Lac La Nonne Water Quality Report 2004: Nutrients, Bacteria and Caffeine

Prepared for:

The Lac La Nonne Enhancement and Protection Association
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Project Area:

Lac la Nonne Watershed

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Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Prairie Farm Rehabilitation Administration | Administration du rétablissement agricole des Prairies

"improves the awareness and management of riparian areas by encouraging community based resource management initiatives"

Introduction

In the spring of 2004, Aquality Environmental Consulting Ltd., Alberta Agriculture Food and Rural Development, the Aspen Regional Health Authority and local volunteers partnered to conduct an assessment of lake water quality and the water quality of several inflow streams around Lac la Nonne for the Lac la Nonne Enhancement and Protection Association (LEPA). The study was undertaken to address local concerns of nutrient input into the lake from tributary streams that drain agricultural and cleared lands, and over concerns of human sewage entering the lake from the various private sewage disposal systems. As Lac la Nonne has several permanent residents, private campgrounds, and is the water source for local agricultural producers, several stakeholders have an interest in the current status of water quality.

Lac la Nonne has historically been one of the most eutrophic (nutrient rich) lakes in central Alberta (Mitchell and Prepas 1991). Alberta Environment currently ranks Lac la Nonne in the top 10 in both chlorophyll *a* and Total Phosphorus (both are measures of lake productivity) concentrations for all lakes sampled in the province (Appendix A). These values are representative of a hypereutrophic lake. However, this is not atypical for lakes in the area, as nearby Sandy Lake has very similar values. High phosphorus concentrations make Lac la Nonne susceptible to algal blooms and excessive aquatic plant growth in the summer. Excessive algal growth often impairs recreational uses of the lake, and decomposing algae causes odor problems and decreases water oxygen content.

Three water quality studies were conducted during the summer of 2004. The first was a survey of major tributaries in the basin (Stream Survey) to gather baseline information on the concentration of water quality parameters from agricultural origin (e.g. nutrients and pesticides). The second study was to collect baseline information on human sewage impacts on Lac La Nonne and two creek sites using a caffeine indicator (Caffeine Study). The third was undertaken by the Aspen Regional Health Authority to collect bacteria samples at the same sites during the caffeine sampling (Bacteria Study).

Stream Survey

The study was designed to determine stream water quality during the times of the year when risks of contamination from agricultural sources are greatest. LEPA and Alberta Agriculture Food and Rural Development (AAFRD) partnered to train local volunteers to collect water samples from the major tributaries and Agriculture and Agri-Food Canada (AAFC-PFRA) provided guidance on how to monitor stream flow. Aquality Environmental Consulting Ltd. analyzed the water quality results and reported on the findings of the study.

Caffeine Study

For the second study, Aquality developed a sampling protocol for caffeine to assess the occurrence of human waste in the waters of Lac la Nonne. Sites of interest were selected by the Committee prior to sampling in May to target several developments adjacent to Lac la Nonne. Sites that tested positive were re-tested in August. For details on the development and use of the caffeine indicator, please see Appendix B.

Bacteria Study

Volunteers from LEPA, in cooperation with the Aspen Regional Health Authority, collected water samples to determine the concentration of fecal coliform and *E. coli*. bacteria. Samples were collected during spring runoff in April during the stream study and from Nakamun Lake, Lac La Nonne and two streams during the May caffeine study.

Methods

Site description:

Lac la Nonne is a large, deep and highly productive lake located in the rolling hills of the Counties of Lac Ste. Anne and Barrhead, about 90 km northwest of Edmonton. The watershed covers over 280 km^2 (Figure 1). Three municipalities are located in the watershed: the Hamlet of Rich Valley, the Summer Village of Birch Cove and the Summer Village of Nakamun Park. Three other large lakes are located in the Lac la Nonne watershed: Majeau Lake is the largest of these and is situated west of highway 33, Kakina Lake is much smaller and is situated in the southeast portion of the watershed and Nakamun Lake is the only other lake with residential development and is situated southeast of Lac la Nonne.

Agriculture is the most common land use in the watershed, with forage farming and livestock operations being most common (Mitchell and Prepas, 1991). Soil types in the area are generally not suitable for other types of agriculture. There are two commercial campgrounds at Lac la Nonne, Elks Beach and Birch Cove, and a youth camp. No provincial or municipal campgrounds exist around the lake. Nakamun Lake has one small day use area on the south shore of the lake and one large youth camp, Camp Nakamun, on the north shore.

Lake water quality

Lac la Nonne has very high nutrient concentrations compared to other lakes throughout the rest of Alberta (ALMS, 2003). Alberta Environment currently ranks Lac la Nonne 8^{th} highest in Alberta lakes for Chlorophyll *a* production (average concentration of 69 µg/L) and 10^{th} highest for Total Phosphorus concentrations (average concentration of 201.1 µg/L; Appendix A). Total

