Report on the Green and Watch Lakes Sewage Contaminated Seepage Detection Study

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Executive Summary

A sewage seepage detection study based on fluorometer readings was conducted for Green and Watch Lakes, British Columbia, in late August, 2008. The study was intended to provide baseline information for the Official Community Plan being developed for the area. A fluorometer was used to identify the presence of soaps as an indicator for sewage in the water column near shores with residential development. Fluorometers can detect wavelengths of brightening and whitening agents found in soaps and detergents. Water samples were collected and analysed for water quality parameters at locations with high fluorometer readings. High readings occurred at two sites each in Green and Watch Lakes. Although results show slightly higher than control levels for fecal coliforms, *Escherichia coli*, and some nutrients at these sites there is no clear indication for sewage contaminated seepage into either Watch Lake or Green Lake.

Acknowledgements

I would like to thank Fred Kuyek from the Green Lake Areas Ratepayers Association for volunteering his time and equipment to this study. I would also like to thank Ken Greenwood for his time and Doug Hughes for providing his boat. Thanks to the Thompson Nicola Regional District and Cariboo Regional District for providing us with maps and resources. Thanks to Bob Grace and Dennis Einarson from the Ministry of Environment for their help with sampling, training, and results interpretation. Thanks also to Gabi Matscha (Ministry of Environment) for help with editing and results interpretation.

Table of Contents

List of Tables

List of Figures

Appendices

Introduction

The Cariboo Regional District (CRD) and the Thompson Nicola Regional District (TNRD) are currently developing a joint Official Community Plan (OCP) in the area around Green and Watch Lakes. As a means to identify whether sewage seepage problems existed in the two lakes, Regional District staff requested that Ministry of Environment (MOE) help them with a seepage survey along the developed shorelines of these lakes.

Based on this request the objectives of this study are:

- to identify shoreline areas that display indicators of sewage contamination from onsite septic systems, and
- to recommend to the Regional Districts which developed areas require management of seepage sources (e.g. dysfunctional on site septic systems).

In an effort to keep costs to a reasonable amount the study was conducted in two steps:

1. Water near developed shoreline was scanned for fluorescent indicators of soap and whiteners which are typical components of human sewage. A fluorometer was used for this step.
2. Due to the possibility of natural substances also causing a fluorometer spike, water samples were collected at the locations where fluorometer readings were above background. These samples were analysed for biological and chemical substances that are connected to feces of warm blooded animals and/or human sewage, including fecal bacteria, nutrients, and caffeine. The presence of caffeine generally distinguishes human sewage from animal droppings.

Study Areas

Green Lake is located in the Cariboo Plateau of British Columbia, approximately 16 km northeast of 70 Mile House. Green Lake is approximately 14 km long, with an average depth of 10.3 m and an average width of 1.5 km (BCLSS, 2004). The surface area is 2760 hectares (ha) and the shoreline perimeter is 54.8 km (FishWizard, 2008). Green Lake is oligotrophic (BCLSS, 2004) meaning that it has low nutrient levels. It is also a marl lake[1] with high pH[2]. At the time of study the shoreland was comprised of approximately 64% Crown and 36% private land. There are approximately 421 developed lots along the lake which support permanent and seasonal homes, RV parks, resorts, and public access parks (Robinson, 2008).

Green Lake's watershed, which includes Watch Lake, covers approximately 709 km^2. Land uses in the watershed include agriculture (35%), forestry (20%), and residential/developed (15%); 30% of the watershed is undisturbed (BCLSS, 2004, see Appendix A).

Watch Lake is located directly northeast of Green Lake (see Appendix A). It is mesotrophic to eutrophic, meaning that it has higher nutrient levels, and is more productive than Green Lake. The surface area of Watch Lake is approximately 261 ha, the shoreline perimeter is 14.6 km, and the mean depth is 4.3 m. The outlet of Watch Lake is Watch Creek which flows into Green Lake. At the time of study the shoreland is comprised of approximately 30% Crown and 70% private land. There are approximately 113 developed lots along the lake which support permanent and seasonal homes, RV parks, resorts, and public access parks (Robinson, 2008).

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[1] A marl lake has hardwater and is saturated with calcium and carbonate ions. Marl lakes are often oligotrophic with low nutrient status. Marl lake sediments have a soft texture and are comprised of sand, clay, and limestone mixtures. During warm temperatures, calcium carbonate precipitates out, removing phosphorus in the process, and the water often becomes a vibrant turquoise colour (Otsuki and Wetzel, 1972; BCLSS, 2004). In cooler temperatures the water colour is usually a deep blue/green. Marl lakes can disguise phosphorus accumulation by storing phosphorus in the calcium carbonate lake sediments. If the calcium carbonate buffer is disrupted, a marl lake can switch from being oligotrophic to eutrophic which can result in algal blooms in areas where previously there were none (NIEA, 2005).

