DRAFT LOWER COWICHAN AND KOKSILAH RIVER BASIN

WATER QUALITY ATTAINMENT STUDY 2022

INCLUDING COWICHAN BAY MARINE SITES

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[Cowichan Tribes Logo]	[Cowichan Watershed Logo]	[Province of BC Logo]	[Shawnigan Basin Society Logo]

FINAL DRAFT REPORT (V10)

September 2023

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Field sampling was completed collaboratively by Cowichan Watershed Board (freshwater sites) and Cowichan Tribes (marine sites).

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Cover Photo: Volunteer Water Quality Samplers in the Cowichan Estuary.
Photo Credit: Jill Thompson, Cowichan Watershed Board

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Executive Summary

Three areas were sampled in the summer (August/September) and fall (October/November) of 2022 for an assessment of water quality. These were seven sites in the lower Koksilah River and its tributaries, nine sites in the tributaries that run directly into Cowichan Bay and nine marine sites in Cowichan Bay. The year 2022 was unusual in that there was less than normal rain in the summer and very much lower than normal rainfall in the fall.

None of the freshwater samples met the water quality objectives for *E. coli*. The source of the *E. coli* was not determined. Only two of the Cowichan Bay marine sites met the fecal coliform objectives for shellfish harvesting and enterococci levels for recreational and cultural use throughout the sampling period: these were CBM1 (Cowichan Bay above Lambourn Holdings) and CBM2 (Cowichan Bay shoreline at PE1538 outfall).

Most freshwater sites met the water quality objectives for water temperature with the exceptions of the two Koksilah River sites sampled in the summer: Koksilah River at Koksilah Road and Koksilah River at Bright Angel Park. A number of Koksilah River Basin sites did not meet the water quality temperature objectives in the fall. Although there are no water quality objective for temperature for the Cowichan Bay Tributaries, they did meet the Cowichan/Koksilah water quality objectives for temperature.

A number of Koksilah River Basin sites did not meet the water quality dissolved oxygen objectives in the summer. All of these sites were characterized by shallow, unshaded slow flowing or no flowing water. On a number of occasions, several of the Koksilah River Basin sites did not meet the fall water quality objectives for dissolved oxygen. This was likely due to the high temperatures till the end of October and low rainfall. Most of the Cowichan Bay tributaries met the summer and fall provisional objectives for dissolved oxygen.

Only two of the Koksilah River Basin sites did not meet the water quality objectives for turbidity: these were Petrolas Creek at Moss Road and Norrie Creek at the Koksilah Road. Only one of the Cowichan Bay tributaries met the provisional objectives for turbidity.

All Koksilah River Basin sites and all Cowichan Bay Tributary sites failed to meet the water quality objectives for total phosphorus. The source of this phosphorus is unclear, but the phosphorus can come from agricultural runoff and subsurface flow as well as decomposition of detritus such as leaf litter from the riparian vegetation that falls into the water.

The Koksilah River Basin sites all met the water quality objectives for total copper, total lead and total zinc. Most of the Cowichan Bay tributaries did not meet the provisional objectives for total copper and total zinc: this may be due to high levels of these metals in groundwater.

The report ends with seven recommendations.

This Executive Summary is subject to the same standard limitations as contained in the report and must be read in conjunction with the entire report.

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LIST OF ACRONYMS

C	Celsius
CBM	Cowichan Bay Marine
CBT	Cowichan Bay Tributary
CFU	Colony Forming Unit
E. coli	*Escherichia coli*
EMS	Environmental Monitoring System
ENV	Ministry of Environment and Climate Change Strategy
INC	Incomplete Data
KRB	Koksilah River Basin
L	Litre
Mg	Milligram
µg	Microgram
mL	Milliliter
MPN	Most Probable Number
ND	No data
NTU	Nephelometric Unit
TCH	Trans-Canada Highway
TSS	Total Suspended Solids
WQAP	Water Quality Action Plan

