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Cowichan Lake: Water Quality Objectives Attainment Report (2012-14)

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EXECUTIVE SUMMARY

Water Quality Objectives (WQO) were developed for Cowichan Lake in 2011 (Epps and Phippen, 2011) based on data collected in 2008 and 2009. WQO attainment monitoring occurred from May 2013 through November 2014 at three deep basin sites, 12 lake perimeter sites, and 16 tributaries to the lake. This report presents attainment monitoring data and documents changes that have occurred in the watershed between 2012 and 2014.

Generally, the water quality of Cowichan Lake is very good, though tributaries to the lake show evidence of introducing microbiological contaminants to the lake. These sources should be further investigated by evaluating more parameters at sites shown to have higher turbidity or microbiological contamination; this will provide data for education opportunities to encourage landowners to reduce inputs into Cowichan Lake.

The WQO were met for the following parameters: dissolved oxygen (aquatic life), total suspended solids/non- filterable residue (drinking water and aquatic life), turbidity in deep basin sites (drinking water and aquatic life), TOC (drinking water) and secchi depth (maintenance of current water quality).

Objectives were not met for *E. coli* (drinking water for human health), temperature (aquatic life and drinking water aesthetics), and turbidity (drinking water and aquatic life) in tributaries to the lake, and chlorophyll *a* (maintenance of oligotrophic conditions).

Recommendations to improve, maintain and monitor water quality in Cowichan Lake:

- conduct regular attainment monitoring, quarterly over a one-year period, every 3 to 5 years;
- ensure that data are collected for all parameters for which there are objectives and as recommended in the WQOs;
- add additional tributary sites and conduct microbial source tracking (MST) analysis for samples collected in the tributaries to the lake to identify potential contaminant sources;
- consider establishing dissolved oxygen and temperature objectives for the tributaries to the lake;
- consider amending the WQO for temperature in Cowichan Lake to better represent the typical thermocline depth;
- as TSS and turbidity are correlated, TSS could be removed from the monitoring parameters if resources are limited; similarly, turbidity could be limited to fall sample periods when higher values are usually observed;
- collect phosphorus data in tributary streams to better understand inputs into Cowichan Lake;
- collect data on additional nutrient parameters in Cowichan Lake and analyze with existing data to thoroughly characterize the nutrient status of the lake; and
- reduce frequency of metals analysis in the lake and focus metals data collection on tributary streams with high turbidity values.

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1. INTRODUCTION

As part of the Province of British Columbia Ministry of Environment and Climate Change Strategy's (ENV) mandate to manage water bodies, water quality assessments and Water Quality Objective (WQO) reports have been created for several lakes, rivers and marine surface waters. These reports constitute acceptable levels of various water quality parameters for the specific water body for which they have been created, considering natural local water quality, water uses, water movement, and waste discharges. While WQO's currently have no legal standing, they can direct resource managers aiming to protect the water body in question and are used as a standard against which to measure any changes in the water quality of that water body. The science-based information and trends identified help inform local government on drinking water, liquid waste and land use planning, water quality targets and effective monitoring of those plans. Once objectives have been developed, periodic monitoring (approximately every three to five years) is undertaken to determine whether they are being met.

Cowichan Lake lies within the Nanaimo Lowlands Ecoregion on the south-eastern portion of Vancouver Island (Figure 1). The Town of Lake Cowichan and the community of Youbou are located within the study area. Cowichan Lake is the second largest lake on Vancouver Island, and supports important fisheries and recreation values. Cowichan Lake provides drinking water to the Town of Lake Cowichan, as well as the Cowichan Valley Regional District. There are also numerous domestic drinking water licences for both Cowichan Lake and the Cowichan River. Cowichan Lake is part of the Cowichan River watershed which includes Mesachie Lake, Bear Lake and Beaver Lake in the upper watershed, and a large number of tributary streams. The Cowichan River drains Cowichan Lake, entering the Strait of Georgia at Cowichan Bay.

The Cowichan watershed supports an abundance and diversity of both anadromous and resident salmonids. Anthropogenic land uses within the watershed include recreational use, forestry, residential use, and historical mining activities. These activities, as well as natural erosion and the presence of wildlife, all potentially affect water quality in Cowichan Lake.

Water quality objectives were developed for Cowichan Lake in 2011 (Epps and Phippen, 2011), based on water quality sampling conducted in 2008 and 2009. Water quality monitoring to determine objectives attainment occurred between May 2013 and November 2014. This report presents any changes in the watershed since 2012 and summarizes 2013-2014 sampling results. Results were compared to applicable Cowichan Lake WQOs or, where objectives did not exist for lake tributaries, to Cowichan and Koksilah River WQOs. Where neither of these existed, results are discussed relative to BC Approved Water Quality Guidelines.

For the purposes of this report, the study area is Cowichan Lake and its tributaries (Figure 1). Water quality in the Cowichan and Koksilah Rivers and Cowichan Bay are addressed in separate ENV reports.

Figure 1: Map of Cowichan Lake showing the location of sample sites.

2. CHANGES IN THE WATERSHED SINCE OBJECTIVES DEVELOPMENT:

The following notable changes or activities occurred in the watershed between 2008 and 2014:

- Initiatives to improve water quality by forestry companies working in the area include:
    - Continuing road construction and improvement program. Including replacing old structures, installing base plates on bridges to stop runoff and grass seeding (Epps, *pers. comm.*, 2018)
    - Island Timberlands has instituted a program that allows managers to shut down hauling operations during extreme rainfall events to reduce high turbidity runoff (Epps, *pers. comm.*, 2018).
- The area of forest harvested between summer 2009 and fall 2014 were obtained from an analysis of LandSat data. The 2977 ha logged during this time represents approximately 5.7% of the land area within the Cowichan Lake watershed (Moore, *pers. comm.,* 2018)
- Land clearing and development occurred in the watershed, which can contribute to increased phosphorus levels and other water quality issues as soil is disturbed (Rutherford, *pers. comm*., 2018).
- The CVRD worked to take over and bring up to provincial standard more of the smaller sewage treatment plants, thus addressing some of the issues related to bacteriological inputs. However, there remain many aging septic fields that continue to contribute to water quality issues in the region (CVRD, 2010).
- Slow population increase in the watershed is placing more demands on water resources (CVRD, 2010).
- To decrease water usage the CVRD and municipalities began providing incentives for homeowners to install water efficient technologies. They also legislated that water saving plumbing fixtures be installed in all new buildings (CVRD, 2015).

3. STUDY DETAILS

A total of 31 Cowichan Lake deep station, perimeter and tributary sites were sampled during the attainment monitoring program (see Figure 1 and Table 1). Sampling occurred from May 2013 through February 2014 following recommendations in the WQO report (Epps and Phippen, 2011) (Table 2).

Attainment data for secchi depth was taken from the BC Lake Stewardship and Monitoring Program (BCLSS) data summary for Cowichan Lake 2004-2013 (BCLSS, 2014).

Table 1: List of sampling stations by waterbody (Cowichan Lake (CL) deep basin, in-lake perimeter or lake tributary sites), including site descriptions, CVRD and ENV EMS identifiers and latitude/longitude.

Area	Station description	CVRD site ID	EMS ID	Latitude	Longitude
CL deep basin	Cowichan Lake # 1 - South Arm	CL Deep 1	E217507	48.8258	-124.1706
CL deep basin	Cowichan Lake # 2 - North Arm	CL Deep 2	E217508	48.8564	-124.1572
CL deep basin	Cowichan Lake # 3 - Main Basin	CL Deep 3	E217509	48.8817	-124.2811
CL in-lake perimeter	Cowichan Lake - Marble Bay	CLP01	E271684	48.833333	-124.119444
CL in-lake perimeter	Cowichan Lake - marina	CLP02	E271683	48.822222	-124.066667
CL in-lake perimeter	Cowichan Lake - Sunset Beach	CLP03	E271692	48.859722	-124.125
CL in-lake perimeter	Cowichan Lake at head of south arm	CLP04	E273063	48.829167	-124.070556
CL in-lake perimeter	Honeymoon Bay - Lake Cowichan	CLP05	E271687	48.821944	-124.181111
CL in-lake perimeter	Honeymoon Bay #2	CLP06	E273064	48.829167	-124.189444
CL in-lake perimeter	McKenzie Bay - Lake Cowichan	CLP07	E271686	48.814722	-124.156944
CL in-lake perimeter	Youbou #1 - Cottonwood Estates	CLP08	E271688	48.880278	-124.219444
CL in-lake perimeter	Youbou #2 - West	CLP09	E271689	48.875	-124.205
CL in-lake perimeter	Youbou #3 - East	CLP10	E271690	48.869722	-124.203889
CL in-lake perimeter	Youbou #4 - Billy Goat Islands	CLP11	E271691	48.866944	-124.185833
CL in-lake perimeter	Bear Lake - Lake Cowichan	CLP12	E271685	48.815278	-124.128333
CL tributary	Ashburnham Creek	CLT01	E294549	48.816228	-124.173353
CL tributary	Beadnel Creek	CLT02	E294558	48.828133	-124.049069
CL tributary	Beaver Creek	CLT03	E294555	48.820411	-124.078311
CL tributary	Coonskin Creek	CLT04	E294552	48.874964	-124.209331
CL tributary	Cottonwood Creek	CLT05	E217511	48.8881	-124.2406
CL tributary	Heather Creek	CLT06	E294554	48.917692	-124.459911
CL tributary	Little Shaw Creek	CLT07	E294553	48.923775	-124.458003
CL tributary	McKay Creek	CLT08	E217512	48.9092	-124.3211
CL tributary	Meade Creek	CLT09	E217510	48.8406	-124.0917
CL tributary	Nixon Creek	CLT10	E217514	48.8889	-124.3822
CL tributary	Oliver Creek	CLT11	E294557	48.827358	-124.050628
CL tributary	Robertson River	CLT12	E217516	48.8058	-124.1392
CL tributary	Shaw Creek	CLT13	E217513	48.9242	-124.3933
CL tributary	Sutton Creek	CLT14	E217515	48.8253	-124.2067
CL tributary	Croft Creek	Crof01	E294550	48.878047	-124.346047
CL tributary	Wardropper Creek	Ward01	E294551	48.906086	-124.30855

Table 2: Proposed schedule for water quality monitoring in Cowichan Lake (from Epps and Phippin, 2011) and detailed 2013 and 2014 variations (boldfaced) from recommended sampling.

