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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 this 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 Lac Pelletier

Lac Pelletier provides many leisure activities and is located just 30 kilometers from Swift Current, Saskatchewan. Lac Pelletier Regional Park, located on the east side of the lake is host to many activities including golf, mini-golf, baseball, and fishing among others. The lake is spring fed has a surface area of 2.8 square kilometers and a maximum depth of 9 meters (m). The full supply level on Lac Pelletier is 828.75 meters above sea level (masl). A single reading is taken in the spring and fall to monitor Lac Pelletier water levels. In 2004, the lake level was 829.003 masl in the spring and 828.814 masl in the fall, operating at full supply.

In 2004, the Lac Pelletier stewardship group was incorporated into Saskatchewan Watershed Authority's *Lake Stewardship Program*. This group was initially organized as part of the Prairie Water Care Program provided by the Saskatchewan Wetland Conservation Corporation (now Saskatchewan Watershed Authority).

2.1 <u>Stewardship Activities</u>

The Lac Pelletier stewardship group was organized in 1999, to investigate the possibility of building a lagoon for effluent collected from holding tanks around the lake. The group represented 250 cottage owners, Lac Pelletier Regional Park, and Camps Elim and Lemieux. The lagoon was completed in 2001 as a result of hard work and dedication by the stewardship group.

The *Prairie Water Care* program educated the Lac Pelletier group on water quality, riparian health assessment, aquatic macro-invertebrate identification, and how to establish local conservation activities. The *Lake Stewardship Program* will build on this educational base by providing water quality data to the group. The data may then be used by the group to educate their community and pursue new goals and projects based on water quality issues specific to Lac Pelletier.

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 Lac Pelletier. 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

Saskatchewan Watershed Authority personnel facilitated the collection of all field measurements and water sampling at Lac Pelletier in 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. Samples collected in 2004 from the baseline station included discrete top and bottom water samples taken using a horizontally orientated Van Dorn water sampler, and 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 2004: June 22, July 26, September 7, and October 4.

2.3.2 Shoreline Stations

Two shoreline stations located at the north and south end of the lake at a beach and boat launch were also sampled. Shoreline stations are sampled to examine water quality for any potential impacts from localized activities. The shoreline stations were sampled on the same day as the baseline station in 2004: June 22, July 26, September 7, and October 4.