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1.0. INTRODUCTION

The British Columbia Ministry of Environment and Climate Change Strategy (ENV) has developed water quality objectives that are unique to numerous lakes, rivers, and marine water bodies. This study provides water quality sampling that addresses attainment objectives for three water systems; the lower Koksilah River Basin (KRB), the various freshwater tributaries that drain into Cowichan Bay (CBT), and marine sites that are located in Cowichan Bay (CBM). The sampling undertaken in this study follows the 5 in 30 sampling approach. This means that each sample site will be sampled for selected water quality parameters on five occasions over a thirty-day period. This allows for statistical analysis of the sampling results. The sampling includes two periods; one sampling period during the summer under low flow conditions, and one sampling period in the fall targeting the first flush caused by rainfall event(s). This report provides figures that describe the actual rainfall that occurred during the sampling periods, to be used as part of the assessment of results.

Previous studies provide a list of water quality objectives that are tailored to the specific water body under investigation. For the locations noted above, there were prior sampling programs in 2012-2014 and 2017 that afford comparative values for the majority of sample sites.

Cowichan Watershed Board has administered this sampling program and seeks to improve water quality generally in these watersheds. This study will seek to identify where water quality objectives have not been met (i.e., results do not meet attainment objectives), with a view towards identifying possible causal relationships that might lead to programs that will improve water quality over time. As part of this process, recommendations may include further studies to clarify why some water quality objectives are not being met. This report does not include background information such as field notes, detailed analytical results, or replicate and duplicate sampling results used to control field and analytical processes. This information is available in the data records.

2.0. SITE DESCRIPTIONS

Due to a limited budget, 30 sites were selected from the whole program initiated a decade previously. These sites were selected based upon historical metals and *E. coli* (or fecal coliforms or enterococci) levels. To mitigate the risks of data errors at all stages of the data collection process (kit preparation, volunteer coordination, data collection, data transcription, quality control, shipping) these sites were given a vernacular ID **(CBT1, CBT2, CBT3, CBT4, etc.)** that generally followed a chronological sampling order and decreased the possibility of data collection errors.

2.1. Koksilah River Basin

The initial aim of the current study was to sample 9 sites in the lower Koksilah River Basin. These sites are labelled KRB1 to KRB9. The Environmental Monitoring System number, Site Location, Current Site Code and Latitude & Longitude of the sites are given in Table 2.1. Two of the listed sites were not sampled. KRB4 was not sampled since there was no water in the ditch during any of the sampling days. KRB8 was not sampled since one had to cross a working quarry to access the site and permission had not been obtained to access the site. The sites sampled are indicated in bold in **Table 1**. The Table also gives the Site Codes used in the two previous studies of the Koksilah River Basin.

There have been a number of water quality studies on the lower Koksilah River basin. Although the sites EMS numbers stayed the same, as noted above the site-specific codes changed with the studies. In the

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report by Obee, 2011, that covered water sampling in 2002, 2003 and 2008, only five sites within the lower Koksilah River Basin were sampled. These sites were labelled K1 to K5. How K1 to K5 relates to the KRB codes is indicated in **Table 1.** The Obee study sites are indicated in the italicized parentheses. Only Obee's K1 site was not sampled in the present study. A map of the site locations is given in **Figure 1**.

Preikshot's 2018 report on the water sampling results of the summer and fall of 2017 uses only site descriptors and not site codes. This study sampled all the sites the present study sampled plus the KRB8 site that was not sampled in the present study because of access issues.

Saso and Smorong, 2021, reported on the water quality studies during 2012, 2013 and 2014. The site codes used differed from that of Obee, 2011. They reported on samples from all the sites currently labelled as KRB1 to KRB9 as well as the Koksilah River at Burnt Bridge next to the Port Renfrew Road.