[2] pH is the measurement of the hydrogen-ion concentration in the water. Green Lake's pH range is from 9.0 (historical MOE data) to 9.45 (at the time of this study). A pH below 7 is acidic (the lower the number, the more acidic the water) and a pH above 7 (to a maximum of 14) is basic (the higher the number, the more basic the water). Natural fresh waters have a pH range from 4.0 to 10.0, although most lakes in B.C. have a pH of 7.0 or greater. High pH values tend to facilitate the solubilization of ammonia, heavy metals and salts. The precipitation of carbonate salts (marl) is encouraged when pH levels are high. Low pH levels tend to increase carbon dioxide and carbonic acid concentrations. Lethal effects of pH on aquatic life occur below pH 4.5 and above pH 9.5. (Taken from MELP, 1998.)

Methods and Materials

In this study a fluorometer was used to detect inflows of sewage contaminated groundwater by detecting the typical wavelength of optical brighteners and whitening agents found in soaps and detergents (415 nm to 445 nm (Hartel et al., 2007)). Brighteners and whitening agents are common in residential and industrial wastewater and their presence in freshwater and marine environments has been shown to be useful indicators for seepage from domestic and community wastewater systems (Hagedorn et al., 2005; Hartel et al., 2007; Petch, 1996). For a full description of how a fluorometer works refer to Petch, 1996.

A Turner Designs Ltd. Model 10-AU-005 Field Fluorometer was used for this study. It was set up with a filter that measures fluorescence between the wavelengths of 410 nm to 600 nm. It is important to note that organic substances such as humic and fulvic acids may also fluoresce within these wavelengths (Hartel et al., 2007; Grace, 1999; Petch, 1995) and may cause high readings that are not attributable to optical brighteners. Since Green Lake is oligotrophic interference from organics was less likely. However, Watch Lake is more productive with a higher chance of interference from organics. Water quality sampling was conducted at locations with elevated fluorometer readings to confirm a sewage seep via additional indicators such as elevated nutrients, bacteria, caffeine, and other water quality parameters.

A 14 foot, aluminium boat, equipped with a gas motor and an electric motor, was used to sample water within approximately 2 m of the developed shores of Watch and Green Lakes. The electric motor was used to move slowly along the developed shoreline, ideally in approximately 0.5 - 1.0 m of water. Background fluorescence readings were recorded at 2 - 4 locations in each lake near undeveloped shoreline. All other readings were compared to these background values. The fluorometer pump was kept at approximately 10 – 20 cm above the lake bottom. Fluorometer values were recorded on 1:5,000 maps overlaid with orthophotos.

Some areas along Green Lake's shoreline were very shallow and extended far into the lake. These areas were not sampled because it was difficult to navigate the boat close enough to shore without risking damage to the electric motor, and the water depth was not sufficient to operate the fluorometer.

Water samples were collected directly from the fluorometer outflow whenever a spike in fluorometer readings occurred. A spike was deemed to be any value that was at least two points above the background fluorometer reading. (One exception was a site on Watch Lake (Watch Lake sample site #1) that only had a reading of 0.23 fluorometer units above background. At this site a water sample was collected because a pipe covered in algae was observed.) Water samples were stored in coolers with ice and sent overnight to be analyzed at Can-Test Ltd., Maxxam Analytics Inc., and the University of Victoria. Samples were analysed for fecal coliforms, *Escherichia coli* (*E. coli*), bromide, total organic carbon, dissolved sulphate, dissolved chloride, total Kjeldahl nitrogen, total organic nitrogen, dissolved phosphorus, ammonia, nitrate and nitrite, total nitrogen, total phosphorus, and caffeine[3]. Replicate samples were taken at one test (sample) site. Control samples were collected from undeveloped shoreline areas and analyzed to compare with test site results.

Results and Discussion

Green Lake

Appendix B shows the areas on Green Lake sampled with the fluorometer as well as the locations where water samples were collected for analysis. Appendix B also contains

[3] Caffeine can be used as a chemical marker for domestic wastewater, especially from septic systems. It can also enter surface water via urine from humans and domestic animals (Aufdenkampe et al., 2006). It is present in foods, beverages, and pharmaceuticals and is considered to be one of the most commonly consumed drugs in the world (Buerge et al., 2003; Glassmeyer et al., 2005; Peeler et al., 2006; Verenitch and Mazumder, 2008). In this study caffeine was sampled as an indicator of human sewage; it was assumed that Green and Watch Lakes residents ingest some form of caffeine on a regular basis. See Appendix D for caffeine levels detected in other sewage contamination studies.

orthophotos of the test and control sites which show land uses in the surrounding areas. See Table 1 for concentrations of water quality parameters at each site.

