

ROUGH DRAFT

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ACKNOWLEDGEMENTS

Funding for this study was provided by the Three Rivers Park District Board of Commissioners, and their support is gratefully acknowledged. The Lake Independence Citizens Association provided many hours of volunteer assistance collecting information on lake levels, feedlots and stream channel conditions. In addition, the lake association was instrumental in bringing the issue of Lake Independence quality impairment to the attention of local governments. The cooperation of the Pioneer-Sarah Creek Watershed Commission in completing the diagnostic study and initiating the lake improvement planning process is much appreciated.

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

Section 1: Problem Statement

1.0 Introduction

Lake Independence (MnDNR Lake ID# 27-0176-00) is an 851-acre lake located approximately 15 miles west of downtown Minneapolis, Minnesota. The lake and its surrounding watershed are located within the municipal boundaries of two Minnesota townships, Independence and Medina. As with many lakes in the Twin Cities metropolitan area, Lake Independence 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 2002, the lake was added to the Minnesota 303(d) impaired waters list as a result of mean summer phosphorus values that exceeded the 40 µg/L phosphorus standard for Class 2 recreational waters.

Three Rivers Park District initiated a comprehensive monitoring plan in 1990 to identify and quantify the factors that affect the water quality of Lake Independence. This included biweekly monitoring of in-lake conditions during ice-free periods from 1990 to 2003, daily tracking of internal mixing in 1999 and 2000, and intensive stream monitoring in 1996, 1997 and 2001 at a majority of the sites where water flowed into the lake. In addition, Three Rivers Park District developed runoff models to identify the major sources of nutrients within the Lake Independence watershed and predict changes in flow volume, pollutant concentration, and nutrient loading at each inflow site based upon proposed management alternatives and potential future changes in land use. In addition, lake models were developed to assess the relative importance of external and internal nutrient sources and predict lake response to proposed nutrient reduction strategies.

In 2004, a diagnostic feasibility study was completed to develop a list of potential management actions for consideration. This list included estimates of associated cost, expected effectiveness, longevity, and technical feasibility for each proposed management alternative. Selection of actions for implementation required public discussion and cooperation between many concerned parties to evaluate and select the most acceptable management alternatives from this list. The finished diagnostic feasibility study provided valuable input for developing the Lake Independence TMDL work plan.

1.1 Description of Lake Independence and the Surrounding Watershed

History of Watershed

The watershed surrounding Lake Independence was predominantly forest and wetland until the mid 1800's. Prior to 1850, Lake Independence was used by Native Americans but was unknown to European settlers. On July 4, 1854, settlers from the Lake Minnetonka area encountered what is now Lake Independence, and named it in honor of the date, Independence Day. Between 1850 and 1870, the lake was the site of a large Native American settlement and the first European settlers began to build homes along the shore. In the 1860's, the village of Perkinsville was platted near the south end of the lake. Perkinsville soon became an active community that catered to vacationers from Minneapolis. During this same period, the area surrounding the lake was steadily being converted from forest to agricultural use. By the early 1900's, Lake Independence became a popular resort lake. At one point, four resorts were in existence along its shores. By the 1950's, the resorts were no longer popular and by 1990, all of these sites had been demolished and the land was sold for other uses. In the late 1950's, a large portion of the watershed east of Lake Independence, including about one sixth of the lake shoreline, was converted into a park reserve and recreation area named for the Baker family that had owned much of the land. The majority of this area is maintained as forest, prairie, and wetland, but the park does include a golf course, campgrounds, public beach, and picnic areas.

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 terrain 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 percolation 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.

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. On average, Lake Independence experiences 132 days of ice cover a year, with the average freeze and thaw dates being November 28 and April 7 respectively.

Table 1. Average monthly temperature (°F), precipitation (inches), and snowfall (inches) for Minneapolis Metropolitan Area

Month	Avg (°F)	Precip (in.)	Snowfall (in.)
Jan	11.8	0.83	9.8
Feb	17.9	0.85	8.4
Mar	31.0	1.6	11.7
Apr	46.4	2.17	2.8
May	58.5	3.38	0.1
Jun	68.2	4.17	0
Jul	73.6	3.55	0
Aug	70.5	3.40	0
Sept	60.5	2.89	0
Oct	48.8	2.01	0.5
Nov	33.2	1.45	7.9
Dec	17.9	0.94	9.3
Annual	44.9	27.24	50.5

Figure 1. Map showing normal annual precipitation for Minnesota. (*Minnesota State Climatology Office*).

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 2). 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.

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.

Figure 2. Map detailing the land-use within the Lake Independence watershed in 1999.

Lake Morphometry and Hydrology

Lake Independence is a relatively deep, 851-acre lake of glacial origin that has 5 major inflow points and one outflow (figure 4 and table 3). Some groundwater likely enters the lake, but the majority of the hydrologic inputs are the result of precipitation runoff from the surrounding watershed. Table 2 summarizes the lake morphometry and figure 3 shows the basic bathymetry of Lake Independence.

Table 2. Lake Independence morphometry.

