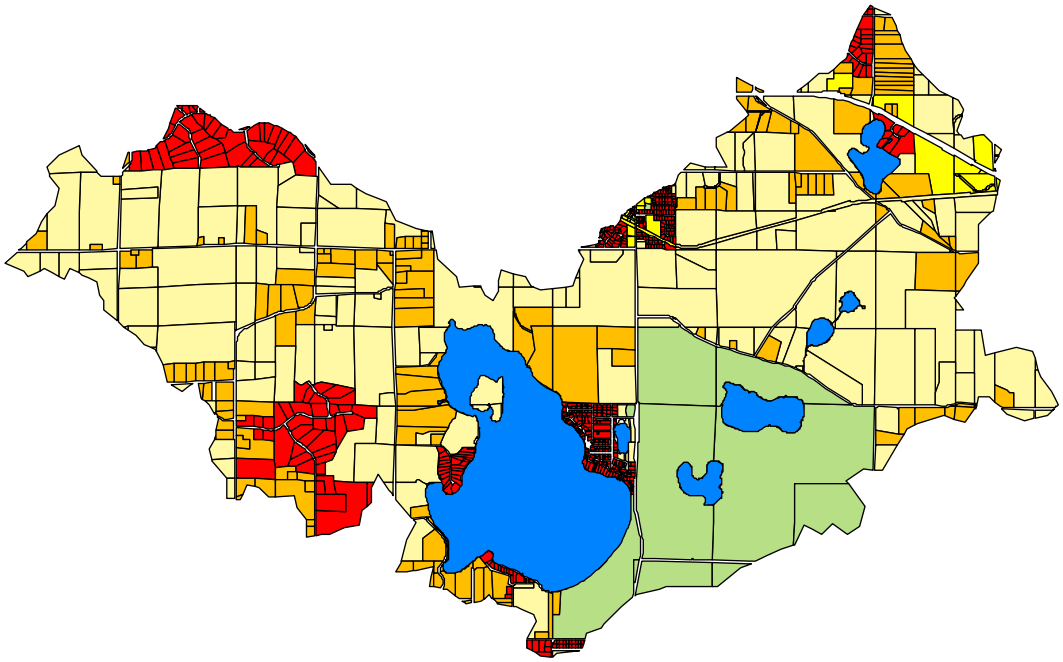
Lake Independence

Diagnostic Feasibility Report



Three Rivers Park District – Water Resources Management
March 2004

Lake Independence
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Prepared by

Three Rivers Park District - Water Resources Management
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ACKNOWLEDGEMENTS

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Finally we wish to thank John Jereczek, Jayson Olson, Ethan Jahnke, Angie Archer, and Laura Gilbertson for their assistance in the field and laboratory.

EXECUTIVE SUMMARY

Lake Independence is an 851-acre lake located approximately 15 miles west of downtown Minneapolis, Minnesota. The lake is located within the municipal boundaries of two cities, Independence and Medina. As with many lakes in the Twin Cities metropolitan area, it is used heavily for recreation and is prized for its aesthetic value by homeowners. Over the past several decades, the lake has experienced increasingly impaired water quality that has reduced the lake's recreational and aesthetic value. In 2003, the lake was designated as an impaired water body by the Minnesota Pollution Control Agency (MPCA) based upon its recent water quality history (MPCA 2002 303(d) list).

To better understand the factors that have been affecting the water quality of Lake Independence, the Three Rivers Park District initiated a comprehensive monitoring plan in 1990. This included biweekly monitoring of in-lake conditions during ice-free periods from 1990 to 2003, and intensive stream monitoring in 1996, 1997 and 2001 at a majority of the sites where water flowed into the lake. In addition, computer models were developed and calibrated with actual field data. These calibrated models were used to estimate additional inflow of water and pollutants from sources that were not monitored and to estimate the relative contribution of pollutants from given land use types.

The data collected indicated that Lake Independence had regularly experienced impaired water quality (as defined with user surveys conducted by the MPCA, Metropolitan Council, and Three Rivers Park District) during the monitored period. The inflow monitoring results and computer modeling identified major sources of pollutants within the Lake Independence watershed and allowed for the characterization of flow volumes, pollutant concentrations, and overall loadings for each inflow site. This information was used to develop a list of potential management activities to address each identified source of pollutants. Where possible, alternative management activities were provided so that any management plan could include activities that would likely offer the most reduction in pollutant loading per dollar spent.

The primary goal of this diagnostic feasibility study was to develop a list of potential management actions and estimate their associated costs, effectiveness, expected longevity, and technical feasibility based upon the observed field data, computer model predictions, and characteristics of each potential source. Development of an actual management plan to improve the water quality of Lake Independence will require cooperation between all concerned parties to evaluate and select the best management alternatives based upon the contents of this report and any additional information deemed to be pertinent.