Frequency and Timing	Characteristic to be Measured	2013 details	2014 details
Deep station sites (3 depths per site) - quarterly sampling (March, May, August, October)	pH, specific conductivity, total suspended solids/non-filterable residue (TSS), turbidity, true colour, total organic carbon (TOC), dissolved organic carbon (DOC), nitrogen species, total phosphorus, total and dissolved metals (spring overturn only), chlorophyll *a*, dissolved oxgyen (DO) and temperature profiles, and secchi disk	Done May 15, Aug 8 and Nov 21; profiles using Hydrolab Surveyor 4 at 1 m intervals also included oxidation-reduction potential (ORP). ***No Nov 2013 profile completed. Did not include TSS or nitrogen species.***	Done Feb 12; profiles using Hydrolab Surveyor 4 at 1 m intervals also included ORP. ***Did not include TSS or nitrogen species.***
Perimeter lake sites (surface grab sample) - summer and fall (weekly for five consecutive weeks in 30-day period)	*Escherichia coli (E. coli)*	Done	no sampling
Tributary sites (surface grab sample) - fall (weekly for five consecutive weeks in 30-day period)	Turbidity and TSS	Done in both summer and fall, added *E. coli*, field DO and temperature	Done at four sites only (Beadnel Creek, Beaver Creek, Meade Creek, and Oliver Creek) for *E. coli* and turbidity. Of these four, all but Oliver Creek was also sampled for total metals on Oct 28. ***TSS not sampled.***
Deep station sites - twice per year (summer and spring overturn)	Phytoplankton and zooplankton	Done	Done

For parameters (*E. coli*, TSS, and turbidity) that have WQO based on a minimum of five weekly samples collected over a 30-day period (5-in-30 sampling) during summer low flow (May - September) and fall high flow (flush) periods (October – April), attainment monitoring results were used to calculate appropriate statistics (30-day averages, maximum values, geometric means, and 90th percentiles). These statistics were compared to the objectives when the sampling regime met the criteria of five weekly samples in 30 days. If less than five samples were collected over a 30-day period, these data were included in the analysis and it was noted that the statistical calculations were based on fewer samples.

4. RESULTS AND OBJECTIVES ATTAINMENT

A summary of the WQO's attainment results are included in Table 3. The WQO's were met for the following parameters: DO, TSS, turbidity in deep basin sites, secchi depth and TOC. Objectives were not met for *E. coli*, temperature, turbidity in tributaries to the lake, and chlorophyll *a*.

Table 3: Summary of the water quality objectives for Cowichan Lake (Epps and Phippen, 2011) and 2013-2014 attainment results.

Variable	Objectives (2011)		Objective met? (yes/no)					
			2013		2013		2013	
	Site	Objective	Deep Basin Sites		Lake Perimeter Sites		Tributary Sites	
			Fall	Summer	Fall	Summer	Fall	Summer
Escherichia coli	All	≤ 10 CFU/100 mL (90th percentile)*	ND	ND	Yes	***No***	-- (No)	-- (No)
Dissolved Oxygen	Deep Basin Sites	≥ 5 mg/L at any depth during the summer months	Yes	Yes	--	--	--	--
Temperature	Sites where samples taken at depth	≤ 15°C (max) - summer hypolimnetic temperature (>10 m depth)	***No***	***No***	--	--	--	--
Non-filterable Residue (Total Suspended Solids)	Tributaries	≤ 26 mg/L (max)* ≤ 6 mg/L (mean)*	-- --	-- --	-- --	-- --	Yes Yes	ND ND
Turbidity	Deep Basin Sites Tributaries	≤ 2 NTU (max) ≤ 5 NTU (max)* ≤ 2 NTU (mean)*	Yes -- --	Yes -- --	ND -- --	ND -- --	-- Yes ***No***	-- ***No*** ***No***
Secchi Depth	Deep Basin Sites	≥ 6.0 m (max) ≥ 8.0 m (mean)**	Yes Yes	Yes Yes	-- --	-- --	-- --	-- --
Total Organic Carbon	Deep Basin Sites	≤ 4 mg/L (max)	Yes	Yes	--	--	--	--
Chlorophyll a	Deep Basin Sites	≤ 2 ug/L	***No***	Yes	--	--	--	--

'ND' means no data was available. "--" means there is no WQO for that situation.

**Based on a minimum of five weekly samples collected over a 30-day period.*

***Based on at least 12 samples collected between spring and fall.*

4.1 Microbiology – *E. coli*

Bacteria often enter surface waters via non-point sources, including wild and domestic animal feces, as well as seepage from leaking or failing septic systems. Microbiological indicators are monitored to evaluate of the risk of disease from these various pathogens (Warrington, 2001). Studies have shown that *E. coli* is the main thermo-tolerant coliform species present in fecal samples (94%) of humans and other endotherms such as birds and mammals, (Tallon *et al*., 2005), and at contaminated bathing beaches (80%) (Davis *et al*., 2005). Where total coliform concentrations are higher than those of *E. coli*, one can assume a high likelihood of contributions from non-fecal sources. Thus, there is limited benefit in measuring both groups.

E. coli was the only bacteriological indicator sampled in Cowichan Lake and its tributaries. As both the Town of Cowichan Lake and the CVRD withdraw water from Cowichan Lake for drinking water, and because there are several domestic licences issued for the lake, the Cowichan Lake *E. coli* WQO is set to protect drinking water (Epps and Phippen, 2011). The WQO is the 90th percentile of a minimum of five weekly *E. coli* samples collected within a 30-day period must not exceed 10 colony forming units (CFU) per 100 mL for *E. coli* at all sites within Cowichan Lake.

4.1.1 Cowichan Lake In-Lake Perimeter Sites

The 2013 *E. coli* 5-in-30 monitoring results from 12 in-lake perimeter sites showed that *E. coli* levels in the lake are low (Table 4, Figure 1). The sites sampled in Cowichan Lake did not exceed the objective, except for the summer samples collected at sites CLP04 (head of south arm, near the drinking water intake for the Town of Lake Cowichan) and CLP12 (Bear Lake). The results from these samples only exceeded the objective by a small margin (10.2 and 11.8 CFU/100 mL, respectively).

4.1.2 Tributaries to Cowichan Lake

Although the *E. coli* water quality objective established for Cowichan Lake does not apply to tributary sites, they were included in the monitoring program and the results obtained from these sites were compared to the Cowichan Lake WQO, as well as the BC Water Quality Guidelines for primary contact and recreation (ENV, 2017).

In 2013, 5-in-30 sampling for *E. coli* was completed at 15 tributary sites during the fall-flush period and 14 tributary sites during the summer low-flow period, with the exception that site CLT09 had only four samples collected over a 30-day period in the summer sampling. In 2014, *E. coli* was measured at four tributary sites during the fall-flush period; one of these sites had only four samples collected over a 30-day period (CLT09).

The Cowichan Lake tributary sites sampled in 2013 and 2014 frequently exceeded the drinking water objective by a large margin (Table 4, Figure 2). There were no exceedances of the BC Water Quality Guidelines for primary recreation for *E. coli* (200 CFU/100mL, based on geometric mean) (ENV, 2017) at any site sampled.

The *E. coli* levels were typically higher in the summer low flow (when contaminants can concentrate due to lower dilution) than in the fall when flows increase and flush contaminants from the system. As *E. coli* was still exceeding the WQO at some sites in the fall, and at CLT06 and CLT14, fall 90th percentiles were higher than summer values, it suggests sources also include flushing of contaminants off the land. As the high levels of microbial contamination in the tributaries is not equating to similarly high levels in the lake, this suggests sufficient dilution occurs once the tributaries enter the lake to keep *E. coli* below the drinking water WQO.

Table 4: Summary statistics for E. coli *(CFU/100 mL) for water samples collected at Cowichan Lake showing exceedances of the WQO's. Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.*