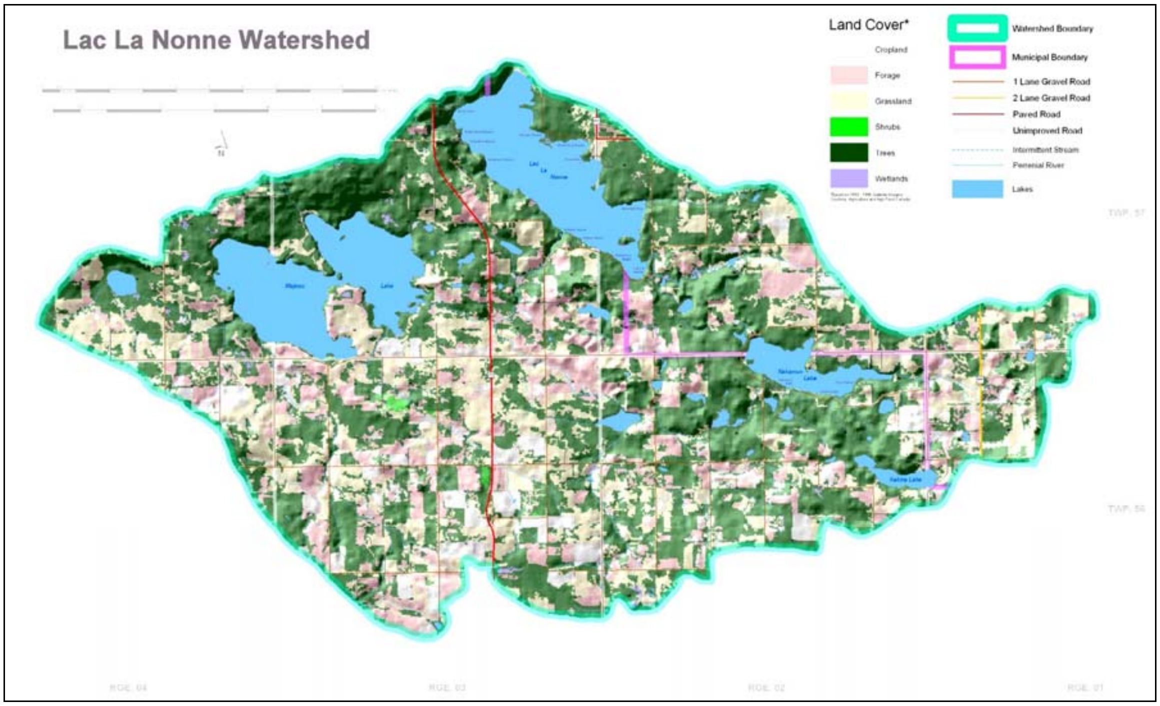

Figure. 1: Digital elevation model of the Lac la Nonne watershed from the website www.lepa-ab.com. Map created by Jason Vanrobaeys, AAFC – PFRA.

phosphorus (TP) concentrations have remained relatively unchanged over time, as TP averaged 168 µg/L in 1988, 183 g/L in 2001, and 148 µg/L in 2003. High nutrient levels have contributed to severe algal blooms in the past. In the summer of 1988, chlorophyll *a* concentrations reached 140 µg/L, and averaged 55.5 µg/L (Mitchell and Prepas, 1991). During the summer of 2003, ALMS reported much lower average chlorophyll *a* concentrations of 28 µg/L (ALMS, 2003).

Stream Sampling:

Stream water quality was sampled by LEPA volunteers in partnership with AAFRD in April of 2004. Eight stream sampling locations were identified (Figure 2). Each stream site was situated at the mouth of a subwatershed so that water quality results could be compared among basins. Water samples were collected in spring immediately following ice-out so that runoff from agricultural land would be captured. Throughout spring thaw, bi-weekly samples were collected and analyzed for nutrients, general chemistry, sediment, and *E. coli*. Stream flow ceased early in the season and sampling was completed earlier than planned, with water samples only being collected on 5 days in the month of April: April 1st, 5th, 7th, 12th, and 20th. Only three of the eight sites (Sites 4, 5 and 6) had flowing water and were sampled on the 1st of April. Pesticides were

Table 2: Chemical characteristics of Lac la Nonne (ALMS, 2003).

Parameter	1988	2001	2003
Total phosphorus (µg/L)	168	183	148
TDP (µg/L)	104	147	101
Chorophyll *a* (µg/L)	55.5	22	28
Secchi disk depth (m)	1.9	2.4	2.1
Total Kjehdal N (mg/L)	2.23	5.55	1.64
NO_{2+3} (µg/L)	<8	3	2.3
NH_4 (µg/L)	43	32	9
Ca (mg/L)	33	31	32
Mg (mg/L)	10	10	11
Na (mg/L)	17	18	21
K (mg/L)	10	11	11
SO_4 (mg/L)	14	12	13
Cl (mg/L)	3	5	4
HCO_3 (mg/L)	164	175	180
CO_3 (mg/L)	<9	6	10
Alkalinity (mg/L $CaCO_3$)	149	154	161
Conductivity (µS/cm)	314	337	333
pH	8.1-9.0	9	8.4
Colour (mg/L Pt)	-	19	-
TSS (mg/L)	-	4	-

Note. TDP = total dissolved phosphorus, NO_{2+3} = nitrate+nitrite, NH_4 = ammonium, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, SO_4 = sulfate, Cl = chloride, HCO_3 = bicarbonate, CO_3 = carbonate, TSS = total suspended solids.

only collected at Site 6, due to cost restrictions. Pesticide samples were collected twice, once on April 5th and on April 20th. Each LEPA volunteer was trained in proper sampling techniques at a workshop presented by AAFRD prior to commencing sampling. This ensured that the analytical laboratories had quality samples available for analysis. The complete training manual used by LEPA Volunteers is available in Appendix C.

Caffeine Collections:

Water samples were collected for caffeine analysis by Aquality Environmental Consulting Ltd. with the assistance of LEPA volunteers May 21 and September 7, 2004. The May sampling included both major stream inflows (Majeau Creek and Nakamun Lake) and 11 in-lake sites chosen by LEPA (Figure 3). Each location was chosen due to close proximity to pre-existing agricultural and residential development. Three sub-samples were collected near each site and later composited prior to analysis, to increase the surface area sampled. Exact sample locations

