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1.0 Background

Saskatchewan Watershed Authority (SWA) developed The *Lake Stewardship Program* in September 1997 to support stewardship groups throughout Saskatchewan. The mandate of the program is to foster communication, collect and share information, and help develop partnerships between stewardship groups and other agencies to protect and preserve water quality and aquatic life.

The Authority provides support to individual stewardship groups based on their specific needs and interests which may include water quality monitoring, environmental education, and community outreach. Stewardship group activities depend on the groups' size, interest, goals, and objectives.

Lake stewards are ambassadors for their lake and community. Knowledge of community achievements and challenges enable stewards to effectively tailor environmental awareness and educational outreach programs to the needs of their community. The *Lake Stewardship Program* will improve understanding and decision making within the watershed and foster relationships between various agencies and stewardship groups to ensure source water protection.

2.0 Moosomin Reservoir

Moosomin Reservoir is a man-made lake located approximately 10 kilometers south of Moosomin, Saskatchewan. The reservoir, located on the Pipestone Creek, is approximately 10 kilometers long and half a kilometer wide. It is used for a number of recreational activities including fishing, boating, and swimming. Most of the development around Moosomin Reservoir is located within the Moosomin and District Regional Park on the west side of the reservoir. The reservoir has a mean and maximum depth of 4.5 and 7.9 meters, respectively. The full supply level is 543.910 meters above sea level (masl) and in 2003 the reservoir was measured at 543.611 masl.

Due to the recreational nature of Moosomin Reservoir, the protection of water quality is of interest to a number of stakeholder groups and individuals. Growing concerns relating to the water quality of Moosomin Reservoir and the need to share information among stakeholders led the Saskatchewan Watershed Authority (formerly Sask Water), together with local residents, to establish a lake stewardship group. As part of the activities of this stewardship group, a water quality monitoring program was established in 2001. This program involved a co-operative effort between local volunteers and Saskatchewan Watershed Authority staff to collect water samples from a baseline station and two shoreline locations with in the Regional Park, as well as the two main tributaries to the reservoir, Pipestone Creek and Little Pipestone Creek. This report presents the results from the 2003 and 2004 water quality monitoring program.

2.1 Stewardship Activities

The Moosomin stewardship group and the Pipestone Watershed Advisory Committee will work together in 2005 to pursue stewardship initiatives in the Moosomin Reservoir watershed that are focused on water quality protection. The Moosomin Reservoir stewardship group has primarily focused on water sampling in the past. The Pipestone Watershed Advisory Committee was formed as part of the Saskatchewan Watershed Authority watershed planning process in 2003. The Pipestone Watershed Advisory Committee has been instrumental over the last two years working with local producers to establish demonstration sites featuring environmental enhancing practices. This year the two groups will work together on a Centennial Shoreline Cleanup in the watershed. The cleanup will not only focus on the Moosomin Reservoir but also the tributary streams and creeks.

2.2 Purpose and Scope

Water quality monitoring is a key component of any lake stewardship activity. Water quality monitoring can serve three primary purposes for local groups and residents:

1. to understand the characteristics of a lake,
2. to understand how activities around a lake can impact water quality, and
3. as a means of assessing water quality.

The scope and purpose of the water quality monitoring program is to assess the current water quality conditions in Moosomin Reservoir. The program is designed to collect water quality data representative of the lake that may be used to establish changes or trends in water quality over time.

2.3 Water Sampling Procedure

2.3.1 Baseline Station

Saskatchewan Watershed Authority personnel facilitated the collection of all field measurements and water sampling at Moosomin Reservoir in 2003 and 2004. A sampling station was established near the point of maximum depth near the center of the lake (Figure 1). This station is referred to as the baseline station. The baseline sampling station's global positioning satellite (G.P.S.) co-ordinates were referenced so that the same location was sampled each time. Sample location consistency enables current and historic water quality data to be compared. Samples collected in 2003 were collected from the top of the water column just below the water surface. In 2004, baseline water samples included discrete top and bottom water samples taken using a horizontally orientated Van Dorn water sampler, as well as an integrated water sample taken from the surface to two times the secchi depth. Sample collection and field monitoring of the baseline station was conducted four times during 2003; May 27, July 8, August 12, and September 23. In 2004, sampling was conducted five times; March 4, June 15, July 13, August 10, and October 6.

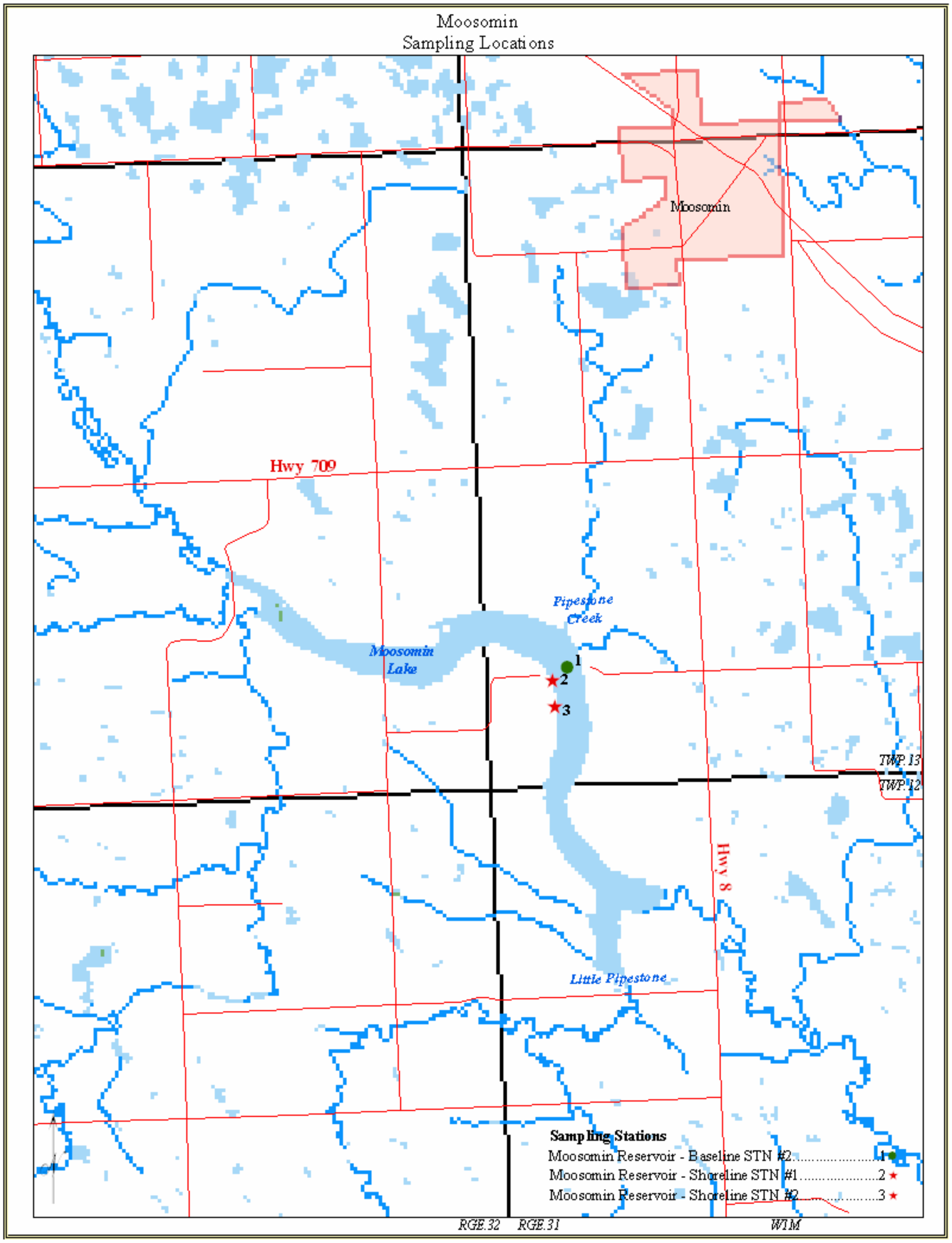

Figure 1 **Moosomin Reservoir 2003 and 2004 Sampling Locations**

2.3.2 Shoreline and Creek Stations

Two shoreline sites on Moosomin Reservoir, close to the Regional Park, were sampled biweekly in 2003 from May 27 until September 23 (Figure 1). In 2004, the same two shoreline stations were sampled four times; June 15, July 13, August 10, and October 6. The 2005 sampling program will include a third shoreline site on Moosomin Reservoir, located approximately 500 meters from the dam. The Pipestone Creek, Site #1 was only sampled on May 27, 2003. In contrast, Pipestone Creek #2, located at Grid 709 was sampled twice in 2003: May 27 and July 8 and three times in 2004: June 15, July 13, and August 10. Little Pipestone Creek was not sampled during 2003 or 2004 sampling program. Monitoring at this location is to be resumed in the 2005 sampling program. All shoreline and creek sampling stations' global positioning satellite (G.P.S.) co-ordinates were referenced so that the same location was sampled each time. Shoreline and creek samples collected in 2003 and 2004 were grab samples collected from the top of the water column just below the water surface.