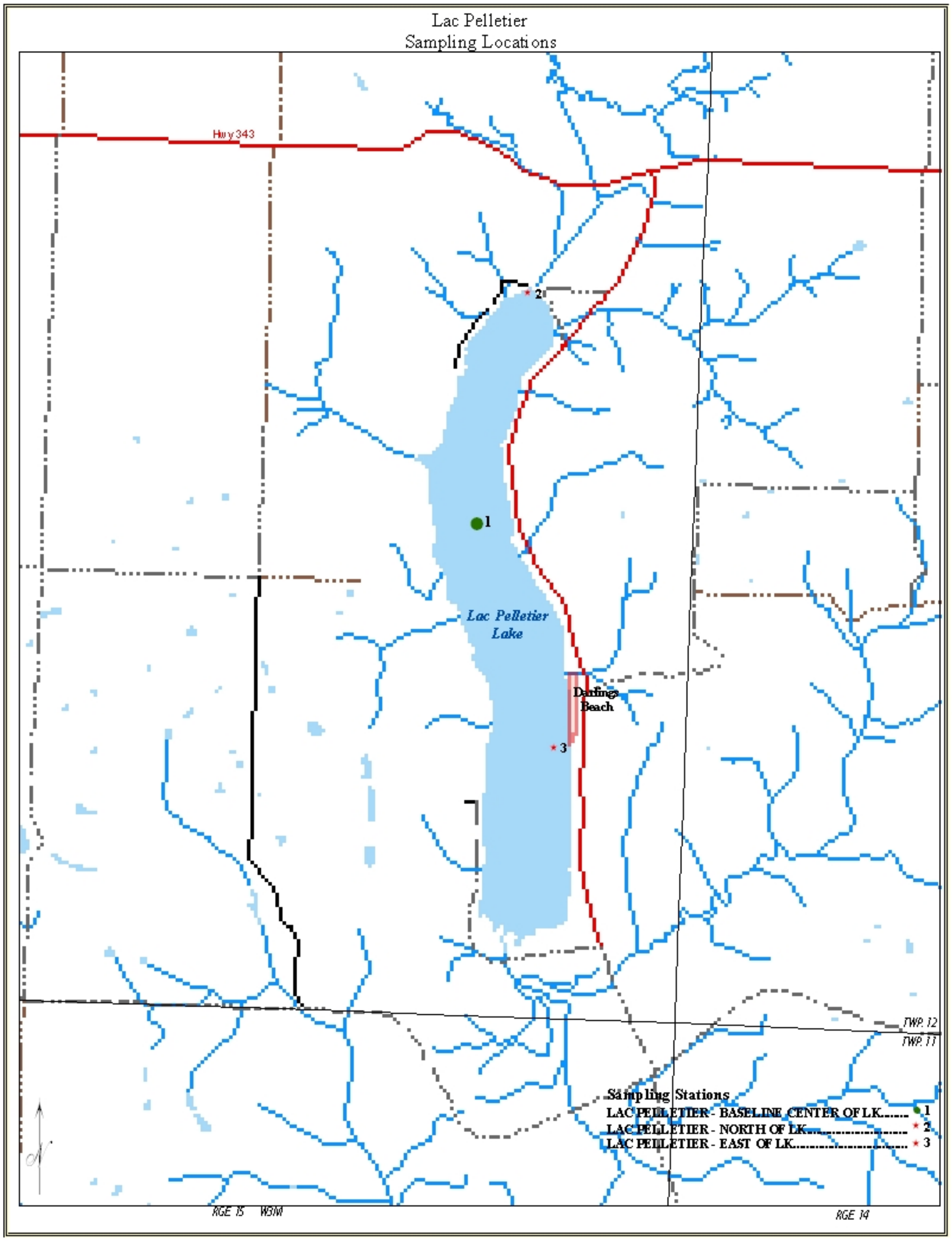

Figure 1 Sampling Locations on Lac Pelletier, 2004

2.3.3 Field Measurements

Field measurements were taken at the baseline station 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 and shoreline samples were analyzed for nutrients, major ions, chlorophyll *a*, dissolved and suspended solids, and bacteria (see Tables 5 to 10). All water samples were collected in plastic bottles and shipped in coolers to the Provincial Laboratory in Regina, Saskatchewan.

2.3.5 Stewardship Involvement

Volunteers are essential to the water monitoring program providing transportation to sampling locations, collection assistance, and local knowledge. In 2004, Joan Williamson, Glenda Kehoe, Glenn Bratvold, Wayne Dawson, Kay Froese, and Gloria Dyck assisted Saskatchewan Watershed Authority technologist Randy Beler with sampling Lac Pelletier.

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 Summary

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 Field Measurements

Field measurements at the baseline station have been summarized in Tables 2 and 3. There are five important field measurements to examine when assessing water quality: dissolved oxygen and temperature profiles, conductivity, secchi disk 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. Temperature profiles indicate Lac Pelletier is well mixed and typically does not stratify (Table 3). Only two dissolved oxygen profiles were obtained in 2004. The data indicates Lac Pelletier may experience a sharp decrease in dissolved oxygen in the bottom two meters. Data collected in 2005 will be used to examine anoxic conditions and effects in Lac Pelletier.

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. For Lac Pelletier in 2004, conductivity at the surface ranged from 723 to 787 µS/cm (Table 3).

The secchi disk 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. Secchi disk transparency depth on Lac Pelletier ranged between 1.6 and 1.9 m (Table 2) exceeding the Saskatchewan *Surface Water Quality Objective* for bathing waters. As a result, Lac Pelletier is relatively clear making it a desirable and popular recreational lake.

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. Lac Pelletier has low turbidity with values between 1.90 and 2.28 NTU with minimal fluctuation (Table 2).

5.2 Lac Pelletier Water Quality Index

The WQI value for Lac Pelletier in 2004 was 87.9 giving the lake with a rating of good water quality (Figure 2). Of the 17 parameters that were measured pH and TDS exceeded the WQI objectives.