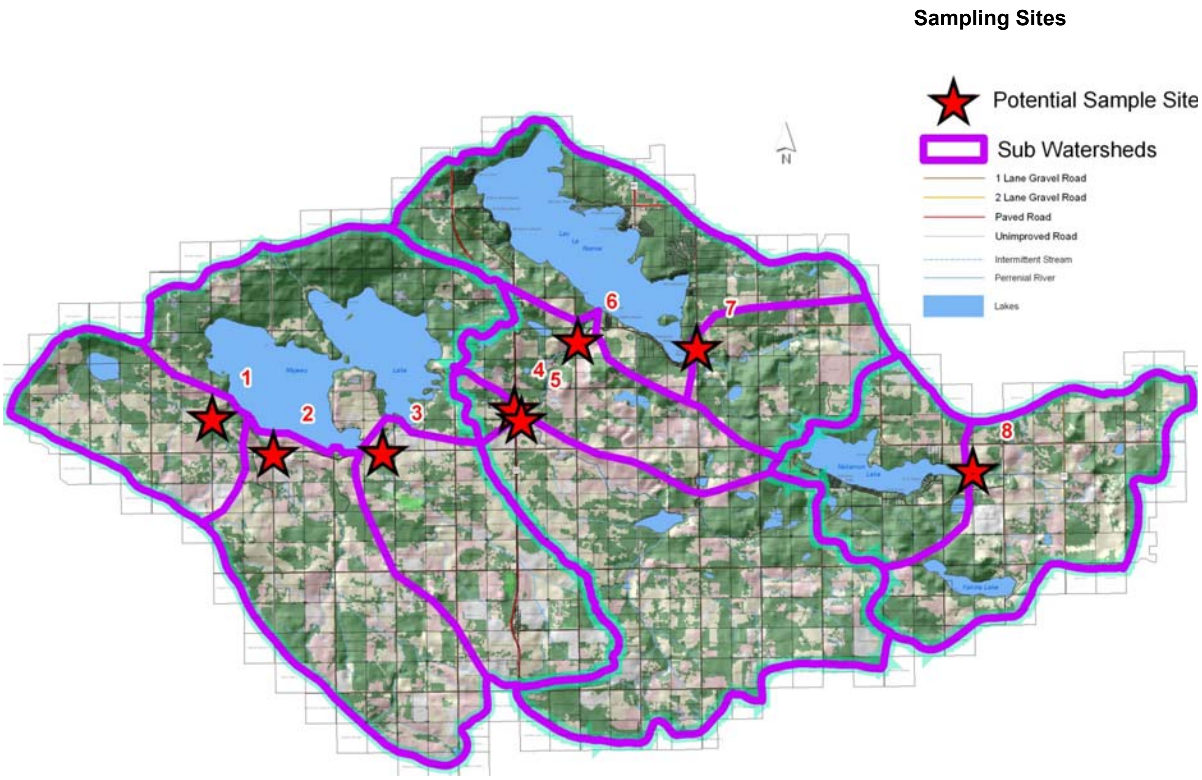

Figure 2: An overview of the Lac la Nonne Watershed. Lac la Nonne stream water quality study sampling sites are highlighted with red stars. (Modified by Sarah Depoe AAAFRD, from map courtesy of Jason Vanrobaeys, PFRA-AAFC)

were recorded using GPS (Appendix D). Two samples were taken from Nakamun Lake, one near the Nakamun Bible Camp, and the other in front of a cabin at Nakamun Park. In September, only the three sites with prior detections were re-sampled.

On both occasions, ultra-clean 1L amber glass bottles were provided by ARC Vegreville for sample collection, and their pharmaceutical sampling protocol was followed. Samples were collected by field staff wearing inert vinyl gloves, holding bottles upstream (into the current) in the middle of the water column until full. Bottles were immediately capped and stored in coolers with ice packs. Care was taken to avoid stirring up sediments, algae and other debris from

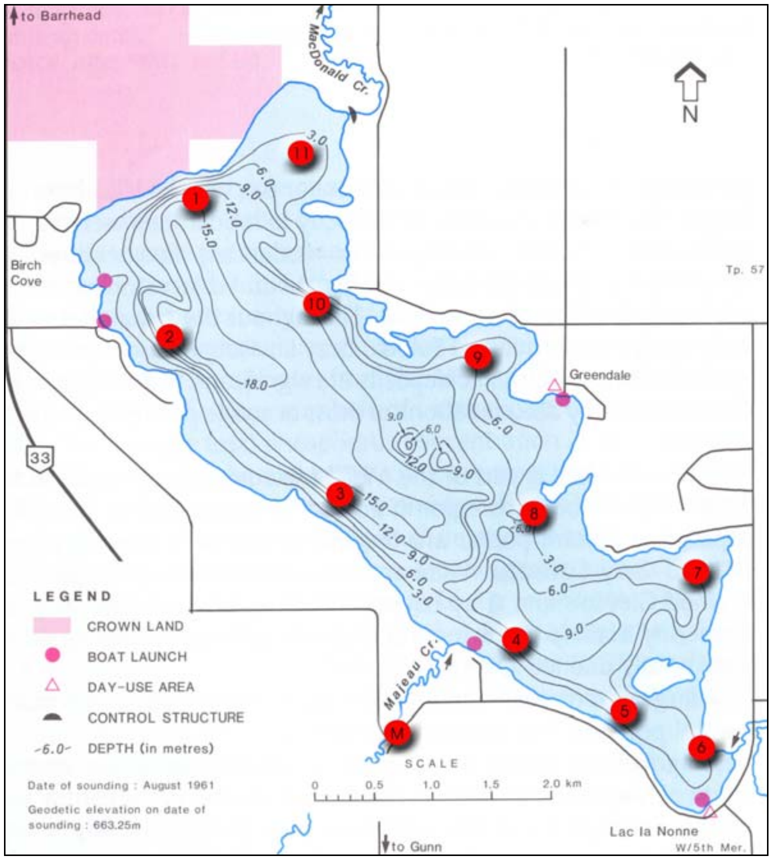

Figure 3: May, 2004 caffeine sampling locations at Lac la Nonne. Figure modified from Mitchell and Prepas (1991).

entering the collection bottles. Bottles were shipped overnight to the ARC lab in Vegreville. Field staff and ARC laboratory staff were not allowed to consume caffeinated beverages or food on the respective days of collection or analysis, and care was taken to avoid caffeine contamination with samples and sample bottles.

Bacterial samples were taken in conjunction with the Aspen Regional Health Authority at both lakes. For Lac la Nonne, samples were taken at 7 sites and one sample was taken at both sites at Nakamun Lake. The standard Aspen Regional Health Authority sampling protocol was used for all samples, and analysis was performed at the Provincial Laboratory at the University of Alberta Health Sciences Center.

Before any samples were collected, *Aquality* predicted (based on caffeine literature) that raw sewage should contain 42 µg/L of caffeine. This assumption was based on the following North American averages (adapted from Buerge et al. 2003):

Adult average urine volume produced per day = 1.4L
Adult average urine caffeine concentration = 1500 µg/L
Adult urine caffeine produced per day = 2100 µg
Adult average urination frequency = 5 times daily
Volume of water per flush = 9.8 L/flush = 49 L/day

$$\frac{\text{Adult caffeine produced per day}}{\text{Total amount of water}} = \frac{2100\ \mu g\ \text{caffeine}}{50.4\ L} = 42\ \mu g/L\ \text{(Predicted)}$$

Using these assumptions and our known minimum detection limit for caffeine we know that it is possible to detect caffeine in lakes that has been diluted up to 2100 times.