EMS Number	Station	Fall				Summer			
		Min	Geomean	90th percentile[2]	Max	Min	Geomean	90th percentile[2]	Max
Cowichan Lake - in-lake perimeter sites (2013 sampling)									
E271684	CLP01	<1	1.32	2.8	4	<1	2.09	7.6	10
E271683	CLP02	<1	1.25	2.2	3	<1	2.7	6	8
E271692	CLP03	<1*	1*	1*	<1*	<1	1	1	<1
E273063	CLP04	<1	1.82	4.6	5	<1	3.42	10.2	13
E271687	CLP05	<1	1	1	1	<1	1.58	3.8	5
E273064	CLP06	<1*	1*	1*	1*	<1	1.15	1.6	2
E271686	CLP07	<1	1.32	2.8	4	<1	1	1	1
E271688	CLP08	<1	1	1	1	<1	1	1	1
E271689	CLP09	<1	1.15	1.6	2	<1	1.32	2.8	4
E271690	CLP10	<1*	1*	1*	1*	<1	1.32	2.8	4
E271691	CLP11	<1	1	1	<1	<1	1	1	<1
E271685	CLP12	1	3.1	6.6	8	<1	3.35	11.8	15
Cowichan Lake Tributaries									
2013 sampling									
E294549	CLT01	<1	1.32	2.8	4	3	13	43.2	62
E294558	CLT02	1	3.39	9.6	10	1	5.5	14.8	20
E294555	CLT03	2	8.94	33.2	48	60	101.5	146	150
E294552	CLT04	<1	2.11	5.4	7	6.5	12.9	29	39
E217511	CLT05	<1	4.37	14.2	19	1	18.6	184.8	290
E294554	CLT06	<1	13.2	56.6	75	3	6.4	12.2	13
E294553	CLT07	<1	1.38	3.4	5	<1	1.82	12.4	20
E217512	CLT08	<1	2.2	11.4	17	5	23.7	666	1100
E217510	CLT09	<1	1.82	3.4	4	9*	36.1*	158.5*	175*
E217514	CLT10	3	8.33	53.8	85	1	6	80.4	130
E294557	CLT11	3	7.36	24.8	26	7	20.5	46	62
E217516	CLT12	<1	1.15	1.6	2	3	13.3	27.8	29
E217513	CLT13	12	19.5	43.6	56	11	32.4	260.8	420
E217515	CLT14	<1	11.6	328	540	4	10.2	28	32
E294551	Ward01	<1	1.15	1.6	2	--	--	--	--
2014 sampling									
E294558	CLT02	14	48.61	96.6	110	--	--	--	--
E294555	CLT03	3	19.29	77.4	99	--	--	--	--
E217510	CLT09	<1*	1.97*	4.4*	5*	--	--	--	--
E294557	CLT11	11	33.6	62.2	69	--	--	--	--

**Based on 4 weekly samples in 30 days.*

[2]Light grey highlighted 90th percentile values exceed the Lake Cowichan WQO of ≤ 10 CFU/100 mL.

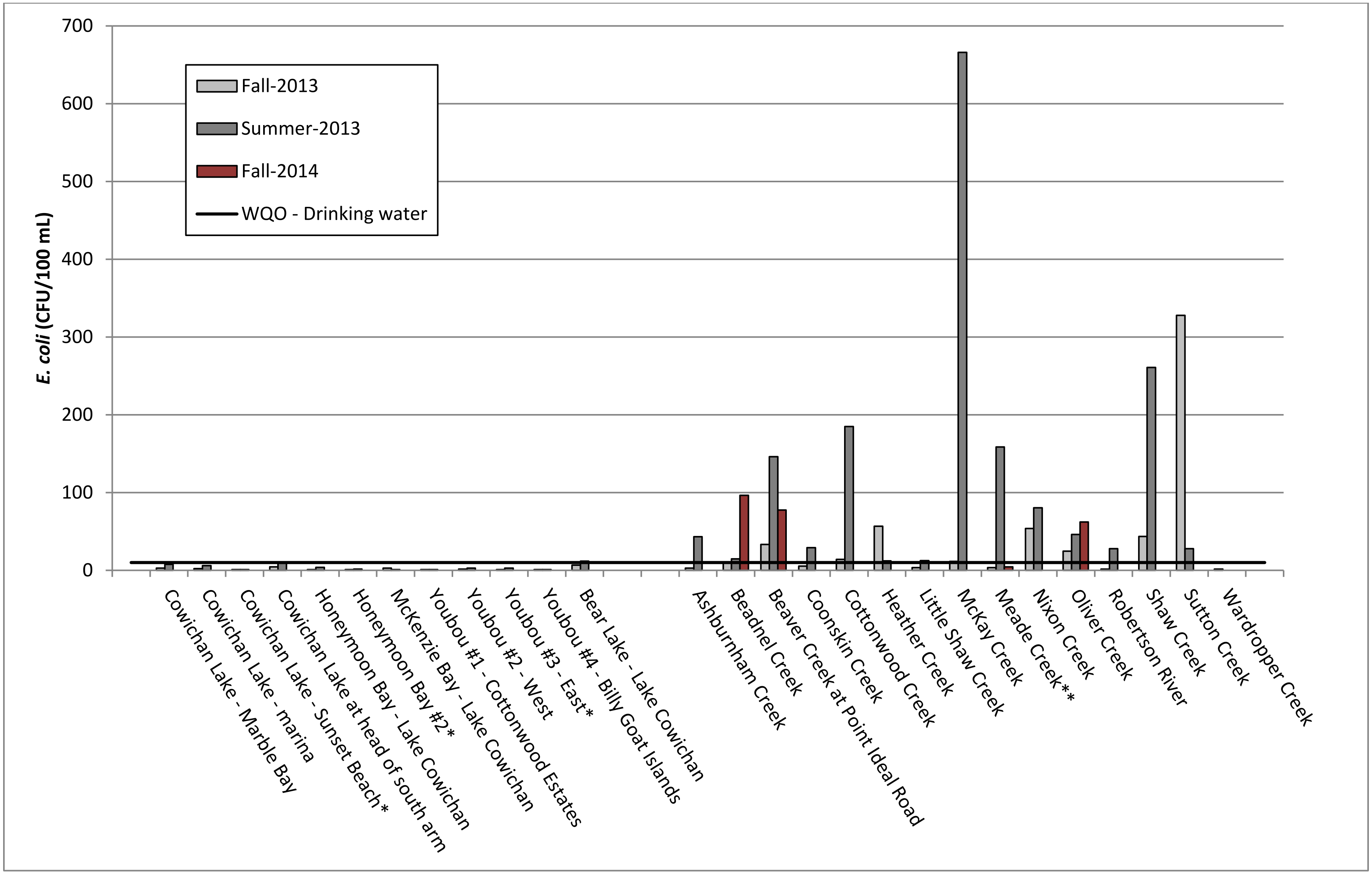

*Figure 2: Summary of 90th percentile results for E. coli analyses (CFU/100 mL) in Cowichan Lake perimeter and tributary sites (2013 and 2014 sampling), compared to the Cowichan Lake WQO for drinking water (90th percentile value of 10 CFU/100 mL). *Fall statistic is based on only four samples in a 30-day period. **summer statistic based on only four samples in a 30-day period.*

4.2 Dissolved Oxygen

DO concentrations are critical for the survival of aquatic organisms, especially species sensitive to low oxygen levels, such as salmonids (BC Environment and Lands, 1997). When deeper waters no longer mix with surface waters due to thermal stratification (see Section 4.3 Temperature), concentrations of DO can decrease. This often occurs because of decomposition of organic material (e.g. phytoplankton algae) which requires oxygen from the water column.

The WQO for DO concentrations in Cowichan Lake states that DO should remain above 5 mg/L at any depth throughout the year (Epps and Phippen, 2011). Although no WQO was set for the tributaries to Cowichan lake, sampling was conducted and values were compared to the objectives for the Cowichan and Koksilah Rivers (Obee and Epps, 2011) which are based on the minimum requirement for eyed or hatched fish eggs ($\geq$ 11.2 mg/L; October to May), or alevin and juvenile fish ($\geq$ 8 mg/L; June to September).

4.2.1 Cowichan Lake Deep Basin Sites

DO measured at the three deep basin sites on Cowichan Lake showed well oxygenated waters throughout the year (Figures 3, 4, and 5), with little stratification during the summer months. The minimum objective of 5 mg/L was not exceeded at any of the sites. The low DO concentration (5.23 mg/L) observed at the south arm site (E217507) at the 10 m depth in February 2014 may be attributed to isolated weather patterns (e.g., mild temperatures and/or low precipitation).

4.2.2 Tributaries to Cowichan Lake

In 2013 DO was measured from one to four times during each of the fall-flush and summer low-flow 5-in-30 sample periods at 16 sites in the Cowichan Lake tributaries (except Crof01 and Ward01) (Figure 6 and Table 5).

DO levels in most tributaries to Cowichan Lake were consistently above the Cowichan and Koksilah River WQO value of 11.2 mg/L for the fall sampling, with only three sites (Beaver Creek, Heather Creek and McKay Creek) having DO levels lower than the objective by a small margin. All but three of the sites sampled in the summer were below the DO objective of 8 mg/L; most of these sites were not substantially below the objective, except for sites Beaver Creek (CLT03; 5.3 mg/L), Robertson River (CLT12; 5.66 mg/L), and Sutton Creek (CLT14; 4.8 mg/L).

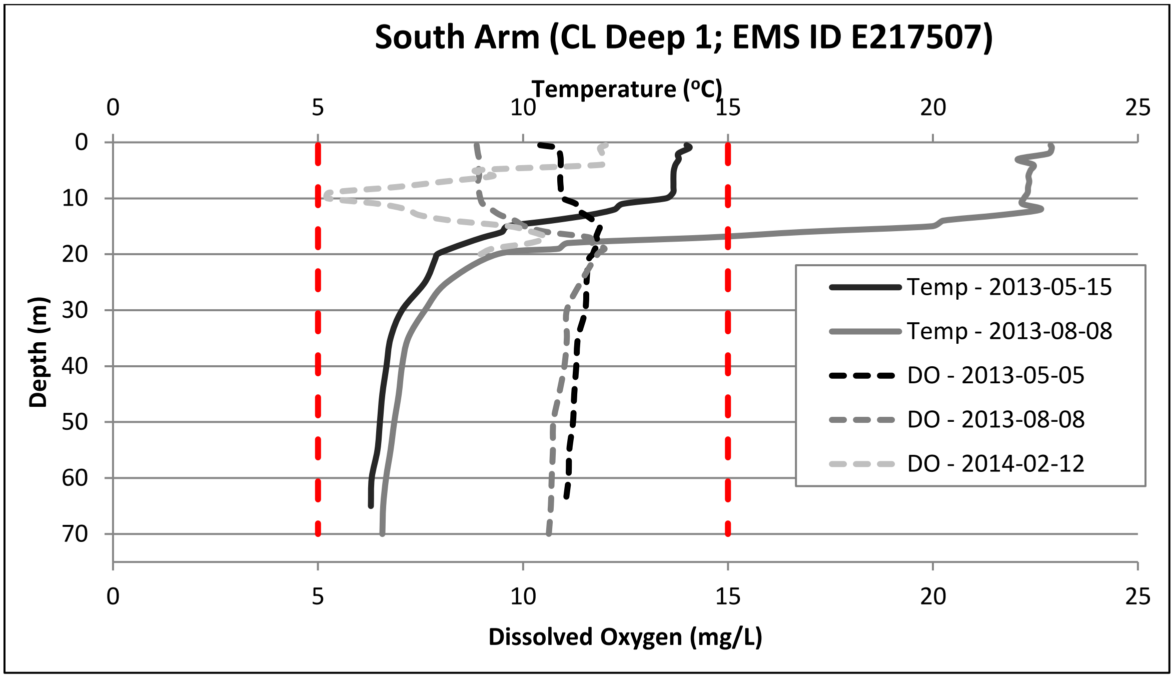

Figure 3: Dissolved oxygen and temperature profiles (2013-2014) for E217507. Red lines show WQOs: DO >5mg/L at any depth; Temperature <15°C at depths greater than 10m.