Area	344 <i>hectares</i>	851 <i>acres</i>
Shoreline Length	11.4 <i>km</i>	7.08 <i>miles</i>
Volume	18.6 million <i>m³</i>	15100 <i>acre-feet</i>
Max Depth	18 <i>meters</i>	58 <i>feet</i>
Mean Depth	5.4 <i>meters</i>	17.8 <i>feet</i>
Residence Time	6.4 <i>years</i>	6.4 <i>years</i>

Figure 3. Map of Lake Independence showing depth contours in feet.

Figure 4. Map detailing the flow of surface water in and out of Lake Independence.

Table 3. Summary of subwatershed areas listed by inflow site

Subwatershed	Area (acres)	Area (hectares)
Ardmore	523	212
County 19 Inflow	3660	1481
Koch’s Creek	1342	543
Mill’s Creek	1174	475
Southwest Inflow	215	87
Direct Runoff	717	290

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. Figure 5 shows the typical within-year variations in water quality that Lake Independence experiences. This within-year variation has the potential to obscure between-year trends, but with a sufficiently long monitoring period, water quality trends are more easily detected. The 14 years of water quality data for Lake Independence were collected to enable the detection of such between-year changes, but no such trend was present. The data indicated that there has been no significant trend of improving or declining water quality since 1990, but when compared to computer model predictions based upon reference lakes in the same ecoregion, Lake Independence has consistently exhibited water quality that is sufficiently impaired to warrant remediation. The graphs in figure 6 show the annual summer means for total phosphorus, chlorophyll-a, and water clarity from each monitored year during the period from 1990 to 2004.

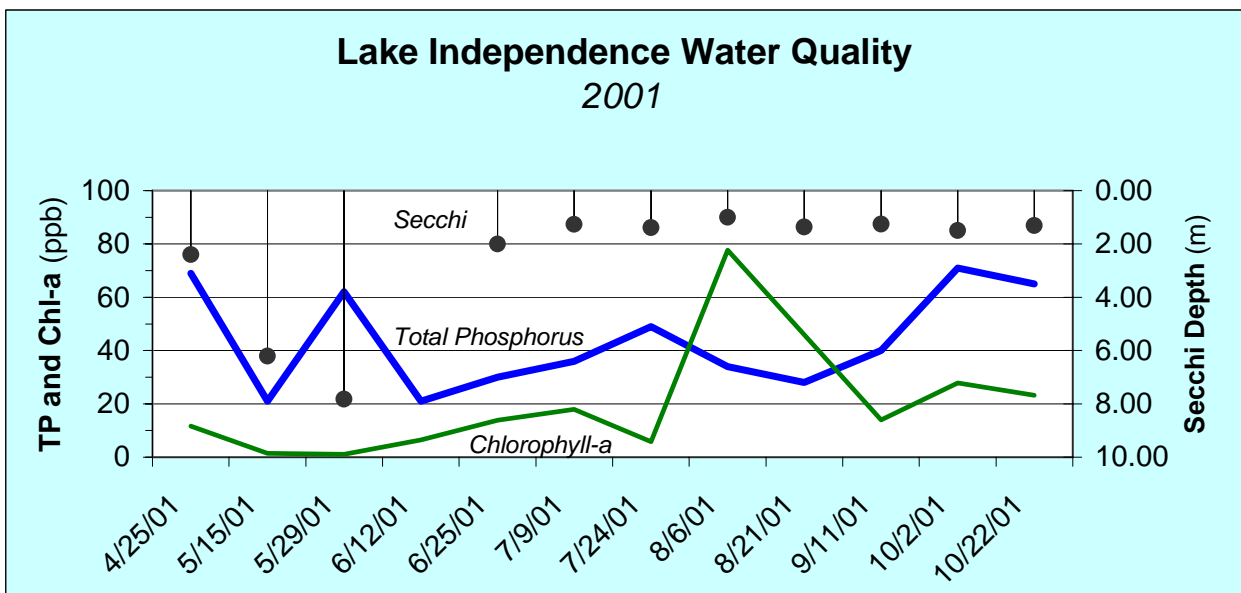


Figure 5. Graph showing typical variation in total phosphorus, chlorophyll-a, and secchi transparency during the 2001 monitoring season.

