

1 MONITORING PROGRAM OVERVIEW: 1991-2006

LAKE MONITORING

Background

The Environmental Operations Section of the Minneapolis Park and Recreation Board (MPRB) implemented a lake water quality monitoring program in 1991 as part of a diagnostic study for the Chain of Lakes Clean Water Partnership. The Chain of Lakes includes Brownie, Cedar, Isles, Calhoun and Harriet. The monitoring program was expanded in 1992 to include Hiawatha, Nokomis, Diamond, Powderhorn, Loring, Webber and Wirth lakes. Spring Lake was added on a limited basis in 1993. Grass and Ryan lakes were added on a limited basis in 2002. Figure 1A shows the location of the lakes in Minneapolis. For purposes of this overview, these fifteen lakes will be collectively referred to as the Minneapolis lakes.

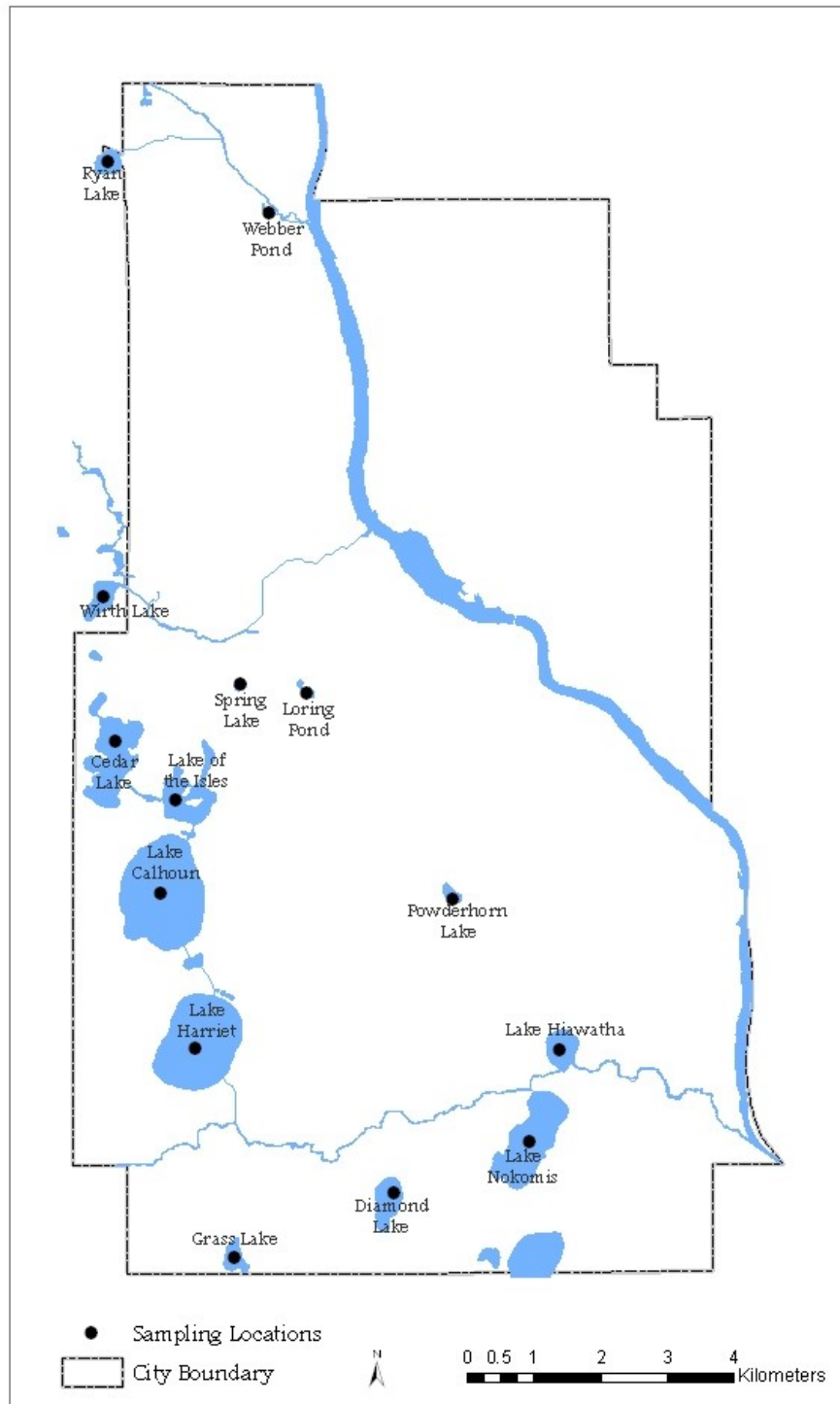


Figure 1A. Location of lakes monitored by MPRB.

The objectives of the MPRB lake monitoring program are to:

- (1) Establish a database for tracking water quality trends
- (2) Quantify and interpret both immediate and long-term changes in water quality

- (3) Provide water quality information to develop responsible water quality goals
- (4) Evaluate the effectiveness of implemented best management practices e.g. wetlands, grit chambers, etc.

The intent of this overview is to provide a description of the MPRB lakes monitoring program schedule and methods. Jensen (1997) and Shapiro (1997) both offer a similar historical water quality analysis of the Chain of Lakes.

The fifteen lakes and the respective watersheds sampled as part of the MPRB lakes monitoring program are located within the cities of Minneapolis, St. Louis Park, Richfield, Golden Valley, Robbinsdale, Brooklyn Center and Edina. Residential housing is the predominant land use within the watersheds; however, industrial/commercial is also prominent in several areas. The watersheds associated with Loring and Webber ponds are predominantly parkland. All of the Minneapolis lakes' watersheds are considered fully developed and little change in land use is projected.