Samples were kept cool (4°C) until extraction, then transferred to a 2L separator funnel and spiked with appropriate surrogate standards. Liquid/liquid neutral extraction with dichloromethane was performed in triplicate, and the combined extracts were concentrated in a Turbo Vap tube. A hexane solvent exchange reduced the sample to approximately 5 mL, and the samples were further concentrated down to a volume of 1 mL. Samples were then analyzed by GC–MS (gas chromatograph–mass spectrography) in total ion chromatogram (TIC) mode. A four point calibration curve with lab grade caffeine was prepared prior to sample analysis to provide a test sensitivity of 0.02 ug/L.

Results

Water Quality

Total Phosphorus (TP) levels ranged from 0.111 to 0.912 mg/L, and averaged 0.289 mg/L in April 2004. Of the 35 samples taken from 8 sample sites, none complied with the Alberta Surface Water Quality Guideline (ASWQG) for the Protection of Aquatic Life (PAL) for TP (Figure 4). Average TP levels were nearly 5 times higher than the ASWQG PAL guidelines, with the highest levels occurring on April 1st at sites 5 and 6. After April 1st, site 8 had the highest overall TP levels. TP tended to decrease in concentration during the course of the month, with the highest readings occurring early in the month.

Total Nitrogen (TN) levels varied from 1.5 to 8.2 mg/L, and averaged 2.49 mg/L (Figure 5). Of the 35 samples analyzed for TN, none complied with Alberta Surface Water Quality Guidelines for the protection of aquatic life established for total nitrogen at 1.0 mg/L. The sites averaged levels approximately 2.5 times higher than the guideline. The highest Total Nitrogen level was seen at Site 4 on April 1st. Site 8 had the highest average TN level after this date, hovering around 4.5 mg/L.

2,4-D was the only pesticide detected, and it was found at Site 6 at a concentration of 0.006 µg/L. This concentration is well below surface water quality guidelines for the protection of aquatic life (4 µg/L) and livestock watering (100 µg/L).

Bacteria

Stream Sites

Most of the 35 samples taken contained fecal coliform levels that were well below the Alberta Surface Water Quality Guideline for Contact Recreation (ASWQG REC). Fecal coliform levels in most streams were low, and decreased over the course of the month. However, sites 1 and 3 produced fecal coliform counts that were well above the ASWQ REC guidelines (Figure 6). At site 1, *E. coli* counts were 490 CFU/100 ml on April 5^{th} (Colony Forming Unit), 65 CFU/100 ml on April 7^{th}, and 85 CFU/100 ml on April 20^{th}. April 12^{th} produced fecal coliform levels that were too numerous for the lab to count. At site 3, fecal coliform levels were 4 CFU/100 ml on April 5^{th}, 100 CFU/100 ml on April 7^{th}, 2 CFU/100 ml on April 12^{th}. *E. coli* levels were too numerous too count on April 20^{th}. In total, 3 samples taken in April 2004 either met or exceeded the ASWQG REC guideline of 200 CFU/100 ml.

Lac la Nonne

Total coliform counts did not exceed 20 CFU in any of the samples taken. The highest CFU found was 20, at Camp Encounter on the southeast shore, and 10, by the McFadzen property on the northwest shore. All other total coliform counts were below 10. Fecal Coliforms were even less numerous, with none of the samples exceeding 10 CFU. None of these counts exceed the Alberta Surface Water Quality Guidelines for Contact Recreation.

Nakamun Lake

Total coliform counts for Nakamun 1 were 20 CFU, and at least 10 for Nakamun 2. Fecal coliform counts were 20 for Nakamun 1 and less than 10 for Nakamun 2. A precise count for Nakamun 2 was not possible due to background growth inhibiting analysis.

Caffeine:

In May, four sites tested positive for caffeine in Lac la Nonne: site 3 (0.01 µg/L), site 5 (0.01 µg/L), site 9 (0.04 µg/L) and Majeau Creek (0.02 µg/L) (Table 3, Figure 9). As the detections for site 3 and 5 were below the minimum detection level, concentrations are estimates only. The September sampling produced no positive results for caffeine. Caffeine was not detected at the other sites sampled, including Nakamun Lake.

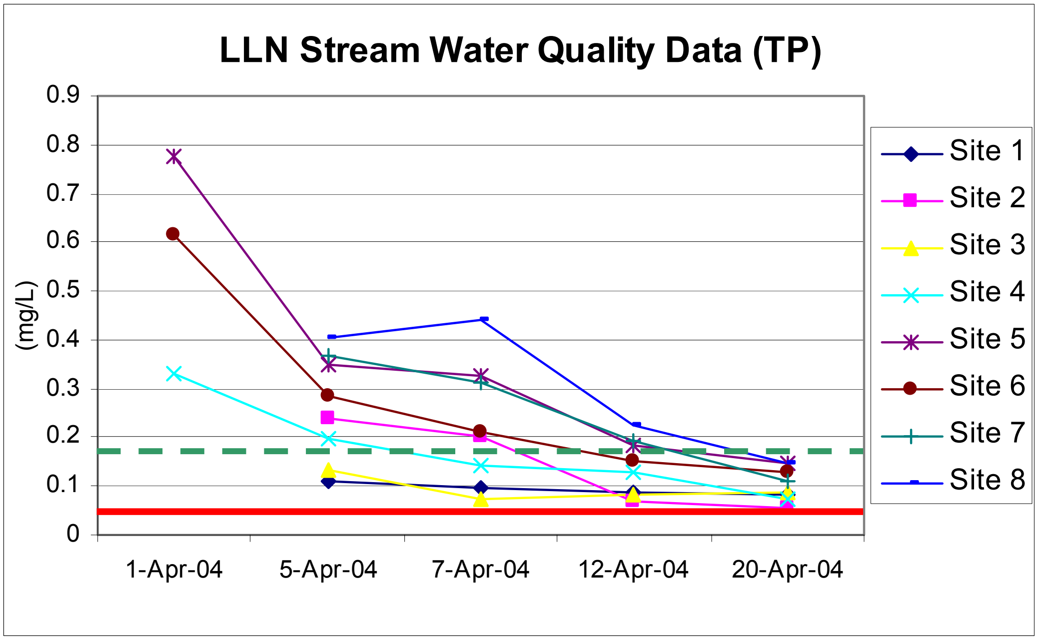

Figure 4: Total Phosphorus in Lac la Nonne tributaries or streams. The red line indicates the ASWQG PAL guideline (0.05 mg/L), and the green line represents average TP concentration in other Alberta Streams (AESA-CAESA 1996-2001).