2.3.3 Field Measurements

Field measurements were taken at the baseline, shoreline, and creek stations and included air temperature, water temperature, cloud cover, wind speed, secchi disk transparency, pH, turbidity, conductivity, and dissolved oxygen. Dissolved oxygen, conductivity, and temperature were measured using a YSI 85D oxygen/temperature/conductivity meter. Calibrations were made using standard reference solutions. pH was determined using a hand held WTW 330i pH meter; calibrated using a two-point calibration with reference solutions at pH 7 and 10. Turbidity was determined using a Lamotte Model 2020 nephelometric turbidity meter. Calibrations were performed with reference solutions of 1.0 and 10 NTU.

2.3.4 Laboratory Analysis

Baseline, shoreline, and creek samples were analyzed for nutrients, major ions, chlorophyll *a*, dissolved and suspended solids, and bacteria (see Tables 6 to 9). All water samples were collected in plastic bottles and shipped in coolers to the Provincial Laboratory in Regina, Saskatchewan for analysis.

2.3.5 Stewardship Involvement

Volunteers are essential to the water monitoring program providing transportation to sampling locations, sample collection assistance, and local knowledge. In 2003 and 2004 Norm Schmidt, Eileen Godon, and Al Ferguson assisted Saskatchewan Watershed Authority technologist Kevin O'Neill with sampling at Moosomin Reservoir.

3.0 Trophic Status

Trophic status is a lake classification system based on the amount of nutrients in the lake and its' resulting biological productivity. Several water quality parameters are measured and used as indicators to determine the trophic status of a lake. The most commonly used "trophic indicators" include nutrients, chlorophyll *a*, and secchi disk transparency (water clarity). Nutrient additions increase biological productivity, which may be measured as chlorophyll *a*, which in turn decreases water clarity, measured by secchi disk transparency. As a result, biological productivity is used to determine lake trophic status. There are four trophic states: oligotrophic, mesotrophic, eutrophic and hypertrophic, which range from low to extreme biological productivity respectively. Oligotrophic lakes have low inputs if nutrients, organic matter and sediment and consequently, little biological productivity. In contrast, eutrophic lakes are very productive with high levels of nutrients, organic matter and sediments. Lakes on the prairies are typically classified as eutrophic lakes due to high nutrient concentrations. As a result, the Water Quality Index has been employed to more accurately assess the quality of water in recreational lakes throughout Saskatchewan.

4.0 Water Quality Index

The Water Quality Index (WQI) is an effective means for summarizing a large number of water quality parameters. Similar to the UV index or an air quality index, it provides an indication of the overall water quality for watershed health.

The advantage of the WQI is that it summarizes key water quality parameters in a single index and is especially meaningful to people who want to know about the state of their local water body. The index also allows water quality data to be reported in a consistent manner.

Values for various water quality parameters (*e.g.*, dissolved oxygen, nutrients, and fecal coliform bacteria) are compared to specific water quality objectives. The results of the comparisons are combined to provide a water quality ranking (*e.g.*, Good, Fair, Poor) for individual water bodies. To assess overall watershed health the Saskatchewan Watershed Authority has selected seventeen parameters to be incorporated into the water quality index including nutrients, minerals, metals, pesticides, and bacteria. The parameters and their corresponding objectives used in the Water Quality Index are shown in Table 1.

The index is based on three components that relate to water quality objectives:

Scope - How many? - The number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.

Frequency - How often? – The number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest.

Amplitude - How much? - The amount by which measurements which do not meet objectives depart from those objectives.

Water Quality Index (WQI) values range between 1 and 100. One represents the worst water quality and 100 represents the best water quality. Once the WQI value has been calculated the value can be further simplified by assigning it to one of several descriptive categories:

Excellent: (WQI value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.

Good: (WQI value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (WQI value 60-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (WQI value 45-59) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor: (WQI value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

5.0 Results

5.1 Baseline Station

Surface water quality parameters measured at the baseline station on Moosomin Reservoir have been summarized in Tables 2 to 5. There are five important field measurements which are analyzed when assessing water quality. These include: dissolved oxygen and temperature profiles, conductivity, secchi disk transparency depth, and turbidity.

Dissolved oxygen concentrations are variable based on time, weather, and temperature. Consequently, sampling needs to be repeated within the same time frame each year to enable year to year comparisons. Dissolved oxygen levels of 1 or 2 mg/L will not support fish populations. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a minimum dissolved oxygen concentration of 5 mg/L for the protection of all stages of warm water biota. Moosomin Reservoir is a shallow well mixed reservoir that does not show any thermal stratification (Tables 3 to 5). During the open water season surface dissolved oxygen concentrations ranged between 7.66 to 12.60 mg/L, well above the 5 mg/L objective for the protection of warm water biota. Moosomin Reservoir has three sources of dissolved oxygen; an automatic aeration machine, oxygen produced by aquatic plants, and atmospheric oxygen mixed into the water column by wind and wave action. As a result, during the open water season dissolved oxygen levels are maintained throughout the water column (Tables 3 to 5). In contrast, during the winter months dissolved oxygen concentrations are depleted throughout the water column with near anoxic conditions near the bottom. Ice and snow on top of the lake surface prevents atmospheric additions of oxygen to the lake and oxygen production by aquatic plants is reduced due to limited light energy. Without oxygen additions dissolved oxygen levels in the lake are rapidly depleted by oxygen consuming processes such as decomposition and respiration.

Conductivity is a measure of waters ability to conduct an electric current, which depends on the concentration of dissolved ions in solution. It is determined by the concentration of specific ions and lake temperature. Conductivity is influenced by watershed geology and soil composition. In 2003, Moosomin Reservoir's conductivity ranged from 948 to 1,289 µS/cm, while in 2004 the conductivity levels ranged from 938 to 1,418 µS/cm (Tables 3 and 5).

Turbidity is the measure of water clarity. A reduction or lack of water clarity is caused by solids suspended in the water including clay, silt, and plankton (small plants and animals). Sources of turbidity are soil erosion, waste discharge, urban runoff, boating, algal growth, or abundant bottom feeders that stir up bottom sediment. Increases in turbidity may decrease light penetration, destroy or modify fish habitat, and increase water temperature which decreases oxygen concentrations. The secchi disk transparency reading is a measure of water transparency. Transparency is affected by suspended sediment, algae, and water colour. The Saskatchewan *Surface Water Quality Objectives* (1997), state that for bathing waters the secchi disk should be visible at 1.2 m. In situ field turbidity measurements may characterize actual lake turbidity levels better than laboratory analysis conducted after the sampling event. As a result, field measurements where used to examine changes in Moosomin Reservoir turbidity, which ranged from 1.8 to 15.2 NTU at the baseline station (Tables 2 and 4). Turbidity, secchi disk transparency depth, chlorophyll *a*, and total suspended solids appear to be well correlated in Moosomin Reservoir. On August 12, 2003 and October 6, 2004 turbidity, total suspended solids, and chlorophyll *a* concentrations peaked decreasing the secchi disk transparency depth to 0.9 m and 1.0 meters, respectively.

5.2 Shoreline Stations

Moosomin Reservoir is mechanically aerated to maintain dissolved oxygen concentrations above 5 mg/L. The aeration system is successful during the open water season maintaining concentrations above the objective for the protection of aquatic life at the shoreline stations.

Results indicate secchi disk depth and chlorophyll *a* concentrations are correlated at shoreline stations (Tables 12 to 15). On May 27, 2003 at Shoreline Station #1, the chlorophyll *a* concentration was low at a level of 2.3 µg/L, with a secchi disk depth of 1.3 meters (Table 12). In contrast, on July 29, 2003 the chlorophyll *a* concentration increased dramatically to177.34 µg/L with an associated decrease in the secchi disk depth to 0.5 meters. As a result, excessive algal growth during the summer months decreased the secchi disk depth below the1.2 meters objective for bathing waters.

5.3 Creek Stations

Dissolved oxygen concentrations were maintained above 6.42 mg/L at all creek stations during the open water season. Secchi disk reading were obtained infrequently but turbidity levels increased in the spring season and decreased in the summer months. Turbidity levels ranged from 87.6 to 4.6 NTU from May to August, respectively (Tables 16 and 17).

5.4 Moosomin Reservoir Water Quality Index

The WQI for Moosomin Reservoir ranged from 71.5 to 81.9 giving the lake a rating of fair to good (Figure 2). Of the 17 parameters that were measured pH, TDS, dissolved oxygen, ammonia, total phosphorus, and chlorophyll *a* exceeded the WQI objectives the most.

