1 MONITORING PROGRAM OVERVIEW: 1991-2003

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 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.

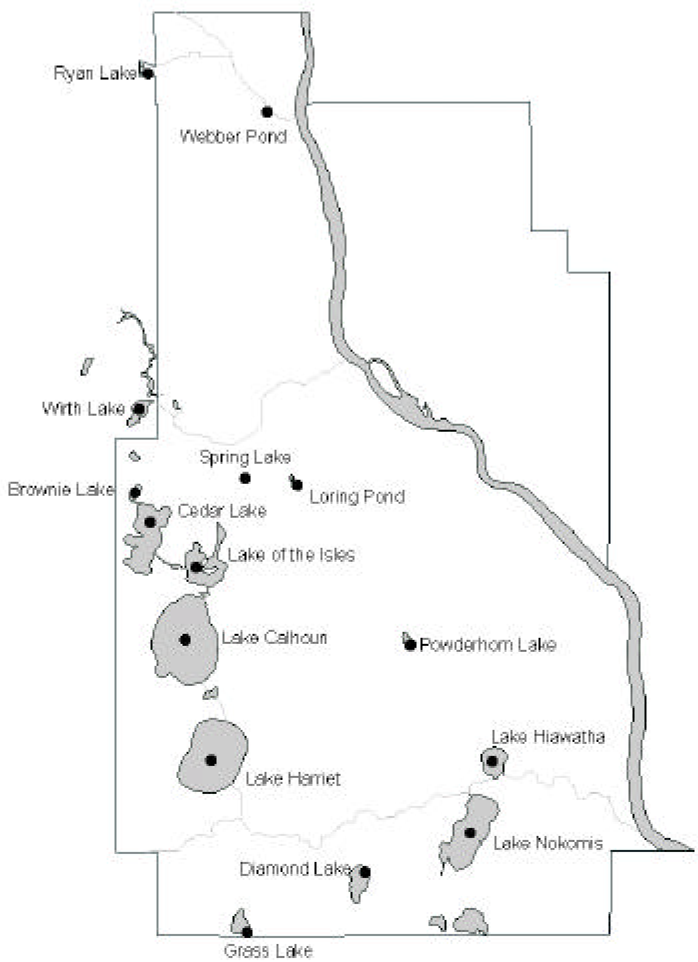

Figure 1A. Location of lakes monitored by MPRB.

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) offer a 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 development is the predominant land use within the watersheds; however, industrial/commercial development 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 tending 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).

Table 1A. Minneapolis lakes morphometric data. NA= Information not available, * littoral area defined as less than 15 feet deep

Lake	Surface Area (acres)	Mean Depth (m)	Maximum Depth (m)	% Littoral Area*	Volume (m^3)	Watershed Area (acres)	Watershed: Lake Area (ratio)	Residence Time (years)
Brownie	18	6.8	15.2	67%	$4.98x10^5$	369	20.5	2.0
Calhoun	421	10.6	27.4	31%	$1.80x10^7$	2,992	7.1	4.2
Cedar	170	6.1	15.5	37%	$4.26x10^6$	1,956	11.5	2.7
Diamond	41	0.9	2.1	100%	$7.15x10^4$	669	16.3	NA
Grass	27	0.6	1.5	NA	NA	386	14.3	NA
Harriet	353	8.7	25.0	25%	$1.25x10^7$	1,139	3.2	3.4
Hiawatha	54	4.1	7.0	26%	$8.95x10^5$	115,840	2145	0.03
Isles	103	2.7	9.4	89%	$1.11x10^6$	735	7.1	0.6
Loring	8	1.5	5.3	NA	$4.88x10^4$	24	3.0	NA
Nokomis	204	4.3	10.1	51%	$3.54x10^6$	869	4.3	4.0
Powderhorn	11	1.2	6.1	99%	$9.04x10^4$	286	26.0	0.2
Ryan	18	NA	10.7	50%	NA	5,510	306	NA
Spring	3	3.0	8.5	NA	$3.65x10^4$	45	15.0	NA
Webber	3	0.9	2.0	NA	$1.10x10^4$	2	0.7	NA
Wirth	39	4.3	7.9	61%	$6.70x10^5$	348	9.4	NA

METHODS

The 2003 schedule of physical and chemical parameters is shown in Table 1B. Most lakes followed this schedule and were sampled once per month in January, April and October and twice per month during the period of May through September. The exceptions to the stated schedule included:

- Diamond Lake and Webber Pond were sampled once per month from April through October.
- Grass Lake was sampled once per month from May through September.
- Spring Lake was sampled once a month April through October, with limited parameters in May, June, August and September.
- Brownie Lake and Ryan Lake were not sampled in 2003.

Table 1B. Schedule of sampled parameters for most Minneapolis lakes in 2003.