The geology of the lakes and watersheds consists of an underlying Paleozoic bedrock that has been altered by fluvial processes. Continental glaciers during the Pleistocene Epoch covered the existing topography and created numerous ice block lakes and wetlands. The bedrock layers are concealed under 200 - 400 feet of unconsolidated deposits. The bedrock surface is composed of plateaus of limestone and dolomite that are penetrated by a system of dendritic preglacial river valleys. These river valleys were filled by a combination of fluvial sedimentation and deposition of late Wisconsin glacial drift. Each glacial advance stripped the landscape of earlier overburden and filled the preglacial and interglacial valleys with drift. The last glacial episode resulted in the formation of most of the lakes in Minneapolis. The glacial ice sheet deposited large ice blocks at its margin as it retreated. Ice blocks that were deposited in a north-south trending preglacial (or interglacial) valley led to the formation of the Chain of Lakes. Lake Nokomis, Lake Hiawatha and Powderhorn Lake formed as a result of a similar series of events in another preglacial valley (Zumberge, 1952; Balaban, 1989).

Nearly all of the Minneapolis lakes were physically altered in the early 1900's (Pulscher, 1997). The Minneapolis lakes currently represent a wide range of morphometric characteristics (Table 1A) including shallow wetland systems (Diamond Lake and Grass Lake), protected meromictic lakes (Brownie Lake and Spring Lake) and more classic, deep dimictic lakes (Lake Harriet and Lake Calhoun).

Methods

The 2006 schedule of physical and chemical parameters is shown in Table 1A. Most lakes followed this schedule and were sampled once per month in February, April and October and twice per month during the period of May through September. There were two exceptions to the stated schedule: Diamond Lake was sampled once in February and then every two weeks April through October. Webber Pond was sampled once per month from April through October.

Table 1A. Schedule of sampled parameters for most Minneapolis lakes in 2006.

Parameter	Winter	March/April	May – Sept	October
Alkalinity	Once	Once	Once	Once
Chloride	Once	Once	Once	Once
Chlorophyll- <i>a</i>	Once	Once	Twice a Month	Once
Conductivity	Once	Once	Twice a Month	Once
Dissolved Aluminum*	Once	Once	Once	Once
Dissolved Oxygen	Once	Once	Twice a Month	Once
Hardness	Once	Once	Once	Once
pH	Once	Once	Twice a Month	Once
Phytoplankton	Once	Once	Twice a Month	Not sampled
Secchi Transparency	Once	Once	Twice a Month	Once
Silica	Once	Once	Once a Month	Once
Sulfate	Not sampled	Not Sampled	Once	Not sampled
Temperature	Once	Once	Twice a Month	Once
TKN, NO _x	Once	Once	Once	Once
Total Aluminum*	Once	Once	Once	Once
TP, SRP, TN	Once	Once	Twice a Month	Once
Zooplankton	Not sampled	Once	Once a Month	Not Sampled

* Lake Calhoun, Lake Harriet and Powderhorn Lake only

All physical measurements and water samples for chemical analyses were obtained from a point directly over the deepest depth in each lake (sampling station). The sampling stations were determined from bathymetric maps and located using shoreline landmarks and an electronic depth finder. Webber Pond samples were taken as grab samples from the shore. Diamond Lake is being monitored under a five year contract with Barr Engineering and MnDOT that adds additional parameters e.g. the metals Ni, Cd, Cu, Pb and Zn. Prior to 2004, Diamond Lake samples were taken as grab samples from the dock.

A Hydrolab Minisonde 4a Multiprobe was used to record temperature, pH, conductivity and dissolved oxygen profiles. These parameters were measured at 1-meter intervals from the surface to the lake bottom. The multiprobe was calibrated according to the manufacturer's guidelines prior to each sampling trip. Secchi disk transparency was determined with a black and white 20-cm diameter disk on the shady side of the boat.

Two composite surface water samples were collected using a stoppered 2-m long, 2-inch diameter white PVC tube and combined in a white plastic bucket. Water from this mixed sample was decanted into appropriate bottles for analysis. Chlorophyll-*a* samples were stored in opaque bottles for analysis. Total phosphorus, soluble reactive phosphorus, total nitrogen and chlorophyll-*a* concentrations were determined from the surface composite sample for all sampling trips.

Phytoplankton samples were collected each sampling trip April through October for all lakes except Spring Lake (Table 1A). Phytoplankton were collected from the 0-2 m surface composite sample and stored in an opaque plastic container with a 25% glutaraldehyde preservative solution.

Vertical zooplankton tow samples were taken at the sampling station for each lake (except Diamond Lake and Webber Pond) once per month during the growing season (Table 1A). Zooplankton were collected using a Wisconsin vertical tow net (of appropriate μm mesh size) retrieved at a rate of 1 m/s through the full water column. The 80- μm mesh Wisconsin bucket was rinsed with distilled water or ethanol from the outside. The sample was preserved with a 50% minimum volume of 90% denatured histological ethanol.

Subsurface samples were collected with a 2-liter Wildco™ Kemmerer water sampler. Total phosphorus and soluble reactive phosphorus concentrations were determined every sampling trip at predetermined depths in each lake (Table 1B). Total aluminum and soluble aluminum samples were taken from surface and subsurface samples in Lake Calhoun, Lake Harriet and Powderhorn Lake once in April, June, August and October. Spring, mid-summer and fall deep subsurface chloride samples were also taken at most lakes. Sulfates were sampled once in the hypolimnion of all lakes except, Brownie, Webber, Grass, and Ryan. Each lake sample collection regime was determined based upon maximum depth, stratification characteristics and the results of previous studies.