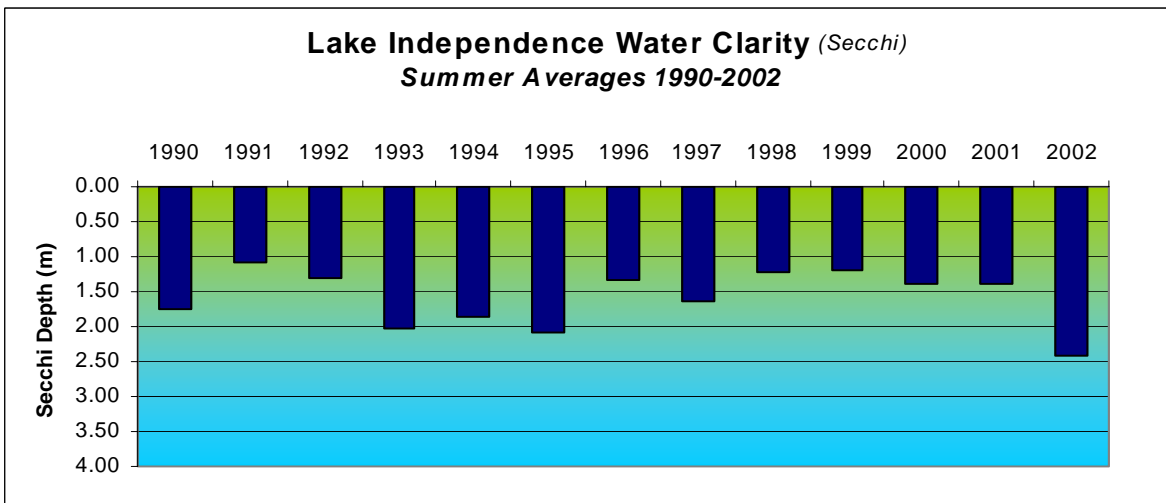
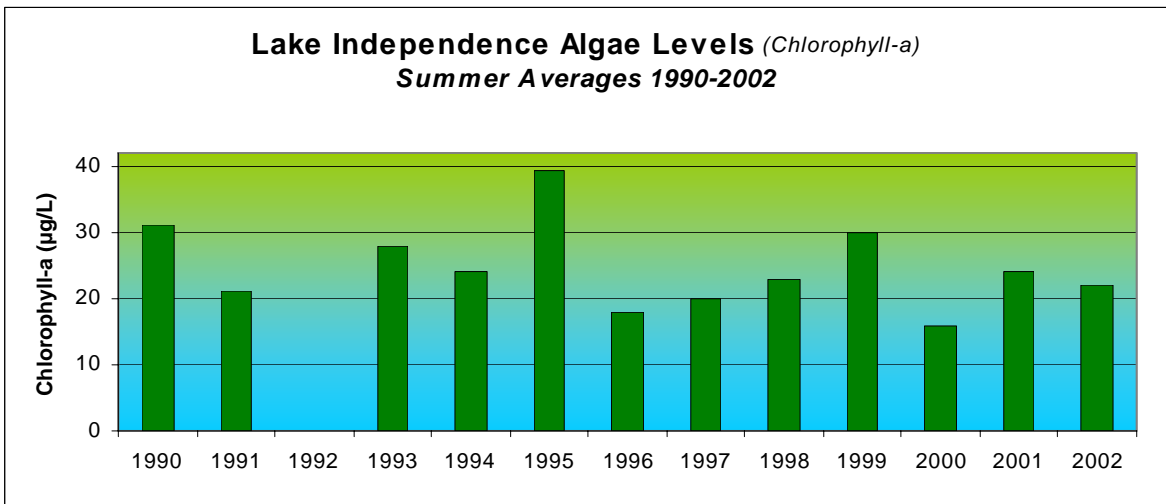
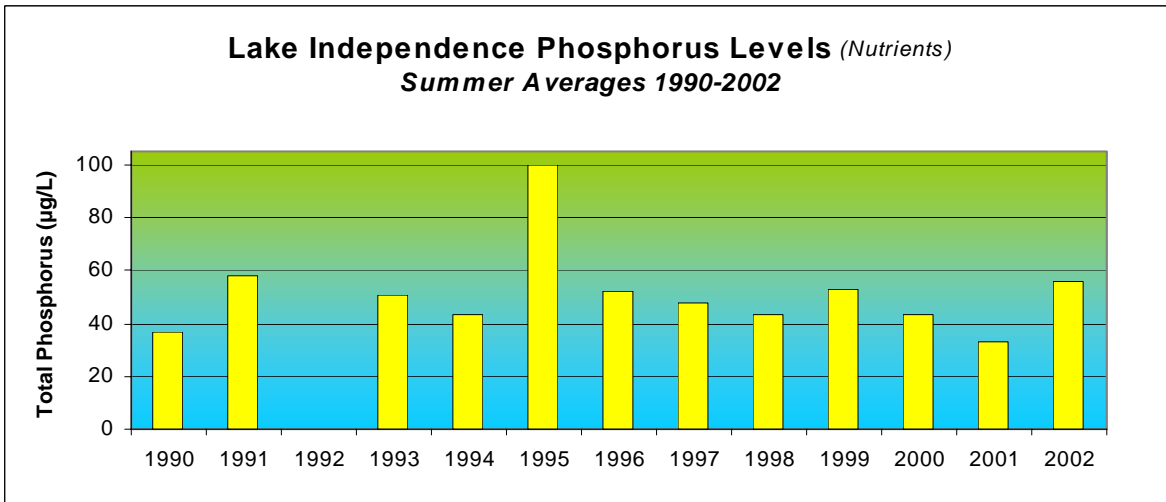


Figure 6. Graphs showing the average annual summer phosphorus (0-2 meter total phosphorus), algae level (0-2 meter chlorophyll-a), and water clarity (secchi depth) for Lake Independence; 1990 to 2004.