Two fluorometer spikes were detected adjacent to developed shoreline on Green Lake (sample sites #1 and #4, see Appendix B). Water sample results for these sites show elevated levels of fecal coliforms (40 - 200 times higher than controls), *E. coli* (32 - 170 times higher than controls), and total and dissolved phosphorus (2 - 3 times higher than controls, see Table 1). Green Lake sample site #4 results also show elevated caffeine levels (4 times higher than the method detection limit of 1 ng/L). All other parameters were similar to controls.

Green Lake sample site #1 is located at the mouth of 83 Mile Creek (see Figure 1). A residence lies directly northeast of the sampling location. The mouth of the creek is a slow flowing section with wetland character and substantial aquatic plant growth. Wetlands commonly have high organic matter and nutrient concentrations and are often utilized by livestock and wildlife for food, water, and shelter (Wetzel, 2001). Due to the lack of caffeine in the sample, the likelihood of the high phosphorus and fecal bacteria values being caused by sewage seepage is low. Most of the elevated total and dissolved phosphorus is more likely caused by decomposition of plants and animals in the wetland or from nutrients in the watershed that accumulated in the stream. Similarly, the source of high fecal coliforms and *E. coli* are likely to originate from animal waste in the watershed and/or the wetland.

Green Lake sample site #4 is located next to a shoreline residence. At the time of sampling a broken pipe was observed spraying water onto the front yard (covered mainly in natural vegetation) which sloped into the lake. The fact that caffeine was detected in one of the two duplicate samples suggests the presence of human waste which may have contributed to the elevated fluorometer readings and the elevated nitrogen, phosphorus, fecal coliform, and *E. coli* results. These results could also be caused in part by runoff containing soil, feces and/or fertilizers from the front yard into the lake. Caffeine levels were elevated in only one of two replicate samples and were close to the detection level

Table 1. Water sampling results for Green Lake sample sites (levels elevated above controls are highlighted in yellow).

Site Name	Sample Date	Fecal Coliform (Col./100 mL)	E.Coli (Col./100 mL)	Bromide (mg/L)	Total Organic Carbon (mg/L)	Dissolved Sulphate (mg/L)	Dissolved Chloride (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total organic Nitrogen (mg/L)	Nitrate plus Nitrite (mg/L)	Total Nitrogen (mg/L)	Dissolved Phosphorus (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Caffeine (ng/L)
Green Lk #1 - 83 Mile Ck	2008-08-26	200	170	0.5	22.1	<0.5	16	0.97	0.97	0.003	0.98	0.018	0.021	<0.005	ND
Green Lk #2 Control - Blue Springs Pk	2008-08-26	<1	<1	0.6	26.1	<0.5	15	1.20	1.20	0.002	1.20	0.006	0.007	<0.005	ND
Green Lk #3 Control - across from Livingston Rd	2008-08-26	<1	<1	0.6	21.8	<0.5	15	1.29	1.29	<0.002	1.29	0.005	0.006	<0.005	1
Green Lk #4 - off Point Rd	2008-08-27	52	44	0.5	23.1	<0.5	16	1.51	1.51	0.007	1.52	0.011	0.011	<0.005	4
Green Lk #4 Replicate	2008-08-27	40	32	0.5	22.9	<0.5	15	1.29	1.29	0.002	1.29	0.012	0.013	<0.005	ND
Historical, background water quality results	1989-2005						9.3 - 10.8	1.02 - 1.14	1.44	<0.002 - 0.029	0.82 - 1.47		0.003 - 0.015	<0.005 - 0.023	

ND = not detected
Col. /100mL = colonies per 100 millilitres of water
mg/L = milligrams (one thousandth of a gram) per litre of water
ng/L = nanograms (one billionth of a gram) per litre of water

Figure 1. The mouth of 83 Mile Creek at Green Lake site #1.

which may indicate a false positive result. The caffeine levels are similar to literature results for natural waters that have low human impact (see Appendix D). However, the possibility for human sewage seepage or runoff cannot be ruled out.

Watch Lake

Appendix C shows the areas on Watch Lake sampled with the fluorometer as well as the locations where water samples were taken for analysis. Appendix C also contains orthophotos of the test and control sites to show the land uses in the surrounding areas. See Table 2 for concentrations of water quality parameters at each site.

One fluorometer spike was detected along the shoreline sampled on Watch Lake. This spike occurred at the outflow of Watch Lake into Watch Creek (Watch Lake sample site #2, see Figure 2 and Appendix C). Water samples were collected at this site and at a location where heavy algal growth covered a pipe (Watch Lake sample site #1, see Figure 3 and Appendix C) but a fluorometer spike was not detected.