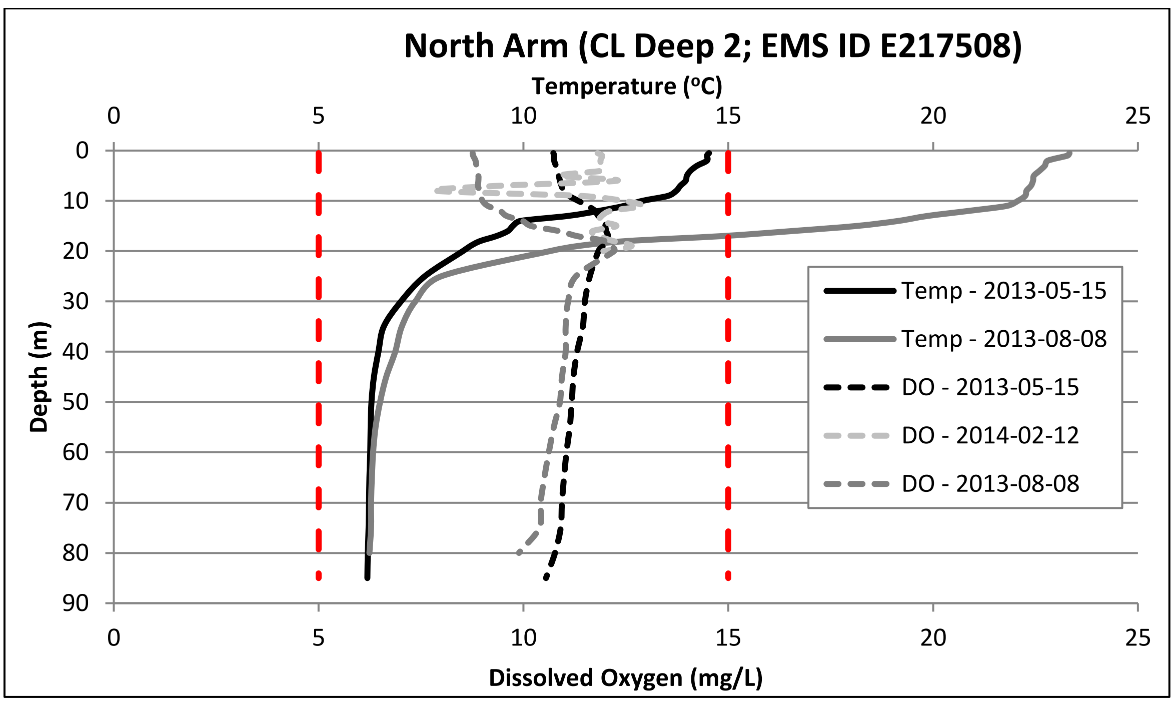

Figure 4: Dissolved oxygen and temperature profiles (2013-2014) for E217508. Red lines show WQOs: DO >5mg/L at any depth; Temperature <15°C at depths greater than 10m.

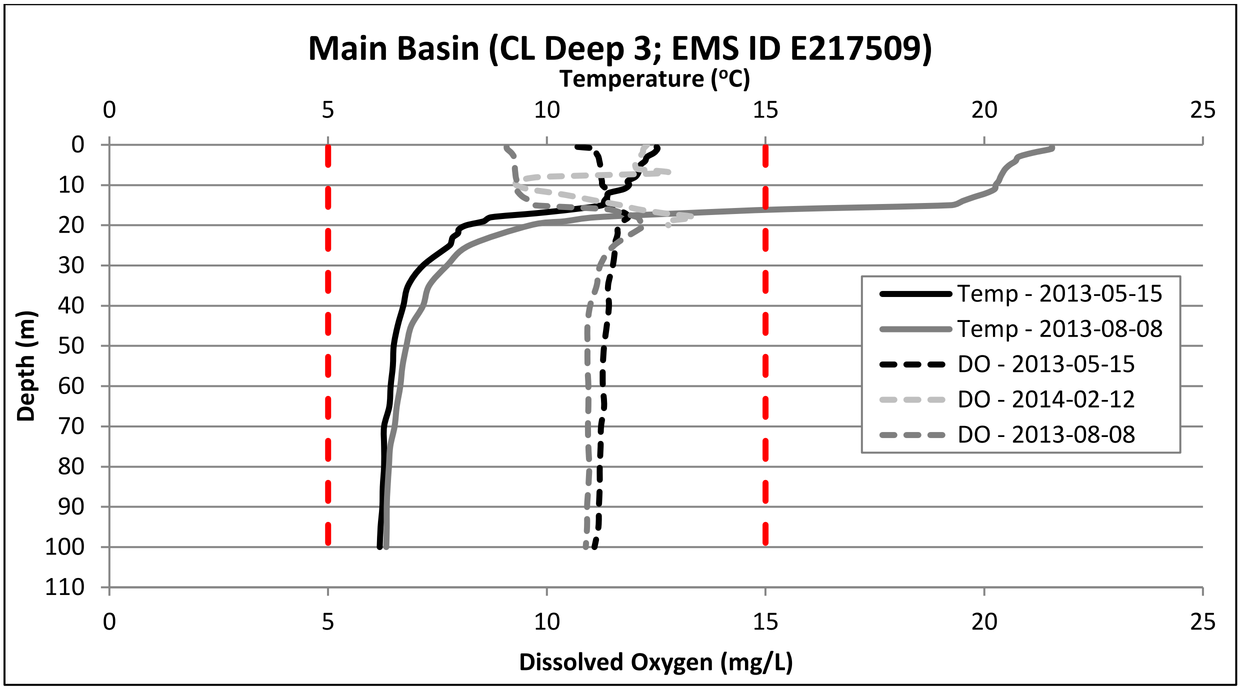

Figure 5: Dissolved oxygen and temperature profiles (2013-2014) for E217509. Red lines show WQOs: DO >5mg/L at any depth; Temperature <15°C at depths greater than 10m.

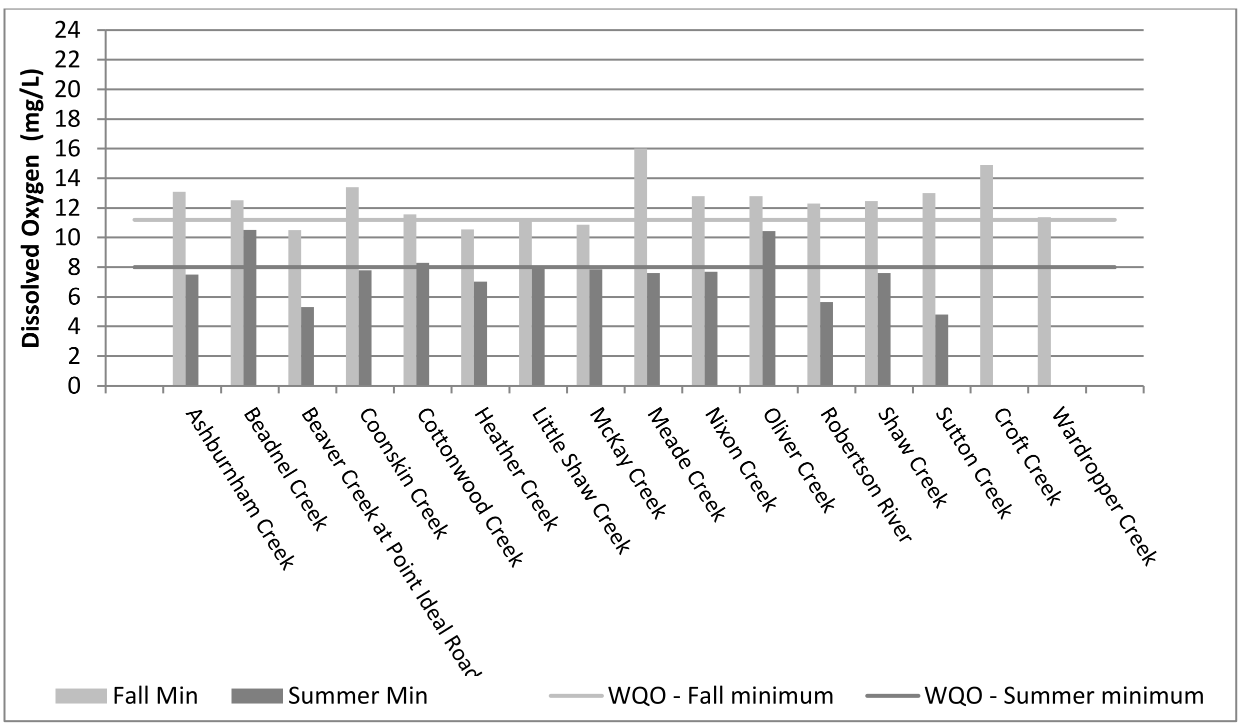

Figure 6: Summary of minimum results for dissolved oxygen (mg/L) in Cowichan Lake tributary sites, compared to the Cowichan and Koksilah River WQOs (> 11.2 mg/L from October to May; (> 8 mg/L from June to September). .