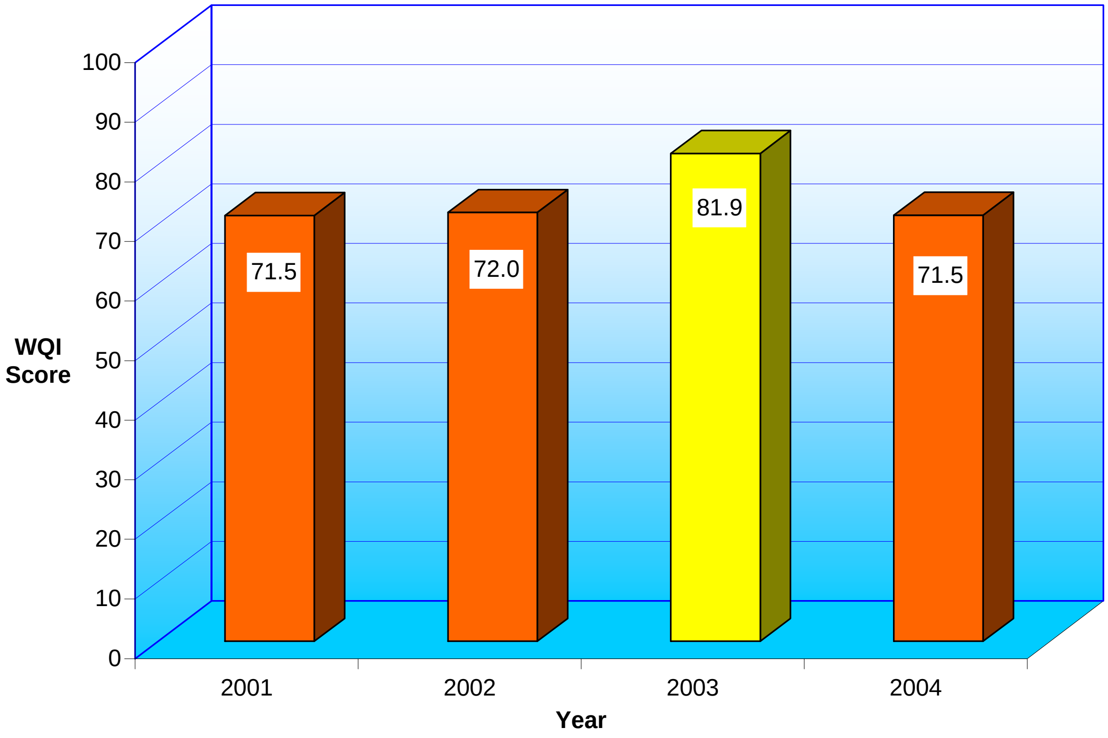

Figure 2 Water Quality Index for Moosomin Reservoir Baseline Station, 2001 - 2004

5.4.1 Baseline Station

Moosomin Reservoir water quality is fair to good with a WQI score between 71.5 and 81.9. The parameters that frequently exceeded the WQI objectives included TDS, pH, dissolved oxygen, total phosphorus, chlorophyll *a*, and ammonia. In all four years, all TDS values exceeded the WQI objective of 700 mg/L. Levels of TDS varied from 746 to 1,192 mg/L. In 2001 and 2002, pH levels ranged between 7.74 and 8.58, marginally exceeding the 8.50 objective. In contrast, during 2003 and 2004 pH ranged between 7.90 and 9.25.

Dissolved oxygen concentrations during the open water season where maintained above the 5 mg/L objective primarily through the use of an aerator. On March 4, 2004 under winter ice conditions the dissolved oxygen concentration at the baseline station became near anoxic with a dissolved oxygen concentration of 1.33 mg/L (Table 5).

The WQI objective for total phosphorus is 0.10 mg/L. In Moosomin Reservoir at the baseline station total phosphorus concentrations have ranged from 0.09 to 0.34 mg/L in the four years sampled. Chlorophyll *a* concentrations are used to estimate the amount of algal growth in an aquatic system. The chlorophyll *a* concentration on Moosomin Reservoir reached a maximum 119.41 µg/L at the baseline station on August 12, 2003 (Table 6).

Moosomin Reservoir is a very productive system with abundant plant and algae growth. When organic material decomposes ammonia is produced as a by-product. Ammonia toxicity is further heightened by corresponding increases in lake temperature and/or pH. As a result, in eutrophic lakes such as Moosomin Reservoir, ammonia concentrations may be elevated due to favorable conditions including: decomposing organic matter, high temperatures, or pH. Baseline ammonia concentrations reached 0.12 mg/L on October 6, 2004 exceeding the calculated objective of 0.11 mg/L (Table 7).

The bacteriological quality of Moosomin Reservoir was good at the baseline station. All samples taken in 2004 had a fecal coliform bacteria concentration below the 200 orgs/100mL objective for contact recreation (Tables 6 and 7). In 2003, the highest fecal coliform bacterial reading was 10 orgs/100 mL, which is also well below the objective.

5.4.2 Shoreline Stations

The shoreline stations on Moosomin Reservoir typically have good bacteriological quality. Fecal coliform bacteria concentrations were low at the shoreline sites with many values being less than 10 orgs/100mL. All samples were below the 200 orgs/100mL objective for contact recreation with one exception (Tables 12 and 14). A single sample collected July 29, 2003 from Shoreline Station #2 had a count of 600 orgs/ 100mL. The following sample, collected on August 12, 2003, had the fecal coliform bacteria count returning to concentrations below the objective with a result of less than 100 orgs/100mL. This shows how important monitoring is in determining whether bacteria levels remain high and pose a health risk or if it is an isolated incident which may have resulted from the sampling procedure or site contamination by a bird or animal.

In 2003, a single water sample collected from Shoreline Station #1 had a total coliform bacteria count greater than 10,000 orgs/100mL, exceeding the 5,000 orgs/100mL objective set by the Saskatchewan *Surface Water Quality Objectives* (1997) for non-contact recreation.

6.0 Discussion and Recommendations

Moosomin Reservoir is undergoing eutrophication with increased biological productivity and consequently, increasing pH. In 2004, only one sample taken during both open water seasons fell below the objective with values between 7.90 and 9.25 pH units. Photosynthesis depletes carbon dioxide and hydrogen ions, which increase the pH, making the lake may become more basic.

Moosomin Reservoir experiences excessive algal growth during the open water season and subsequent decomposition. As a result, in order to maintain dissolved oxygen concentrations above 5 mg/L for the protection of aquatic biota aeration of Moosomin Reservoir is essential. Excessive algal growth can pose two challenges for recreational lake use. The first concern which results from algae blooms is oxygen depletion. Death and decomposition of algae blooms decrease the oxygen available to biota in the lake such as fish. Alternately, excessive algal growth is not only aesthetically unappealing but may also promote the growth of blue-green algae, also known as cyanobacteria. Cyanobacteria may produce unpleasant odours, irritate the skin of recreational users, and produce toxins which can negatively affect the health of pets and livestock which drink the lake water.

Moosomin Reservoir experiences anoxic conditions during the winter season when mechanic aeration is inadequate. Anoxia threatens the survival of aquatic biota and affects nutrient cycling within the lake. When water becomes anoxic phosphorus is released from the sediment into the water. This increases the phosphorus available for plant growth in the spring and summer months.

Total phosphorus is a measure of all forms of phosphorus including: dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particles and other solids, polyphosphates from detergents, and dissolved orthophosphates. Consequently, only a portion of total phosphorus may be available for algae uptake and growth. Orthophosphate is the only directly usable form of soluble inorganic phosphorus by aquatic plants and algae. As shown in Tables 6 and 7, ortho-phosphorus constitutes a large portion of the total phosphorus concentration measured in Moosomin Reservoir. High concentrations at both baseline and shoreline stations maintain significant algal growth and productivity within Moosomin Reservoir.

The water quality monitoring program at Moosomin Reservoir will remain similar in 2005 as compared to 2004. The addition of a third shoreline station and the continuation of the monitoring at Little Pipestone Creek in 2005 will be the only variations from the 2004 sampling program. Currently, both shoreline stations are located close to Moosomin Regional Park. The third shoreline station will be situated in an area located away from the Regional Park and developed areas. Shoreline stations will be used to determine whether elevated total phosphorus levels measured at the baseline are associated with watershed land use or alternately the result of phosphorus recycling within the basin. Results from this investigation would function as an initial investigation into total phosphorus sources in the watershed of Moosomin Reservoir. This data will aid future investigation and help to create remediation strategies to decrease phosphorus availability in Moosomin Reservoir.

Moosomin Reservoir has a Water Quality Index rating of fair to good quality water which should be maintained for the enjoyment of future generations. Residents and other lake users are encouraged to become actively involved in the *Pipestone Watershed Advisory Committee* dedicated to the stewardship of the Pipestone watershed. The Saskatchewan Watershed Authority encourages lake users to follow healthy shoreline living practices outlined in *On the Living Edge – Your Handbook for Waterfront Living,* published by Nature Saskatchewan (See References). This handbook provides excellent tips and facts focused on shoreline landscaping, erosion, construction, and septic systems.