Section 1: Introduction and Project Background

1.0 Introduction and History

1.1 Project Purpose
The Lake Independence Improvement Project was initiated to improve the overall quality of Lake Independence as a recreational, ecological, and aesthetic resource. Lake Independence was included on the Minnesota list of impaired waters in 2003 based upon ten years of water quality data that showed elevated phosphorus levels and overall poor water quality. The goal of the project is to reduce in-lake nutrient levels sufficiently to improve overall water quality such that contact recreation can be fully supported and to improve the overall ecological and aesthetic quality of the lake.

1.2 Project Description
Lake Independence is an 851-acre lake located in the west central portion of Hennepin County, approximately 15 miles west of downtown Minneapolis, Minnesota. The lake is within the Pioneer-Sarah Creek Watershed, and is also within the municipal boundaries of the City of Independence and the City of Medina. The lake has a drainage area of approximately 7,720-acres, the majority of which is currently used for crop and livestock agriculture. However, the watershed is currently undergoing urbanization, with typical developments consisting of large, 2.5 to 5 acre, single family residential lots.

Three intermittent streams, convey the majority of runoff water from the watershed to the lake. A large stream enters Lake Independence on the east side of the lake after flowing through Baker Park Reserve and under County Road 19, approximately two miles south of Loretto. This stream conveys water from the City of Medina and includes overflow water from Peter, Spurzem and Half Moon Lakes. Two large streams discharge runoff water from mainly agricultural land in the City of Independence west of the lake. Both streams discharge into the bay north of the island. A smaller drainage area discharges into the north lobe of the outlet bay at the south west side of the lake. In addition, Lake Independence receives overflow water from Ardmore Lake, located on the northeast side of Lake Independence. Lake Independence forms the headwaters of Pioneer Creek and overflows to the creek at the southwest corner of the lake

1.3 Project Participants
The Lake Independence Project has been a cooperative effort involving the Three Rivers Park District (formerly Hennepin Parks), the Pioneer-Sarah Creek Watershed Management Commission, and the Lake Independence Citizens Association (LICA). In addition, valuable information was provided by municipalities within the Lake Independence watershed.

1.4 Summary of Previous Studies and Monitoring
1.4.1 Assessment of Horse Farms and Feedlots in Rural Hennepin County
In 1997, the Hennepin Conservation District completed an inventory of feedlots and horse farms in rural Hennepin County, utilizing aerial photographs and field surveys. The inventory documented the number of animals, the type of animal, and distance to water. The survey located 710 feedlots and horse farms in Hennepin County, and estimated that a total of 128,298 tons of manure per day were produced in the county.

1.4.2 Assessment of Livestock Agriculture

In 1999, the Three Rivers Park District conducted an assessment of the effects of livestock agriculture within the Lake Independence watershed on phosphorus loading to Lake Independence. Parcels used for livestock agriculture were identified from the Hennepin Conservation District survey, and livestock numbers on each parcel were confirmed by Three Rivers Park District staff. Geographic Information System software was used to digitize each identified site from aerial photographs. The homestead, wetland and forested areas on each land parcel were subtracted from total parcel acreage to estimate upland available for cropland and livestock pasture. This allowed Three Rivers Park District staff to calculate livestock density ratings based on available manure disposal areas. The analysis showed that the drainage areas on the west side of the lake had a large number of high density livestock operations. Using conservative literature values for phosphorus export from grazing areas and feedlots, computer models were developed to estimate the expected total phosphorus export from livestock areas within each subwatershed (Coote et al. 1978, Chichester et al. 1979, Krebs and Golley 1977, Olness et al. 1980, Correll et al.1977, Menzel et al. 1978).

Section 2: Diagnostic Feasibility Study

A diagnostic feasibility study was initiated in 1996 by the Three Rivers Park District and lakeshore property owners to address the issue of water quality degradation in Lake Independence. The intended purpose was to identify the sources of nutrients entering the lake and assess the potential to improve and protect water quality by investigating management alternatives and an analyzing their feasibility, effectiveness, longevity, and cost. This required several years of monitoring to characterize sources of inflow, assess the water quality and biological condition of Lake Independence, and determine watershed characteristics such as land use, soil types, and surface hydrology.

2.1 Methods

2.1.1 Lake and Stream Monitoring

Three Rivers Park District staff monitored Lake Independence biweekly during the ice-free periods each year from 1990 to 2002, with the exception of 1992, for dissolved oxygen, temperature, pH, total phosphorus, dissolved phosphorus, total nitrogen, chlorophyll, and water clarity. In addition, an automated lake monitoring raft (Remote Underwater Sampling Station (RUSS)) was deployed over the deepest part of the lake in 1999 and 2000. The RUSS collected measurements of temperature, oxygen, pH, and conductivity every six hours at one meter intervals from the surface to the bottom of the lake. The readings collected by the RUSS were used to assess the importance of internally recycled phosphorus in reducing the water quality of Lake Independence.

