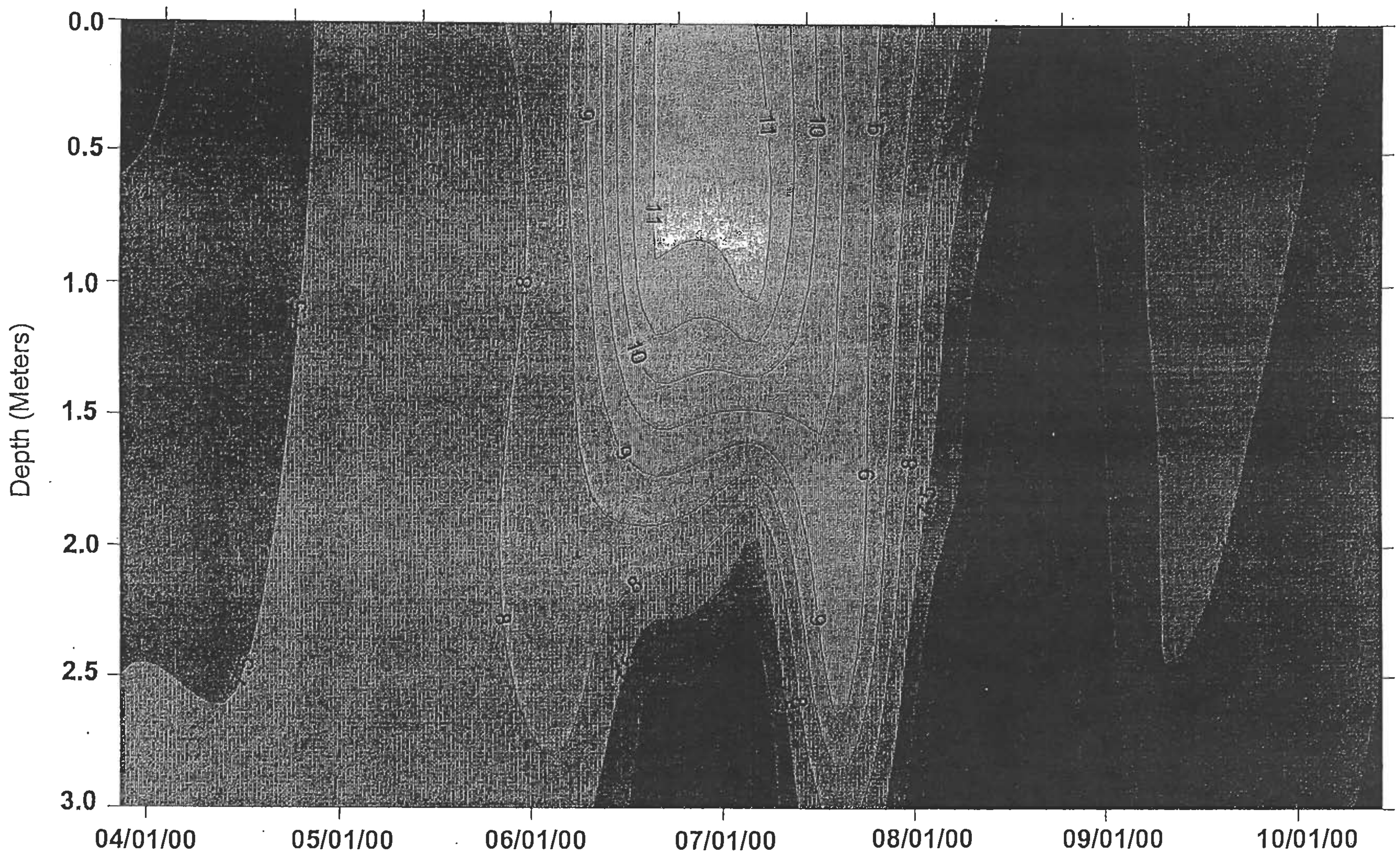
Table E-4. Phytoplankton in the Top 2 Meters of Hyland Lake