Table 1B. Sampling depth profiles for the 2006 Minneapolis lakes monitoring program.

Lake	Sampling Depths				
Lake Calhoun	0-2m composite	6m	12m	18m	22m
Cedar Lake	0-2m composite	5m	10m	14m	
Diamond Lake	0-2m composite				
Lake Harriet	0-2m composite	6m	12m	15m	20m
Lake Hiawatha	0-2m composite	4m			
Lake of the Isles	0-2m composite	5m	8m		
Loring Pond	0-2m composite	4m			
Lake Nokomis	0-2m composite	4m	6m		
Powderhorn Lake	0-2m composite	4m	6m		
Spring Lake	0-2m composite	5m	7m		
Webber Pond	Grab (surface)				
Wirth Lake	0-2m composite	4m	7m		

Immediately following collection, all samples were placed on ice in a cooler and stored at approximately 4°C. Samples were transported to the contract laboratory for analysis within 8 hours of collection. Sampling procedures, sample preservation, and holding times followed procedures described in Standard Methods (2005) or U.S. Environmental Protection Agency (US EPA, 1979 (revised 1983)). The 2006 contract laboratory for chemical analyses was Instrumental Research, Inc. (IRI). PhycoTech, Inc. analyzed the phytoplankton and zooplankton samples. The methods and reporting limits for all parameters are listed in Table 1C.

Table 1C. Methods and reporting limits used for parameter analysis in the 2006 Minneapolis lakes monitoring program.

Parameter	Method	Reporting Limit
Alkalinity	STANDARD METHODS 2320 B.	2.0 mg/L
Ammonia	STANDARD METHODS 4500-NH ₃ C.	0.500 mg/L
Chloride	STANDARD METHODS 4500-Cl ⁻ B.	2.0 mg/L
Chlorophyll-a	Acetone extraction/spectrophotometric determination (pheophytin corrected) SM 10200 H.	1.0 mg/m ³
Conductivity	Hydrolab Minisonde 4a Multiprobe (field)	0.1 µS/cm
Dissolved Oxygen	Hydrolab Minisonde 4a Multiprobe (field)	0.01 mg/L
Fecal Coliform	STANDARD METHODS 9221 C E.	1 CFU
Hardness	STANDARD METHODS 2340 C.	1.0 mg/L
Nitrate+Nitrite Nitrogen	STANDARD METHODS 4500-NO ₃ E.	0.03 mg/L
pH	Hydrolab Minisonde 4a Multiprobe (field)	0.01 standard unit
Silica	STANDARD METHODS 4500-Si D.	0.500 mg/L
Soluble Aluminum	STANDARD METHODS 3113 B. EPA 200.9	5 µg/L
Soluble Reactive Phosphorus	STANDARD METHODS 4500-P A. B. E.	0.005 mg/L
Sulfate	EPA 375.4	20 mg/L
Temperature	Hydrolab Minisonde 4a Multiprobe (field)	0.01 °C
Total Aluminum	STANDARD METHODS 3113 B. EPA 200.9	5 µg /L
Total Arsenic	STANDARD METHODS 3113 B.	20 µg/L
Total Cadmium	STANDARD METHODS 3113 B.	5 µg/L
Total Copper	STANDARD METHODS 3113 B.	5 µg/L
Total Dissolved Phosphorus	STANDARD METHODS 4500-P A. B. E.	10 µg/L
Total Kjeldahl Nitrogen	STANDARD METHODS 4500-Norg B.	0.500 mg/L
Total Lead	STANDARD METHODS 3113 B.	5 µg/L
Total manganese	STANDARD METHODS 3113 B.	20 µg/L
Total Nickel	STANDARD METHODS 3113 B.	5 µg/L
Total Nitrogen	STANDARD METHODS 4500 N C. Alkaline persulfate oxidation/automated cadmium reduction method.	0.500 mg/L
Total Phosphorus	STANDARD METHODS 4500-P A. B. E.	0.010 mg/L
Total Zinc	STANDARD METHODS 3113 B.	50 µg/L
Transparency	Secchi disk depth measurement	0.01 m

More information and results for the physical and chemical parameters can be found in individual lake sections and the Appendix (Lakes Monitoring Data). The phytoplankton and zooplankton monitoring sections in this overview contains more details on the methodology.

PIEZOMETRIC AND AUGMENTATION WELLS

Background

Groundwater levels are monitored by the MPRB staff at piezometric wells. Piezometric wells are drilled to discrete depths to help monitor the flow of groundwater. Irrigation wells use groundwater for golf course turf and greens area maintenance. Augmentation wells are used to maintain water levels at lakes and ponds, and if permitted are occasionally used for winter ice rinks. Figure 1B is a map of the piezometric, irrigation, and augmentation well locations in Minneapolis.

The Minnesota Department of Natural Resources (MDNR) issues the permits and determines pumping limits for irrigation and augmentation wells. The MPRB is not allowed to exceed these limits without paying fines. Annual fees and reports are sent to the MDNR. The MPRB staff records groundwater levels from piezometric wells throughout Minneapolis.

Methods

Piezometric well readings are taken with a Herron Instrument Water Level Meter. This water tape is read at the top of the well casing to +/- 0.01 feet and its accuracy complies with US GGG-T-106E EEC Class III protocols. Piezometric wells A, B, C are monitored once a month January, February, March and December and twice a month April through November. Wells D, E, F and G are monitored quarterly.