Three major inlet streams were monitored in 1996, 1997, and 2001 to characterize the nutrient loading to Lake Independence at each site. Inflow monitoring was conducted using computerized flow loggers and automated sampling equipment. This monitoring produced continuous flow measurements and event mean concentrations based on flow-weighted sample collection. Flow calculation at each site was calibrated against custom rating curves developed by Three Rivers Park District staff using hand-held flow measuring equipment and flow channel dimensions.

2.1.2 Aquatic Macrophyte Surveys

The Three Rivers Park District surveyed the aquatic plant community of Lake Independence in 1993, 1995, and 2003. The 1993 and 1995 surveys were conducted using a weed-hook transect method (Jessen and Lound 1962). Transects were defined as straight lines extending from random points along the shoreline toward the middle of the lake. At designated points along each transect based upon water depth and distance from the last sample site, four hook tosses were completed and retrieved plant species were identified and assigned a density rating. Transect points along shore were identified using global positioning system (GPS) equipment. Identical transect locations were used in both 1993 and 1995. The 2003 survey was conducted using a random point-intercept sampling method (Madsen et al. 1989). In this method, the lake was divided into four sections of equal area, each containing 50 randomly generated points. At each of these points, three hook tosses were completed and the plant species retrieved were identified and assigned a density rating.

2.1.3 Watershed Assessment

The Lake Independence watershed was delineated using USGS orthoquad aerial photographs and desktop Geographic Information System software. Delineated areas were verified using ground-truthing methods, including walking and windshield surveys. Land use information was obtained in 1999 from each individual municipality within the Lake Independence watershed.

2.1.4 Data Management and Quality Control/Quality Assurance

Field data collected by automated flow loggers were downloaded periodically in the field using a laptop computer and the database of flow readings was managed using Flowlink-4 software. Additional databases of sample analysis results were maintained using Microsoft Excel spreadsheets and Access database software. Databases were regularly backed up to prevent the loss of data.

To ensure the accuracy of inflow measurements, probe-recorded levels were regularly calibrated against installed staff gauges at each monitored site and manual flow measurements were used to develop custom level/discharge rating curves. Field samples and measurements recorded by Three Rivers Park District staff were collected according to the *Three Rivers Park District Water Resources Quality Assurance Plan*.

2.1.5 Computer Modeling

The data collected as a part of the monitoring programs conducted by the Three Rivers Park District were used to develop FLUX, BATHTUB (Walker 1996), MINLEAP (Wilson and Walker, 1989) and LTROPHIC computer models to simulate Lake Independence and its watershed. These computer models were calibrated to reflect the observed conditions and then used to predict the effects of potential management activities on runoff, nutrient loading, and in-lake water quality. The computer model predictions were used to assess the potential effectiveness some of the management options listed later in this report.

2.2 Results

2.2.1 Soils and Geology

Lake Independence is located in an area where the soil association has been determined to be Erin-Kilkenny-Peaty muck. This soil association is characterized by gentle undulating areas with some larger hills, medium to moderately-fine textured soils of glacial origin, and areas of level organic soils (USDA, SCS 1974). This soil association is noted as having severe limitations for the use of onsite sewage disposal systems (septic tanks) due to low percholation rates, a high shrink-swell potential, and generally high water table conditions. The soils within the Lake Independence watershed are predominantly Erin and Hayden loams with some clay loams. In addition, large areas of marsh and peaty muck exist in low areas immediately east and west of Lake Independence. The near-shore areas immediately adjacent to Lake Independence are predominantly Erin loam with some organic marsh soils along the western shoreline.

The topographic elevations in the area range from 955 ft to 1080 feet with the highest elevations in the eastern areas of the watershed within Baker Park Reserve, and the lowest areas predominantly located in the area immediately west of Lake Independence.

2.2.2 Climatological Summary

Average annual precipitation for the Lake Independence area is 29 inches (74 cm), and the average growing season is 152 days in length. The summer of 2002 was exceptionally wet. This resulted in higher than normal amounts of runoff throughout the western Twin Cities metropolitan area (based upon flow data collected by Three Rivers Park District).

2.2.3 Watershed Characteristics

The watershed surrounding Lake Independence is predominantly used for crop and livestock agriculture, but also includes residential developments, commercial areas, industrial plots, wetlands, and parkland (figure 1). The current land-use patterns will likely shift dramatically over the next ten to fifteen years as new residential and commercial developments spring up and displace the predominant agricultural areas. The western metropolitan area has experienced very rapid development in recent years, and new residential developments are beginning to appear within and adjacent to the Lake Independence watershed.