Table 5: Summary statistics for dissolved oxygen (mg/L) for water samples collected at sites in the tributaries to Cowichan Lake during the fall (Oct-Apr) and summer (May-Sept) seasons (2013 sampling).

			Fall				**Summer**		
EMS Number	**Station**	**n**	**Min**	**Mean**	**Max**	**n**	**Min[1]**	**Mean**	**Max**
Cowichan Lake Tributaries									
E294549	CLT01	4	13.1	13.65	14.6	2	7.5	8.41	9.32
E294558	CLT02	4	12.5	13.45	14.1	2	10.53	10.955	11.38
E294555	CLT03	4	10.5	11.65	12.5	2	5.3	5.45	5.6
E294552	CLT04	3	13.39	15.397	16.5	2	7.78	8.09	8.4
E217511	CLT05	3	11.56	13.95	15.4	2	8.3	8.67	9.04
E294554	CLT06	3	10.54	11.9	12.8	2	7.03	7.875	8.72
E294553	CLT07	3	11.22	13.64	15	2	7.96	7.99	8.02
E217512	CLT08	3	10.87	13.19	14.5	2	7.84	7.965	8.09
E217510	CLT09	3	16	17.88	21.55	1	7.61	7.61	7.61
E217514	CLT10	4	12.8	14.325	15.5	2	7.7	8.07	8.44
E294557	CLT11	4	12.8	13.6	14	2	10.44	10.835	11.23
E217516	CLT12	4	12.3	12.7	13.6	2	5.66	5.73	5.8
E217513	CLT13	3	12.47	14.12	15.1	2	7.61	8.19	8.77
E217515	CLT14	4	13	14.275	15.1	2	4.8	5	5.2
NA	Crof01	1	14.9	14.9	14.9	--	--	--	--
NA	Ward01	3	11.37	13.69	15.1	--	--	--	--

[1]Light grey highlighted minimum values exceed the Cowichan and Koksilah River WQO for dissolved oxygen: fall WQO is eggs $\geq$ 11.2 mg/L; summer WQO is $\geq$ 8 mg/L

4.3 Temperature

The WQO for Cowichan Lake is that during the summer, water temperatures should not exceed 15°C at depths greater than 10 m to avoid physiological stresses to fish and protect the aesthetic quality of drinking water, provided that water intakes are located at least 10 m deep in the lake (Epps and Phippen, 2011; Oliver and Fidler, 2001).

Although no WQO was set for temperature in the Cowichan Lake tributaries, temperature data from the tributaries were compared to the temperature WQO for the Cowichan and Koksilah Rivers. This WQO is that the average weekly temperature should not exceed 17°C at any time during the year in order to protect trout and juvenile salmonids (Obee and Epps, 2011). Though weekly mean temperatures (to allow direct comparison to the Cowichan and Koksilah Rivers WQO) were not available in this dataset, maximum values of the tributary temperature data were considered relative to the WQO.

4.3.1 Cowichan Lake Deep Basin Sites

The water column in Cowichan Lake was stratified during the spring, becoming strongly stratified during the summer months, with a thermocline occurring between 5 m and 30 m in depth (Figures 3, 4, and 5). Data were not collected during the winter months. At all sites, temperatures between the surface and the bottom (about 70 to 100 m) varied strongly, with surface temperatures being approximately 16°C higher than water near the bottom of the lake during August sampling.

At all three of the deep basin sites, the WQO was exceeded during August 2013 sampling, at depths between 10 and 16 meters. As surface water temperatures can reach 21.5 to 23.3°C in August, fish would typically need to stay within or below the thermocline to avoid physiological stresses associated with elevated water temperatures. The dissolved oxygen and temperature profiles obtained for 2013 indicate that deeper waters remain cool and oxygenated and would provide adequate refuge for fish during the summer months.

4.3.2 Tributaries to Cowichan Lake

Summary statistics for Cowichan Lake tributary temperature data were calculated based on the available results (i.e., between one and four samples collected over a 30-day period) (Table 6). Temperature maximums were higher than 17°C at five of the 14 sites sampled in the summer months in the tributaries. In these cases, the exceedance was by a small margin, ranging from 0 – 2.5 °C. If these temperatures persisted over a week-long period to allow calculation of a weekly mean for direct comparison to the WQO, there is potential for the Cowichan and Koksilah River WQO to be exceeded.

Table 6: Summary statistics for temperature (°C) for water samples collected at sites in Cowichan Lake tributaries during the fall (Oct-Apr) and summer (May-Sept) seasons (2013 sampling).

				Fall				Summer	
EMS Number	**Station**	**n**	**Min**	**Mean**	**Max**	**n**	**Min**	**Mean**	**Max[1]**
Cowichan Lake Tributaries									
E294549	CLT01	4	4.8	6.275	7.9	2	10.6	11.6	12.6
E294558	CLT02	4	5.6	6.825	8.8	2	12.7	12.9	13.1
E294555	CLT03	4	3.1	5.675	8.5	2	14.3	15.4	16.5
E294552	CLT04	3	2.7	3.9	5.7	2	15.9	16.55	17.2
E217511	CLT05	3	4.3	5.03	5.9	2	15	15.8	16.6
E294554	CLT06	3	5.7	6.33	6.8	2	16.6	17.5	18.4
E294553	CLT07	3	3.6	4.8	6.3	2	15.2	15.9	16.6
E217512	CLT08	3	4.6	5.4	6.1	2	15.8	15.95	16.1
E217510	CLT09	3	4.2	5.13	6.5	1	17.7	17.7	17.7
E217514	CLT10	4	4	5.525	7.8	2	17.3	18.4	19.5
E294557	CLT11	4	5	6.55	9.1	2	11.11	12.555	14
E217516	CLT12	4	5	6.4	8.1	2	13.9	14.35	14.8
E217513	CLT13	3	4.6	5.27	6.2	2	15.4	16.15	16.9
E217515	CLT14	4	4.5	6	8	2	14.6	15.8	17
NA	Crof01	1	7.8	7.8	7.8	--	--	--	--
NA	Ward01	3	4.5	5.33	5.9	--	--	--	--

1Maximum values exceeding the Cowichan and Koksilah River WQO for temperature of <17°C are shaded grey.

4.4 Total Suspended Solids (TSS)

Total suspended solids (TSS, also referred to as non-filterable residue or NFR) include all the undissolved particulate matter in a water sample. The WQO for Cowichan Lake tributaries is that TSS should not exceed 26.0 mg/L at any time and the mean of five weekly samples in 30 days should not exceed 6.0 mg/L (Epps and Phippen, 2011). For the dates where data were available (5-in-30s during fall flush 2013), TSS ranged from below detectable limits (1 mg/L) to 1.9 mg/L (Table 7). There were no WQO exceedances.

Table 7: Summary statistics for TSS (mg/L) for water samples collected at Cowichan Lake tributary sites during the fall (Oct-Apr) (2013 sampling).

		Fall			Summer		
EMS Number	**Station**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
Cowichan Lake Tributaries							
E294549	CLT01	<1	1	<1	--	--	--
E294558	CLT02	<1	1.04	1.2	--	--	--
E294555	CLT03	<1	1.14	1.7	--	--	--
E294552	CLT04	<1	1.12	1.6	--	--	--
E217511	CLT05	<1	1	<1	--	--	--
E294554	CLT06	<1	1.41	1.8	--	--	--
E294553	CLT07	<1	1.06	1.3	--	--	--
E217512	CLT08	<1	1.12	1.6	--	--	--
E217510	CLT09	<1	1	<1	--	--	--
E217514	CLT10	<1	1.12	1.6	--	--	--
E294557	CLT11	<1	1.3	1.9	--	--	--
E217516	CLT12	<1	1	<1	--	--	--
E217513	CLT13	<1	1	<1	--	--	--
E217515	CLT14	<1	1.02	1.1	--	--	--
NA	Crof01	<1*	1*	<1*	--	--	--
NA	Ward01	<1	1	<1	--	--	--

**Based on 2 weekly samples in 30 days.*

4.5 Turbidity

4.5.1 Cowichan Lake Deep Basin Sites

Turbidity is a measurement of suspended particulate matter in water (e.g. silt, clay, organic material, micro-organisms), and high levels of turbidity increases the risk of bacterial growth on the suspended particulates, along with interfering with the disinfection of drinking water. The WQO for the three deep lake monitoring locations states that the maximum turbidity should not exceed 2 NTU (Epps and Phippen, 2011). Turbidity results from May 15th, August 8th, November 21st, 2013 and February 12th, 2014 at the deep basin sites were consistently very low (<0.5 NTU) and there were no WQO exceedances.

4.5.2 Tributaries to Cowichan Lake

The WQO for the tributaries to Cowichan Lake states that turbidity should not exceed 5 NTU at any time and the mean of five weekly samples in 30 days in should not exceed 2 NTU (Obee and Epps, 2011). Turbidity in the tributaries to Cowichan Lake was generally low (Table 8). The objectives were exceeded at only two locations: CLT03 - both the mean (2 NTU) and maximum (5 NTU) objectives were exceeded in the summer of 2013 and the fall of 2014; CLT06 - the mean (2 NTU) objective was marginally exceeded in the fall of 2013 (2.2 NTU) and both the mean (2 NTU) and maximum (5 NTU) objectives were exceeded in the summer of 2013. The elevated turbidity values during the summer could reflect sediment being stirred up while samples were collected in low flowing or still waters, and/or the presence of algal growth in the water which can affect water clarity.