Results & Discussion

The piezometric well readings are taken throughout the year.

The 2006 lake augmentation well readings and annual usage of 2006 are found in each respective lake section (Powderhorn and Loring). In 2006, all of the irrigation and augmentation wells used were below their MDNR allotted groundwater pumping volumes.

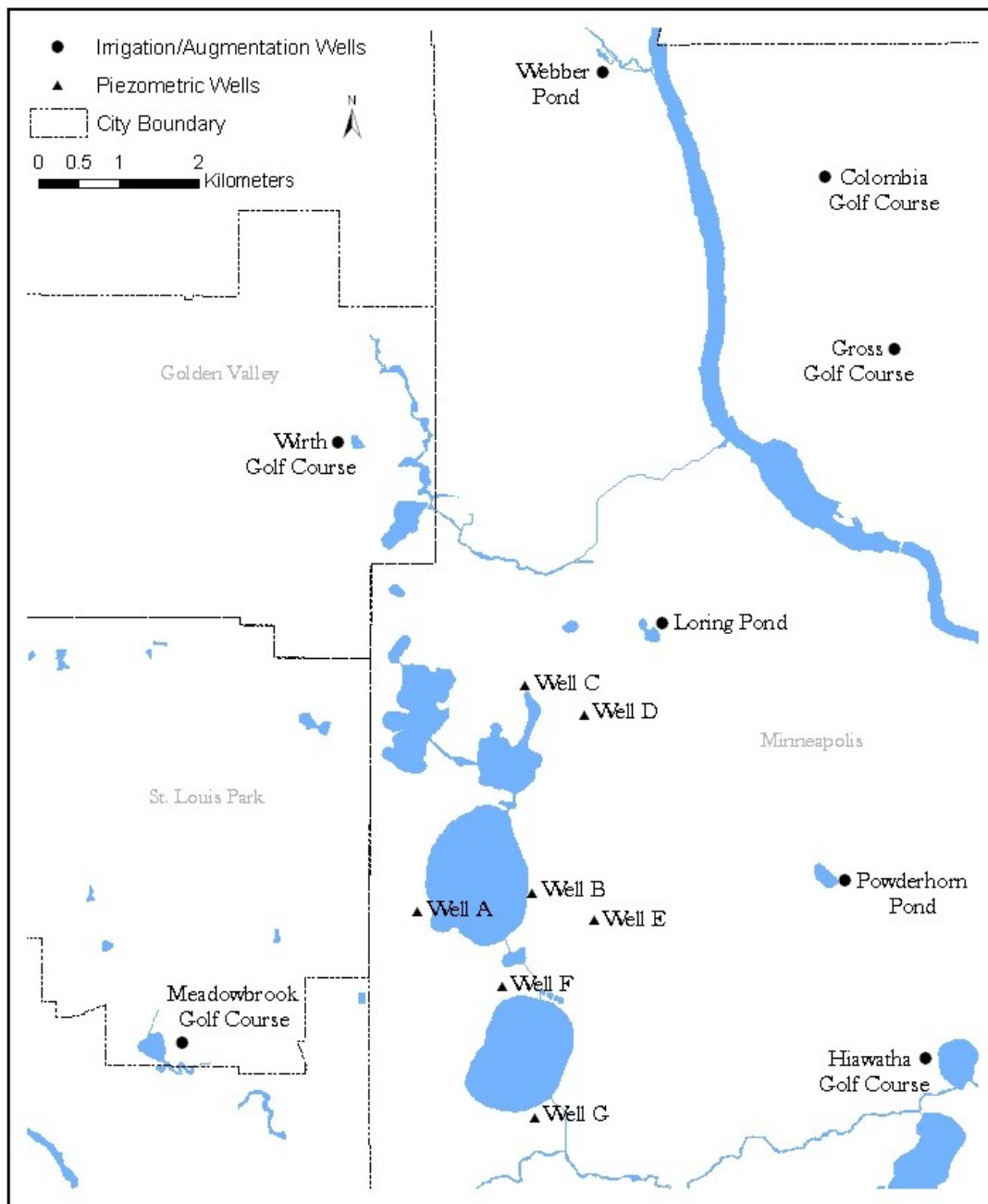


Figure 1B. Map of piezometric and irrigation/augmentation well locations monitored by MPRB Environmental Operations staff.

WATER QUALITY TRENDS (TSI)

Scientists have analyzed water quality parameters in Minneapolis lakes sporadically since 1927, but consistent, bi-weekly monitoring did not begin until 1991. In 2006, the MPRB monitored 13 city lakes according to the current schedule and protocols (Table 1A). The data collected was

used to determine nutrient related water quality (trophic status) and general usability.

Trophic status is used to estimate water quality and is based on Carlson's Trophic State Index (TSI). Trophic state is calculated using three nutrient related water quality parameters collected from surface water: water transparency (Secchi depth), chlorophyll-*a* (chl-*a*) and total phosphorus (TP).

Water transparency is measured using a black and white Secchi disk. The Secchi disk is lowered into the water until it cannot be seen. Then it is lowered a short distance further and raised until it is seen again. The average of these two numbers represents the Secchi depth. The Secchi depth is dependant on algal biomass or other factors that may limit light penetration (i.e. suspended solids).

Chlorophyll-*a* is a pigment algae used to capture sunlight and is a measure of how much algal biomass is in the lake.