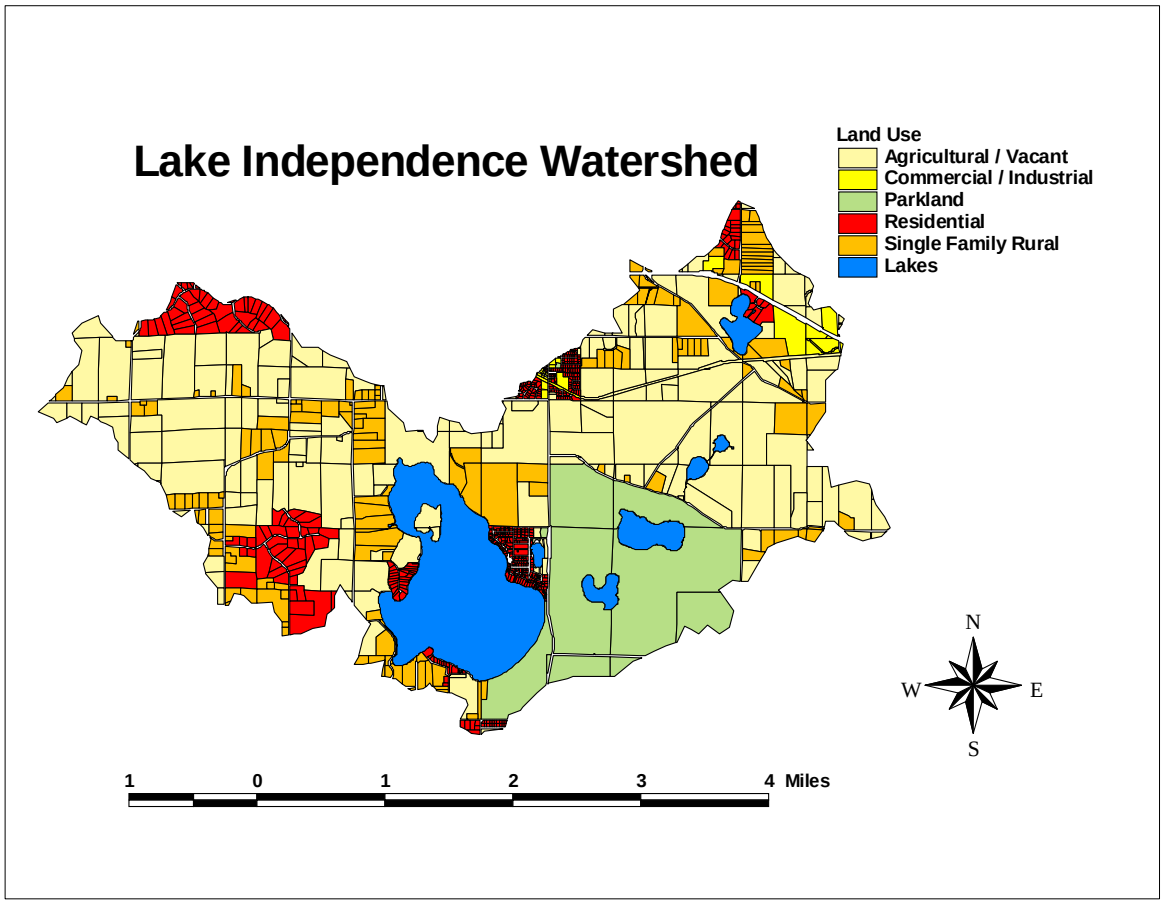


Figure 1. Map detailing the land-use within the Lake Independence watershed in 1999.

The shore of Lake Independence is fairly developed but large stretches of natural shoreline still exist. There are just under 200 permanent and seasonal homes along its shoreline. Most of the current residential developments along the southern and eastern shores of Lake Independence are connected to public sewer systems associated with the cities of Maple Plain or Loretto. Sanitary sewers from these residential areas flow to treatment facilities, but street runoff from these areas drains into Lake Independence or associated ponds untreated. Other residential areas in the watershed generally use septic tank systems for sewage disposal.

2.2.4 Description of Lake Independence

Recreational Use

Lake Independence has generally experienced moderate to heavy recreational use in the last twenty years. In addition to use by shoreline homeowners, the lake is regularly visited by many people from the surrounding metropolitan and rural areas. The majority of these visitors access Lake Independence via Baker Park Reserve located along a one-mile stretch of shoreline at the southeastern corner of the lake. The park offers opportunities for swimming, fishing, camping, and boating. In addition, the lake is used heavily for ice fishing during the winter.