Fisheries Status

Lake Independence supports a good assemblage of fish and is stocked with walleye and muskellunge in alternating years by the Minnesota Department of Natural Resources. The lake also supports perch, bluegill, largemouth bass, bowfin, carp, pumpkinseed sunfish, hybrid sunfish, and yellow bullhead. Based upon fish surveys conducted in 2001, the DNR lists the lake as having an excellent fishery for black crappie and northern pike. 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 presents a slightly different problem than milfoil in that it also has the potential to degrade water quality. This invasive plant grows under the ice 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 that can fuel algae blooms 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 both have the ability to displace native plant species through shading effects, thus decreasing the quality of available fish habitat and food sources for wildlife.

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

Figure7. 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.

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 4). 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 7). 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.

Water Level

The average water level elevation for Lake Independence over the past ten years has been 957.32 feet above sea level. The ordinary high water elevation (OHW) as listed on the Minnesota Department of Natural Resources web site is 956.8 feet. In the past three years, Lake Independence has experienced elevated water levels due to abnormally high amounts of rainfall (figure 8). 2002 was extremely wet, and consequently the water level of Lake Independence remained high for a majority of the summer. Elevated water levels may be responsible for increased shoreline erosion, especially in areas exposed to severe wave action from wind or motorboat wake. The water level in the lake is controlled by a concrete spillway located under the bridge on Independence Road at the extreme southwest corner of the lake. The spillway is set to maintain a water surface elevation of 956.5 feet.

Figure 8. Graphs showing the recorded water level of Lake Independence during the period from 1991 to 2003 and the frequency of occurrence for water levels during that same period.

1.2 303(d) Listing

In 2002, the lake was added to the Minnesota 303(d) impaired waters list as a result of mean summer phosphorus values that exceeded the 40 µg/L phosphorus standard for Class 2 recreational waters.

Section 2: Applicable Water Quality Standards and Water Quality Numeric Targets

2.0 Water quality standards for designated uses

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 the Baker Regional Park Reserve located along a one-mile stretch of shoreline at the southeastern corner of the lake. The park includes two swimming beaches, a public boat launch, a fishing pier, canoe rental facility, picnic area, playground, and campground. In 2003, Baker Park accommodated over 300,000 visitors, of which 51% reported using Lake Independence for swimming, 34% for boating, and 25% for fishing. The lake is also used heavily for ice fishing during the winter months. The Three Rivers Park District master plan for Baker Park incorporates swimming, boating, and fishing as primary designated uses for the park and contiguous portion of Lake Independence. This master plan was reviewed and approved by the Metropolitan Council. In order to maintain water quality conditions that warrant full support of these primary designated uses, the Three Rivers Park District has adopted a phosphorus standard of 36 ppb for Lake Independence.

2.1 Decision process and basis for the adopted numeric phosphorus target

To better define a threshold level of acceptable impairment, the Minnesota Pollution Control Agency (MPCA), Metropolitan Council, and Three Rivers Park District conducted lake user surveys to correlate public impressions of lake usability with more objective water quality measurements. The results of these surveys indicated that 75% of those 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, specifically for water contact recreation. For this reason, a target phosphorus concentration of 36 ppb was adopted for Lake Independence by the Three Rivers Park District Board. This target is 11 ppb lower than the average summer concentration observed during the monitored period (1990 to 2004), and would represent a 23% reduction in the mean summer phosphorus level of Lake Independence when compared to current conditions.

The MINLEAP computer model 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 markedly better water quality than what had been observed in Lake Independence during the fourteen-year monitoring period from 1990 to 2004 (table 5).

	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 5. Summary of Lake Independence average summer water quality from 1990 to 2004.

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 public decision process consisted of ...

Section 3: Pollutant Assessment

3.0 Source inventory

Nutrient loading to Lake Independence predominantly originates from non-point sources associated with crop agriculture, livestock rearing, and urban and residential runoff. Currently, the only identifiable point source within the watershed is the Loretto Municipal Waste Water Treatment Facility. The relative importance of the urban and residential runoff may increase markedly in the future as vacant and agricultural lands are developed.

3.1 Determination and analysis of pollutant loads from identified sources

The subwatersheds within the Lake Independence watershed exhibited different land use patterns; the western areas were generally more agricultural while the eastern subwatersheds contained substantially more urban, residential, and parkland areas. To better assess the relative importance of non-point sources associated with these different land use types, assessments and analyses were focused on a subwatershed scale. This allowed for better isolation of nutrient contributions associated with each land use and enabled better calibration of computer models based upon field data collected at the inflow points from each subwatershed. The following paragraphs give descriptions of pollutant load determination and analysis results for identified nutrient sources within the Lake Independence watershed.