Table 8: Summary statistics for turbidity (NTU) for water samples collected at Cowichan Lake tributary sites during the fall (Oct-Apr) and summer (May-Sept) seasons (2013 and 2014 sampling), showing exceedances of the Cowichan Lake Water Quality Objectives (WQO). Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

		Fall			Summer		
EMS Number	**Station**	**Minimum**	**Mean[1]**	**Maximum[2]**	**Minimum**	**Mean[1]**	**Maximum[2]**
Cowichan Lake Tributaries							
2013 sampling							
E294549	CLT01	<0.1	0.566	2.31	<0.1	0.252	0.49
E294558	CLT02	0.3	0.598	1.05	0.16	0.196	0.24
E294555	CLT03	1.18	1.501	1.995	3.04	4.485	6.86
E294552	CLT04	0.15	0.236	0.41	<0.1	0.11	0.15
E217511	CLT05	<0.1	0.118	0.17	<0.1	0.108	0.12
E294554	CLT06	0.49	2.167	4.935	0.44	2.944	9.53
E294553	CLT07	0.1	0.224	0.55	<0.1	0.132	0.16
E217512	CLT08	0.11	0.162	0.29	<0.1	0.124	0.17
E217510	CLT09	<0.1	0.141	0.255	<0.1*	0.1125*	0.13*
E217514	CLT10	0.12	0.971	2.2	<0.1	0.229	0.56
E294557	CLT11	0.27	1.227	4.36	0.33	0.489	0.76
E217516	CLT12	<0.1	0.144	0.18	0.245	0.691	0.9
E217513	CLT13	<0.1	0.156	0.24	<0.1	0.122	0.16
E217515	CLT14	0.11	0.622	2.24	<0.1	0.142	0.24
NA	Crof01	<0.1**	0.13**	0.16**	--	--	--
NA	Ward01	<0.1	0.31	1.04	--	--	--
2014 sampling							
E294558	CLT02	0.47	1.114	2.1	--	--	--
E294555	CLT03	0.7	2.229	5.37	--	--	--
E217510	CLT09	0.11*	1.068*	2.91*	--	--	--
E294557	CLT11	0.32	0.963	1.48	--	--	--

**Based on 4 weekly samples in 30 days.*
***Based on 2 weekly samples in 30 days.*
[1]Light grey highlighted mean values exceed the Cowichan Lake WQO for turbidity of < 2 NTU.
[2]Dark grey highlighted maximum values exceed the Cowichan Lake WQO for turbidity of < 5 NTU.

4.6 Secchi Depth Summary

Another common measure of water clarity in lakes is Secchi depth, which is assessed by lowering a standard 20 cm black and white Secchi disc into the water column until it is no longer visible. As water clarity is primarily affected by colour, suspended solids, and algal growth, Secchi disc readings provide a simple, inexpensive means of indicating changes in water quality (Epps and Phippen, 2011). Furthermore, it can be compared to historical data which has been collected for decades.

The WQO for clarity measured by secchi depth are ≥ 6.0 m minimum, ≥ 8.0 m average (Epps and Phippen, 2011), and were met according to the summaries for the North and South Arms of the lake, as referenced in a report summarizing local stewardship group data produced by the BC Lakes Stewardship Society (BCLSS, 2014) (Figures 7 and 8).

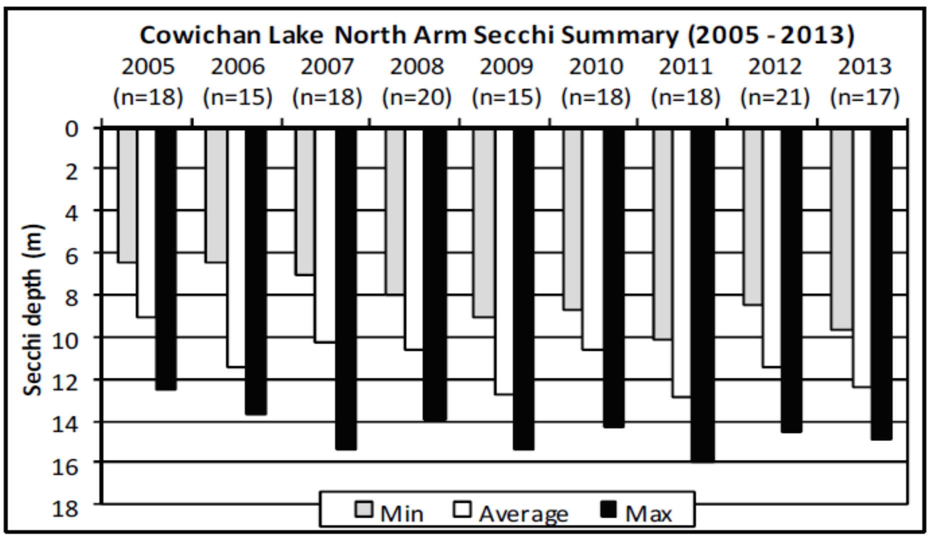

Figure 7: Cowichan Lake North Arm Secchi Summary (BCLSS, 2014)

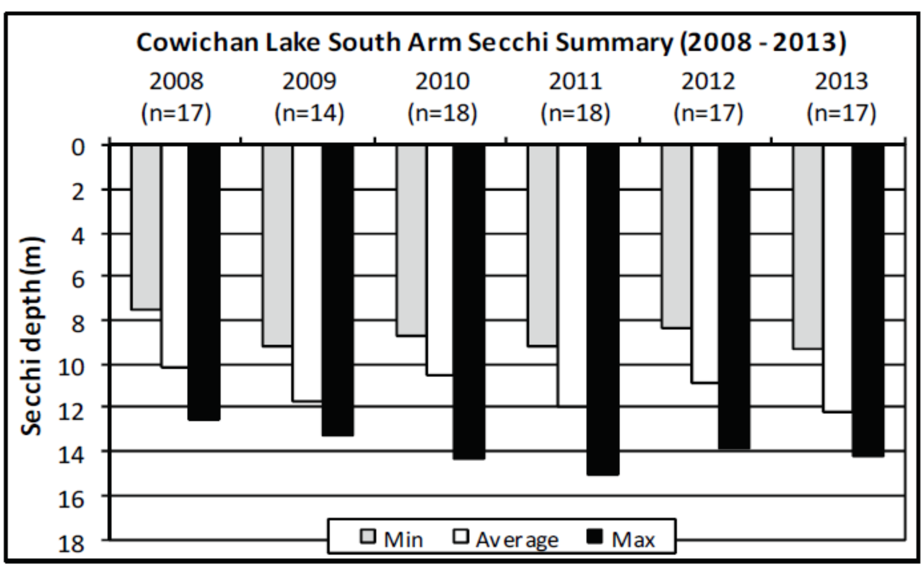

Figure 8: Cowichan Lake South Arm Secchi Summary (BCLSS, 2014)

4.7 Total Organic Carbon

Elevated TOC levels can result in higher levels of disinfection by-products in finished drinking water if chlorination is used to disinfect the water (Moore and Caux, 1997; Moore, 1998). As the Town of Lake Cowichan and the CVRD use chlorine to disinfect their drinking water, TOC concentrations in Cowichan Lake are of interest. The WQO for Cowichan Lake is that the maximum concentration of TOC in any sample collected at any of the three deep water stations should not exceed 4 mg/L (Epps and Phippen, 2011).

TOC results from May 15th, August 8th, November 21st, 2013 and February 12th, 2014, at the three water column depths sampled at the deep basin sites, were consistently very low (generally <2 mg/L) and there were no exceedances of the Cowichan Lake WQO (Figure 9).

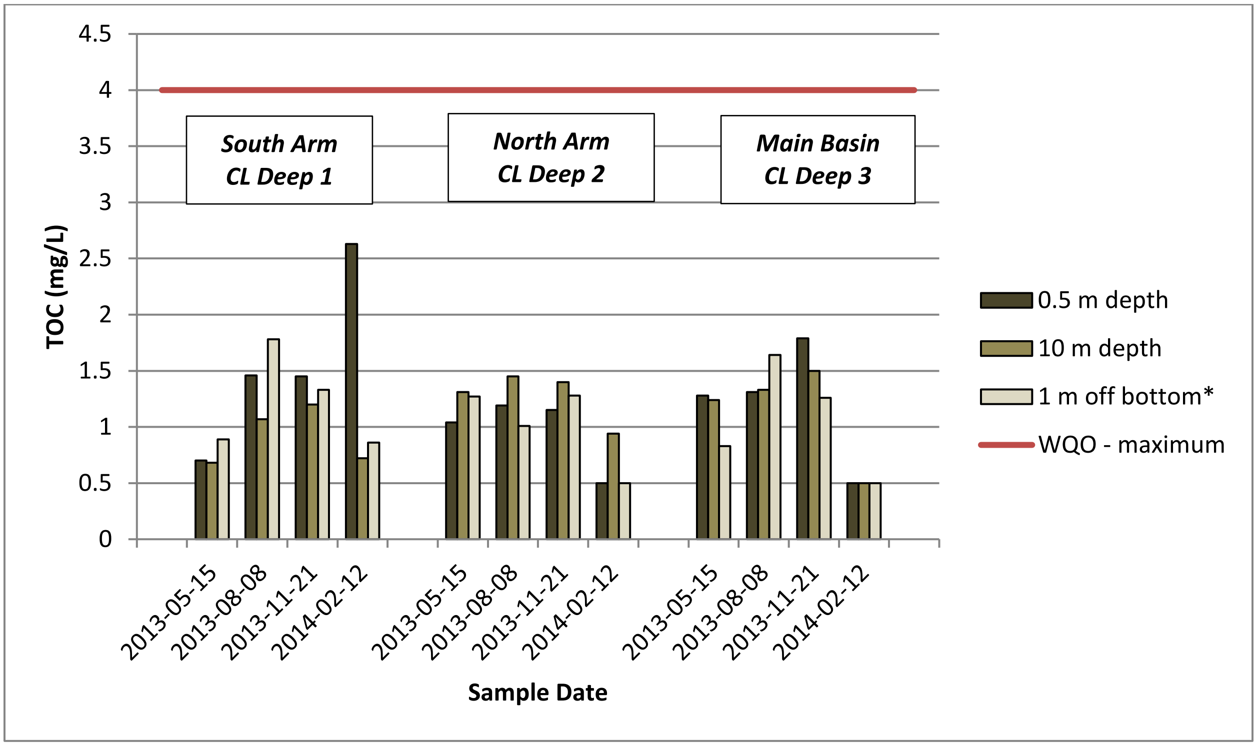

*Figure 9: Summary of results for TOC (mg/L) for water samples collected at the Cowichan Lake deep basin sites (2013-2014), compared to the Cowichan Lake WQO (< 4 mg/L maximum).*Note that bottom sample depth ranged from 68-100m.*