Phosphorus is the limiting nutrient in most freshwater lakes and, therefore, controls the growth of algae. By measuring TP in lake water, it is possible to estimate algal growth and the potential for algal blooms (high algal growth).

TSI scoring is based on a 0-100 scale (although theoretically the scale has no upper or lower bounds) with higher numbers relating to higher trophic status and generally lower water quality. Three TSI scores are possible using the parameters described above and can be reported separately or as an average. The TSI score based on chl-*a* is thought to be the best measure of trophic state because it is the most accurate at predicting algal biomass (Carlson, 1977).

It is important to consider soil type and land use in the surrounding watershed when using the TSI to determine lake water quality. The state of Minnesota has seven ecoregions determined by land use, soil type and natural vegetation. Minneapolis lies within the North Central Hardwood Forests (NCHF) ecoregion, an area with fertile soils and agriculture as a dominant land use in rural areas. Lakes in this ecoregion generally have higher concentrations of nutrients and 90% of the TSI scores are between 41 and 77. In the Twin Cities metro area, it is recommended that a TSI score of 59 or lower be maintained in lakes used for swimming. This recommendation is based upon the aesthetic appeal of the water body.

Changes in lake water quality can be tracked by analyzing long-term trends in TSI scores. The MPRB uses TSI scores to assess changes in water quality and evaluate the effectiveness of restoration and management activities on the trophic state of the lakes. One of the methods used to classify lakes involves using categories based on the TSI score. Lakes generally fall into one of three categories based on trophic status that include: eutrophic, mesotrophic and oligotrophic, Horne and Goldman (1994).

Eutrophic ($50 > \text{TSI} < 70$) lakes are considered fertile and characterized by high algal biomass and may have macrophyte problems in some systems. Hypolimnetic anoxia occurs in stratified lakes and only warm water fisheries can be sustained.

Mesotrophic ($40 > \text{TSI} < 50$) lakes generally are moderately clear and have an increased probability of experiencing hypolimnetic anoxia during the summer months.

Oligotrophic (TSI < 30) lakes are characterized by low nutrients, oxygen throughout the water column and clear water. Salmon fisheries may dominate.

Lakes that have a TSI score greater than 70 are termed hypereutrophic and generally have very high algal biomass and low macrophyte densities due to light limitation by algae.

Lakes in the NCHF ecoregion frequently fall into the eutrophic category and the lowest trophic status lakes typically fall into the mesotrophic category. All the sampled lakes in Minneapolis are either eutrophic or mesotrophic with one lake, Calhoun, bordering on oligotrophic due to restoration activities. TSI scores dating back to 1991 are presented in Table 18B. For more detailed information on TSI scores and nutrient related water quality parameters, see the individual lake sections.

Individual Secchi, chl-*a* and TP TSI scores are calculated for the growing season (May - September) for each lake. Then the yearly lake TSI score is the average of the individual (Secchi, chl-*a* and TP growing season) TSI scores. It should be noted that some yearly lake TSI scores are an average of only two parameters (chl-*a* TSI, TP TSI) if a Secchi is not or cannot be taken on a particular lake. The individual TSI formulas are below.

Secchi TSI= (60-14.41)*ln (Average growing season Secchi in meters)

Chl-*a* TSI= 9.81*ln (Average growing season chl-*a* in µg/L)

TP TSI= 14.42*ln (Average growing season TP in mg/L*1000)+4.15

Yearly TSI= (Secchi TSI + chl-*a* TSI + TP TSI)/3

Linear regression analysis is a common method used for determining trends in average TSI over time. A graph was made of annual average TSI scores for each lake (found in each individual lake's section). A trend line was fit through the data points. The linear regression dashed line is defined as $y = mX + b$, where m is the slope of the line. The slope indicates the general trend of the data. The R^2 is a measure of how well the line fits the data; for example a perfect R^2 is 1.00. Based upon these results, it is possible to describe the direction of the trend (a negative or positive slope) and the degree of confidence one can place upon the trend. Water quality decreasing fertility is generally indicated by a decreasing TSI score and negative slope of the regression equation (TSI Figures in each individual lake's section and Table 18C, Section 18). Conversely, a positive slope and increasing TSI scores generally indicates increasing fertility in water quality.

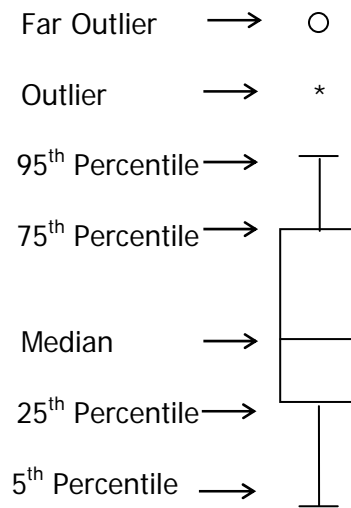
BOX AND WHISKER PLOTS

Additional analysis of the three TSI parameters can be accomplished using box and whisker plots. The box and whisker plots for each lake are another way to determine trends and are valuable for assessing variability over the years. The management goals for Minneapolis lakes are to reduce long-term fertility and the variability of water quality within a given year. Box and whisker plots can be used to look at short-term (seasonal) and long-term trends at the same time. Box plots for the three trophic state parameters (transparency, surface chlorophyll-*a* levels

and surface total phosphorus levels) were created for each lake, see individual lake sections.

For each plot, the box represents the middle 50 percent of the data from the 25th percentile to the 75th percentile. The “whiskers” (the vertical lines extending off of the boxes) represent the data from the 25th and 75th percentiles to the 5th and 95th percentiles, respectively. Any data falling above the 95th percentile or below the 5th percentile are marked as outliers. The horizontal line that cuts across the box represents the median value.