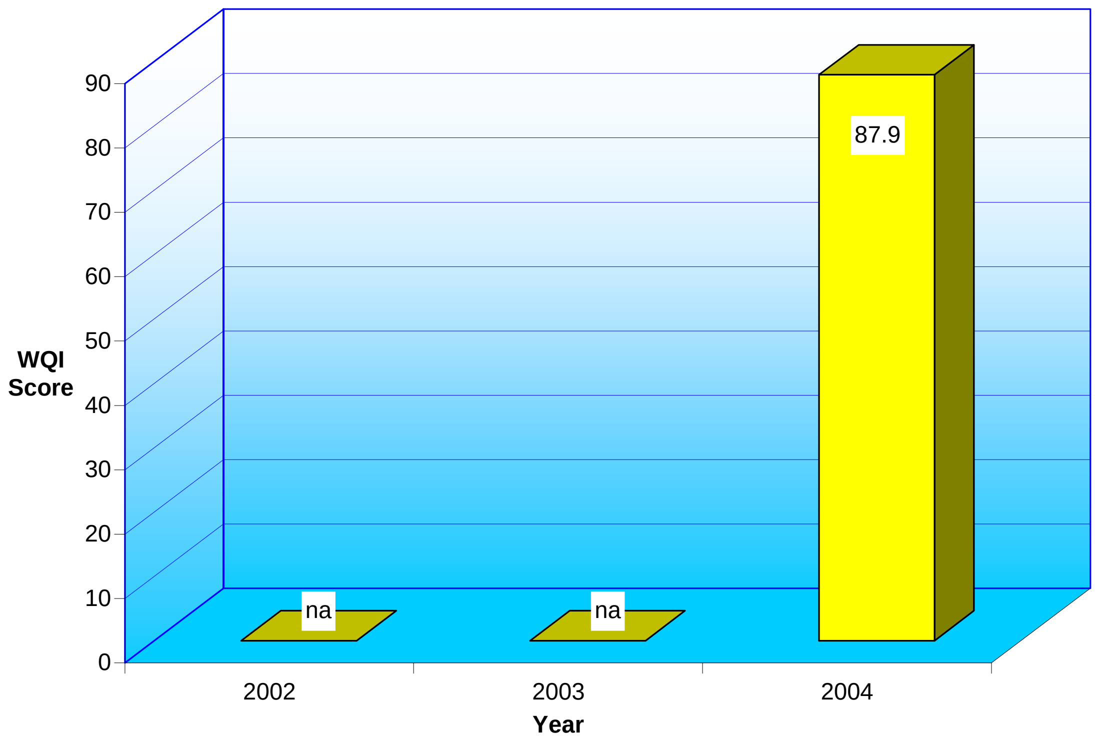

Figure 2 Water Quality Index for Lac Pelletier Baseline Station, 2002 - 2004

5.2.1 Baseline Results

The Water Quality Index (WQI) requires a minimum of three or more sampling events to determine the annual WQI score. The greater the number of samples, the greater the confidence in the WQI score. Lac Pelletier data collected in previous years through Hach kit analysis was not sufficient to calculate the water quality index score from those years. In 2004, the WQI score was 87.9 indicating good water quality. Good water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels. Two parameters measured at Lac Pelletier, pH and total phosphorus, exceeded the WQI objectives.

Lac Pelletier is an alkaline lake with a pH value ranging from 8.9 to 9.1. The Saskatchewan *Surface Water Quality Objectives* (1997) sets a pH range of 6.5 to 8.5 as optimal for surface waters. All samples collected from Lac Pelletier had a pH value which exceeded the Water Quality Index objective of 8.5 (Table 1).

Phosphorus is typically the least abundant essential nutrient in freshwater lakes. Availability often limits biological productivity and consequently, phosphorus is referred to as the "limiting nutrient". Since the rate and extent of primary production is dependent on phosphorus availability, high concentrations result in increased plant and algae growth. In 2004, total phosphorus concentrations were 0.10 to 0.12 mg/L at the baseline station (Table 4).