4.8 Nutrients

4.8.1 Total Phosphorus

Phosphorus is a limiting nutrient that is used by phytoplankton (floating algae) and is the biological limiting nutrient in most freshwater systems. Increased phosphorus leads to increased algal production, reduced water clarity, increased taste and odour concerns for drinking water purveyors, and undesirable conditions (e.g. reduced oxygen) for some fish species. Phosphorus levels in lakes increase due to inputs of sewage, sediments eroded from soils in the watershed, seepage from septic tanks, fertilizers from agricultural activities and internal loading (Wetzel, 2001).

A WQO was not established for total phosphorus in Cowichan Lake as the concentrations found in previous monitoring were low (Epps and Phippen, 2011). However, phosphorus was monitored May 15th, August 8th, November 21st, 2013 and February 12th, 2014 at the three depths at the deep station sites; results are compared to the BC Water Quality Guideline for phosphorus in lakes to protect drinking water (<10 µg/L) from algal blooms and foul-tasting water. No nutrient data were collected in the Cowichan Lake tributaries.

Total phosphorus concentrations were generally low in the samples obtained in the spring (May) and winter (November and February), except for May 2013 samples taken 1 m from the bottom at the north arm and main basin sites (Figure 10), and a 10m depth sample from the main basin site taken in November 2013, that were greater than the guideline for drinking water (< 10 mg/L). Elevated total phosphorus concentrations (ranging from 12.5 to 20.6 µg/L) were observed during the summer (August) in all deep basin sites and at all depths; these exceeded the drinking water guideline of <10 mg/L. These results were contrary to what is expected as generally spring turnover is when the highest concentrations of phosphorus are found. Later in the season, phosphorus is usually bound in micro-organisms such as phytoplankton, and is therefore found in lower quantities in solution (Epps and Phippen, 2011). It is unclear what may have caused the unusually high phosphorous levels observed in August 2013 relative to ENV available historical data (Epps and Phippen, 2011), though chlorophyll α levels may partially explain these observations (see Section 4.8.2). Total phosphorus patterns in Cowichan Lake should be further investigated. In addition, monitoring total phosphorus in tributary streams should be considered to better understand phosphorus inputs into the lake.

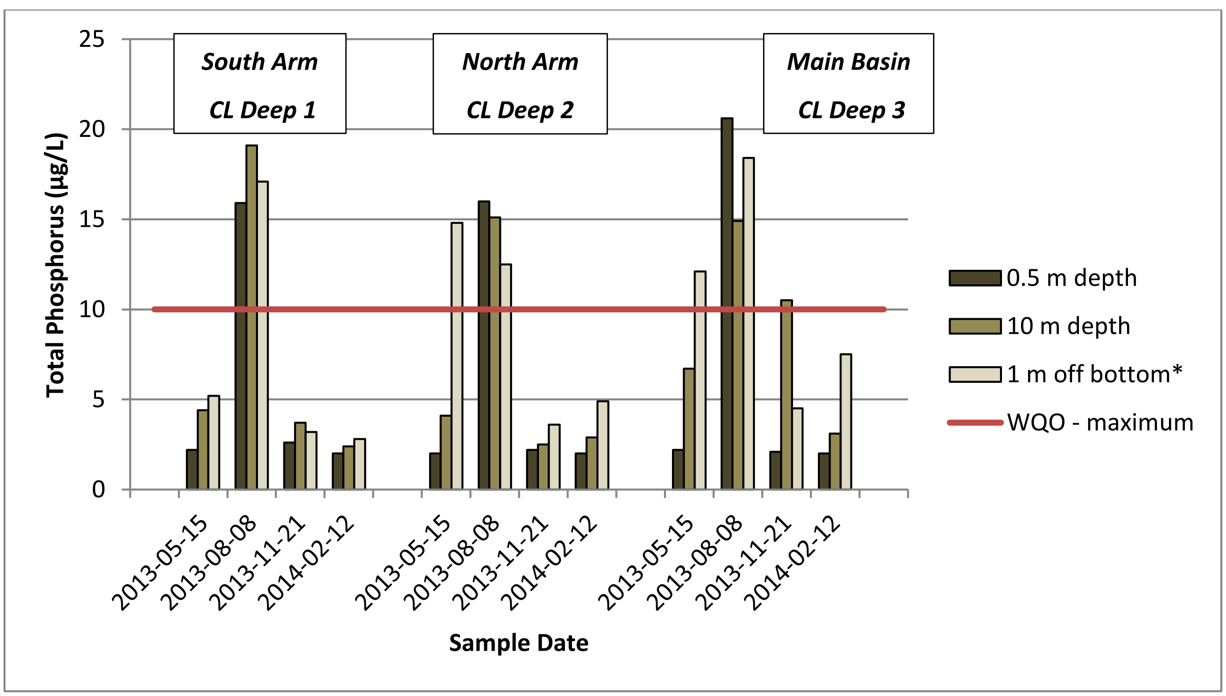

*Figure 10: Summary of results for total phosphorus (µg/L) for water samples collected at the Cowichan Lake deep basin sites (2013-2014), compared to the BC MOE Water Quality Guidelines to protect drinking water (< 10 µg/L).*Note that bottom sampling depth ranged from 68-100m.*

4.8.2 Chlorophyll a

Chlorophyll α is the primary photosynthetic pigment of algae, cyanobacteria, and other photosynthetic organisms (Wetzel, 2001). Measuring chlorophyll α is a standard approach used to quantify phytoplankton in lakes and is used as a surrogate of phytoplankton biomass. There is generally a strong positive relationship between phosphorus and chlorophyll α, and often an inverse relationship with water clarity (Nordin, 2001).

The WQO for Cowichan Lake is a maximum of 2.0 µg/L chlorophyll α at any of the deep water monitoring stations (Epps and Phippen, 2011). Surface samples (0.5 m) collected May 15th, August 8th, November 21st, 2013 and February 12th, 2014 showed two exceedances of the WQO for chlorophyll α, both occurring during the November 21st, 2013 sampling, at the south arm and north arm deep basin sites (Figure 11). Notably, chlorophyll α levels in August of 2013 were lower than the other sample periods, supporting that total phosphorus would not have been as bound in phytoplankton as on the other sample dates, thus partially explaining higher total phosphorus observed in samples collected in August of 2013 (see Section 4.8.1).

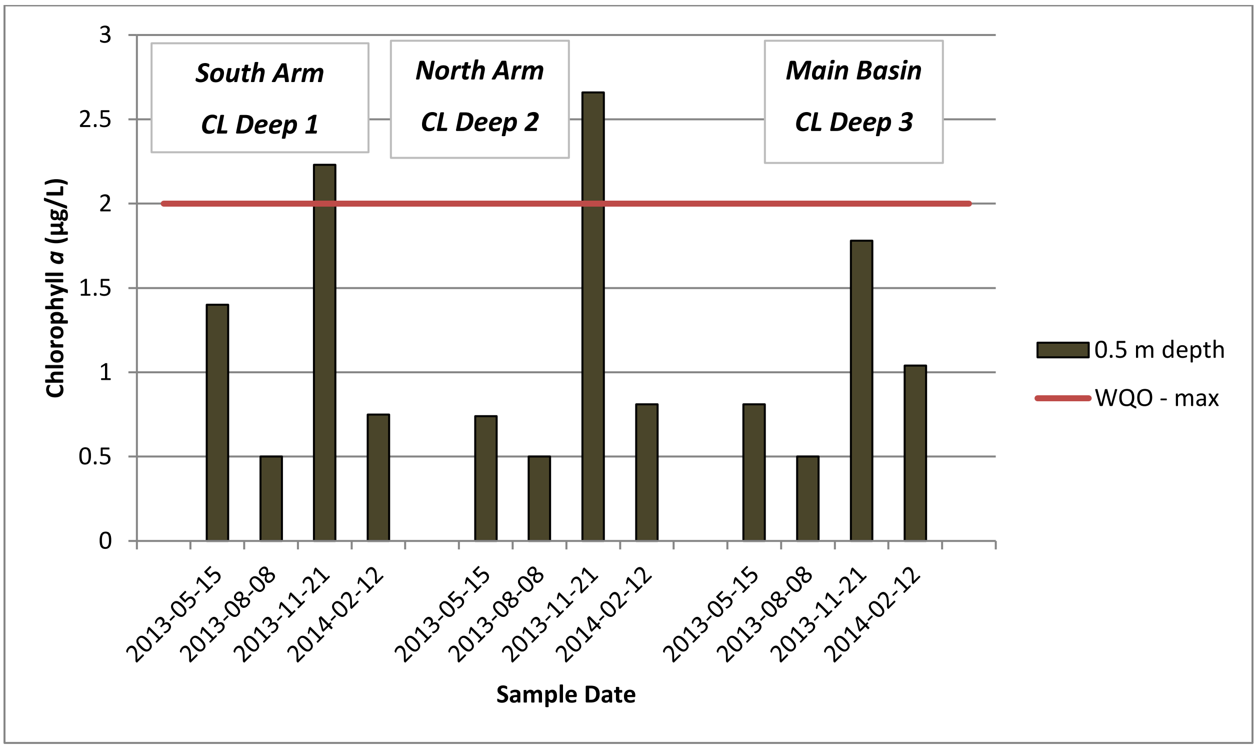

Figure 11: Summary of results for chlorophyll a (µg/L) for water samples collected at the Cowichan Lake deep basin sites (2013-2014), compared to the Cowichan Lake WQO (< 2 µg/L).