Table 1: Koksilah River Sampling Sites

EMS Number	Site Location	Site Code	Latitude; Longitude
0123981	Koksilah River @ TCH	**KRB1** *(K5)*[*KR09]†	48.7562; -123.6765
E230098	Patrolas Creek @ Moss Rd	**KRB2** [KR03]†	48.7245; -123.6593
E206976	Koksilah River @ Koksilah Rd	**KRB3** *(K2)** [KR04]†	48.7288; -123.6710
E291189	Ditch by Bright Angel Park	KRB4 [Ditch @ Bright Angel Park]†	48.7377; -123.6777
E295429	Koksilah River @ Bright Angel Park downstream of where ditch enters river	**KRB5** [BAP01]†	48.7368; -123.6788
E234128	Norrie Creek @ Koksilah Rd	**KRB6** [KR05]†	48.7312; -123.6851
E207427	Kelvin Creek @ Koksilah Road	**KRB7** *(K3)** [KR07]†	48.7488; -123.6953
E207433	Koksilah River downstream of Kelvin Creek and upstream of landfill	KRB8 *(K4)** [KR08]†	48.705; -123.6903
E230099	Glenora Creek @ Doupe Rd	**KRB9** [KR06]†	48.7460; -123.71568
E207425	Koksilah River @ Port Renfrew Road @ Burnt Bridge	*(K1)** [KR01]†	48.6425; -123.7383

**Sites codes used by Obee, 2011 †Sites codes used by Saso and Smorong, 2021 Bolded are the sites sampled in 2022*

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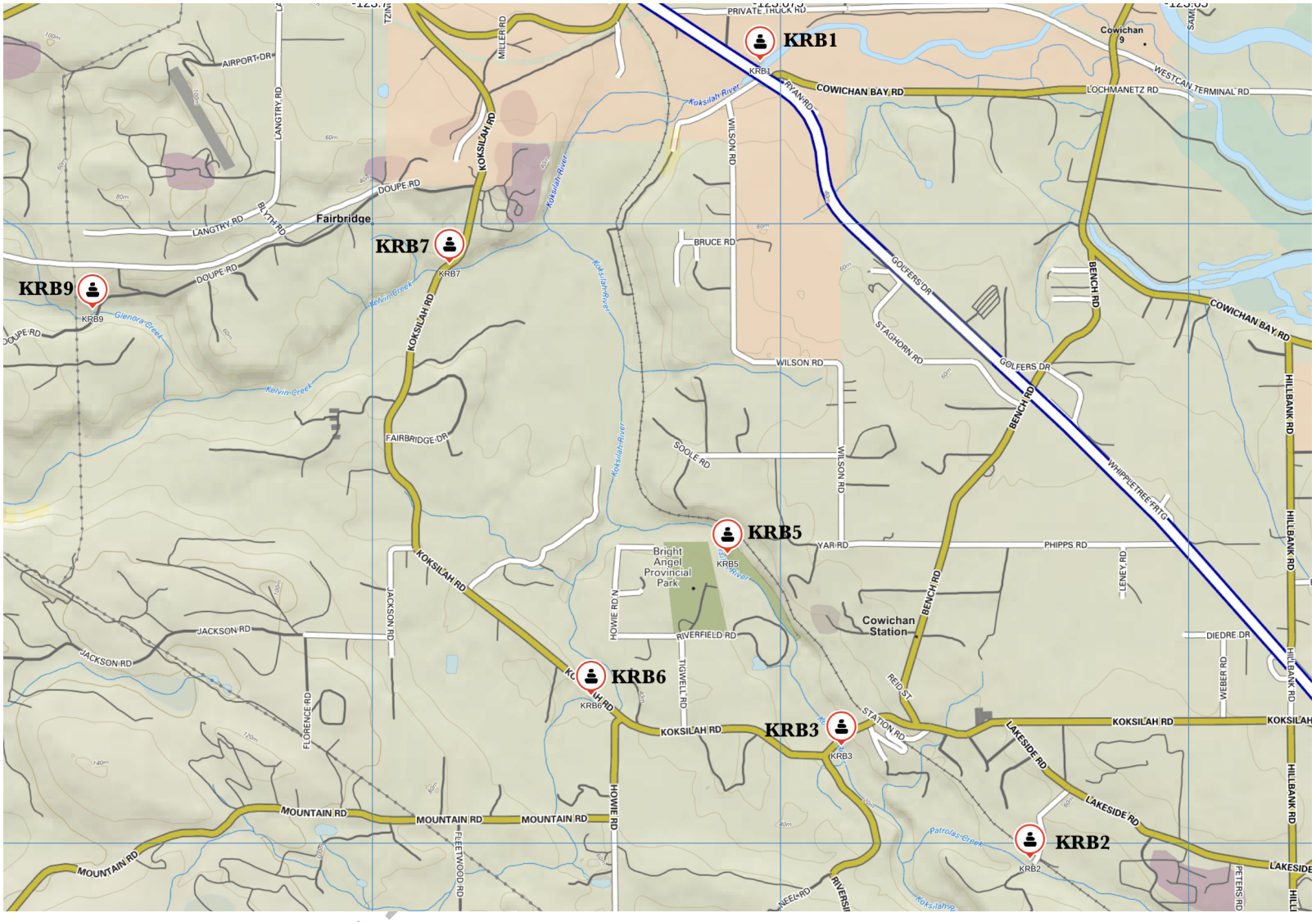