The remaining parameters used to calculate the WQI score such as fecal coliform bacteria, total dissolved solids (TDS), and chlorophyll *a* maintained concentrations well below their objective (Table 4). The WQI objective for fecal coliform bacteria concentrations is 200 orgs/100mL. In 2004, fecal coliform bacteria concentrations were measured below 10 orgs/100 mL. The Saskatchewan, *Surface Water Quality Objectives* (1997) recommends that TDS be below 1,000 mg/L for livestock watering and 700 mg/L for irrigation. The WQI objective for TDS is 700 mg/L. In 2004, Lac Pelletier had a TDS concentration that ranged between 617 and 626 mg/L at the surface. The WQI objective for chlorophyll *a* is 50 µg/L. Recorded chlorophyll *a* concentrations for 2004 ranged between 3.07 and 9.70 µg/L (Table 4).

In 2004, water quality samples were collected from the surface, integrated, and bottom of the water column to assess the variation within the water column (Table 7 to 10). Results showed that there were no significant difference in water quality parameters measured at the top, integrated, and bottom of the water column. Surface samples were indicative of conditions throughout the water column and consequently, may be used to assess lake water quality. In 2005, surface sampling will be resumed at the baseline station to maintain monitoring activities while minimizing associated cost and time constraints.

5.2.2 Shoreline Results

In Saskatchewan, the bacteriological quality of the water is assessed using tradition bacterial indicators such as fecal streptococci or fecal and total coliforms. Fecal coliform bacteria are present in the lower intestine of warm blooded animals and are rare in unpolluted waters; their presence is used as an indicator of sewage or human fecal contamination. For contact recreation, the Province sets water quality objectives using fecal coliform bacteria as an indicator of microbial water quality. For contact recreation, the Saskatchewan *Surface Water Quality Objectives* (1997) state that the density of fecal coliform bactria should not exceed 200 organisms per 100mL of water nor should the total coliform bacteria exceed a density of 5,000 organisms per 100 mL of water. In 2004, at both the North and South shoreline stations, fecal coliform bacteria concentrations were less than 10 orgs/100 mL with the exception of one sample taken September 7, 2004 from the North Shoreline station which had 30 orgs/100 mL. In 2004, Lac Pelletier had a fecal coliform bacteria concentration well below the 200 orgs/100 mL objective. Total coliform bacteria concentrations were also substantially lower than the

5,000 orgs/100 mL objective. The highest total coliform bacteria concentration was 1,300 orgs/100 mL measured October 4, 2004 at the North shoreline station. During the height of the recreational season in July, fecal coliform bacteria were less than 10 orgs/100 mL and total coliform bacteria concentrations at both shoreline sites were 10 orgs/ 100mL. As a result, Lac Pelletier has good bacteriological water quality.

6.0 Discussion and Recommendations

Lac Pelletier has good quality water which meets the Saskatchewan Surface *Water Quality Objectives* (1997) for contact and non-contact recreation. Lac Pelletier is a prairie alkaline lake. The lake did not stratify remaining well mixed with a consistent temperature maintained throughout the water column. Problems with the dissolved oxygen probe in 2004 limited our ability to understand the oxygen environment of Lac Pelletier. In 2005, we will further investigate dissolved oxygen profiles in Lac Pelletier and its effect on water quality.

Lac Pelletier is an ideal location for water based recreational activities. The bacterial water quality of Lac Pelletier is good with very low fecal and total coliform concentrations. The water clarity was good with low turbidity and chlorophyll *a* concentrations. Total phosphorus concentrations need to be maintained to preserve water clarity and limit algal growth. Lac Pelletier is a healthy and aesthetically pleasing recreational area.