Loretto Sewage Effluent Discharge (point source)

The municipal wastewater treatment facility in Loretto, Minnesota is currently permitted to periodically release treated sewage effluent into a wetland complex that flows to Spurzem Lake within the Lake Independence watershed. Spurzem Lake is hydrologically connected to Lake Independence via a small intermediate lake and a series of creeks that flow approximately 2 kilometers to Lake Independence. In recent years, the Loretto treatment facility has been applying alum to their treatment ponds prior to discharge. This measure has drastically reduced the concentration of phosphorus in the effluent. Currently, the treatment facility is permitted to discharge up to 7 lbs of phosphorus per day, at a maximum effluent concentration of 1000 ppb. Actual discharges have been reported annually to the MPCA and are given in table 6 below.

Table 6. Reported effluent discharge volumes and concentrations reported by the Loretto Municipal Wastewater Treatment Facility to the MPCA in 2001 and 2002. Also included are the calculated loads of phosphorus for each reported discharge. Note that discharge periods may include multiple days.

Discharge Period	Discharged Vol. (million gallons)	Phosphorus Conc. (ppb)	Exported Phosphorus (lb)
April 2001	2.24	1090	20.4
Sept 2001	1.03	2730	23.5
Nov 2001	7.28	260	15.5
May 2002	9.90	380	31.4
Sept 2002	1.60	1200	16.0
Nov 2002	8.00	490	32.7

In 2001 and 2002, the treatment facility reported discharging 59 and 80 lbs. of phosphorus respectively, or 70 lbs. as a two-year annual average. Due to some additional removal by small lakes and wetland systems downstream (estimated 25% removal of phosphorus), the loading to Lake Independence from this point source was estimated to be 53 lbs./yr. Spurzem Lake has experienced substantially higher nutrient levels and poorer water quality than expected based upon ecoregion and lake morphometry. While the effluent discharge from the treatment facility appears to be leading to nutrient enrichment of downstream waters, the latest measures

used by the Loretto treatment facility to reduce the phosphorus concentration in discharged effluent (alum treatment and settling ponds) have effectively reduced the potential impact of such discharges to Lake Independence. Stricter adherence to the 1000 ppb concentration limit would yield even greater reductions.

Agricultural Non-point Sources

The stream data collected in 1996, 1997, and 2001 indicated that the highest nutrient concentrations occurred in Mill’s Creek and Koch’s Creek (table 3). Recent studies conducted by the Three Rivers Park District showed that these two subwatersheds had substantially more area devoted to livestock rearing and crop agriculture than the other subwatersheds. This suggests that these land uses may be major contributors to the nutrient levels in these two creeks. In 1997 Three Rivers Park District staff determined that there were an estimated 572 livestock animals within these subwatersheds that produced 19 million pounds of manure, 16,755 lbs of phosphorus, and 85,000 lbs of nitrogen. A more intensive survey in 2005 determined that there was a conservative estimate of 298 animal units within the watershed which annually produced 2.3 million pounds of solid manure, 5478 lbs of phosphorus, and 13,393 lbs of nitrogen. 2005 estimates for manure production and phosphorus content were revised from those used in the 1997 survey to reflect the latest data on manure characteristics from different livestock. The exact amount of this manure that washes into Lake Independence is difficult to determine, but research and computer model simulations of the Lake Independence watershed suggest that most of the livestock production areas within the watershed are potential sources of nutrients that contribute to the water quality degradation of the lake. These agricultural non-point sources would be an attractive management targets if cost-effective ways to control nutrient export can be implemented.

Figure 9. Summary of livestock animals and their associated annual manure production within the Lake Independence Watershed. Based upon a 1997 survey of livestock areas conducted by the Suburban Hennepin Regional Park District and literature values for manure production (MSUE).

Annual Manure Production Summary

Manure (wet)	19 million lbs
Phosphorus	16,755 lbs
Nitrogen	85,186 lbs

Urban and Residential Sources

As of 2004, several residential areas drain to Lake Independence via municipal stormwater systems. Some of this runoff is directed into small ponds where some nutrient removal occurs, but much of the area drains directly to the lake in an untreated state. Nutrient loading from these areas was estimated based upon monitored water quality data, literature nutrient export values for residential land use in Minnesota, and computer model estimates (table 7).

Watershed Monitoring and Modeling Results

The vast majority of the water that runs off of the watershed enters Lake Independence via several small creeks. These creeks were monitored independently to determine differences in the nutrient loading from different areas of the watershed and offer insight into the relative importance of different land uses in the overall lake nutrient budget. The four major inflows were monitored in 1996, 1997, and 2001 (figure 4

and table 3). This monitoring included the collection of continuous flow data and flow-weighted composite samples from a range of flow events.

The collected data were used to develop calibrated FLUX and BATHTUB models that estimated total nutrient inflow from each subwatershed based upon land use characteristics, local climate, and literature values for nutrient export from given land use areas. These models predicted that 2339 pounds of phosphorus and 16,096 pounds of nitrogen entered Lake Independence annually from the surrounding watershed. The largest loadings occurred at County Road 19, Koch’s Creek, and Mill’s Creek.

Table 7. Summary of the FLUX and BATHTUB model outputs for Lake Independence based upon current inflow.