Figure 1. *Map indicating the locations of the Koksilah River Basin sampling sites. Map is based upon Gaia GPS Topo map that uses OpenStreetMap data.*

2.2. Cowichan Bay Tributaries

The Cowichan Bay Tributary (CBT) sites are listed in **Table 2**. A map of the sampling sites is given in **Figure 2.** CBT site codes in bold were sampled in 2022. Note that there was no water flowing in the summer and the fall at the CBT4 and CBT6 sites and there was no water course found at CBT7, nor is this site present in the report by Smorong *et al.* 2021. This Table also lists the site codes used in the Smorong *et al.*, 2021 report. As with the Koksilah codes used 2022, the Cowichan Bay Tributary sites were given codes in the order the samples were taken to reduce the chance of confusion.

Table 2. Cowichan Tributaries Sampling Sites

EMS Number	Site Location	Site Code	Latitude; Longitude
E291163	Treffery Creek @ Cowichan Bay Rd	**CBT1** *(CB13)**	48.7500; -123.6574
E291160	Speirs Creek @ Cowichan Bay Rd	**CBT2** *(CB10)**	48.7469; -123.6491
E291158	Wessex Creek @ Wessex Inn	**CBT3** *(CB08)**	48.7428; -123.6275
E291155	Wessex Creek @ Wilmot Rd	CBT4 *(CB09)**	48.7340; -123.6306
E291155	Storm drain @ Botwood Lane	**CBT5** *(CB07)**	48.7405; -123.6146
E295430	Waldy Creek @ Cherry Point Rd	CBT6 *(CB14)**	48.7293; -123.6009
E291192	Sparwood Creek @ end of Sparwood Rd	CBT7	48.7360; -123.5936
E291152	Storm drain @ Cherry Point Marina	**CBT8** *(CB04)**	48.7356; -123.5915
E291150	Garnett Creek @ Cherry Point Beach	**CBT9** *(CB02)**	48.7103; -123.5564
E291151	Garnett Creek @ Telegraph Rd	**CBT10** *(CB03)**	48.7108; -123.5774
E291149	Manly Creek at end of Hatch Point Rd	**CBT11** *(CB01)**	48.6924; -123.5528
E291161	Speirs Creek @ Hillbank Rd	**CBT12** *(CB11)**	48.7368; -123.6437
E291162	Treffery Creek @ TCH	**CBT13** *(CB12)**	48.7436; -123.6590

**Sites codes used by Smorong, D., Phippen, B. and Barlak, R. 2021. Cowichan Bay and Tributaries: Water Quality Assessment and Recommended Objectives. Environmental Quality Series. Prov. B.C., Victoria B.C.*