Generally, more compact box plots with short “whiskers” and few outliers indicate low yearly variability for the lakes. Long-term trends can be seen by the box plot moving in an up or down direction.



It is also important to note that before 2000, only growing season values were used to create the box and whisker plots. Since 2000, the entire monitoring season is included in the data set for the box and whisker plots.

LAKE AESTHETIC AND USER RECREATION INDEX (LAURI)

Existing lake monitoring programs use Carlson’s TSI to track the environmental health of a lake. This index is not entirely adequate for recreational purposes. In an effort to track changes from year to year, such as the Eurasian watermilfoil infestation, in 2004 the MPRB worked with Barr Engineering, with funding from Minneapolis Public Works, to develop a new index.

The Lake Aesthetic and User Recreation Index (LAURI) was developed to fill this niche. It was field tested and modified by MPRB in 2004. LAURI was designed to give recreational users another source of information about using MPRB lakes. The goal was to have an easily understandable recreational indicator for MPRB lakes. The two major constraints in developing the indices were that they were to be collected by existing water quality staff, within the existing budget. LAURI has four categories:

- Aesthetic considerations (color and odor of water, garbage and debris)
- Environmental quality (water clarity/Secchi depth)
- Public health (*E. coli* measured at public swimming beaches)
- Recreational interferences (aquatic plants)

Data was collected during the growing season, May to September 2005, during regular lake monitoring activities. The results are presented in the individual lake sections.

Aesthetic Considerations

The lakes were scored for water color, odor and debris (Table 1D) based on an assessment done from shore, dock or boat. Higher numbers indicate worse aesthetics. The scores were averaged over the season. Aesthetics can be difficult to evaluate as they are strongly qualitative and dependent on one's own experience.

Table 1D. Scoring for the aesthetic portion of LAURI.

Color	Score	Odor	Score	Debris	Score
Clear	0	None/Natural	0	None	0
lt. Brown or green	2	Musty - faint	1	Natural	1
Bright Green	5	Musty - strong	2	Foam	2
Milky White	6	Sewage/fishy/ garbage -faint	5	Trash: floating (>3)	4
Brown/Reddish/ Purple	8	Sewage/fishy/ garbage - strong	8	Trash: fixed (>3)	5
Gray/Black	10	Anaerobic/septic	10	Piles of milfoil (>3)	6
				Many dead fish (>5)	8
				Green scum	8
				Oil film	9
				Sewage Solids	10

Recreational Interferences

While aquatic plants are a necessary part of a healthy lake ecosystem, they can also interfere with recreational uses of the lake. Invasive, non-native, aquatic plants are the most problematic for MPRB lakes. The two culprits are Eurasian watermilfoil and Curly-leaf pondweed. Dense growth may limit swimming, boating and other activities. In addition, dense growth that occurs, especially when plants mat on the surface, can be unsightly. The LAURI assessments were done as a visual survey from a boat and during beach *E. coli* sampling, similar to what users would experience. Scoring was based on presence of exotic species, density of plants and amount of coverage (Table 1E). The higher the score, the more recreational interference there was from aquatic plants.

Table 1E. Scoring for the recreational interference portion of LAURI.

Exotic Species	Score	Density	Score	Coverage <15 feet	Score
None	0	Low	0	0-25 %	0
		Low-med	2.5	25-50 %	2.5
One	5	Medium	5	50-75 %	5
		Med-high	7.5	75-100 %	10
More than one	10	High	10		

Other recreational interferences, such as swimmer's itch and leeches, were not included in

LAURI. These may need to be incorporated at a later date, if the need arises.

Environmental Quality

Water clarity is a very straightforward parameter, easy to measure and easy to understand. This simple measure of how clear the water is, gives good information on the eutrophication status of a lake, see Water Quality Trends above. The average Secchi transparency reading from all the data collected during the growing season was used. The lakes were separated into deep lakes and shallow lakes using criteria developed by the Minnesota Pollution Control Agency (MPCA). Calhoun, Cedar, Harriet, Hiawatha, Nokomis and Wirth were considered deep lakes. Loring, Isles and Powderhorn were considered shallow lakes. Higher numbers indicate clearer water.

Public Health

To determine whether a lake meets guidelines for full-body recreational contact for people, the existing beach monitoring program data were used. *E. coli*, the indicator recommended by the Environmental Protection Agency (EPA), was measured at every public beach in the park system. Beaches exist on Calhoun, Cedar, Harriet, Nokomis and Wirth Lakes. The scoring used the season long geometric mean, from the beach monitoring program, for each lake (Table 1F). Lakes with more than one beach were averaged together. The EPA guidelines stated that beaches should not exceed 235 organisms per 100 mL, for a single sample, or a geometric mean of 126 organisms per 100 mL during a 30-day time period. See Public Beach Monitoring, Section 19 for more details. Lower numbers indicate less risk of illnesses for lake users.

Table 1F. Scoring for the public health portion of LAURI. ND = not detected.

E. coli bacteria, CFU/100mL	Score
<2 (ND)	0
2 - 10	1
11 - 20	2
21 - 35	3
36 - 50	4
51 - 76	5
77 - 110	6
111 - 150	7
151 - 200	8
201 - 235	9
>235	10

Hopefully, LAURI will be useful to users of the Minneapolis park system. Someone interested in walking or biking around a lake may use only the aesthetic score. A swimmer may compare lakes based on the public health, aquatic plant, aesthetic, and water quality scores. A sailor or kayak user may be primarily concerned with the aquatic plant (recreational interference) score.