7.0 References

Kipp, Sarah & Callaway, Clive. (2003). *On The Living Edge: Your Handbook For Waterfront Living.* Saskatchewan/Manitoba Edition. Federation of British Columbia Naturalist: British Columbia.

Wetzel, Robert G. (2001). *Limnology: Lake and River Ecosystems, 3rd Edition.* Academic Press: San Diego, CA.

8.0 Appendix A - Water Quality Summary Tables

Table 1 Water Quality Index Objectives

Parameter	Objective
Total Arsenic (µg/L)	50
Dissolved Chloride (mg/L)	100
Total Chromium (mg/L)	0.02
Mercury (µg/L)	0.1
Total Ammonia (mg/L)	calculated
Dissolved Oxygen (mg/L)	5
pH (units)	6.5-8.5
Dissolved Sodium (mg/L)	100
2'4-D (µg/L)	4
MCPA (µg/L)	0.025
Total Aluminum (mg/L)	5
Sulphate (mg/L)	500
Fecal Coliform Bacteria (units/100mL)	200
Total Phosphorus (mg/L)	0.1
Dissolved Nitrate and Nitrite (mg/L)	1
Total Dissolved Solids (mg/L)	700
Chlorophyll *a* (µg/L)	50

Table 2 Field Measurements from Moosomin Reservoir Baseline, 2003

Field Data	May 27	July 8	Aug 12	Sept 23
Surface Parameters				
Air Temperature (ºC)	17	na	na	na
Water Temperature (ºC)	16.2	20.3	23.8	12.5
Dissolved Oxygen (mg/L)	8.88	9.41	10.07	9.74
pH (pH units)	8.39	8.23	8.77	8.96
Conductivity (µS/cm)	948	1,051	1,289	1,092
Secchi Disk (meters)	2.0	2.0	0.9	1.8
Turbidity (NTU)	2.30	2.10	7.22	3.71

Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Moosomin Reservoir Baseline, 2003

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
27/5/03	0	8.88	16.2	948
	1	8.90	16.2	950
	2	8.99	16.2	940
	3	9.04	16.3	944
	4	8.93	16.1	935
8/7/03	0	9.41	20.3	1,051
	1	9.41	20.3	1,054
	2	9.29	20.2	1,053
	3	8.96	20.0	1,051
	4	8.33	19.8	1,049
12/8/03	0	10.07	23.8	1,289
	1	9.97	23.7	1,289
	2	9.61	23.7	1,288
	3	9.53	23.6	1,289
	4	9.37	23.6	1,289
23/9/03	0	9.74	12.5	1,092
	1	9.68	12.5	1,093
	2	9.60	12.5	1,094
	3	9.83	12.3	1,098

Table 4 Field Measurements at Moosomin Reservoir Baseline, 2004

Field Data	**March 4**	**June 15**	**July 13**	**Aug 10**	**Oct 6**
Surface Parameters					
Air Temperature (ºC)	na	na	24	12	15
Water Temperature (ºC)	0.4	15.7	20.4	18.3	10.1
Dissolved Oxygen (mg/L)	1.33	7.66	9.51	8.34	12.60
pH (pH units)	7.90	8.61	8.81	8.97	9.25
Conductivity (µS/cm)	752	940	968	938	799
Secchi Disk (meters)	na	3.9	2.4	1.3	1.0
Turbidity (NTU)	1.98	1.80	2.40	4.20	15.20

Table 5 Dissolved Oxygen, Temperature, and Conductivity Profiles for Moosomin Reservoir Baseline, 2004

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
04/03/04	0	1.33	0.4	1,418
	1	1.25	0.4	1,418
	2	0.52	2.8	1,417
	3	0.59	3.0	1,435
	3.5	0.74	3.0	1,445
15/06/04	0	7.66	15.7	940
	1	7.60	15.7	940
	2	7.40	15.7	940
	3	7.43	15.7	940
	4	7.51	15.7	940
13/07/04	0	9.51	20.4	968
	1	9.20	20.3	1,030
	2	9.24	20.2	1,032
	3	9.03	20.2	1,033
	4	6.35	19.0	1,023
10/08/04	0	8.34	18.3	938
	1	8.33	18.5	944
	2	8.43	18.6	950
	3	8.42	18.6	951
06/10/04	0	12.60	10.1	799
	1	12.50	9.8	781
	2	12.34	9.7	780
	3	12.10	9.7	779
	4	12.08	9.6	779

Table 6 Moosomin Reservoir Baseline Surface Parameters, 2003

Parameters	**May 27**	**July 8**	**Aug. 12**	**Sept. 23**
Nutrients (mg/L)				
Dissolved Organic Carbon	13	na	15	15
Nitrate, as Nitrogen	0.04	na	0.03	0.02
Ammonia, as Nitrogen	0.08	na	0.07	0.07
Total Kjedahl Nitrogen	1.3	na	2.6	2.7
Total Phosphorous	0.14	na	0.30	0.25
Ortho-Phosphate, as P	0.10	na	0.18	0.18
Solids (mg/L)				
Total Dissolved	870	na	842	896
Suspended, Fixed	2	na	3	3
Suspended, Volatile	2	na	11	5
Suspended, Total	4	na	14	8
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	na	<100	10
Fecal Streptococci	<10	na	<10	20
Total Coliform	<100	na	<100	<100
Major Ions (mg/L)				
Alkalinity, Total	280	na	246	262
Alkalinity, Phenol	2	na	24	24
Bicarbonate	337	na	242	261
Calcium	78	83	68	69
Carbonate	2.4	na	28.8	28.8
Chloride	15	na	16	19
Hardness, Total	450	na	454	480
Iron	na	0.058	0.082	0.035
Magnesium	62	69	71	72
Manganese	na	0.11	0.31	0.05
Potassium	13	20	20	20
Sodium	53	50	60	77
Sulphate	310	na	340	359
Other				
Chlorophyll *a* (µg/L)	4.72	na	119.41	36.05
Conductivity (µS/cm)	1,060	na	1,047	1,099
pH (pH units)	8.3	na	8.8	8.7
Turbidity (N.T.U.)	1.42	na	9.80	3.50
Biochemical Oxygen Demand (mg/L)	0.7	na	6.6	2.0
Chemical Oxygen Demand (mg/L)	25.6	na	58.4	45.0
Metals				
Preserved Mercury (µg/L)	na	<0.05	<0.05	<0.05
Aluminum (mg/L)	na	0.040	0.036	<0.005
Arsenic (mg/L)	na	5.5	7.0	7.1

Table 7 Moosomin Reservoir Baseline Surface Parameters, 2004

Parameters	Mar. 4	Jun. 15	July 13	Aug 10	Oct. 6
Nutrients (mg/L)					
Dissolved Organic Carbon	na	11.9	12.2	12.4	13.7
Nitrate, as Nitrogen	na	<0.04	<0.04	0.09	<0.04
Ammonia, as Nitrogen	0.10	0.03	0.03	0.04	0.12
Total Kjedahl Nitrogen	na	1.0	1.0	1.7	2.5
Total Phosphorous	na	0.10	0.09	0.14	0.20
Ortho-Phosphate, as P	na	0.06	0.05	0.08	0.06
Solids (mg/L)					
Total Dissolved	1,192	933	928	846	846
Suspended, Fixed	na	<1	1	2	3
Suspended, Volatile	na	1	3	6	11
Suspended, Total	na	1	5	9	14
Bacteria (orgs/100 mL)					
Fecal Coliform	<2	<10	<10	<10	<10
Fecal Streptococci	na	<10	<10	<10	na
Total Coliform	2	<10	10	<10	10
Major Ions (mg/L)					
Alkalinity, Total	340	274	259	204	202
Alkalinity, Phenol	na	14	19	20	22
Bicarbonate	415	300	270	200	193
Calcium	103	89	81	61	57
Carbonate	na	16.8	22.8	24.0	26.4
Chloride	24.0	16.9	17.4	17.8	18.2
Hardness, Total	640	523	503	461	459
Magnesium	93	73	73	75	77
Potassium	17	12	12	12	12
Sodium	92	69	72	74	77
Sulphate	443.0	356.2	379.9	382.4	385.5
Other					
Chlorophyll *a* (µg/L)	na	3.15	14.44	45.46	2.97
Conductivity (µS/cm)	1,420	1,142	1,158	1,094	1,106
pH (pH units)	7.8	8.6	8.7	8.8	8.9
Turbidity (N.T.U.)	na	1.0	1.7	2.5	6.5
Biochemical Oxygen Demand (mg/L)	na	<2.0	2.2	4.4	>7.6
Chemical Oxygen Demand (mg/L)	na	28.1	30.7	48.2	43.2
Metals					
Preserved Mercury (µg/L)	na	<0.02	<0.02	<0.02	na
Aluminum (mg/L)	na	<0.02	0.02	<0.02	na
Arsenic (mg/L)	na	0.003	0.003	0.004	na