Inflow Site	Water Inflow <i>acre-feet/year</i>	Avg TP Concentration <i>ppb</i>	Estimated TP Load <i>lb/year</i>	Avg TN Concentration <i>ppb</i>	Estimated TN Load <i>lb/year</i>
Ardmore	194.6	253	135	2440	1299
County 19	1159.3	199	626	1434	4515
Koch's Creek	267.5	515	370	4709	3386
Mill's Creek	372.9	773	776	3811	3825
Southwest	178.4	473	234	4000	1971
Direct Runoff	105.4	698	198	3874	1100
<u>Totals</u>	<u>2278.1</u>	-	<u>2339</u>	-	<u>7301</u>

Figure 10. Graphs showing the relative percent of the total annual water volume and phosphorus load entering Lake Independence by site, as well as the annual mean total phosphorus concentration for each monitored inflow site (as determined by FLUX model).

The phosphorus entering Lake Independence in the inflow streams originates from many sources. A sizeable amount of research has been conducted over the last few decades to determine phosphorus runoff rates from different land use types and activities, including the Environmental Protection Agency, numerous universities, state agencies, and others (EPA 1980). Phosphorus export rates reported from these studies were used to estimate the phosphorus export from each land use type in the Lake Independence watershed (figure10).

GIS Model

The portion of the exported phosphorus that actually flows into Lake Independence is likely reduced significantly from the initial source export values by management practices, wetlands, infiltration areas, and biological uptake as the phosphorus moves through the watershed on its way to the lake. To estimate the amount of phosphorus that actually flows into Lake Independence, Three Rivers Park District developed a Geographic Information System (GIS) model that identified all parcels within the watershed containing livestock, calculated the area of land actually used for pasture and feedlot, and estimated the potential that each site posed for loading phosphorus to the lake. The model assessed this *loading potential* for each individual site by considering the slope of the land, proximity to creeks, and distance from Lake Independence. Sites on steep slopes, closest to creeks, and closest to the lake would be expected to contribute more phosphorus to the lake and thus received the highest loading potential scores. These scores were then used to calculate the percent of the phosphorus flowing directly off of each site that would be expected to flow into Lake Independence. Figure 11 and table 8 summarize the results of this model for the properties within the Lake Independence watershed that were determined to have livestock.

Figure 11. Map showing areas of pasture and feedlot within the Lake Independence watershed color coded to indicate the *loading potential* for each site (bright blue sites have the lowest potential, red the highest)

Table 8. Summary of calculated manure production and adjusted P-loadings based upon the % transmission determined using the GIS watershed model.

Individual Property P-Export Model

Lake Independence Watershed

Manure Produced <i>lbs/year</i>	Manure Rank	Manure Phosphorus <i>lbs/year</i>	%Transmission	P-Load to Lake Indep. <i>lbs/year</i>	% of Total <i>from livestock</i>	P-Load Rank	Cumulative P-load <i>lbs/year</i>
154395	4	222	60.0%	25.36	16.9%	1	25
321200	3	715	32.3%	15.96	10.6%	2	41
428510	1	953	25.5%	13.93	9.3%	3	55
87491	8	126	66.9%	12.20	8.1%	4	67
357226	2	766	43.5%	12.16	8.1%	5	80
128480	6	286	13.6%	10.57	7.0%	6	90
128480	5	286	32.3%	9.34	6.2%	7	100
20586	20	30	53.8%	8.49	5.7%	8	108
64240	11	143	25.8%	8.47	5.6%	9	116
87491	7	126	16.9%	6.52	4.3%	10	123
41172	14	59	39.6%	5.03	3.4%	11	128
20586	19	30	41.5%	5.01	3.3%	12	133
10293	31	15	52.1%	4.38	2.9%	13	137
55845	12	578	63.2%	2.21	1.5%	14	140
66905	10	96	22.3%	1.77	1.2%	15	141
71431	9	601	23.6%	1.38	0.9%	16	143
25733	17	37	18.7%	1.07	0.7%	17	144
20586	18	30	39.6%	1.03	0.7%	18	145
10293	30	15	19.6%	0.87	0.6%	19	146
10293	29	15	23.3%	0.77	0.5%	20	146
15440	26	22	22.6%	0.75	0.5%	21	147
15440	25	22	23.9%	0.73	0.5%	22	148
25733	16	37	17.2%	0.62	0.4%	23	149
15440	24	22	21.4%	0.46	0.3%	24	149
44968	13	100	8.3%	0.39	0.3%	25	149
15440	23	22	30.5%	0.35	0.2%	26	150
10585	27	15	22.3%	0.21	0.1%	27	150
15440	22	22	6.9%	0.16	0.1%	28	150
10293	28	15	19.3%	0.15	0.1%	29	150
15440	21	22	28.8%	0.09	0.1%	30	150
5147	32	7	22.3%	0.09	0.1%	31	151
31463	15	45	19.3%	0.08	0.1%	32	151

2,332,058

lbs of manure produced / year

5478

lbs of P produced / year

151

Annual P-Load from Livestock

Previous modeling by Three Rivers Park District estimated that 43% of the phosphorus entering Lake Independence originated from livestock, 36% from vacant and agricultural cropland, and 9% from urban runoff. The remaining 12% could be attributed to rural homes, sewage treatment effluent, park area, wind-blow soil, golf course runoff, erosion, and wildlife. While the total phosphorus export from many of these listed sources was small compared to the export from livestock feedlots and cropland, larger portions of their exported phosphorus may enter Lake Independence due to the proximity of these areas to the lake.