4.9 Metals

Total metals were analyzed in samples collected on a single date (October 28th, 2014) at 3 sampling stations in the Cowichan Lake tributaries (Beadnel Creek, Beaver Creek, and Oliver Creek). In addition, dissolved and total metals were analyzed in grab samples collected on a single date (February 12th,

2014) at three depths in the water column (0.5 m, 10 m and 1 m from the bottom) at the three deep basin sites.

Maximum results for 24 total and dissolved metals were compared to the ENV approved water quality guidelines or working water quality guidelines (BC MOE, 2015a and b), as a screening measure. None of the metals measured at Cowichan Lake sampling sites exceeded the screening guidelines. Based on the above data, metals are not currently of concern in Cowichan Lake.

4.10 Plankton

4.10.1 Phytoplankton

A total of 76 species were identified in the August 2013 and February 2014 data. In February, all three sites had 35 or 36 different species, but in August the south arm had slightly more species present (48 species vs. 35 and 36 at the other two sites). Fewer species and one quarter to one third of the total cells/mL were found in August 2013-14 data compared to August 2008-09 data (Epps and Phippen, 2011), which supports that less phosphorus was bound in plankton (as discussed in Section 4.8.1). Consistent with 2008-09 data, the phytoplankton community in Cowichan Lake was dominated by diatoms from the Order Centrales in August, with *Cyclotella glomerata* comprising the majority of the plankton community at the three sites; in February pennate diatoms of the Order Pennales were dominant at all three monitoring sites with *Fragilaria crotonensis* comprising the majority of the plankton community and *Cyclotella glomerata* the next dominant species (Table 9).

Table 9. Summary of dominant (i.e. >10% of sample) phytoplankton species for Cowichan Lake (number of cells/mL and % of total sample).

Site	**E217507 South Arm**				**E217508 North Arm**				**E217509 Main Basin**			
Date	**08-Aug-13**		**12-Feb-14**		**08-Aug-13**		**12-Feb-14**		**08-Aug-13**		**12-Feb-14**	
Order: Centrales												
Cyclotella cf. glomerata	14.0	36%			14.0	25%			18.2	37%		
Cyclotella glomerata			82.6	37%			91.0	32%			64.4	25%
-												
Order: Chlorococcales												
Oocystis cf. lacustris	8.4	21%										
-												
Order: Cryptomonadales												
Chroomonas acuta							36.4	13%			29.4	12%
-												
Order: Dinokontae												
Peridinium cf. inconspicuum	9.8	25%			16.8	30%			11.2	23%		
-												
Order: Pennales												
Fragilaria crotonensis			102.2	46%			133.0	47%	5.6	11%	145.6	57%

4.10.2 Zooplankton

A total of 16 zooplankton species were identified in the August 2013 and February 2014 data for Cowichan Lake. Overall zooplankton species richness was similar at all three sites with 11 or 12 different species observed at each. However, the density of zooplankton tended to be slightly higher in the north arm than at the other sites, at 18448 cells/mL (August) and 5376 cell/mL (February), compared with 14058 cells/mL (August) and 2589 cell/mL (February) in the south arm and 1414 cells/mL (August) and 3323 cells/mL (February) in the main basin. August 2013 densities were slightly lower than August 2008 (Epps and Phippen, 2011) densities in the south arm (14058 vs. 16219 cells/mL), slightly higher in the north arm (18 448 vs. 17 978 cells/mL) and much lower in the main basin (1414 vs. 13637 cells/mL). This is likely associated with the lower phytoplankton densities described above.

Consistent with 2008-2009 phytoplankton results (Epps and Phippen, 2011) the zooplankton community of Cowichan Lake was composed predominately of rotifers in August, with Copepod nauplii predominant in February, though rotifers were present in more than 10% of sample in February as well. At all three sites, the zooplankton community was dominated by two rotifer genera: *Keratella cochlearis* and *Polyarthra*. *Keratella* and *Polyartha* species are known to be cold water rotifers and develop maximal population densities in midwinter to early spring (Wetzel, 2001).

Additional zooplankton species, such as cladocerans, calanoid copepods and cyclopoid copepods, were present in most of the samples collected at all three basins however they were deemed non-dominants, as they comprised of less than 10% of the total sample size. Overall, the zooplankton species, similar to the phytopkankton species, are indicative to oligotrophic lake conditions and consistent with 2008 and 2009 sample results (Epps and Phippen, 2011).

Table 10. Summary of dominant (i.e. >10% of sample) zooplankton species for Cowichan Lake (number of cells/mL and % of total sample).

Site:		E217507				E217508				E217509			
Sample date:		08-Aug-13		12-Feb-14		08-Aug-13		12-Feb-14		08-Aug-13		12-Feb-14	
Sub-class: Copepoda													
Order: Cyclopoida													
Order: Calanoida													
UID Calanoida / Cyclopoida	nauplii	1,485	11%	1,273	49%			2,380	44%	465	33%	1,538	46%
Phylum: Rotifera													
Kellicottia longispina								644	12%				
Keratella cochlearis		9,735	69%	532	21%	11,780	64%	1,148	21%	667	47%	769	23%
Polyarthra sp.		1,485	11%			2,635	14%					369	11%

5. CONCLUSIONS AND RECOMMENDATIONS

Generally, the water quality of Cowichan Lake is very good, though tributaries to the lake show evidence of introducing microbiological contaminants to the lake. These sources should be further investigated, evaluating more parameters at sites shown to have higher turbidity or *E.coli*, to best provide data and education opportunities to landowners for reducing inputs into Cowichan Lake.

Given that the attainment monitoring for several parameters showed exceedances of the Cowichan Lake WQOs, it is recommended that regular attainment monitoring continue as outlined in Epps and Phippen (2011), ensuring that data is collected for all recommended parameters, with the following suggested additions.

E. coli has been shown to be elevated in the tributaries to Cowichan Lake and is a significant concern. Levels were lower in the lake suggesting that, once the tributaries enter the lake, dilution occurs to keep *E. coli* below the drinking water WQO. Monitoring for *E. coli* should continue for all water courses, and additional sites and microbial source tracking should be added to assist with characterizing the contamination sources and assess effectiveness of mitigative actions. It is also recommended that a specific WQO is set for *E. coli* for Cowichan Lake tributaries.

Dissolved oxygen concentrations in the tributaries to Cowichan Lake were found to be low during the summer months, as compared to the Cowichan and Koksilah River WQOs. Therefore, it is recommended that monitoring of DO in the tributaries to Cowichan Lake should be continued and a WQO set for dissolved oxygen in the tributaries.

The 2013 profiles for dissolved oxygen and temperature in Cowichan Lake show that deeper waters remain cool and oxygenated below the typical summer thermocline, providing a refuge for fish in summer when surface water temperatures can be elevated. Based on the data collected showing temperatures at all three sites to be higher than 15°C WQO until around 18 and 19 m depth, the existing WQO that water temperatures should not exceed 15°C at depths greater than 10 m in Cowichan Lake is likely to continue to be exceeded regularly in summer. Also, based on this, water intakes should be deeper than the 10m suggested in the current WQO. Keeping the objective at this value can be used to protect the existing water quality of the lake but an amendment to the WQO (i.e. to not exceed 15°C at depths greater than 20 m) could be considered to better reflect typical summer stratification patterns while still not being of concern to fish.

Limited temperature measurements in the tributaries to Cowichan Lake were found to be occasionally high during the summer months relative to Cowichan and Koksilah River WQOs. It is recommended that temperature monitoring Cowichan Lake tributaries continue at frequency to allow direct comparison to WQOs. Consideration should be given to establishing a WQO for water temperature specific to the Cowichan Lake tributaries.

As turbidity and TSS measurements are closely related, both provide a measure of suspended solids in the water column, and turbidity results show the same general pattern as for TSS (and have shown to be statistically correlated, with a Pearson correlation coefficient of 0.68 based on 2013 data; Smorong, 2014), TSS monitoring could be removed from the monitoring program if resources limit parameters that can be monitored. Similarly, while attainment monitoring for turbidity should continue, exceedances of the objectives have only been seen in fall sampling; thus, summer sampling could be reduced, or restricted to only certain sites.

Total phosphorus results were elevated relative to previous monitoring and at times in exceedance of the BC Water Quality Guideline for total phosphorus for the protection of drinking water. More thorough characterization of total phosphorus levels during future attainment monitoring would be beneficial. Monitoring total phosphorus in tributary streams should be considered to better understand phosphorus inputs into the lake.

Chlorophyll α levels obtained during attainment monitoring showed exceedances of the objective, highlighting the need for continued monitoring of nutrients and chlorophyll α. Future monitoring efforts need to include analyses for nitrogen species as outlined in Epps and Phippen (2011), specifically, nitrate (as N) and nitrite (as N), to better characterize nutrient levels in the lake. In addition, a nutrient budget study should be conducted to help understand nutrient status and cycling.

Finally, as metal concentrations measured in samples collected from the tributaries to the lake were low and did not exceed the ENV approved or working water quality guidelines, it is recommended that metals in Cowichan Lake are analyzed infrequently and metals analysis focus on tributary streams where turbidity is shown to be higher relative to Cowichan Lake.

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