Parameter	Winter	March/April	May – Sept	October
Secchi Transparency	Once	Once	Twice a Month	Once
Dissolved Oxygen	Once	Once	Twice a Month	Once
Temperature	Once	Once	Twice a Month	Once
pH	Once	Once	Twice a Month	Once
Conductivity	Once	Once	Twice a Month	Once
Chlorophyll-*a*	Once	Once	Twice a Month	Once
TP, SRP, TN	Once	Once	Twice a Month	Once
TKN, NO_x	Once	Once	Once	Once
Hardness	Once	Once	Once	Once
Alkalinity	Once	Once	Once	Once
Total Aluminum*	Once	Once	Once	Once
Dissolved Aluminum*	Once	Once	Once	Once
Chloride	Once	Once	Once	Once
Silica	Once	Once	Once a Month	Once
Phytoplankton	Once	Once	Twice a Month	Not Sampled
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 points in each lake (sampling station). The sampling stations were determined from bathymetric maps and located using shoreline landmarks and an electronic depthfinder. Diamond Lake, Grass Lake and Webber Pond were taken as grab samples from the shore.

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 Grass, Ryan, Brownie and Spring lakes (Table 1B). Phytoplankton samples were not collected on Grass or Ryan lakes. Phytoplankton samples were taken from Brownie and Spring in April, July and October when all physical and chemical parameters were measured on the two lakes. Phytoplankton were collected from the 0-2 m surface composite sample and stored in a opaque plastic container with 25% glutaraldehyde.

Vertical zooplankton tow samples were taken at the sampling station for each lake (except Diamond Lake, Webber Pond, Grass Lake, Ryan Lake, Brownie Lake and Spring Lake) once per month during the growing season (Table 1B). Diamond, Webber, Grass and Ryan lakes had no zooplankton samples taken during the season. Brownie and Spring lakes had zooplankton samples collected in April, July and October. Zooplankton were collected using a Wisconsin vertical tow net retrieved at a rate of 1 m/s through the full water column. The 80-µm mesh Dolphin bucket was rinsed with distilled water 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 1C). 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. Each lake sample collection regime was determined based upon maximum depth, stratification characteristics and the results of previous studies.

Table 1C. Sampling depth profiles for the Minneapolis lakes monitoring program, 2003.

Lake	**Sampling Depths**						
Brownie Lake	Not Monitored						
Lake Calhoun	0-2m composite	3m	6m	9m	12m	18m	22m
Cedar Lake	0-2m composite	3m	5m	7m	10m	14m	
Diamond Lake	Grab (surface)						
Grass Lake	Grab (surface)						
Lake Harriet	0-2m composite	3m	6m	9m	12m	15m	20m
Lake Hiawatha	0-2m composite	4m					
Lake of the Isles	0-2m composite	3m	5m	7m			
Loring Pond	0-2m composite	4m					
Lake Nokomis	0-2m composite	4m	6m				
Powderhorn Lake	0-2m composite	4m	6m				
Ryan Lake	Not Monitored						
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 ~ 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 (APHA, 1998) or U.S. Environmental Protection Agency (US EPA, 1979). The 2003 contract laboratory for chemical analyses was Instrumental Research Inc. (IRI). Phycotech laboratory analyzed the phytoplankton and zooplankton samples. The methods and reporting limits for all parameters are listed in Table 1D.

Table 1D. Methods and reporting limits used for parameter analysis in the 2003 Minneapolis lakes monitoring program.

Parameter	**Method**	**Reporting Level**
Alkalinity	STANDARD METHODS 2320 B.	1.0 mg/L
Chloride	STANDARD METHODS 4500-Cl^- B.	2.0 mg/L
Chlorophyll-*a*	Acetone extraction/spectrophotometric determination (pheophytin corrected) SM 10200 H.	0.5 mg/m^3
Hardness	STANDARD METHODS 2340 C.	1.0 mg/L
Nitrate+Nitrite Nitrogen	STANDARD METHODS 4500-NO_3 E.	0.03 mg/L
Silica	STANDARD METHODS 4500-Si D.	0.500 mg/L
Soluble Aluminum	EPA 200.9	5 µg/L
Soluble Reactive Phosphorus	STANDARD METHODS 4500-P A. B. E.	0.003 mg/L
Total Aluminum	EPA 200.9	5 µg/L
Total Kjeldahl Nitrogen	STANDARD METHODS 4500-Norg B.	0.500 mg/L
Total Nitrogen	Alkaline persulfate oxidation/automated cadmium reduction method, SM 4500-N C.	0.500 mg/L
Total Phosphorus	STANDARD METHODS 4500-P A. B. E.	0.010 mg/L
Transparency	Secchi disk depth measurement	0.01 m
Conductivity	Hydrolab Minisonde 4a Multiprobe (field)	0.1 µS/cm
pH	Hydrolab Minisonde 4a Multiprobe (field)	0.01 standard unit
Temperature	Hydrolab Minisonde 4a Multiprobe (field)	0.01 °C
Dissolved Oxygen	Hydrolab Minisonde 4a Multiprobe (field)	0.01 mg/L

More information and results for the physical and chemical parameters can be found in Section 1.2 (Trophic State Report 1991-2003) and Appendix C (2003 Minneapolis Lakes Data).

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 and laboratory performance standards were analyzed every month. Laboratory split samples were analyzed twice a year. 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 second calibration 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 2003, see the Quality Assurance/Quality Control Assessment Report, Section 13.

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