		Units of Phytoplankton/mL								
DIVISION	**TAXON**	**5/15/00**	**6/5/00**	**6/19/00**	**7/5/00**	**7/18/00**	**8/7/00**	**8/21/00**	**9/6/00**	**10/11/00**
BACILLARIOPHYTA (DIATOMS)	*Cocconeis placentula*	39	0	0	0	0	0	0	0	0
	Cymbella sp.	39	0	0	0	0	0	0	0	0
	Stephanodiscus Hantzschii	78	0	0	0	0	0	0	0	0
	BACILLARIOPHYTA TOTAL	156	0	0	0	0	0	0	0	0
CRYPTOPHYTA (CRYPTOMONADS)	*Cryptomonas erosa*	4958	2655	390	468	0	390	39	0	1249
	CRYPTOPHYTA TOTAL	4958	2655	390	468	0	390	39	0	1249
EUGLENOPHYTA (EUGLENOIDS)	**EUGLENOPHYTA TOTAL**	0	0	0	0	0	0	0	0	0
PYRRHOPHYTA (DINOFLAGELLATES)	*Ceratium hirundinella*	0	0	0	78	0	0	0	0	0
	PYRRHOPHYTA TOTAL	0	0	0	78	0	0	0	0	0
	TOTALS	14328	7037	4060	6246	3245	14250	6676	20106	11322

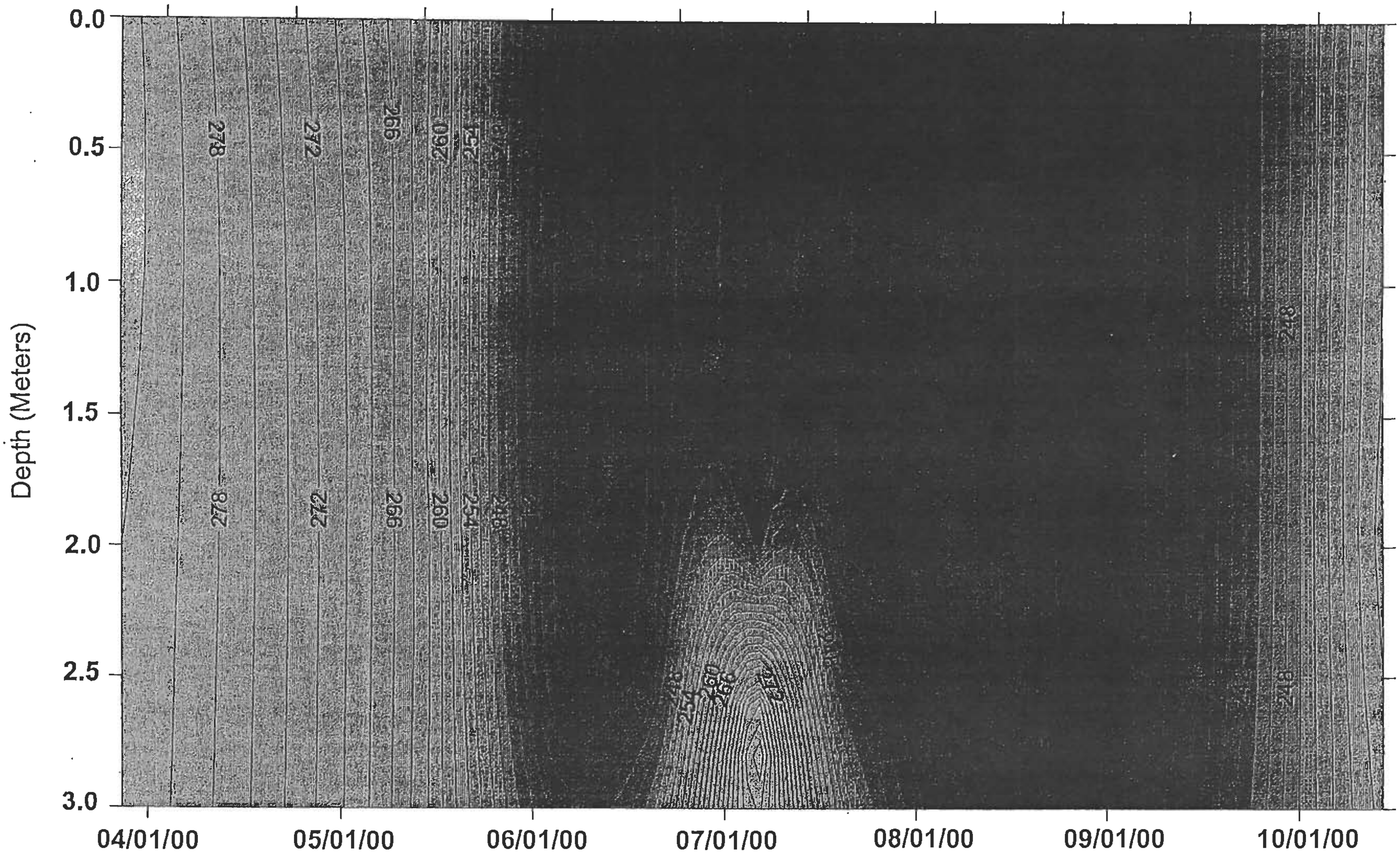
Table E-5. Zooplankton in the Top 2 Meters of Hyland Lake