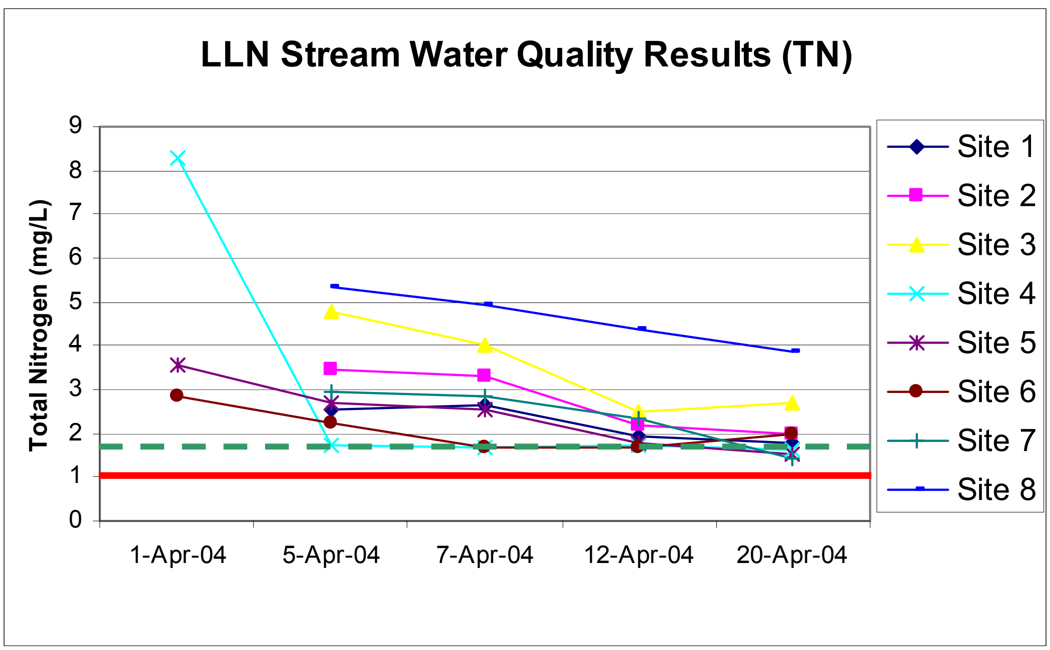

Figure 5: Total Nitrogen in Lac la Nonne streams. The red line represents the ASWQG PAL (1.0 mg/L) and the green line represents average TP concentration in other Alberta Streams (AESA-CAESA 1996-2001).

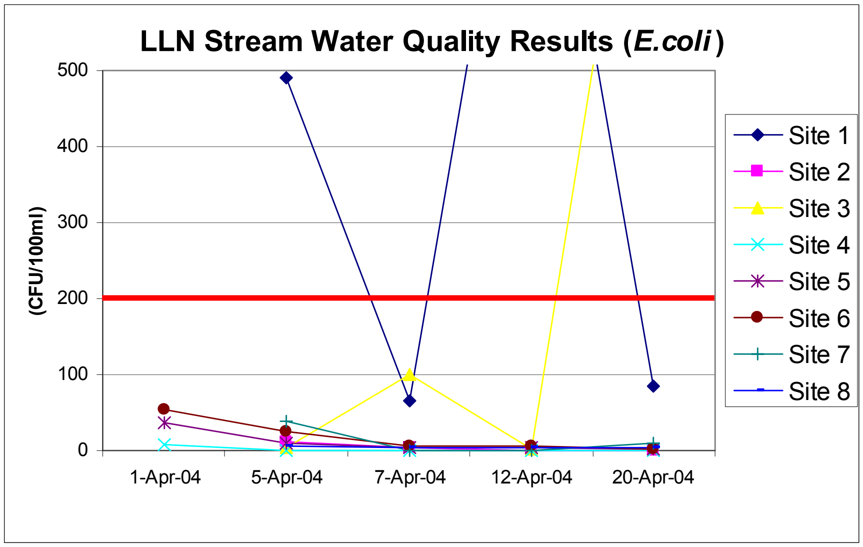

Figure 6. *E. coli* counts for Lac la Nonne streams. The red line indicates the Alberta Surface Water Quality Guideline for Contact Recreation (200 CFU/100 mL). Values for site 1 on April 12 2004 were considered too numerous to count.

Table 3: Table of caffeine detections in Lac la Nonne, only samples with positive results in the May sampling run were resampled in September, except for Majeau Creek

Site Name	May 21st, 2004 MDL = 0.02 mg/L	Sept 7th, 2004 MDL = 0.02 mg/L
Majeau Creek	0.02	NA
Nakamun Creek	ND	-
Site 1	ND	-
Site 2	ND	-
Site 3	0.01*	ND
Site 4	ND	-
Site 5	0.01*	ND
Site 6	ND	-
Site 7	ND	-
Site 8	ND	-
Site 9	0.04	ND
Site 10	ND	-

* Caffeine was found below the minimum detection level for concentration in these samples

Discussion

Nutrients

Nutrient concentrations were highest in early April, then dropped off over the course of the month. All phosphorus levels and most nitrogen and Nitrate-N levels were well above the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (Table 4). Generally, nutrient concentrations were similar at all sites.

Alberta Agriculture, Food and Rural Development calculated water quality indices for the streams sampled at Lac la Nonne based on the Alberta Agricultural Water Quality Index (AAWQI). All sites sampled ranked marginal to poor, with site 8 being the worst, and site 4 being the best (Table 5).

It is important to note that these nutrient concentrations and water quality indices are typical of other Alberta streams. From 1997-2001, Alberta Environmentally Sustainable Agriculture (AESA) studied water quality in 26 agricultural streams around the province. Each stream was classified as either having low, medium or high agricultural intensity. Anderson et al. (1999) classified the Lac la Nonne subwatershed as having moderate agricultural intensity. Results from the 2004 stream water quality survey at Lac la Nonne showed similar results as those in other moderate agricultural intensity watersheds.