Morphometry

Lake Independence is a relatively deep lake that has 5 major inflow points and one outflow. Some groundwater likely enters the lake, but the majority of inflow water comes from precipitation running off of the surrounding watershed. Table 1 summarizes the lake's physical measurements, or morphometry and figure 2 shows the depth contours of Lake Independence.

Table 1. Lake Independence morphometry.

Area	344 *Hectares*	851 *acres*
Shoreline Length	11.4 *Km*	7.08 *miles*
Volume	18.6 million M^3	15100 *acre-feet*
Max Depth	18 *Meters*	58 *feet*
Mean Depth	5.4 *Meters*	17.8 *feet*
Residence Time	6.4 *years*	6.4 *years*

Figure 2. Map of Lake Independence showing depth contours.

Water Quality

Lake Independence has been monitored biweekly by the Three Rivers Park District since 1990 with the exception of 1992 when no monitoring occurred. The monitoring data indicated that there has been no significant trend of improving or declining water quality in the past ten years, but when compared to other similar area lakes and computer model predictions, Lake Independence has consistently exhibited poor water quality (table 2). Figure 3 shows the typical water quality variations that occurred in 2000. This normal annual variation can make it difficult to discern long-term water quality trends. When looking for such trends, it is most useful to compare the annual summer averages for various water quality parameters over a period of several years (figure 4).

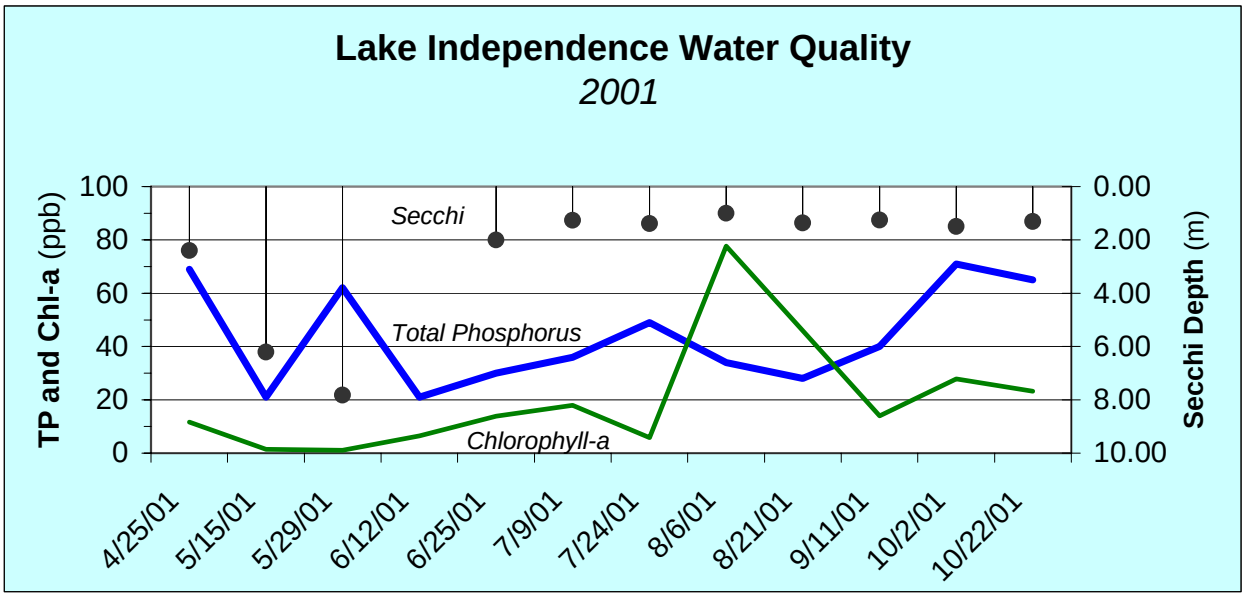


Figure 3. Graph showing typical variation in total phosphorus, chlorophyll-a, and secchi transparency during the 2001 monitoring season.

To better define *impairment*, the Minnesota Pollution Control Agency (MPCA), Metropolitan Council, and Three Rivers Park District conducted lake user surveys to correlate people's impressions of a lake's usability to scientifically measured water quality data. The results of these surveys indicated that 75% of the people surveyed felt comfortable swimming in metro-area lakes that had mean summer total phosphorus levels at or below 36 ppb. While there is no inherent health risk at higher phosphorus levels, the 36 ppb threshold was used to define the level where phosphorus begins to impair recreational usability of a lake. For this reason, a target phosphorus concentration of 36 ppb has been adopted by the Three Rivers Park District Board as the goal for Lake Independence. This target is 11 ppb lower than the average observed summer concentration in 1990-2002, and would represent a 23% drop in the mean summer phosphorus level of Lake Independence.