Lac Pelletier has 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 Lac Pelletier stewardship group. 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 Lac Pelletier Baseline Site, 2004

Field Data	June 22	July 26	Sept 7	Oct 4
Surface Parameters				
Air Temperature (ºC)	14	20	11	17
Water Temperature (ºC)	15.4	21.6	16.1	11.6
Dissolved Oxygen (mg/L)	7.93	8.81	8.63	9.52
pH (pH units)	8.9	9.1	9.1	9.0
Conductivity (µS/cm)	723	785	779	757
Secchi Disk (meters)	1.8	1.9	1.6	1.7
Turbidity (NTU)	2.28	2.09	1.90	2.21

Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Lac Pelletier, 2004

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
22/6/04	0	7.93	15.4	na
	1	8.52	15.4	723
	2	8.56	15.4	723
	3	8.63	15.3	725
	4	8.44	15.3	725
	5	8.58	15.3	725
	6	8.46	15.1	724
	7	8.36	15.0	726
	8	2.08	14.4	735
	9	0.18	14.5	727
26/7/04	0	8.81	21.6	785
	1	9.04	21.6	784
	2	8.23	21.4	784
	3	8.74	21.2	783
	4	8.36	21.1	784
	5	8.05	21.0	784
	6	8.32	21.0	785
	7	3.40	20.1	791
	8	0.36	18.8	797
	9	0.12	18.2	821

Table 3 Dissolved Oxygen, Temperature, and Conductivity Profiles for Lac Pelletier, 2004, continued

Date (d/m/y)	Depth (m)	Dissolved Oxygen (mg/L)	Water Temperature (ºC)	Conductivity (µS/cm)
7/9/04	0	8.63	15.9	779
	1	na	15.9	778
	2	na	15.9	778
	3	na	15.9	778
	4	na	15.9	778
	5	na	15.9	778
	6	na	15.9	778
	7	na	15.9	779
	8	na	15.9	779
	9	na	15.9	779
4/10/04	0	9.52	11.9	787
	1	na	11.7	786
	2	na	11.6	787
	3	na	11.6	788
	4	na	11.5	788
	5	na	11.5	788
	6	na	11.5	788
	7	na	11.5	788
	8	na	11.5	788
	9	na	11.5	788
	10	na	11.5	788

Table 4 Summary of Lac Pelletier Surface Baseline Parameters, 2004

Parameters	**June 22**	**July 26**	**Sept 7**	**Oct 4**
Nutrients (mg/L				
Dissolved Organic Carbon	10.8	10.8	11.3	11.4
Nitrate, as Nitrogen	<0.04	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.03	0.06	0.04
Total Kjedahl Nitrogen	1.1	1.2	1.1	1.0
Total Phosphorous	0.12	0.10	0.11	0.11
Ortho-Phosphate, as P	0.07	0.09	0.08	0.09
Solids (mg/L)				
Total Dissolved	622	617	na	626
Suspended, Fixed	3	2	2	2
Suspended, Volatile	3	3	4	4
Suspended, Total	6	5	5	7
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	<10	10
Fecal Streptococci	<10	<10	na	na
Total Coliform	<10	<10	<10	280
Major Ions (mg/L)				
Alkalinity, Total	342	348	na	346
Alkalinity, Phenol	29	36	na	26
Bicarbonate	346	337	na	359
Calcium	23	22	na	21
Carbonate	34.8	43.2	na	31.2
Chloride	8.4	8.8	na	8.6
Hardness, Total	333	323	na	312
Magnesium	67	65	na	63
Potassium	16	15	na	15
Sodium	50	48	na	48
Sulphate	76.6	77.7	na	80.5
Other				
Chlorophyll *a* (µg/L)	4.98	4.15	9.70	3.07
Conductivity (µS/cm)	744	736	na	750
pH (pH units)	8.9	9.0	na	8.9
Turbidity (N.T.U.)	2.4	2.7	2.4	2.8
Biochemical Oxygen Demand (mg/L)	<2	<2	<2	<2
Chemical Oxygen Demand (mg/L)	29.0	35.6	35.8	33.8
Metals				
Preserved Mercury (µg/L)	<0.02	0.02	na	na
Aluminum (mg/L)	<0.02	<0.02	na	na
Arsenic (mg/L)	0.003	0.003	na	na