Table 8 **June 15, 2004 Comparison Between Moosomin Reservoir Baseline Surface and Bottom Parameters**

Nutrients (mg/L)	**Surface**	**Bottom**
Dissolved Organic Carbon	11.9	11.7
Nitrate, as Nitrogen	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.03
Total Kjedahl Nitrogen	1.0	1.1
Total Phosphorous	0.1	0.1
Ortho-Phosphate, as P	0.06	0.06
Solids (mg/L)		
Total Dissolved	933	926
Suspended, Fixed	<1	<1
Suspended, Volatile	1	1
Suspended, Total	1	2
Bacteria (orgs/100 mL)		
Fecal Coliform	<10	<10
Fecal Streptococci	<10	<10
Total Coliform	<10	<10
Major Ions (mg/L)		
Alkalinity, Total	274	273
Alkalinity, Phenol	14	13
Bicarbonate	300	301
Calcium	89	87
Carbonate	16.8	15.6
Chloride	16.9	16.8
Hardness, Total	523	510
Magnesium	73	71
Potassium	12	12
Sodium	69	68
Sulphate	356.2	355.0
Other		
Chlorophyll *a* (µg/L)	3.15	5.85
Conductivity (µS/cm)	1,142	1,142
pH (pH units)	8.6	8.6
Turbidity (N.T.U.)	1	1
Biochemical Oxygen Demand (mg/L)	<2	<2
Chemical Oxygen Demand (mg/L)	28.1	33.1
Metals		
Preserved Mercury (µg/L)	<0.02	0.02
Aluminum (mg/L)	<0.02	<0.02
Arsenic (mg/L)	0.003	0.003

Table 9 **July 13, 2004 Comparison Between Moosomin Reservoir Baseline Surface, Integrated, and Bottom Parameters**

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	12.2	12.4	12.2
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.04	0.04
Total Kjedahl Nitrogen	1.0	1.2	1.2
Total Phosphorous	0.09	0.09	0.09
Ortho-Phosphate, as P	0.05	0.05	0.05
Solids (mg/L)			
Total Dissolved	928	934	934
Suspended, Fixed	1	1	2
Suspended, Volatile	3	4	3
Suspended, Total	5	5	4
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	<10
Fecal Streptococci	<10	<10	<10
Total Coliform	10	20	<10
Major Ions (mg/L)			
Alkalinity, Total	259	258	259
Alkalinity, Phenol	19	18	17
Bicarbonate	270	271	275
Calcium	81	83	82
Carbonate	22.8	21.6	20.4
Chloride	17.4	17.8	17.5
Hardness, Total	503	512	509
Magnesium	73	74	74
Potassium	12	12	12
Sodium	72	73	72
Sulphate	379.9	381.9	380.8
Other			
Chlorophyll *a* (µg/L)	14.44	14.09	15.33
Conductivity (µS/cm)	1,158	1,159	1,159
pH (pH units)	8.7	8.7	8.7
Turbidity (N.T.U.)	1.7	1.4	1.7
Biochemical Oxygen Demand (mg/L)	2.2	<2.0	<2.0
Chemical Oxygen Demand (mg/L)	30.7	32.0	27.8
Metals			
Preserved Mercury (µg/L)	<0.02	<0.02	<0.02
Aluminum (mg/L)	0.02	0.02	0.02
Arsenic (mg/L)	0.003	0.003	0.003

Table 10 August 10, 2004 Comparison Between Moosomin Reservoir Baseline Surface, Integrated, and Bottom Parameters

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	12.4	12.4	12.3
Nitrate, as Nitrogen	0.09	0.10	0.09
Ammonia, as Nitrogen	0.04	0.09	0.05
Total Kjedahl Nitrogen	1.7	1.5	1.8
Total Phosphorous	0.14	0.13	0.15
Ortho-Phosphate, as P	0.08	0.08	0.07
Solids (mg/L)			
Total Dissolved	846	842	836
Suspended, Fixed	2	2	2
Suspended, Volatile	6	6	6
Suspended, Total	9	8	9
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	10	<10
Fecal Streptococci	<10	<10	<10
Total Coliform	<10	<10	<10
Major Ions (mg/L)			
Alkalinity, Total	204	204	204
Alkalinity, Phenol	20	20	20
Bicarbonate	200	200	200
Calcium	61	60	59
Carbonate	24	24	24
Chloride	17.8	17.7	17.7
Hardness, Total	461	459	448
Magnesium	75	75	73
Potassium	12	12	12
Sodium	74	74	73
Sulphate	382.4	378.8	377.5
Other			
Chlorophyll *a* (µg/L)	45.46	47.32	42.85
Conductivity (µS/cm)	1,094	1,094	1,094
pH (pH units)	8.8	8.8	8.8
Turbidity (N.T.U.)	25	20	17
Biochemical Oxygen Demand (mg/L)	4.4	4.5	4.3
Chemical Oxygen Demand (mg/L)	48.2	40.6	53.5
Metals			
Preserved Mercury (µg/L)	<0.02	<0.02	<0.02
Aluminum (mg/L)	<0.02	<0.02	<0.02
Arsenic (mg/L)	0.004	0.004	0.004

Table 11 October 6, 2004 Comparison Between Moosomin Reservoir Baseline Surface, Integrated, and Bottom Parameters

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	13.7	13.8	13.7
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.12	0.11	0.12
Total Kjedahl Nitrogen	2.5	2.8	2.4
Total Phosphorous	0.20	0.26	0.19
Ortho-Phosphate, as P	0.06	0.06	0.06
Solids (mg/L)			
Total Dissolved	846	852	850
Suspended, Fixed	3	3	2
Suspended, Volatile	11	12	8
Suspended, Total	14	15	10
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	<10
Total Coliform	10	900	10
Major Ions (mg/L)			
Alkalinity, Total	202	202	202
Alkalinity, Phenol	22	20	20
Bicarbonate	193	198	198
Calcium	57	58	57
Carbonate	26.4	24.0	24.0
Chloride	18.2	18.3	18.2
Hardness, Total	459	462	459
Magnesium	77	77	77
Potassium	12	12	12
Sodium	77	78	78
Sulphate	385.5	387.0	385.4
Other			
Chlorophyll *a* (µg/L)	2.97	0.78	1.67
Conductivity (µS/cm)	1,106	1,104	1,107
pH (pH units)	8.9	8.9	8.9
Turbidity (N.T.U.)	6.5	6.9	4.4
Biochemical Oxygen Demand (mg/L)	>7.6	>7.6	6.4
Chemical Oxygen Demand (mg/L)	43.2	59.5	45.9

Table 12 **Moosomin Reservoir Shoreline Station #1, Field and Laboratory Water Quality Data, 2003**

Surface Parameters	**May 27**	**July 15**	**July 29**	**Aug. 12**
Field Measurements				
Air Temperature (ºC)	22	25	24	na
Water Temperature (ºC)	16.0	19.9	22.1	23.9
Dissolved Oxygen (mg/L)	9.26	8.25	8.85	12.03
pH (pH units)	8.36	na	na	8.90
Conductivity (µS/cm)	872	na	na	1,297
Secchi Disk (meters)	1.30	1.20	0.60	0.65
Turbidity (NTU)	0.82	na	na	5.37
Laboratory Analyzed Parameters				
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	<100	<1,000
Fecal Streptococci	40	70	130	90
Total Coliform	<100	<1,000	<1,000	<10,000
Other				
Chlorophyll *a* (µg/L)	2.30	33.21	177.34	92.65

Table 13 Moosomin Reservoir Shoreline Station #1, Field and Laboratory Water Quality Data, 2004

Surface Parameters	**June 15**	**July 13**	**Aug. 10**	**Oct. 6**
Field Measurements				
Water Temperature (ºC)	16.1	20.4	18.4	na
Dissolved Oxygen (mg/L)	7.29	9.79	9.59	na
pH (pH units)	8.62	8.83	9.01	na
Conductivity (µS/cm)	943	1,055	954	na
Secchi Disk (meters)	2.0	2.2	0.5	na
Turbidity (NTU)	1.6	3.5	1.5	na
Laboratory Analyzed Parameters				
Nutrients (mg/L)				
Dissolved Organic Carbon	12.1	12.1	12.3	13.6
Nitrate, as Nitrogen	<0.04	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.02	0.03	0.18
Total Kjedahl Nitrogen	1.1	1.2	3.6	1.8
Total Phosphorous	0.10	0.09	0.28	0.15
Ortho-Phosphate, as P	0.06	0.05	0.07	0.07
Solids (mg/L)				
Total Dissolved	na	na	837	na
Suspended, Fixed	<1	2	3	2
Suspended, Volatile	2	4	22	5
Suspended, Total	2	6	25	7
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	<10	<10
Fecal Streptococci	<10	<10	10	na
Total Coliform	<10	<10	<10	40
Other				
Chlorophyll *a* (µg/L)	4.82	12.27	202.54	1.08
Conductivity (µS/cm)	na	na	1,099	na
pH (pH units)	na	na	8.8	na
Turbidity (N.T.U.)	1.1	2.0	22.0	5.1
Biochemical Oxygen Demand (mg/L)	<2.0	2.2	18.0	3.0
Chemical Oxygen Demand (mg/L)	29.7	25.3	75.1	41.1