A computer model (MINLEAP) was used to predict the expected water quality of Lake Independence if it had experienced "typical" nutrient inflows similar to those measured for unimpaired lakes in east central Minnesota. The model predicted significantly better water quality than what had been observed in Lake Independence during the twelve-year monitoring period (table 2). This was another indicator that suggested that the lake has been experiencing impaired water quality.

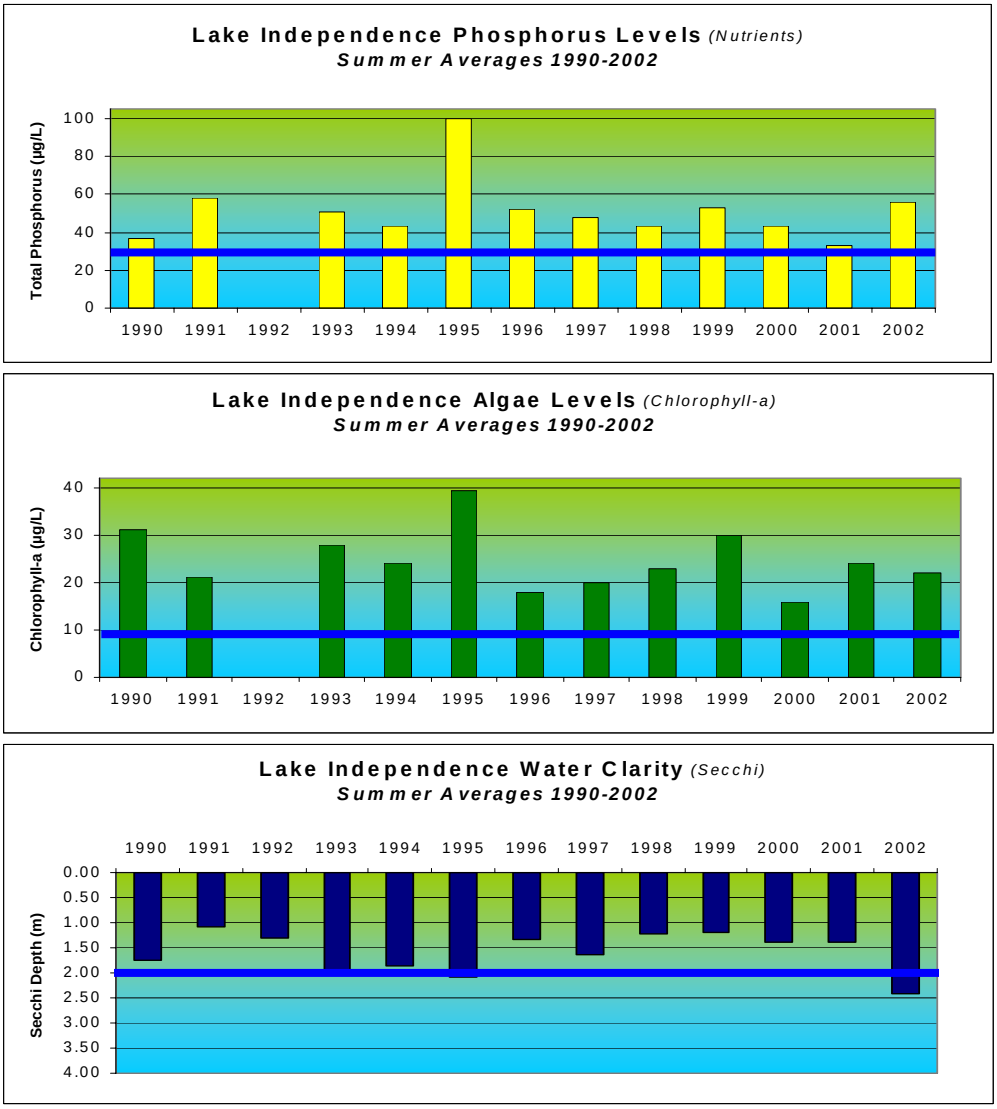
	OBSERVED	***PREDICTED (MINLEAP)***
Water Clarity (secchi)	1.6 meters (5.25 feet)	*2.0 meters (6.6 feet)*
Chlorophyll-a	25.0 *ppb*	9.7 *ppb*
Total Phosphorus	47 *ppb*	31 *ppb*
Total Nitrogen	1324 *ppb*	NA
Trophic State Index	58.4	52.3

Table 2. Summary of Lake Independence average summer water quality from 1990 to 2002.