Watch Lake sample site #2 results show elevated levels of fecal coliforms and *E. coli* (2 - 7 times higher than controls), total and dissolved phosphorus (2 times higher than controls), and ammonia (15 times higher than controls). The other parameters at Watch Lake sample site #2 were similar to control results. Water sample results for Watch Lake sample site #1 were similar to control sites results. Caffeine was not detected at either sample site.

At the time of sampling the water around Watch Lake sample site #2 had a brownish tinge and abundant aquatic plant growth, suggesting high levels of organic matter and nutrients. It is likely that the elevated fluorometer readings were caused by organic acids. Elevated fecal coliforms, *E. coli*, and phosphorus could be attributed at least in part to the wetland environment as described above (see discussion of Green Lake sample site #1). In addition, concentrations at the lake outflow reflect lake water quality that is cumulatively influenced by factors from the entire lake. As such, a combination of

Table 2. Water sampling results for Watch Lake sample sites (levels elevated above controls are highlighted in yellow).

Site Name	Sample Date	Fecal Coliform (Col./100mL)	E.Coli (Col./100mL)	Bromide (mg/L)	Total Organic Carbon (mg/L)	Dissolved Sulphate (mg/L)	Dissolved Chloride (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Total organic Nitrogen (mg/L)	Nitrate plus Nitrite (mg/L)	Total Nitrogen (mg/L)	Dissolved Phosphorus (mg/L)	Total Phosphorus (mg/L)	Ammonia (mg/L)	Caffeine (ng/L)
Watch Lk #1 - off Pioneer Rd	2008-08-19	24	22	0.4	13.0	<0.5	7.7	0.46	0.46	<0.002	0.46	0.007	0.007	<0.005	ND
Watch Lk #2 - Watch Ck outflow	2008-08-19	90	89	0.4	14.1	<0.5	7.7	0.89	0.60	0.004	0.89	0.018	0.019	0.290	ND
Watch Lk #3 Control - Pineridge Rd	2008-08-26	38	38	0.3	13.6	<0.5	7.6	0.72	0.70	<0.002	0.72	0.007	0.009	0.019	3
Watch Lk #4 Control - Eden Rd	2008-08-26	12	12	0.3	11.8	<0.5	7.6	0.46	0.46	0.004	0.47	0.007	0.008	0.008	3
Historical, background water quality results	1994 - 2005							0.55 - 0.88	0.72	<0.002 - 0.024	0.51 - 0.73		0.002 - 0.069	<0.005 - 0.082	

Figure 2. Aquatic macrophyte growth at Watch Lake site #2.

Figure 3. Heavy algal growth at Watch Lake site #1.

sources was likely responsible for the elevated values including runoff from lawns, natural wetland characteristics, and possible septic seepage.

At Watch Lake site #1 fluorometer readings and nutrient, fecal coliform, and *E. coli* levels were within the range of control values. No caffeine was detected. This clear lack of sewage indicators makes any recent, local sewage seepage or discharge unlikely. The heavy algal growth at the site could be due to the pipe providing suitable habitat or irregular, high nutrient availability. Based on the sampling results there is no proof that the heavy growth was caused by sewage contaminated seepage or inflows; however, infrequent seepage or discharge cannot be completely ruled out.

Conclusion and Recommendations

Study results show no clear indication for sewage contaminated seepage into either Watch or Green Lakes. Elevated fluorometer readings, fecal coliforms, *E. coli*, and nutrient levels were likely due to natural causes (such as typical wetland conditions), nutrient accumulation from the watershed, and direct runoff from land at most sites. Caffeine, an indicator for human waste, was detected at only one test site, Green Lake site #4, adjacent to a residence. The caffeine levels detected are similar to literature results for natural waters that have low human impact.

Based on the study results, seepage from sewage systems does not appear to be a concern in either Green or Watch Lake. In order to maintain current nutrient conditions in these lakes future development plans should include requirements to sufficiently prevent sewage contamination. Existing lakeshore residents should also be encouraged to limit nutrient inputs into the lakes. For tips on how to minimize human impact on lake water quality we recommend the BC Lakes Stewardship Society's reports for Green and Watch Lakes; these reports are available online at: http://bclss.accounts.nhwi.ca/library/library/cat_view/60-bclsmp-lake-reports/81-level-2.html.

Although this study was not intended to assess water quality for the purpose of guideline attainment monitoring it should be noted that the samples collected at Green Lake site #1 and Watch Lake site #2 exceeded the primary contact recreation guideline for *E. coli* of 77 CFU / 100 mL[4] (geometric mean, 5 in 30 days sampling) (MOE, 2006). Also, all four test sites exceeded the raw drinking water guidelines for *E. coli* and fecal coliforms of 0 CFU / 100 mL. As such, residents should be advised to refrain from drinking raw or untreated lake water[5].