Table 14 Moosomin Reservoir Shoreline Station #2, Field and Laboratory Water Quality Data, 2003

Surface Parameters	**May 27**	**July 15**	**July 29**	**Aug. 12**
Field Measurements				
Air Temperature (ºC)	19	25	24	27
Water Temperature (ºC)	16.5	20.2	21.8	24.2
Dissolved Oxygen (mg/L)	9.19	11.05	8.09	14.84
pH (pH units)	8.25	na	na	8.97
Conductivity (µS/cm)	883	na	na	1,295
Secchi Disk (meters)	1.1	1.5	0.6	0.5
Turbidity (NTU)	1.36	na	na	5.86
Laboratory Analyzed Parameters				
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<100	600	<100
Fecal Streptococci	60	100	120	10
Total Coliform	<100	<1,000	<1,000	na
Other				
Chlorophyll *a* (µg/L)	2.57	87.89	168.10	175.73

Table 15 Moosomin Reservoir Shoreline Station #2, Field and Laboratory Water Quality Data, 2004

Surface Parameters	**June 15**	**July 13**	**Aug. 10**	**Oct. 6**
Field Measurements				
Air Temperature (ºC)	na	na	na	21
Water Temperature (ºC)	15.4	20.7	18.5	10.2
Dissolved Oxygen (mg/L)	7.68	10.23	9.60	11.79
pH (pH units)	8.64	8.85	9.00	9.20
Conductivity (µS/cm)	934	1,066	958	785
Secchi Disk (meters)	1.6	2.2	0.9	1.7
Turbidity (NTU)	2.2	2.6	6.5	5.4
Laboratory Analyzed Parameters				
Nutrients (mg/L)				
Dissolved Organic Carbon	11.8	12.1	12.2	13.7
Nitrate, as Nitrogen	<0.04	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.02	0.04	0.16
Total Kjedahl Nitrogen	1.5	1.6	3.6	2.0
Total Phosphorous	0.11	0.09	0.29	0.14
Ortho-Phosphate, as P	0.06	0.05	0.07	0.07
Solids (mg/L)				
Total Dissolved	na	na	849	na
Suspended, Fixed	<1	2	3	3
Suspended, Volatile	2	5	22	3
Suspended, Total	2	7	25	6
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	10	<10	<10
Fecal Streptococci	<10	<10	<10	na
Total Coliform	<10	<10	<10	20
Other				
Chlorophyll *a* (µg/L)	5.96	24.46	141.90	0.83
Conductivity (µS/cm)	na	na	1,103	na
pH (pH units)	na	na	8.8	na
Turbidity (N.T.U.)	1.2	4.2	21.0	5.0
Biochemical Oxygen Demand (mg/L)	<2.0	2.8	16.0	3.4
Chemical Oxygen Demand (mg/L)	29.0	37.2	86.1	42.2

Table 16 Pipestone Creek Station #1, Field and Laboratory Water Quality Data, 2003

Surface Parameters	**May 27**
Field Measurements	
Air Temperature (ºC)	16
Water Temperature (ºC)	17.8
Dissolved Oxygen (mg/L)	8.5
pH (pH units)	8.32
Conductivity (µS/cm)	1,211
Secchi Disk (meters)	1
Turbidity (NTU)	15
Laboratory Analyzed Parameters	
Nutrients (mg/L)	
Dissolved Organic Carbon	15
Nitrate, as Nitrogen	<0.02
Ammonia, as Nitrogen	0.07
Total Kjedahl Nitrogen	1.5
Total Phosphorous	0.14
Ortho-Phosphate, as P	0.1
Solids (mg/L)	
Suspended, Fixed	7
Suspended, Volatile	3
Suspended, Total	9
Bacteria (orgs/100 mL)	
Fecal Coliform	20
Fecal Streptococci	70
Total Coliform	<100
Other	
Chlorophyll *a* (µg/L)	2.6
Turbidity (N.T.U.)	4.68
Biochemical Oxygen Demand (mg/L)	1
Chemical Oxygen Demand (mg/L)	32.1

Table 17 Pipestone Creek Station #2 at 709 Grid, Field and Laboratory Water Quality Data, 2003 and 2004

Surface Parameters	2003		2004		
	May 27	**July 8**	**Jun 15**	**July 13**	**Aug 10**
Field Measurements					
Water Temperature (ºC)	19.9	19.6	19.0	23.4	17.0
Dissolved Oxygen (mg/L)	9.05	8.14	7.56	6.42	7.95
pH (pH units)	8.22	8.20	8.37	8.00	8.42
Conductivity (µS/cm)	1,195	1,230	1,263	1,195	1,053
Secchi Disk (meters)	na	0.75	na	na	na
Turbidity (NTU)	87.60	9.32	45.00	26.00	4.60
Laboratory Analyzed Parameters					
Nutrients (mg/L)					
Dissolved Organic Carbon	13.0	na	na	12.7	12.2
Nitrate, as Nitrogen	<0.02	na	na	<0.04	0.28
Ammonia, as Nitrogen	0.02	na	na	<0.02	<0.02
Total Kjedahl Nitrogen	1.5	na	na	0.8	0.9
Total Phosphorous	0.26	na	na	0.16	0.16
Ortho-Phosphate, as P	0.07	na	na	0.09	0.15
Solids (mg/L)					
Suspended, Fixed	107	na	na	26	3
Suspended, Volatile	19	na	na	7	2
Suspended, Total	126	na	na	33	5
Bacteria (orgs/100 mL)					
Fecal Coliform	50	na	na	150	30
Fecal Streptococci	30	na	na	150	160
Total Coliform	300	na	na	50	130
Other					
Chlorophyll *a* (µg/L)	19.69	na	na	4.17	4.76
Turbidity (N.T.U.)	51.7	na	na	23.0	2.9
Biochemical Oxygen Demand (mg/L)	2	na	na	<2	<2
Chemical Oxygen Demand (mg/L)	35.3	na	na	36.1	35.1

9.0 Appendix B

9.1 Lake Stewardship Manual

This manual is intended to provide lake stewards with an explanation of the parameters commonly analyzed as part of a water quality monitoring program. Water quality monitoring is a key component of any lake stewardship activity. Monitoring enables local groups and residents to understand the characteristics of their lake and how activities around a lake may impact water quality. This knowledge enables stewards to set goals and objectives to improve and protect lake water quality. Lake stewardship groups may aid in the collection of water quality data, share acquired information, educate the public on sound lake and drainage basin management, foster partnerships with government and research personnel, and develop lake enhancement and protection projects.

The Saskatchewan Watershed Authority, *Lake Stewardship Program* provides technical assistance and guidance in order to facilitate lake stewardship goals and objectives. The *Lake Stewardship Program* may include a water monitoring program. The scope and purpose of water quality monitoring programs are to assess current water quality conditions by collecting representative data which may be used to examine changes or trends in water quality over time. Baseline stations are typically located close to the center of the lake at the deepest point. Shoreline sampling sites, identified by lake stewards, may also be included in the monitoring program to assess localized point or non-point source pollution from the watershed. These cooperative efforts result in a well planned sampling program which over time provides information on temporal changes in water quality resulting from storm events, drought, season, or increased lake use.

In Saskatchewan, *Surface Water Quality Objective* (1997) are set for various uses of water including protection of aquatic life, contact and non-contact recreation, irrigation, livestock, watering, municipal, and domestic uses. As a result, no one set of objectives or guidelines can be used in the assessment of surface water quality. Consequently, water quality parameters are discussed in this manual, in terms of the Saskatchewan *Surface Water Quality Objectives* (1997), for contact and non-contact recreation, as well as the protection of aquatic life.

9.2 Parameter Summary

1. Trophic Status - is a lake classification system based on the amount of nutrients in the lake and its' resulting biological productivity. Several water quality parameters are measured and used as indicators to determine the trophic status of a lake. The most commonly used "trophic indicators" include nutrients, chlorophyll *a*, and secchi disk transparency (water clarity). Nutrient additions increase biological productivity, which may be measured as chlorophyll *a*, which decreases water clarity, measured by secchi disk transparency. As a result, biological productivity is used to determine lake trophic status. There are four trophic states: oligotrophic, mesotrophic, eutrophic, and hypertrophic, which range from low to extreme biological productivity respectively. Oligotrophic lakes have low inputs if nutrients, organic matter and sediment and consequently, little biological productivity. In contrast, eutrophic lakes are very productive with high levels of nutrients, organic matter and sediments.