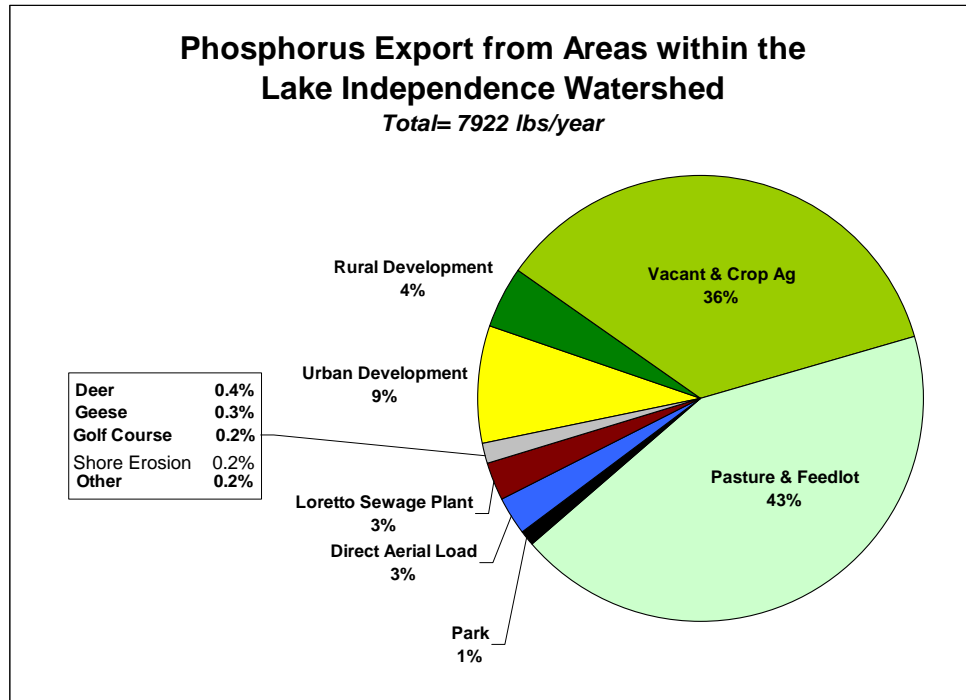


Figure 12. Phosphorus export from sources within the Lake Independence Watershed.

Nutrient Recycling within Lake Independence

Lake Independence regularly experiences stratification that is sufficiently stable to promote the near total loss of oxygen below the thermocline (figure 13). This typically results in a significant accumulation of phosphorus, released from the sediments, in deeper areas of the lake. Data collected by an automated sampling raft (RUSS unit) in 1999 and 2000 indicated that the lake often experienced significant partial mixing during thunderstorms and windy days. This periodic partial destratification mobilized phosphorus that had accumulated in the deeper waters and mixed it into the surface layer of the lake where it became available to algae and plants. Additional internal loading may occur due to the substantial release of phosphorus when curlyleaf pondweed dies off and begins to break down in early summer.

Three Rivers Park District used a calibrated LTROPHIC model to estimate the total annual phosphorus load to Lake Independence. It predicted that the lake would have to receive 3858 lbs of phosphorus loading per year to explain the observed water quality. By subtracting the estimated external load (2339 lbs.) from this predicted total load, we get an estimate of the internal

nutrient recycling; 1519 lbs/year or 39% of the total annual phosphorus load.

Internal phosphorus recycling has likely been a major factor in producing the frequent algae blooms that have impaired the water quality of Lake Independence in recent decades. Management alternatives that focus on reducing this internal nutrient recycling would likely result in a drastic nutrient reduction and greatly improved water quality within the lake, but the longevity of such a treatment would likely be shortened substantially if the external loading of phosphorus was not reduced first.

Figure 13. Water column profile of Lake Independence from August of 2000 showing lake stratification.

Section 4: Linkage Analysis – Relating Adopted Phosphorus Target to Source Loads

Rationale for analysis methods

Results of water quality and load modeling

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 LTROPIC 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.

Section 5: TMDL and Allocations

Total Maximum Daily Load (TMDL)

Wasteload Allocations (WLA's)

Load Allocations (LA's)

Seasonal Variation

Margin of Safety (MOS)

Critical Conditions

Section 6: Follow-up Monitoring Plan

Monitoring1...

Monitoring2...