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[4] Coliform results are reported as colony forming units (CFU) of total coliform bacteria counted in 100 millilitres of water submitted for analysis (taken from MELP, 1998).

[5] The sampling protocol to formally assess lake water quality for the purpose of guideline attainment includes multiple samples collected over a specific period of time, which differed from the sampling regime used in this study. However, residents and recreationalists should be reminded to avoid drinking untreated lake water. The full suite of British Columbia Approved Water Quality Guidelines can be viewed online at http://www.env.gov.bc.ca/wat/wq/BCguidelines/approv_wq_guide/approved.html#1

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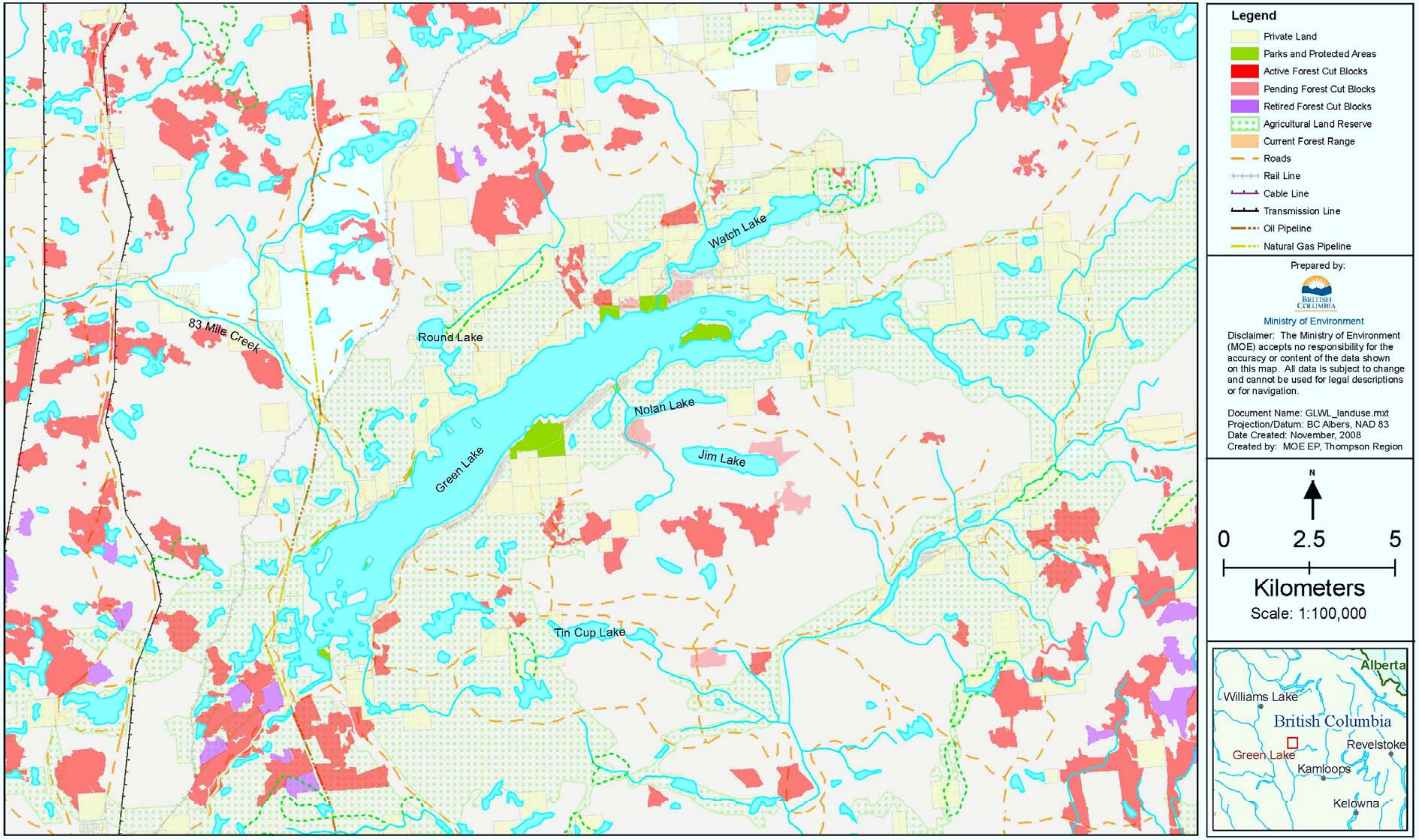
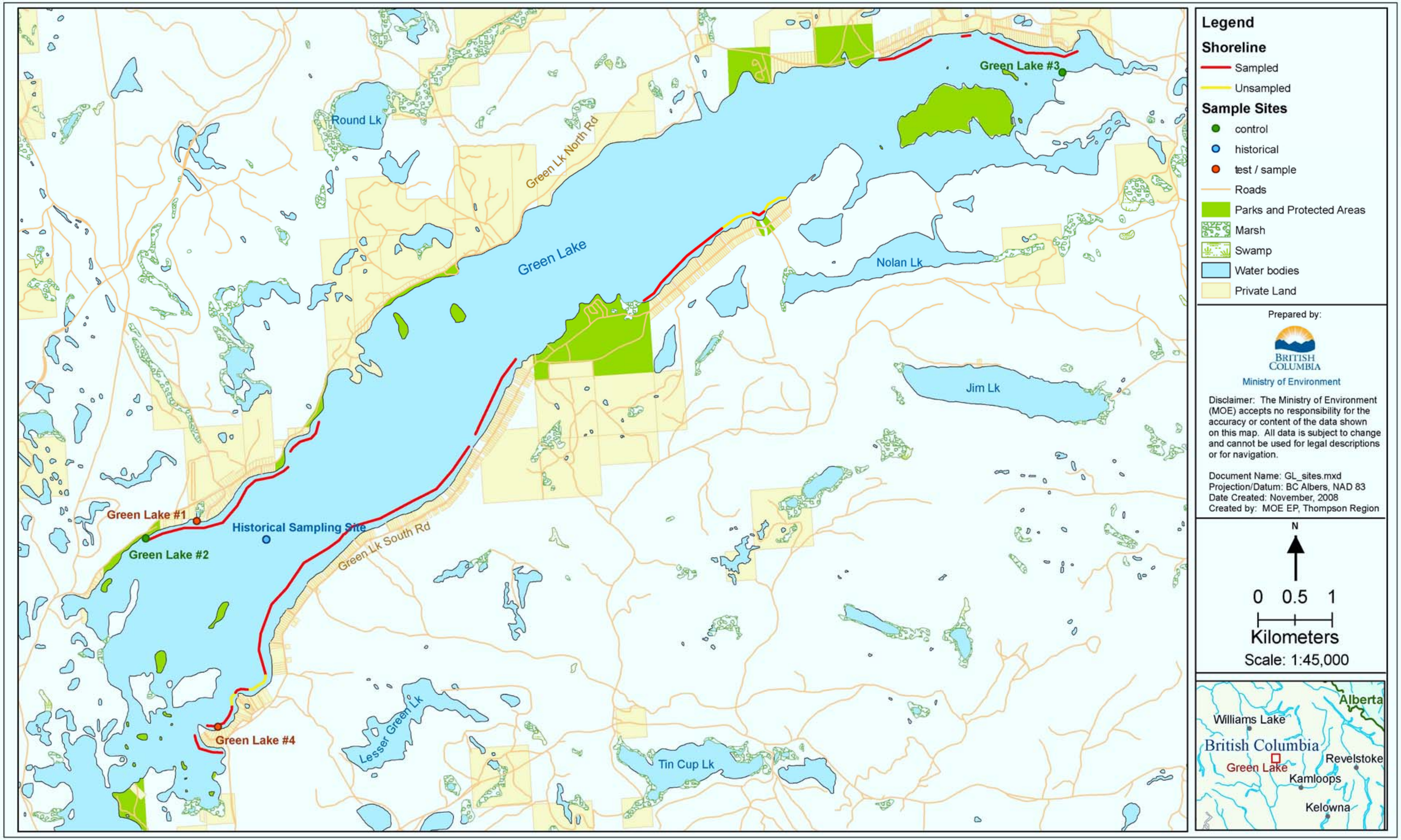