WINTER ICE COVER

An interesting climatological statistic to track over time is the date that a lake freezes in the fall and the date it thaws in the spring. Ice phenology affects migration and breeding patterns of birds, food supply of fish and animals, and water chemistry. Ice out and on dates are given in

the individual lake sections. A comparison among lakes can be found in Section 18.

Some caution must be shown when interpreting this data. Over the years, many different people have been responsible for writing down the dates and ice dates can be somewhat subjective with people using different observation techniques. Since 2000, the MPRB has been using the definition of ice on as occurring when the lake is 100% covered with ice, preferably in the afternoon (when ice may break up on a sunny day). Ice off occurs when the lake is essentially ice free (<10% covered with ice).

AQUATIC PLANTS

Aquatic plants, also known as macrophytes, form the foundation of a healthy lake ecosystem. They produce oxygen and protect water quality by absorbing nutrients like phosphorus and nitrogen that could otherwise stimulate algae blooms. Plant beds stabilize soft lake bottoms and limit shoreline erosion by dampening the effect of waves and current. Aquatic plants provide important habitat for insect larvae, snails and other invertebrates which are food sources for fish, frogs, turtles and birds. Aquatic plants also provide shelter for fish and food for waterfowl. The health of a lake depends upon having a healthy plant community.

Algae blooms occur from time to time. Filamentous algae are responsible for the green scum sometimes seen floating on the surface of lakes and ponds. Filamentous algae can sometimes be seen growing attached to sediments and to macrophytes. They can grow as part of large colonies. As the colonies die, they float to the surface and create a nuisance. Other types of algae can also cause problems like decreasing the clarity of the water. As algae die and decompose, oxygen gets used up which can create additional problems, such as fish kills or odor problems. Despite these problems, algae are a necessary part of the food chain.

Lakes with macrophytes are usually clearer than lakes without macrophytes. Plants stabilize sediments and shorelines and prevent the suspension of sediments (from wind or fish) that would otherwise result in turbid, murky waters. Aquatic plant growth uses nutrients from the water column and from the sediments, which could otherwise be used by aquatic algae. Aquatic plants also provide enormous amounts of surface area for biofilms and provide habitat for microscopic plants and animals to grow, which utilizes nutrients that otherwise would be used by planktonic algae. Large zooplankton use aquatic plants as a refuge against fish. This improves water clarity as the zooplankton consume algae. Lakes with a vegetation-dominated clear state are characterized by having a more diverse fish community and larger numbers and diversity of waterfowl.

Eurasian Watermilfoil Control Program

Eurasian watermilfoil (*Myriophyllum spicatum*) has been a growing problem evident in several Minneapolis lakes. Milfoil causes problems on several levels. From an ecological standpoint, it out-competes native species and reduces the available habitat for fish and other organisms. From a recreational perspective, milfoil is problematic in that it forms dense floating mats that interfere with boating and swimming. It also reduces the overall aesthetic appeal of area lakes.

No environmentally safe method has been proven to rid lakes of milfoil, but several management methods exist to treat the symptoms of infestation. The MPRB primarily uses harvesting to control the growth of milfoil in city lakes. Harvesting milfoil is analogous to

mowing a lawn. Only the top two meters of the milfoil plants are removed, but this temporarily allows for problem-free boating and swimming. Harvesting was completed on Calhoun, Harriet and Isles in 2006. Lake Nokomis and Wirth Lake also received limited harvesting in 2006. For acreage, see individual lake sections. In 2006, 405 flatbeds full of milfoil were removed. This is roughly 2,200 cubic yards.

PHYTOPLANKTON AND ZOOPLANKTON MONITORING

Background

Biological parameters are routinely measured as part of a lake's assessment. Phytoplankton and zooplankton are two of the common biological parameters collected because they are essential to the aquatic food web and influence other aspects of the lake, including color and clarity of the water and fish production.

Phytoplankton (algae) are microscopic plants that are an integral part of the lake community. Phytoplankton use nutrients in the water and sunlight to grow and are the base of the aquatic food web. Chlorophyll-*a* is the primary photosynthetic pigment contained in algae. Because the chlorophyll-*a* concentration can be easily measured in a water sample, it is a common way to estimate the phytoplankton biomass in the water (Paerl and Sandgren, 1998).

Zooplankton are tiny animals that feed on phytoplankton and other zooplankton. They are vital to the lake community and form the second level in the food web. The two main categories of zooplankton found in Minneapolis lakes are rotifers and arthropods. Both copepods and cladocerans are arthropods; rotifers tend to be the smallest of the zooplankton. Despite their small size, they are important in the aquatic food web because of their abundance, distribution and wide range of feeding habits. Copepods and cladocerans are larger zooplankton and members of the class Crustacea. Copepods are the most diverse group of crustaceans. A cladoceran, *Daphnia* (the common "water flea"), is probably the most commonly known zooplankton.