		Number of Zooplankon/m^2							
DIVISION	**TAXON**	**5/15/00**	**6/5/00**	**6/19/00**	**7/5/00**	**7/18/00**	**8/7/00**	**8/21/00**	**9/6/00**
CLADOCERA	*Daphnia galeata mendotae*	2,204	0	9,111	15,088	2,376	2,229	0	7,164
	Diaphanosoma sp.	0	2,425	15,945	23,709	40,389	31,204	61,771	33,433
	Bosmina sp.	249,093	29,098	20,501	12,932	57,019	4,458	0	2,388
	Chydorus sp.	28,657	12,124	34,168	32,331	178,186	269,691	194,817	1,186,865
	Ceriodaphnia sp.	0	0	0	38,797	42,765	0	2,376	0
	Simocephalus sp.	0	0	6,834	0	0	0	0	0
	Leptodora kindtii	0	0	0	0	2,376	0	0	0
	SUBTOTAL	**279,954**	**43,646**	**86,558**	**122,856**	**323,110**	**307,582**	**258,964**	**1,229,850**
COPEPODA	*Nauplii*	116,831	196,409	300,675	308,219	168,683	49,035	76,026	64,478
	Cyclops sp.	4,409	9,699	50,112	21,554	2,376	0	0	4,776
	Mesocyclops sp.	8,817	12,124	2,278	2,155	33,261	13,373	4,752	2,388
	Diaptomus sp.	119,036	38,797	20,501	8,622	11,879	17,831	7,127	11,940
	SUBTOTAL	**249,093**	**257,029**	**373,566**	**340,549**	**216,199**	**80,239**	**87,905**	**83,582**
ROTIFERA	*Kellicottia sp.*	0	0	0	0	0	0	2,376	2,388
	Conochilus sp.	242,480	29,098	102,503	4,311	0	0	0	0
	Keratella cochlearis	806,797	484,960	621,851	349,171	7,127	53,493	477,538	394,030
	Polyarthra vulgaris	2,204	33,947	47,835	0	0	0	0	0
	Brachionus sp.	0	0	0	109,924	0	0	0	0
	Trichocerca sp.	0	0	0	0	0	0	7,127	23,881
	SUBTOTAL	**1,051,481**	**548,004**	**772,188**	**463,406**	**7,127**	**53,493**	**487,042**	**420,298**
	TOTAL	**1,580,528**	**848,679**	**1,232,312**	**926,812**	**546,437**	**441,313**	**833,910**	**1,733,731**