Table 5 Summary of Lac Pelletier North Shoreline Surface Parameters, 2004

Surface Parameters	**June 22**	**July 26**	**Sept. 7**	**Oct. 4**
Field Measurements				
Air Temperature (ºC)	12	23	11	17
Water Temperature (ºC)	16.4	22.8	15.6	12.1
Dissolved Oxygen (mg/L)	8.38	11.02	12.2	11.2
pH (pH units)	8.9	9.1	9.2	9.0
Conductivity (µS/cm)	467.2	731.0	739.0	759.0
Secchi Disk (meters)	1.2	na	na	na
Turbidity (NTU)	1.79	2.17	1.82	7.64
Laboratory Analyzed Parameters				
Nutrients (mg/L)				
Dissolved Organic Carbon	10.6	11.2	11.4	11.1
Nitrate, as Nitrogen	<0.04	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.02	0.02	0.05	0.04
Total Kjedahl Nitrogen	0.9	1.1	1.0	1.0
Total Phosphorous	0.12	0.10	0.10	0.12
Ortho-Phosphate, as P	0.06	0.07	0.08	0.09
Solids (mg/L)				
Total Dissolved	616	na	na	na
Suspended, Fixed	2	2	2	13
Suspended, Volatile	3	3	4	8
Suspended, Total	5	5	6	21
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	30	<10
Fecal Streptococci	<10	30	na	na
Total Coliform	<10	10	500	1,300
Other				
Chlorophyll *a* (µg/L)	2.72	3.68	6.89	2.27
Conductivity (µS/cm)	741	na	na	na
pH (pH units)	8.9	na	na	na
Turbidity (N.T.U.)	2.0	2.6	2.7	8.4
Biochemical Oxygen Demand (mg/L)	<2	<2	<2	<2
Chemical Oxygen Demand (mg/L)	33.5	35.3	39.5	36.4

Table 6 Summary of Lac Pelletier South Shoreline Surface Parameters, 2004

Surface Parameters	June 22	July 26	Sept. 7	Oct. 4
Field Measurements				
Air Temperature (ºC)	14	25	11	17
Water Temperature (ºC)	8.3	21.3	15.1	10.7
Dissolved Oxygen (mg/L)	7.66	9.07	9.23	11.32
pH (pH units)	8.9	9.1	9.1	9.2
Conductivity (µS/cm)	671	737	742	673
Secchi Disk (meters)	1	2	na	na
Turbidity (NTU)	5.71	3.49	3.88	2.65
Laboratory Analyzed Parameters				
Nutrients (mg/L)				
Dissolved Organic Carbon	11.5	11.2	11.2	11.8
Nitrate, as Nitrogen	<0.04	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.05	0.05	0.05
Total Kjedahl Nitrogen	1.1	1.4	1.1	1.0
Total Phosphorous	0.11	0.14	0.10	0.10
Ortho-Phosphate, as P	0.06	0.08	0.08	0.09
Solids (mg/L)				
Total Dissolved	633	na	na	na
Suspended, Fixed	5	10	2	3
Suspended, Volatile	5	6	5	3
Suspended, Total	10	16	6	6
Bacteria (orgs/100 mL)				
Fecal Coliform	<10	<10	<10	<10
Fecal Streptococci	20	<10	na	na
Total Coliform	<10	10	10	260
Other				
Chlorophyll *a* (µg/L)	3.20	2.79	9.70	1.48
Conductivity (µS/cm)	755	na	na	na
pH (pH units)	8.8	na	na	na
Turbidity (N.T.U.)	4.6	3.8	2.4	2.7
Biochemical Oxygen Demand (mg/L)	2	<2	<2	<2
Chemical Oxygen Demand (mg/L)	35.0	33.6	40.0	33.6

Table 7 June 22, 2004 Comparison Between Surface, Integrated, and Bottom Parameters

Nutrients (mg/L)	Surface	Integrated	Bottom
Dissolved Organic Carbon	10.8	11.0	10.7
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.04	<0.02
Total Kjedahl Nitrogen	1.1	1.0	1.5
Total Phosphorous	0.12	0.12	0.12
Ortho-Phosphate, as P	0.07	0.08	0.07
Solids (mg/L)			
Total Dissolved	622	629	619
Suspended, Fixed	3	3	3
Suspended, Volatile	3	3	4
Suspended, Total	6	6	6
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	342	342	342
Alkalinity, Phenol	29	29	27
Bicarbonate	346	346	351
Calcium	23	24	22
Carbonate	34.8	34.8	32.4
Chloride	8.4	8.4	8.8
Hardness, Total	333	352	318
Magnesium	67	71	64
Potassium	16	16	15
Sodium	50	52	48
Sulphate	76.6	76.3	77.3
Other			
Chlorophyll *a* (µg/L)	4.98	3.61	3.65
Conductivity (µS/cm)	744	742	744
pH (pH units)	8.9	8.9	8.8
Turbidity (N.T.U.)	2.4	2.5	2.4
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	29.0	29.4	31.0
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 8 July 26, 2004 Comparison Between Surface, Integrated, and Bottom Parameters