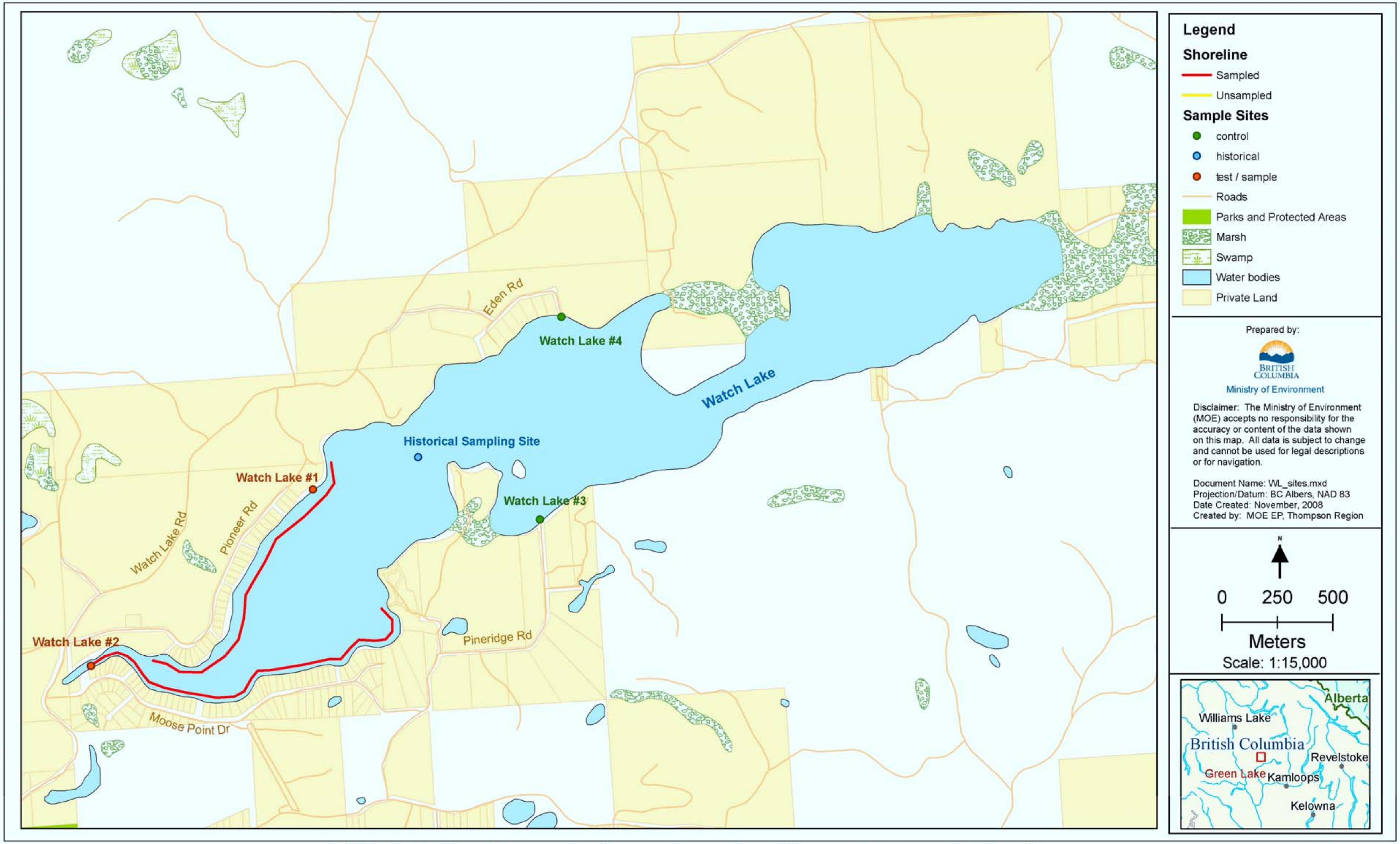
Land use around Green and Watch Lakes.