Methods

Phytoplankton

Phytoplankton samples were collected, twice a month, from most of the thirteen city lakes that are monitored (Calhoun, Cedar, Diamond, Harriet, Hiawatha, Isles, Loring, Nokomis, Powderhorn and Wirth). Samples were collected, once a month, from Grass Lake and Webber Pond. Surface water composite samples were collected for phytoplankton using a 2-m long, stoppered, 2-inch diameter, PVC tube. The PVC tube was first cleaned with a brush and rinsed three times with lake water. Two such samples were mixed in a clean white plastic bucket that was also rinsed with lake water. Water from this mixed sample was decanted for analysis into amber bottles containing 25% glutaraldehyde, a preservative. In 2003, PhycoTech Incorporated (St. Joseph, MI) laboratory was used for the first time. Analysis was completed using the phytoplankton rapid assessment count, developed by Edward Swain and Carolyn Dindorf of the MPCA. This method involves a sub-sample being placed in a counting chamber and analyzed using an inverted microscope. The algal division, taxa, genus, and species are identified and the percent abundance, by volume, is estimated. Identification protocol is according to Weber (1971) and Prescott (1951). The results are presented by division (phylum) in the individual lake sections. Phytoplankton divisions and a common description are given in Table 1G.

Table 1G. Phytoplankton divisions and brief descriptions.

Division	Description
Bacillariophyta	diatoms
Chlorophyta	green algae
Chrysophyta	golden-brown algae
Cryptophyta	cryptomonads
Cyanophyta	blue-green algae
Euglenophyta	euglenoids
Pyrrophyta	dinoflagellates

Chlorophyll-*a* concentrations were used to estimate phytoplankton biomass in the lakes from April through October. In each lake section, graphs show the minimum and maximum chlorophyll-*a* concentrations and the dominant phytoplankton division throughout the sampling season.

Zooplankton

Zooplankton samples were collected monthly from most Minneapolis lakes, see Table 1A. Zooplankton samples were not taken from Webber Pond, Grass Lake, or Diamond Lake. The samples were collected using an appropriate μm mesh, Wisconsin-type plankton net with an appropriate μm mesh, Wisconsin-type bucket. The Wisconsin-type plankton net was viewed under a microscope March of 2005, by IRI, and determined to be a 50 μm mesh. The net was raised from the bottom of the water column, to the surface vertically, at a rate of 1 meter per second. The contents were rinsed into a bottle containing an approximately 100% denatured histological ethanol as a preservative solution. The distance the net was pulled through the water column (tow depth) was recorded on field sheets and on the bottle label. Analysis was conducted, at the lab, using a compound microscope to identify and enumerate all the zooplankton found in a 1 mL sub sample. The zooplankton were identified as completely as possible: class, subclass, order, suborder, family, genus, species and subspecies. Zooplankton were identified according to standard protocols and twelve taxonomic authorities (Edmondson, 1959). The zooplankton were divided into arthropoda, protozoa and rotifera. The results are in the individual lake sections.

FISH STOCKING

Many of the lakes in Minneapolis are stocked with fish by the MDNR. This information is on the MDNR's website (<http://www.dnr.state.mn.us/lakefind/index.html>).

Stocking Fish Sizes:

Fry - Newly hatched fish. Walleye fry are 1/3 of an inch or around 8 mm.

Fingerling - Fingerlings are one to six months old and can in size from one to twelve inches.

Yearling - Yearling fish are at least one year old and can range from three to twenty inches.

Adult - Adult fish are fish that have reached maturity age.

FISH KILLS

Many of the summer fish kills in Minneapolis lakes are attributed to *Columnaris* bacteria. The naturally occurring *Flexibacter columnaris* bacteria cause the disease. This disease is usually

associated with a stress condition such as high water temperature, low dissolved oxygen concentration, crowding or handling. Symptoms of this disease include grayish-white lesions on parts of the head, fins, gills or body usually surrounded by an area with a reddish tinge. On crappies, the lesions are generally confined to the fins and gills and rarely extend to the body.

Columnaris is known to only infect fish species and is not a health risk to humans. The bacteria is most prevalent in lakes when water temperatures approach 65-70 degrees F, from late May to late June. The bacteria levels can increase after a major rainfall and runoff which, supply additional nutrients for the bacteria into area lakes.

Bluegill, crappie, yellow perch and bullhead fish species are most affected by the disease. The bacteria works by eroding the fishes' skin, causing a leakage of the bodily fluids and an influx of lake water into the fishes' body. There is little that the MDNR or the public can do to prevent this naturally occurring phenomenon.

For more information see:

<http://www.dnr.state.wi.us/org/caer/ce/news/rbnews/2003/061803nor.htm>

http://www.michigan.gov/dnr/0,1607,7-153-10364_10950-27387--,00.html

Winter fish kills on lakes are likely due to thick ice and snow cover leading to low dissolved oxygen conditions in the water below. Usually small lakes and ponds are most affected by winter fish kills.

QUALITY ASSURANCE/QUALITY CONTROL

The contract laboratory analyzed blanks and appropriate standards with each set of field samples. Equipment blanks were analyzed on 10% of all sampling trips (spring and fall). In addition, field duplicate samples were analyzed each lake sampling trip (weekly) and laboratory performance standards were analyzed every month sampling occurred. Laboratory split samples were analyzed twice a year, ideally between a minimum of three labs. Field blanks were done every sampling trip.

Calibration blanks, reagent blanks, quality control samples, laboratory duplicate samples and matrix spike/duplicate samples were analyzed at a 10% frequency by the contract laboratory.

The quality control samples analyzed by the laboratory consisted of two sets:

- (1) Samples of known concentration (control standards) that served as a independent verification of the calibration standards and as a quality control check for the analytical run,
- (2) Blind samples (of unknown concentration) provided by the MPRB Environmental Operations staff.

In addition, duplicate zooplankton and phytoplankton samples were collected by MPRB staff and analyzed once during the sampling season (Lee J.T., 1997 and US EPA, 1980).

For more details and QA/QC results for 2006, see the Quality Assurance Assessment Report, Section 28.