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	10.8	11.1	11.1
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.03	0.05	0.02
Total Kjedahl Nitrogen	1.2	1.1	2.0
Total Phosphorous	0.10	0.14	0.14
Ortho-Phosphate, as P	0.09	0.09	0.09
Solids (mg/L)			
Total Dissolved	617	613	615
Suspended, Fixed	2	2	1
Suspended, Volatile	3	4	4
Suspended, Total	5	6	5
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	348	348	348
Alkalinity, Phenol	36	36	36
Bicarbonate	337	337	337
Calcium	22	21	22
Carbonate	43.2	43.2	43.2
Chloride	8.8	8.8	8.7
Hardness, Total	323	316	318
Magnesium	65	64	64
Potassium	15	14	15
Sodium	48	47	48
Sulphate	77.7	77.6	77.0
Other			
Chlorophyll *a* (µg/L)	4.15	4.15	6.89
Conductivity (µS/cm)	736	736	734
pH (pH units)	9	9	9
Turbidity (N.T.U.)	2.7	2.3	2.6
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	35.6	31.7	32.9
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 9 September 7, 2004 Comparison of Surface, Integrated, and Bottom Parameters

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	11.3	11.2	11.3
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.06	0.03	0.06
Total Kjedahl Nitrogen	1.1	1.1	1.0
Total Phosphorous	0.11	0.11	0.12
Ortho-Phosphate, as P	0.08	0.08	0.08
Solids (mg/L)			
Suspended, Fixed	2	1	1
Suspended, Volatile	4	4	4
Suspended, Total	5	6	6
Bacteria (orgs/100 mL)			
Fecal Coliform	<10	<10	<10
Total Coliform	<10	<10	<10
Other			
Chlorophyll *a* (µg/L)	9.70	9.11	12.59
Turbidity (N.T.U.)	2.4	2.4	2.8
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	35.8	37.4	37.3

Table 10 October 4, 2004 Comparison Between Surface, Integrated, and Bottom Parameters

Nutrients (mg/L)	**Surface**	**Integrated**	**Bottom**
Dissolved Organic Carbon	11.4	11.4	11.1
Nitrate, as Nitrogen	<0.04	<0.04	<0.04
Ammonia, as Nitrogen	0.04	0.02	0.03
Total Kjedahl Nitrogen	1.0	0.9	0.9
Total Phosphorous	0.11	0.11	0.11
Ortho-Phosphate, as P	0.09	0.09	0.09
Solids (mg/L)			
Total Dissolved	626	630	629
Suspended, Fixed	2	3	3
Suspended, Volatile	4	4	5
Suspended, Total	7	7	7
Bacteria (orgs/100 mL)			
Fecal Coliform	10	<10	<10
Total Coliform	280	140	200
Major Ions (mg/L)			
Alkalinity, Total	346	348	348
Alkalinity, Phenol	26	26	26
Bicarbonate	359	361	361
Calcium	21	21	21
Carbonate	31.2	31.2	31.2
Chloride	8.6	8.6	8.6
Hardness, Total	312	316	316
Magnesium	63	64	64
Potassium	15	15	15
Sodium	48	49	48
Sulphate	80.5	80.4	80.3
Other			
Chlorophyll *a* (µg/L)	3.07	1.48	2.27
Conductivity (µS/cm)	750	750	750
pH (pH units)	8.9	8.9	8.9
Turbidity (N.T.U.)	2.8	3.3	2.8
Biochemical Oxygen Demand (mg/L)	<2	<2	<2
Chemical Oxygen Demand (mg/L)	33.8	33.9	33.9

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* which is 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 Transparency 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.