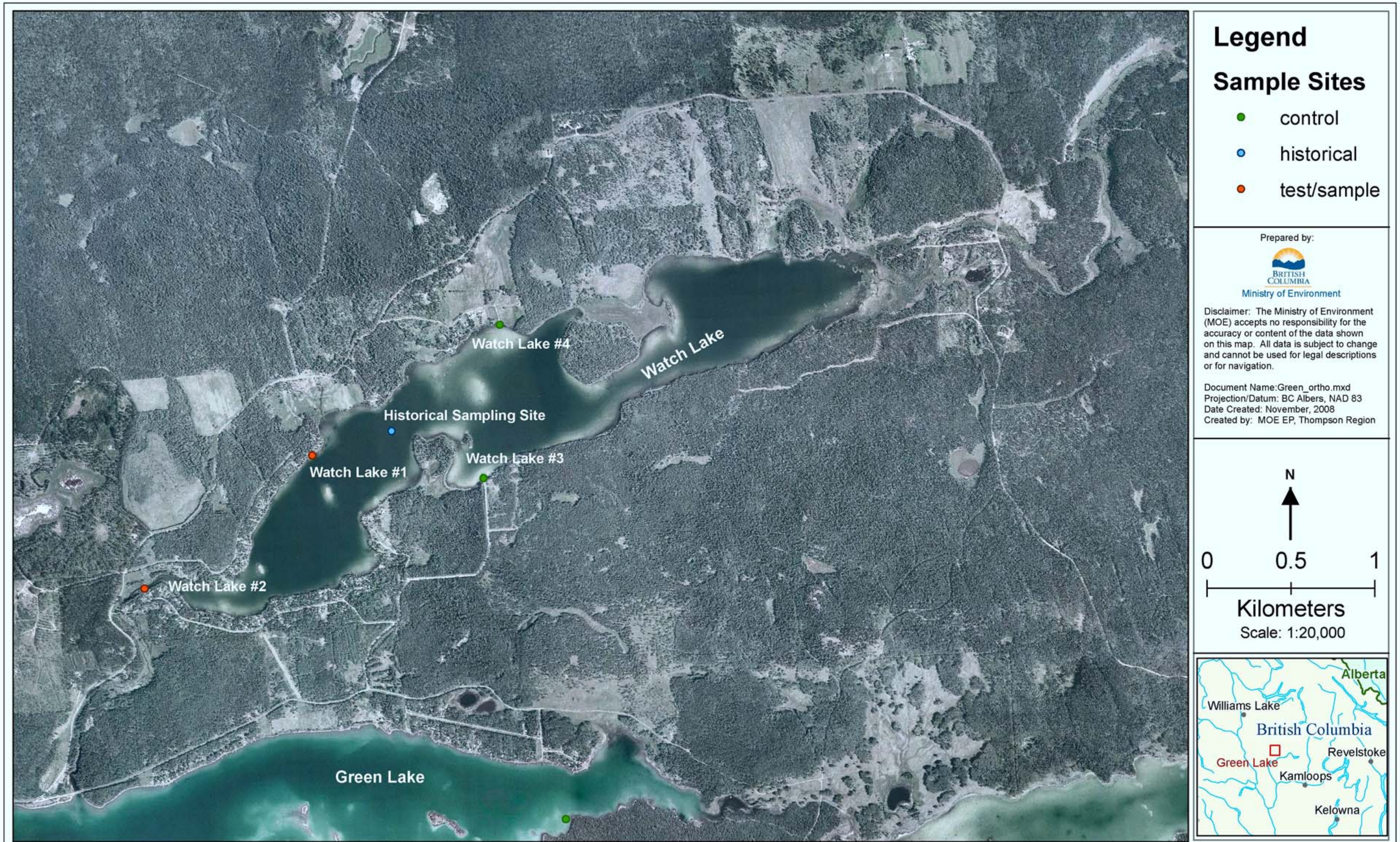
Green Lake fluorometer survey locations and sample sites.