Table 4: ASWQ guideline summary n = number of samples taken during study, C = number of samples compliant

	TP		TN		NO_2-N		*E. coli*	
Guideline:	ASWQG		ASWQG		ASWQG		ASWQG	
Protection:	PAL		PAL		PAL		Recreation	
Guideline Value:	0.05 mg/L		1.0 mg/L		0.018 mg/L		200/100 mL	
	n	C	n	C	n	C	n	C
Site 1	4	0	4	0	4	2	4	2
Site 2	4	0	4	0	4	1	4	4
Site 3	4	0	4	0	4	1	4	2
Site 4	5	0	5	0	5	3	5	5
Site 5	5	0	5	0	5	1	5	5
Site 6	5	0	5	0	5	2	5	5
Site 7	4	0	4	0	4	2	4	4
Site 8	4	0	4	0	4	2	4	4
# Samples	35	0	35	0	35	14	35	31
% Compliant		0.0%		0.0%		40%		91%

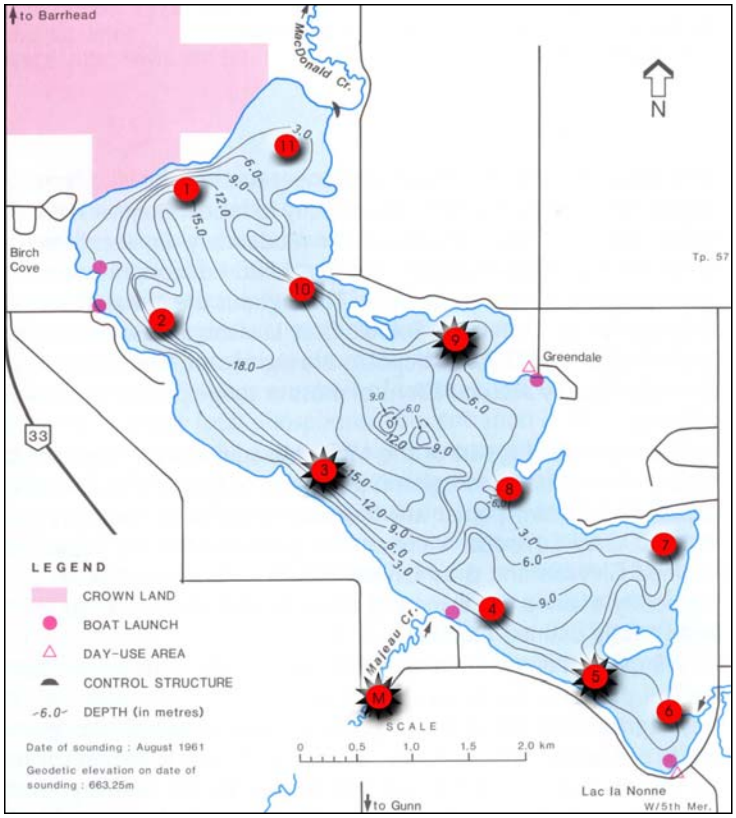

Figure 7: Sampling sites collected at Lac la Nonne. Stars represent positive caffeine hits.

Table 5: Alberta Agricultural Water Quality Index based on data from the Lac la Nonne Stream Water Quality Survey. Data courtesy of Sarah Depoe, Alberta Agriculture Food and Rural Development

Site No.	AAWQI Nutrient Sub-Index Score	Ranking
1	24.5	Poor
2	17.0	Poor
3	13.3	Poor
4	53.3	Marginal
5	15.6	Poor
6	23.0	Poor
7	19.7	Poor
8	8.8	Poor

High flow periods during the spring runoff period are associated with the lowest water quality in the streams observed. This is likely due to overland flow from surrounding lands washing accumulated nutrients into the streams. For this reason, we assume that Lac la Nonne receives most of its nutrient input from one main pulse event in the spring, and possibly a series of smaller pulses following summer rain events. Efforts should be taken to minimize runoff from surrounding lands by encouraging property owners to rehabilitate and restore the riparian areas and wetlands that act as natural filters for runoff.

There is debate as to the most significant source of nutrients into Lac la Nonne. Mitchell and Prepas (1991) speculated that approximately 57% of all nutrient loading into Lac la Nonne was from surrounding cleared agricultural lands. However, their assessment made assumptions which may well prove incorrect with further study. While the Lac la Nonne Water Quality Assessment and Improvement Project has conclusively demonstrated that nutrient levels in the streams feeding Lac la Nonne are high, loading from other sources has not been accurately determined at this time. In order to better steer future management efforts of the Lac la Nonne watershed, an accurate nutrient budget taking into account all sources should be developed.

Bacteria

Like nutrients, Fecal coliform and *E. coli* counts showed a decreasing trend in most streams during the study period. Most recorded counts were well below the ASWQ REC guideline. However, two problem areas were identified. The streams at Site 1 and Site 3 produced *E. coli* counts at or well above the ASWQG REC guideline. High *E. coli* counts such as this are a sign of recent fecal contamination and can pose a human and animal health risk. All mammalian feces, whether they are from livestock, pets, humans or wild sources contain pathogens potentially harmful to humans.

The exact source of the fecal contamination in our streams is difficult to trace with the methods used in this study. *E. coli* is known to survive in all mammalian, and many bird digestive tracts. Possible sources of the contamination could be livestock, local bird colonies, beavers, or even illegal sewage disposal by septic pumpers. More refined tests such as microbial source tracking could determine the exact source of fecal contamination in the future. Microbial source tracking involves analyzing fecal bacteria DNA and matching fecal bacteria DNA with the animal species from which it came. This technique could pinpoint fecal bacteria sources in the Lac la Nonne watershed and proper mitigation steps could be taken to reduce the human health risk.

Pesticides

The pesticide 2,4-D was detected at one site. 2,4-D is the active compound in a broadleaf herbicides and is widely used across the province in both agricultural and residential formulations. Toxicity information is included in Table 6, for informational purposes only as 2,4-D was detected at levels much lower that the ASWQG PAL.