2. Nutrients - primary productivity, aquatic plant and algae growth, is dependent on nutrients to stimulate and sustain growth. As a result, the availability of particular essential nutrients such as phosphorus and nitrogen often determines lake productivity.

3. Phosphorus - there are numerous forms of phosphorus. The two most commonly measured forms of phosphorus are total phosphorus (TP) and orthophosphate (PO_4). Total phosphorus is a measure of all phosphorus forms including dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particles and other solids, and polyphosphates from detergents and dissolved orthophosphates. Orthophosphate is the only directly usable form of soluble inorganic phosphorus by aquatic plants and algae.

4. Nitrogen - there are five forms of nitrogen found in freshwater lakes: elemental nitrogen (N_2), organic nitrogen, ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2). Only three forms of nitrogen (ammonia, nitrate, and nitrite) are readily available to aquatic plants and algae for growth. As a result, these three nitrogen compounds, plus total kjeldahl nitrogen (TKN), a measurement of organic and ammonia nitrogen, are usually analyzed in most monitoring programs. Common anthropogenic nitrogen sources include sewage, feedlots and fertilizers.

   Ammonia-nitrogen is the preferred form of nitrogen for uptake by aquatic plants and algae. Typically concentrations are low in healthy lakes at less than 1 mg/L. Decomposing organic material produces ammonia as a byproduct. Ammonia concentrations increase with corresponding increases in lake temperature and/or pH. As a result, in eutrophic lakes ammonia concentration can reach toxic levels due to favorable conditions including: decomposing organic matter, high temperatures and pH.

Nitrate-nitrogen is used by aquatic plants and algae but must be reduced to ammonia prior to use. As a result, ammonia is the preferred form of nitrogen. Nitrate concentrations are less than 0.05 mg/L in healthy lakes, most surface waters are less than 0.3 mg/L. In eutrophic lakes nitrate will be depleted at the top due to algae consumption and high at the bottom from release by decomposing organic material.

Nitrite-nitrogen is readily oxidized to nitrate. As a result, nitrite is typically found at very low concentrations, less than 0.005 mg/L. When nitrite concentrations are high it may indicate organic pollution by sewage systems.

Total Kjehldahl nitrogen is a measure of the organic and ammonia nitrogen. When samples are analyzed for TKN and nitrate the values may be subtracted to estimate the ammonia concentration.

5. Chlorophyll *a* - all plants and algae contain the photosynthetic pigment, chlorophyll *a*, used to absorb light energy and produce living matter. In the laboratory chlorophyll *a* is easily extracted from algae and measured. As a result, chlorophyll *a* is used to determine the amount of algae in a water sample and therefore the intensity of lake primary productivity. This parameter is commonly used as a trophic status indicator.

6. pH - is an important water quality parameter. It affects most chemical and biological reactions within the lake. Extremes in pH or rapid changes in pH can be detrimental to aquatic life. pH is a measurement of the hydrogen ion concentration, expressed on a logarithmic scale, ranging from 0 (acidic) to 14 (alkaline). Waters with a pH of 7 are neutral. The logarithmic scales means that with every unit increase in pH the hydrogen ion concentration increases ten times. Lake pH is influenced by the addition of salts, acids, bases, and increased photosynthesis. Lakes may be acidified by the accumulation of acidic runoff and humic substances drained from igneous deposits in the watershed. Normal rainwater has a pH of 5.6 making it another acidic addition. In contrast, drainage of calcareous or limestone deposits are basic additions. Photosynthesis also depletes the carbon dioxide and hydrogen ions, which increase the pH, and the lake may become more basic. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a pH range of 6.5 to 8.5 as optimal for surface waters.

7. Total Alkalinity - is a measure of water's acid-neutralizing capacity. pH is the measure of acid and base reactions in water, while alkalinity is a measure of the ability of water to resist acid and base reactions through buffering. Lakes with low alkalinity have large daily pH fluctuations indicating they are poorly buffered. The capability of the system to buffer additions is dependent on the carbonate, bicarbonate and hydroxide content. Water with an abundance of buffering materials is more resistant to changes in pH. As a result, soft water lakes have poor buffering capacity and are therefore vulnerable to the addition of acid. A total alkalinity level of 100 to 200 mg/L will stabilize the pH of most

water bodies. Consequently, lakes with total alkalinity levels greater than 200 mg/L are typically well buffered and should resist sudden changes in pH.

8. Conductivity - is a measure of the ability of water to conduct an electric current, which is dependent on the concentration of dissolved ions in solution. Conductivity is variable and is dependent on the geology and soil in the watershed and is determined by the concentration of specific ions and lake temperature. As a result, once the ion concentration is known, changes in conductivity reflect modifications of ion concentrations. Conductivity is corrected to 25°C and reported as specific conductance (umhos/cm @ 25°C) to enable direct comparison of samples collected at different temperatures.

9. Turbidity - is the measure of water clarity. A reduction or lack of water clarity is indicative of turbidity. Turbidity is caused by solids suspended in the water including clay, silt and plankton (small plants and animals). Sources of turbidity are soil erosion, waste discharge, urban runoff, algal growth, or abundant bottom feeders, such as carp, that stir up bottom sediment. Increases in turbidity may decrease light penetration, destroy or modify fish habitat and increase water temperature which decreases oxygen concentrations. As a result, the Saskatchewan *Surface Water Quality Objectives* (1997), state that turbidity should not be increased by more than 25 turbidity unit above ambient values. Turbidity may be measured using a secchi disk or a more precise turbidimeter.

10. Secchi Disk Readings - is a measure of water transparency. Transparency is affected by suspended sediment, algae, and water colour. Secchi depth is determined by lowering a weighted black and white disk, 20 cm in diameter, from the shaded side of a boat and averaging the depth were the disk disappears and then reappears from view. Volunteers taking secchi measurements must remember to remove their sunglasses which enhance their ability to look down into the water. The secchi disk reading is a simple measurement that may be used as a trophic status indicator. The Saskatchewan *Surface Water Quality Objectives* (1997), state that for bathing waters the secchi disk should be visible at 1.2 m.

11. Biological Oxygen Demand (BOD 5-Day) - Aerobic bacteria decompose organic matter such as plants and animals. In this process, bacteria breakdown organic matter and oxidize it by adding oxygen. Biological oxygen demand is the quantity of oxygen used in the oxidation of organic matter. When organic matter is decomposed and oxidized, nutrients are released and plant growth is stimulated. This increases the amount of organic material requiring decomposition and leads to an increased biological oxygen demand (BOD). Consequently, when BOD levels are high, oxygen is being consumed by decomposition processes and this limits the oxygen available for other organisms such as invertebrates and fish. Biological oxygen demand can be measured in the laboratory to determine the amount of dissolved oxygen consumed by oxidative processes in water over a 5 day period at 20°C. *Surface Water Quality Objectives* (1997), state the BOD must not exceed a limit which would create dissolved oxygen content of less than 5 mg/L.

12. Chemical Oxygen Demand (COD) - is the quantity of oxygen consumed by biological and non-biological oxidation of organic matter in water. In contrast to BOD, COD may be measured in a matter of hours. As a result, COD is often used to measure the oxygen demand of waste water discharged, including sewage and industrial effluent.

13. Dissolved Oxygen - oxygen is readily dissolved in water and is supplied to surface water through the diffusion of atmospheric oxygen and the production of oxygen by aquatic plants and algae during photosynthesis. Although oxygen is very soluble in water, a number of factors can determine the amount of dissolved oxygen found in a lake including: water temperature, atmospheric pressure (or altitude), wind and wave action (mixing), salinity, respiratory and decomposition processes, and the shape and depth of a lake.

    In lakes, dissolved oxygen levels can fluctuate with depth and taking dissolved oxygen and temperature profiles can provide information on the mixing patterns in the water. Dissolved oxygen and temperature profiles are measured at the baseline monitoring stations. Dissolved oxygen is more soluble in cold water than in warm water. Consequently, dissolve oxygen concentrations may vary throughout the day with temperature. The solubility of oxygen is greater in water than in the atmosphere. As a result, oxygen from the atmosphere diffuses into water. Oxygen diffusion is enhanced by wind and wave action which distributes oxygen throughout the water. Dissolved oxygen concentrations are variable based on time, weather and temperature. Consequently, sampling needs to be repeated within the same time frame to enable year to year comparisons.

    Dissolved oxygen is essential to aquatic life. Fish, invertebrates, and aerobic bacteria all require oxygen for respiration. If dissolved oxygen levels are depleted, aquatic organisms may become stressed or die. Some organisms are more tolerant of low oxygen levels than others. The amount of oxygen required depends on the species and life stage. Dissolved oxygen levels of 1 or 2 mg/L will not support fish populations. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a minimum dissolved oxygen concentration of 5 mg/L for the protection of all stages of warm water biota.