The model prediction of 31 ppb for phosphorus is relatively close to the recommended target concentration of 36 ppb. This means that the target concentration is likely attainable based upon geographic location and lake morphometry, but the technical and financial feasibility of management alternatives need to be determined to truly assess how easily this target goal can be achieved.

The graphs in figure 4 show the annual summer means for total phosphorus, chlorophyll-a, and water clarity from each monitored year during the period from 1990 to 2002. In addition, each plot has a line that indicates the values predicted by MINLEAP based upon geographic location and lake morphometry. The current estimated phosphorus load to Lake Independence is 3858 pounds per year (2339 external, 1519 internal). To reach the goal of 36 ppb for in-lake phosphorus, the LTROPHIC model predicts that the annual phosphorus load to Lake Independence would need to be reduced to 2976 pounds. This translates to a reduction of 882 lbs/yr, or 23% of the current estimated total annual load.

Figure 4. Graphs showing the average annual summer phosphorus (0-2 meter total phosphorus), algae level (0-2 meter chlorophyll-a), and water clarity (secchi depth) for Lake Independence; 1990 to 2002. The blue line in each graph marks the predicted level for each parameter based upon typical nutrient inflow for the bioregion (*MINLEAP model*).



Fisheries

Lake Independence supports a good assemblage of fish and is alternately stocked with walleye and muskellunge annually by the Minnesota Department of Natural Resources. The lake also supports perch, bluegill, largemouth bass, bowfin, carp, pumpkinseed sunfish, hybrid sunfish, and yellow bullhead. The DNR lists the lake as having an excellent fishery for black crappie and northern pike based upon fish surveys conducted in 2001. Maintaining a high quality fishery should remain a high priority since the lake is heavily used by anglers.

Aquatic Macrophytes

Lake Independence supports an aquatic plant community that includes coontail, bladderwort, bullrush, flat-stem pondweed, sago pondweed, white water lily, bushy pondweed, northern watermilfoil, elodea, and two exotic nuisance species; curlyleaf pondweed and Eurasian watermilfoil. Curlyleaf pondweed has likely been present in the lake since the 1950's and infests most shallow areas of the lake, but Eurasian watermilfoil was not reported in Lake Independence until 1989. In the past 15 years, the exotic milfoil has spread substantially and now infests most of the shallower areas of the lake.

Curlyleaf pondweed grows early in the year and usually forms dense growth by late spring but then naturally dies off by mid July. This die-off releases a substantial amount of nutrients into the water and may lead to an overall decline in water clarity. Milfoil generally begins to form dense surface growth by mid-summer, but does not experience the same level of summer die-off as curlyleaf pondweed. Both of these nonnative plant species can lead to impaired usability for motorboats due to very dense growth at the surface of the lake and they regularly displace native plant species through shading effects, thus decreasing the quality of available fish habitat and food sources for wildlife.

In order to better track the effects of the curlyleaf and milfoil infestations, the Three Rivers Park District surveyed the aquatic plant community of Lake Independence in 1993, 1995, and 2003 (table 3). These surveys indicated that curlyleaf pondweed and Eurasian watermilfoil consistently ranked in the top three most common plants in Lake Independence. These surveys were conducted in the late summer of each year after the curly-leaf pondweed had begun to die off. Additional spring plant surveys were conducted in 1998 and 1999 to document the curly-leaf growth. These surveys showed that plants were generally only present in water shallower than 8.0 feet (figure 5). Under conditions of high water quality, plants would be expected to grow out to areas that were up to 16 feet deep. The lack of plant growth in areas deeper than 8.0 feet is most likely the result of shading that has occurred from the poor summer water clarity in recent years. When water clarity is poor, deeper areas do not receive enough light to support vigorous plant growth. If water clarity in Lake Independence improves, aquatic plants would likely colonize deeper areas of the lake. This may translate into expanding areas of curlyleaf pondweed and Eurasian watermilfoil growth.

	19 93		19 95		20 03	
	Max Depth (m)	*Abundance*	*Max Depth (ft)*	*Abundance*	*Max Depth (ft)*	*Abundance*
Eurasian watermilfoil	2.3	Abundant	2.6	Abundant	2.3	Common
Curly-leaf Pondweed	2.1	Abundant	2.1	Common	-	-
Coontail	2.0	Abundant	2.3	Abundant	2.7	Abundant
Flat-stem Pondweed	2.0	Rare	1.8	Common	2.7	Rare
Sago Pondweed	2.0	Rare	-	-	-	-
Elodea	1.2	Rare	1.8	Common	-	-
Bushy Pondweed	2.3	Rare	-	-	-	-
Leafy Pondweed	-	-	1.5	Rare	1.5	Rare
White Lily	1.2	Rare	0.9	Rare	1.0	Rare
Yellow Lily	-	-	-	-	0.9	Rare
Northern Watermilfoil	1.2	Rare	2.6	Rare	-	-
Bur-reed	-	-	0.9	Rare	0.5	Rare
Chara	1.8	Rare	2.0	Rare	-	-