Table 6: Toxicity values of various forms of 2,4-D. Data courtesy of C. Vanin - PFRA

Chemical	Brand Name	Acute Mammalian Toxicity	Toxicity to Fish	Toxicity to Birds
2,4-D	2,4-D Amine	moderate	toxic	NA
	2,4-D LV Ester	moderate	toxic	NA
	Diphenoprop BK700 (+ dichlorprop)	moderate	NA	NA
	Estaprop (+ dichlorprop)	moderate	NA	NA
	Turboprop (+ dichlorprop)	moderate	NA	NA
	Dichlorprop (+ dichlorprop)	moderate	NA	NA
	Interprop (+ dichlorpropr)	moderate	NA	NA
	Weedone CB (+ dichlorprop)	moderate	NA	NA
	Dyvel DS (+ mecoprop + dicamba)	low	non	non
	Embutox 625 (2,4-DB)	low	toxic	non
	Caliber 400 (2,4-DB)	low	toxic	non
	Cobutox 600 (2,4-DB)	low	toxic	non
	2,4-DB	low	toxic	non

<u>Caffeine</u>

Caffeine was detected in May only at three sites on Lac La Nonne, and at one site on Majeau Creek. These results confirm that human sewage dumping has recently taken place on Lac La Nonne and Majeau Creek, and that sewage is likely having an impact on the water quality of the lake.

Non-detects at the remaining eight sites does not necessarily mean that sewage is not present. Non detects (false negatives) may be due to (i) sample collections occurred too long after a sewage release; or that (ii) our detection limits were not sensitive enough to detect diluted caffeine levels. The latter point is especially true when dealing with composited samples, where water from three sites are mixed together and analyzed. The detection resolution decreases with each additional site added to the composite.

Even though the 10 ng/L detection limit can measure dilutions of raw sewage concentrations of up to 82-fold, possible sewage inputs into Lac La Nonne may be diluted to a greater degree than could be detected by the current analytical technique. Further refinement of the analytical technique to improve detection limits to the nanogram/L range (ng/L) is recommended for future samplings.

Sources of Human Sewage in the Environment

Human sewage may be entering Lac la Nonne from a variety of sources, including urban settlements, field systems and recreational areas (i.e. pit toilets). Older or improperly maintained septic systems at cottages can gradually leak waste into the surrounding lake, as can improperly placed outhouses (i.e. on sandy soils, or soils with high percolation rates). More study into how these systems age and continue to perform is required (e.g. what is the expected life of a typical system?). Future caffeine sampling in older areas around the lake will follow from results of the land-use survey, so that collections target areas with older septic systems that are more susceptible to leakage.

Septic system leakage around the lake may be cause for some concern, as a comparison between septic tank waste and municipal wastewater indicated that septage may be 6 to 80 times as concentrated as typical domestic wastewater (Metcalf and Eddy, 1991). More specifically, total phosphorus was found to be 31 times more concentrated in septic tank wastewater than from municipal wastewater. The impact of phosphorus and nitrogen loading from septic tanks on the lake may be considerably higher than thought. Past phosphorus budgets had estimated that sewage and runoff from urban and cottage areas contribute minor amounts (i.e. less than 2%) of phosphorus to the lake, based on studies at other Alberta lakes (Mitchell and Prepas, 1991). A phosphorus budget that specifically identifies the forms of phosphorus that are biologically available (i.e. soluble reactive phosphorus) should be calculated for the lake.

Urban sources of human waste include discharges from waste treatment lagoons, and outfall from combined sewers. Both of these types of discharge usually occur during or soon after periods of high precipitation when water treatment systems cannot handle the extra volume of stormwater. However this possibility is not probable at Lac la Nonne. Finally, human waste is sometimes applied on agricultural lands as a fertilizer, as it is very high in nutrients. If the fertilizer is improperly applied, or heavy precipitation occurs soon after application, it can subsequently be washed into waterbodies that drain into the lake.

Fate of Caffeine in the Natural Environment

In natural systems, caffeine is removed through lake flushing and through physical, chemical and biological degradation. Of all these processes, photodegradation by direct and indirect photolysis removes caffeine most effectively (Buerge et al. 2003). When wastewater is released into a sunny environment, caffeine has a half-life of approximately 12 days (Buerge et al. 2003). For our purposes this half life means that within 24 days water with detectable levels of caffeine can have its concentration lowered to below detectable levels.

Recommendations and next steps

High nutrient concentrations in streams during spring runoff indicate that runoff is a significant source of nutrients into Lac la Nonne. Immediate steps should be taken to minimize the impact of runoff from surrounding lands into the streams feeding Lac la Nonne. These include improving riparian health throughout the watershed, and maintaining and enhancing wetlands that act as a natural sponge for nutrients and other contaminants. Current efforts like the Lac la Nonne Riparian Improvement Project could be expanded to other farms in the watershed.

Our knowledge of nutrient inputs into Lac la Nonne is incomplete. In order to better identify issues and direct future management efforts of the Lac la Nonne watershed, a State of the Watershed Report should be prepared that would include data on human population, water quality, water quantity and the state of wildlife, especially fish populations, in the watershed. Finally, a nutrient budget that quantifies all nutrient sources should be developed. The State of the Watershed report would become the basis for a future Watershed Management Plan under the Alberta Water Act and direct future development in the Lac la Nonne Watershed.

Suspicions of untreated human sewage wastes entering Lac la Nonne have been confirmed with the detection of caffeine at several sites around the lake. An investigation should be undertaken to identify the exact sources of human waste. Caffeine sample collection timing could be altered in the future to capture a heavy rainfall event or spring melt. Finally, if so desired an expanded sampling program could be undertaken to determine caffeine levels in the various streams and inflows of the Lac la Nonne watershed. Remote streams are often ideal candidates for rogue sewage dumping by septic pumpers, and the perception that sampling is being performed on these streams may be a powerful tool to deter this practice.

In terms of human health, sewage in Lac la Nonne is a cause for concern. Human waste is known to contain several pathogens, viruses, bacteria and other substances which can have an adverse effect on human health. Contact recreation should be limited at those sites where caffeine has been detected, until follow-up sampling by the Aspen Regional Health Authority for coliforms shows that these sites are safe for recreational use.

Environmentally, sewage contains forms of nutrients that contribute to poor water quality and lead to excessive plant growths, algal blooms, fish kills and taste and odour problems. As these are all highly undesirable outcomes, there should be significant public support to remediate these problems. Sources of human waste in tributaries and lake waters include dumping into the lake, streams or storm drains by septic pumpers or improper disposal by recreational vehicles. Septic tank inspections and cottager education could help address these issues. Illegal dumping may require enforcement by Alberta Environment and Alberta Municipal Affairs.