14. Dissolved Organic Carbon (DOC) - is responsible for making lake water look “tea” coloured. DOC is decomposed organic material in the form of humic and fulvic acids which are relatively stable with low solubility. Precipitation, leaching and decomposing from surrounding terrestrial and wetland areas are the primary source of dissolved organic carbon additions to freshwater lakes. Plants and algae within the lake can also provide a contribution to DOC concentrations within a lake. Lake productivity, nutrient cycling, temperature, and light penetration are all affected by DOC concentrations. Currently, research is focused on the attenuation of UV radiation by DOC for the protection of aquatic life.

15. Microbiological Water Quality - the bacterial quality of surface water supplies is of importance for a number of water uses, including contact and non-contact

recreation such as swimming, boating, or fishing. The bacterial quality of a water supply can also be important for irrigation of certain crops, such as fruits and vegetables, and as a supply for domestic or municipal systems. All surface waters are open to the environment and will contain a variety of bacterial species. These organisms play an important role in the decomposition of organic material and recycling of nutrients. While bacteria are present in all surface waters, it is the sanitary quality of the reservoir that is of concern.

In Saskatchewan, the bacterial quality of surface waters is assessed by the presence of indicator organisms, such as total coliform and fecal coliform bacteria. The Saskatchewan *Surface Water Quality Objectives* set guidelines for the number of these organisms acceptable within a surface water body based on the various uses of the water. For contact recreation, the *Surface Water Quality Objectives* (1997) state that the mean density of fecal coliforms should not exceed 200 organisms per 100 mL of water. For non-contact recreation and general surface water quality, the *Surface Water Quality Objectives* state that the density of fecal coliforms should not exceed 1,000 organisms per 100 mL of water, nor should the total coliforms exceed a density of 5,000 organisms per 100 mL of water.

16. <u>Total Dissolved Solids (TDS)</u> - is a measure of the dissolved ions (minerals) in water. The cations (calcium, magnesium, sodium, and potassium), and their associated anions (bicarbonate, sulphate, and chloride) are the main ions that contribute to the total dissolved solids of a water supply. The amount of minerals found in a water supply depends mainly on the types of rock or soil the water comes into contact with and the amount of water lost to evaporation relative to precipitation. A high mineral concentration can restrict the use of the water, depending on the specific minerals present and their individual concentration. TDS can also be used as an indicator of the salinity of a water body. While a high TDS can affect the use of water for irrigation, livestock watering, municipal and domestic uses, it generally does not have a significant impact on lake recreation activities.

17. <u>Total Suspended Solids (TSS)</u> - is organic and inorganic material present in the water including: algae, plant material, micro-organisms, and sand, silt, and clay particles. Total suspended solids can be divided into categories: fixed and volatile suspended solids.

18. <u>Total Hardness</u> - is the concentration of calcium and magnesium ions in the water, expressed as calcium carbonate. Calcium carbonates precipitates from hard waters encrusting water pipes and forming scale deposits when heated. Hard waters are usually found were water drainage is derived from calcareous deposit. In contrast, soft waters have low ions concentration, low salinity, and are usually derived from acidic igneous rock drainage.

19. <u>Salinity</u> - is defined as the sum concentration of all ionic components dissolved in fresh and saline water. Ionic concentration is dependent on ion exchanges with

the atmosphere and watershed including rock, soil, human activity, the ocean, and lake sediment. Four major cations: calcium, magnesium, sodium, and potassium, and four major anions: bicarbonate, carbonate, sulphate, and chloride determine 99% of total ionic salinity. Consequently, other elements such as nitrogen, phosphorus, iron, and manganese contribute little to the total ionic salinity of the water.

20. Cations: Calcium, Magnesium, Sodium & Potassium - The concentration of cations in lake water is primarily determined by the watershed geology. Calcium is derived from the watershed from weathering of rocks and soil, especially limestone. Calcium is readily soluble in water and is one of the most abundant cations in lake water. Magnesium is a component of igneous rock as ferromagnesium minerals and sedimentary rock as magnesium carbonates, and is the eighth most abundant natural element. Industrial and municipal wastes in addition to natural weathering determine calcium and magnesium concentrations. Together calcium and magnesium salts determine the hardness of the water.

    Calcium concentrations are strongly influenced by biological metabolism. In contrast, concentrations of magnesium, sodium and potassium are not modified substantially by biological use. Calcium is an essential nutrient used by algae in physiological process. Magnesium helps form chlorophyll and consequently is a micronutrient required by all plants and algae. Magnesium concentrations are relatively unaffected by biological use because quantities consumed are significantly less than the quantity available. Sodium and potassium may be used by certain types of algae but concentrations remain relatively stable.

21. Anions: Sulphate, Chloride, Bicarbonate & Carbonate - Sulphate is the primary form of dissolved sulfur. Sulfur is required by all living organisms. The cycling of sulphur within a lake is complex and results in variable concentrations spatially and seasonally. Chloride concentrations are also determined by spatial and season distribution, relatively unaffected by biological uptake. In contrast, bicarbonate and carbonate concentrations are determined by the lake's alkalinity and productivity.

22. Elements: Iron & Manganese - Iron and manganese are essential elements to physiological processes of algae, plant and animals. Although these elements are biologically important they also have a role in phosphorus cycling within the lake and affect phosphorus availability. As a result, iron and manganese concentrations are often measured as part of a water quality sampling program.

23. Metals: Mercury, Aluminum, and Arsenic - Mercury, aluminum, and arsenic are metals which naturally occur in all rock types. Natural rock weathering and erosion results in the addition of these elements to lake water. However, the concentration of these metals may be dramatically higher than natural concentration due to human activity causing pollution.

Mercury is used in the chlor-alkali, paint, pulp and paper industries. Products include chlorine, hydrogen, paint pigments, and preservatives, electrical equipment such as thermometers, batteries and lamps. In the lake mercury is transformed by microorganisms into methlymercury. There are two forms of methlymercury: monomethylmercury, and dimethylmercury. The amount of each form is dependent on amount of mercury, presence of microbes, organic carbon concentrations, pH and lake temperature. Dimethylmercury is produced under high pH conditions, while monomethlymercury formation is favoured under acidic conditions. These methylated forms of mercury accumulate in aquatic organisms, such as fish and invertebrates. Mercury is an acute neurotoxin, which negatively affects the biota of a polluted lake. Biological organisms may accumulate mercury directly from the water or through the food chain. Bioconcentration of mercury are high in aquatic organisms due to the rapid uptake of methylmercury by organisms. The concentration of mercury is magnified up the food chain. As a result, organisms at the bottom of the food chain have lower concentrations of mercury accumulated from the water. In contrast, predatory fish, such as lake trout, accumulate higher concentrations of mercury from their food source as well as the water. Consequently, it is said that mercury concentrations are biomagnified up the food chain. The Saskatchewan *Surface Water Quality Objectives* (1997) specifies that mercury concentration should be less than 0.001 mg/L or 1 µg/L for the protection of aquatic life and wildlife.

Aluminum is abundant in the natural environment but typically inorganic and biological processes maintain aluminum in an unreactive form. Acidic precipitation and poorly buffered soils result in reactive aluminum additions from upland soil and rock weathering. The primary source of aquatic aluminum pollution is from effluent produced by industries using aluminum in their processing or alum as a flocculent. Aluminum may enter the lake from local or long distance atmospheric transportation and deposition. The concentration of reactive aluminum increases with water acidity. As a result, decreases in pH and increases in organic carbon result in increased concentrations of aluminum in the lake water. Aluminum is highly reactive and can be toxic to biological organisms at low concentrations. The Saskatchewan *Surface Water Quality Objectives* (1997) for livestock watering, aluminum concentrations should be less than 5 mg/L or 5,000 µg/L.

Arsenic is naturally released into the environment by rock weathering and volcanic release. However, human activities can cause twice as much arsenic to be released into the environment as natural sources. Arsenic is used in many industrial processes and products. Common products which may be used around lakes are pesticides and herbicides containing arsenic. Aquatic arsenic concentrations are dependent on geological chemistry, industrial and human activity in the watershed. In the lake, arsenic is removed from the water and deposited in the sediment by adsorbing to suspended organic matter which settles to the bottom of the lake. Consequently, arsenic may form a wide variety of compounds with elements found in lake water. Arsenic is toxic at low concentrations to aquatic organisms. Aquatic organisms bioaccumulate arsenic in their tissue and organs. Accumulated arsenic concentrations depend on the organism, its age, water temperature and the concentration of arsenic present. In contrast to mercury, there is no evidence of arsenic biomagnification. The Saskatchewan *Surface Water Quality Objectives* (1997), for the protection of aquatic life and wildlife, arsenic concentrations should be less than 0.05 mg/L or 50 µg/L.