Section 7: Public Participation

Section 8. Implementation Plan

Implementation will focus on reducing the movement of phosphorus from the watershed land area into Lake Independence. As previously indicated, a reduction of 23% (882 pounds) in the current nutrient loading to the lake is necessary to achieve the adopted quality goal. The stakeholder group agreed that the following reductions from each identified phosphorus source could be achieved:

Source	Proposed reduction
Agricultural Cropland	440 pounds
Animal waste	330 pounds
Urban Development	159 pounds
Loretto sewage treatment plant	53 pounds
Geese	18 pounds

Identified Reduction Strategies

8.1 Agricultural cropland

The committee agreed that establishment of buffer strips along drainage ditches, streams, and wetlands would significantly reduce nutrient runoff from agricultural cropland in the watershed.

Priority areas for buffer establishment in the watershed will be determined using the NRCS Universal Soil Loss Equation. Areas with the greatest erosion potential and proximity to sediment and nutrient conveyance systems will be targeted for buffers zone establishment. The Pioneer-Sarah Creek WMO and Three Rivers Park District will undertake the prioritization process. Buffer establishment will be on a voluntary basis. State and federal grant monies will be solicited by the Pioneer-Sarah Creek Watershed Management Commission to cost share buffer establishment. Contact with prospective landowners will be initiated by ????????

8.2 Animal waste

The committee agreed that improved management of animal waste in the watershed would significantly reduce the phosphorus load to Lake Independence. Reduction of phosphorus runoff from existing feedlots will require improved manure storage, improved land application practices, and better pasture management. In addition, because of high animal density at many sites and existing high soil fertility, land application of manure is not practical. Thus, proper management of feedlots will require removal of manure from the watershed.

Three Rivers Park District staff inventoried the livestock operations in the watershed and developed a priority ranking to determine the feedlots with the greatest potential to affect the lake (Table 8). Optimal implementation of animal waste BMP's will focus on the highest ranking feedlots. Pasture and feedlot management plans will be developed by the Hennepin County Extension Agency in consultation with landowners on a voluntary basis. The Pioneer-Sarah Creek Watershed Commission and the Cities of Independence and Medina will solicit State and Federal Grant monies to assist in the implementation of the waste management plans.

In the event that voluntary implementation of manure management plans does not occur on the majority of feedlot, Medina and Independence will revise existing Conditional Use Permits or Zoning Ordinances to require compliance. In cooperation with the Pioneer-Sarah Creek Watershed Management Commission, Three Rivers Park District, and Hennepin County Environmental Services, Medina and Independence will develop a manure hauling and disposal service to assist landowners with manure management.

8.3 Urban Development

The stakeholder committee agreed that improved management of urban runoff, particularly from lakeshore properties would reduce nutrient loading to Lake Independence. Urban runoff management will include the following components; installation of rain gardens, street sweeping, removal of leaf litter from streets, installation of shoreline buffers, and stabilization of eroding lake shore.

Rain garden installation will be coordinated by the Lake Independence Citizens Association (LICA). LICA members will contact homeowners to determine interest in rain garden construction. Hennepin County Environmental Services will assist LICA with rain garden design. HCES will also apply for grant monies to design and construct demonstration sites for homeowners to view.

Shoreline stabilization on Lake Independence will be coordinated by LICA with technical assistance from HCES. HCES will coordinate a grant application to solicit funds to assist homeowners with lakeshore stabilization projects. Three Rivers Park District staff inventoried the Lake Independence shoreline to develop a priority ranking to determine where initial stabilization efforts should focus.

Street sweeping in areas immediately adjacent to Lake Independence will be completed by Medina and Independence. Street sweeping will focus on springtime removal of debris accumulated during the winter, and during leaf drop in the fall.

Removal of leaf litter from lakeshore lawns and streets adjacent to Lake Independence will be coordinated by LICA. Independence and Medina will assist with transport of leaf litter off site and disposal.

Installation of shoreline buffers will be coordinated by LICA with technical assistance from HCES. Three Rivers Park District inventoried the lake shoreline to determine where lawns currently extend to the waters edge along the lake. These areas will be targeted by LICA.

8.4 Goose Removal

A reduction in phosphorus loading will be achieved by reducing the resident goose population. Three Rivers Park District, Medina and Independence will develop a cooperative program to capture and remove geese from the lake in late summer when the birds are flightless. LICA will assist in obtaining permission to enter private property to collect geese. Removal will be contracted to Dr. Jim Cooper, the only licensed removal firm.

8.5 Loretto Wastewater Treatment Facility

A reduction in phosphorus loading to Lake Independence will be achieved by reducing the discharge of phosphorus from the Loretto wastewater treatment facility. Medina will facilitate the connection of the Loretto discharge to the Metropolitan Council Wastewater Treatment System.

Summary of Load Reductions

Reduction Strategy	Reduction
Goose control	18 pounds
Shoreline stabilization	44 pounds
Street sweeping	11 pounds
Leaf litter removal	31 pounds
Shoreline buffers	11 pounds
Rain Garden Installation	62 pounds
Livestock waste management	330 pounds
Buffer strips	322 pounds
Eliminate Loretto waste water discharge	53 pounds