Table 3. Summary of Lake Independence aquatic plant surveys for 1993, 1995, and 2003. (Rare= 0-20% occurrence, Common = 20-50%, Abundant= 50-100%)

Lake Independence

Aquatic Vegetation Survey

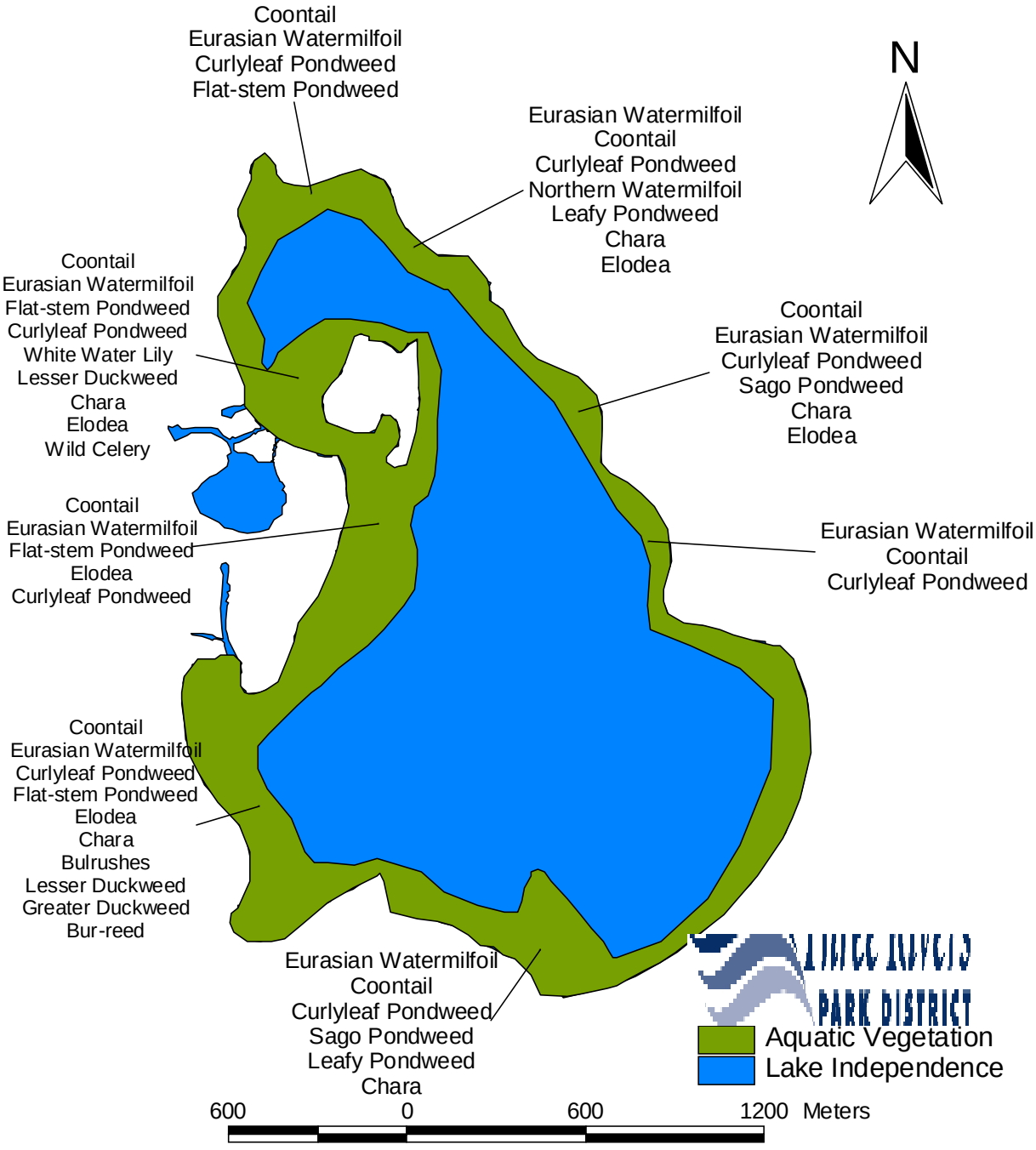


Figure 5. Map showing areas of Lake Independence where aquatic plants were encountered in 1993, 1995, and 2003. This vegetated area (301 acres) represents 71% of the MNDNR-defined littoral area (<15 ft). In addition, species that were encountered at given points along the shore are listed in order of decreasing abundance.