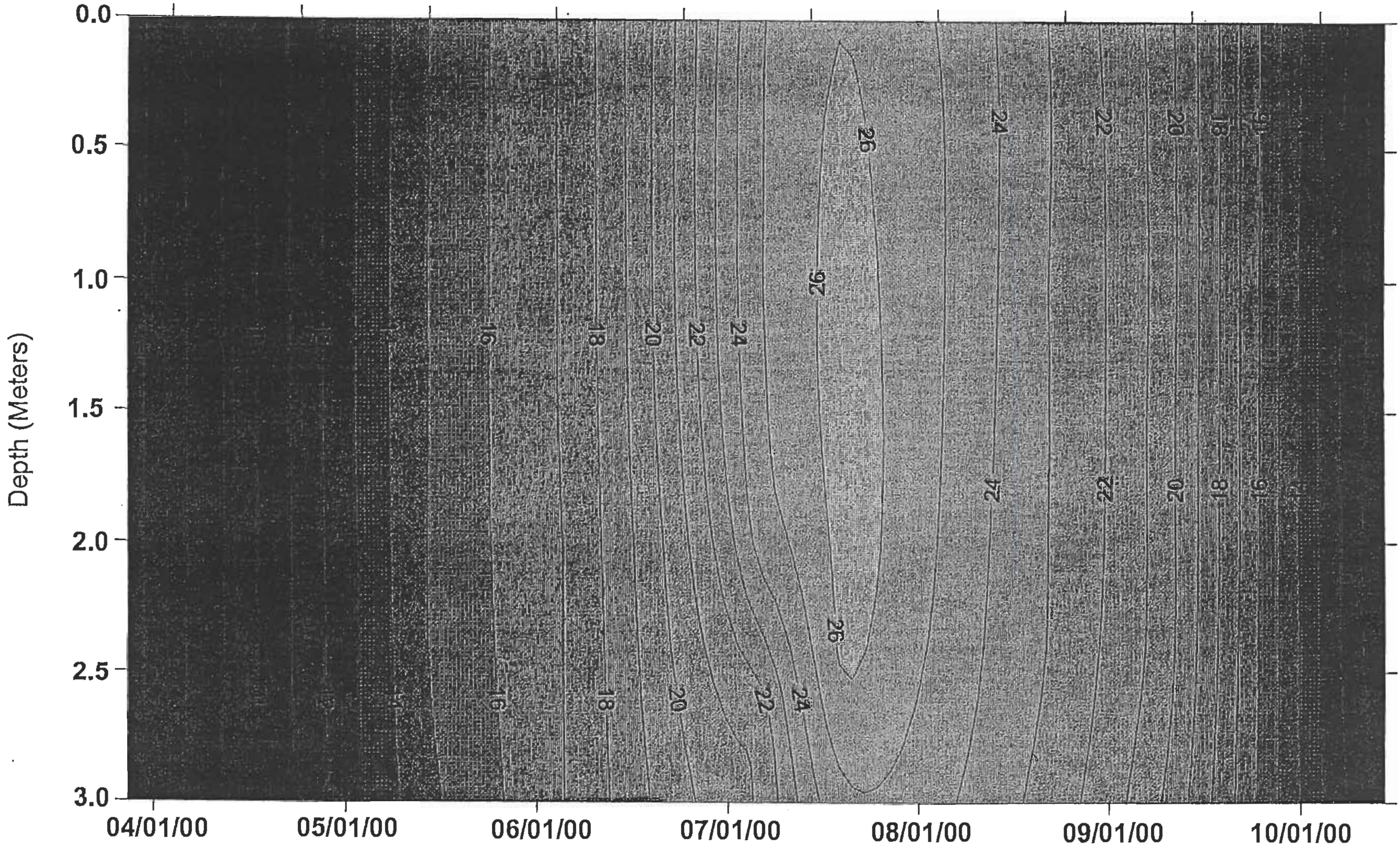
Hyland Lake (2000)
Dissolved Oxygen Isopleth (mg/L)



Hyland Lake (2000)
Specific Conductance Isopleth (umhos/cm @ 25°C)



Hyland Lake (2000)
Temperature Isopleth (°C)



Hyland Lake (2000)
Total Phosphorus Isopleth (µg/L)