Orthophoto of Green Lake sites #1, #2, and #4 and surrounding area.

Orthophoto of Green Lake site #3 and surrounding area.



Watch Lake fluorometer survey locations and sample sites.



Orthophoto of Watch Lake sites and surrounding area.

Appendix D

Caffeine concentrations literature data for rivers and lakes (natural waters). Modified from Buerge et. al, 2003.

Caffeine concentration	Location	Sampling location comments	Reference
3 - 1440 ng/L, median 160 ng/L	USA	not available	1
10 - 47 ng/L	USA	not available	1
<50 - 1270 ng/L	Germany	not available	1
10 - 100 ng/L	USA	Sampled the Mississippi River which is unlikely to be pristine.	1
13 ± 28 ng/L, up to 115 ng/L	USA	Sampled surface water ranging from pristine to heavily urbanized.	7
median 81 ng/L, up to 6 µg/L	USA	Sampled surface water susceptible to contamination from urbanization and livestock production.	8
130 - 370 ng/L	Massachusetts, USA	Samples the Charles River which receives effluent from small sewage treatment plants.	9
median 530 ng/L, up to 880 ng/L	Germany	Sampled rivers that pass through populated areas; water is unlikely to be pristine.	10
up to 171 ng/L	Netherlands	Sampled the Rhine River which is likely impacted.	11
160 ng/L	Greece	Samples collected from the Axios River which receives industrial, communal, and agricultural wastes.	12
43 - 160 ng/L	Calgary, AB, Canada	Sampled the Bow River, upstream of Calgary, which receives effluent from small communities upstream.	2
8.4 - 120 ng/L	Calgary, AB, Canada	Sampled the Elbow River, upstream of Calgary, which is unlikely to be pristine	2
0 - 5.6 ng/L	Michigan and Montana, USA	Sampled remote sites in areas with minimal human impact.	3
<5 - 14.6 ng/L	Georgia, USA	Sampled wetlands isolated from human effluent.	4
<5 - 62.3 ng/L	Georgia, USA	Sampled in a rural area dominated by agriculture and wetlands.	4
<2 - 6.5 ng/L	Vancouver Island, BC, Canada	Sampled a lake of low human impact.	5
1.8 - 10.4 ng/L	Vancouver Island, BC, Canada	Sampled a lake of moderate human impact.	5
6.1 - 21.7 ng/L	Vancouver Island, BC, Canada	Sampled a lake of high human impact.	5
<2 ng/L	Switzerland	Sampled remote mountain lakes.	6
6 - 164 ng/L	Switzerland	Sampled lakes with population densities ranging from sparse to dense.	6
<1 - 4 ng/L	Watch and Green Lakes, BC, Canada		this study

Notes: No sites were completely devoid of human impact. Studies highlighted in blue show caffeine concentrations similar to those seen in this study.

References

1 cited in Buerge et al., 2003
2 Chen et al., 2006
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