References

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Appendix A: Trophic Status of Several Alberta Lakes

Appendix B: Caffeine Indicator

At Lac la Nonne there was concern over the disposal of untreated sewage into the lake from older or improperly maintained septic systems. Such problems are illegal, difficult to identify and difficult to enforce. The *Environmental Enhancement and Protection Act* (EEPA) states that:

> "No person shall dispose of waste except:
>
> a) at a waste management facility, or in a container the content of which will be taken to a waste management facility, that is subject of appropriate approval, registration or notice required under the Act, or
> b) in accordance with written authorization of the Director."

Human waste is undesirable in natural water systems for a variety of health and environmental reasons, particularly when the receiving waters are a drinking water source or used for recreation. Human sewage contains various pathogens and other substances that can be dangerous to human health (EPA, 1994). These include bacteria such as *Escherischia coli* (*E. coli)*, parasites such as *Giardia* and *Cryptosporidium* and other non-natural chemical compounds such as pharmaceuticals (Table 1). Pathogens in human fecal waste have the greatest potential to cause infection in other humans, and the failure to appropriately process human sewage poses a great threat to human health (Olson, 2002).

These substances can be harmful to human health by accidental ingestion and through recreational contact (i.e. swimming). Drinking and recreational water quality guidelines have been established for many of these substances that, when followed, minimize the risk to human health. Alberta Environment is responsible under the *Environmental Enhancement and Protection Act* to authorize and require that drinking water is treated by the drinking water supplier to Provincial standards. The Aspen Regional Health Unit is responsible for ensuring the safety of recreational areas (i.e. beaches and popular swimming areas).

Human waste has traditionally been very difficult to detect in aquatic systems, as very few of its components are unique to human waste. For example, fecal coliform bacteria such as *E. coli* has been used by some researchers in the past. However, the presence of coliform bacteria are ambiguous as they are found in all mammalian feces and it is difficult, without using sophisticated DNA-fingerprinting, to identify the exact animal source of this bacteria. A similar problem exists for commonly used antibiotics, which have both human and veterinary uses.

Table 1: Examples of pathogens and related diseases associated with raw human sewage and sewage solids. Table modified from EPA (1992).

Pathogen Class	Examples	Disease
Bacteria	*Shigella spp.*	Bacillary disease
	Salmonella spp.	Salmonellosis (gastroenteritis)
	Salmonella typhi	Typhoid fever
	Vibrio cholerae	Cholera
	Enteropathogenic-Escherichia coli	A variety of gastroenteric diseases Haemolytic Uretic Syndrome
	Yersina spp.	Yersiniosis (gastroenteritis)
	Campylobacter jejuni	Campylobacteriosis (gastroenteritis)
Viruses	Hepatitis A Virus	Infectious hepatitis
	Norwalk Virus	Acute gastroenteritis
	Rotaviruses	Acute gastroenteritis
	Polioviruses	Poliomyelitis
	Coxsackie viruses	"Flu-like" symptoms
	Echoviruses	"Flu-like" symptoms
	Reoviruses	Respiratory infections, gastroenteritis
	Astroviruses	Epidemic gastroenteritis
	Calciviruses	Epidemic gastroenteritis
Protozoa	*Entamoeba histolytica*	Amebiasis (amoebic dysentery)
	Giardia lambilia	Giardiasis (gastroenteritis)
	Cryptosporidium spp.	Cryptosporidiosis (gastroenteritis)
	Balantidium coli	Balantidiasis (gastroenteritis)
	Toxoplasma gondii	Toxoplasmosis
Nematodes (Roundworms)	*Ascaris lumbricoides*	Digestive and nutritional imbalances, abdominal pain, vomiting, restlessness
	Trichuris trichiura	Abdominal pain, diarrhea, anemia, weight loss
	Ascaris suum	Symptoms such as coughing, chest pain and fever
	Toxocara canis	Fever, abdominal discomfort, muscle aches, neurological symptoms
	Necator americanus	Hookworm disease, anemia
Cestodes (Tapeworms)	*Taenia spp.*	Nervousness, insomnia, anorexia, abdominal pain, digestive disturbances
	Hymenolepsis nana	Same as for *Taenia sp.*

Appendix C: Lac la Nonne Water Quality Assessment and Improvement Project Quality Assurance/Quality Control Manual

Appendix D: GPS Locations of caffeine collections.

Majeau Creek		N53 54 730, W114 16 801	Site 7	A	N53 55 004, W114 16 978
				B	N53 55 004, W114 16 978
				C	N53 55 004, W114 16 978
Site 1	A	N53 53 789, W114 21 956	Site 8	A	N53 55 041, W114 17 927
	B	N53 54 359, W114 21 725		B	N53 56 043, W114 17 927
	C	N53 57 033, W114 21 568		C	N53 56 043, W114 17 927
Site 2	A	N53 56 797, W114 21 320	Site 9	A	N53 56 043, W114 17 508
	B	N53 56 720, W114 21 018		B	N53 56 852, W114 18 314
	C	N53 56 531, W114 20 910		C	N53 56 853, W114 18 666
Site 3	A	N53 56 183, W114 20 051	Site 10	A	N53 56 853, W114 19 632
	B	N53 55 960, W114 19 629		B	N53 56 188, W114 19 814
	C	N53 55 636, W114 19 038		C	N53 57 189, W114 20 092
Site 4	A	N53 55 489, W114 18 773	Site 11	A	N53 57 524, W114 19 878
	B	N53 55 360, W114 18 368		B	N53 57 715, W114 19 899
	C	N53 55 173, W114 17 839		C	N53 57 768, W114 20 422
Site 5	A	N53 55 166, W114 17 835	Nakamun Creek		N53 54 706, W114 16 357
	B	N53 55 013, W114 17 224			
	C	N53 54 878, W114 17 041			
Site 6	A	N53 54 730, W114 16 801	Nakamun Lake 1		N53 57 755, W114 20 455
	B	N53 55 003, W114 16 975			
	C	N53 55 004, W114 16 978			
			Nakamun Lake 2		N53 57 755, W 114 20 445