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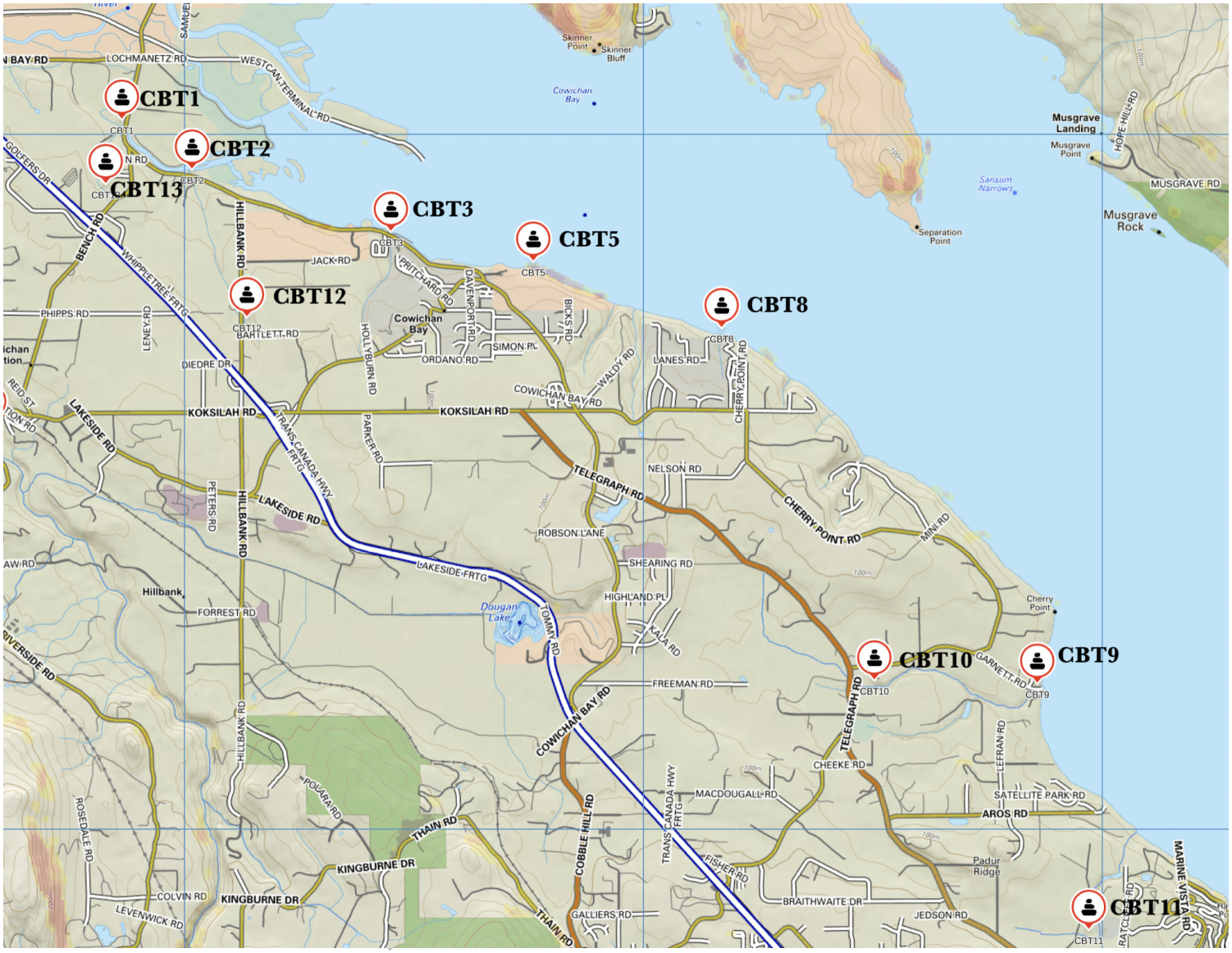

Figure 2. *Map illustrating the locations of the Cowichan Bay tributary sampling sites. Map is based upon Gaia GPS Topo map that uses OpenStreetMap data.*

2.3. Cowichan Bay Marine

The locations of the Cowichan Bay marine sampling sites are provided in **Table 3**. Nine sites were sampled. The site codes used for the 2022 sampling are given as well as the previous codes used by Smorong *et al.*, 2021. As indicated for the Koksilah River Basin and the Cowichan Bay Tributary sites, the codes used for the 2022 marine sampling generally were in the order in which the sites were sampled. A map of the sites sampled is given in **Figure 3**.

Table 3. Cowichan Bay Marine Sampling Sites

EMS Number	Site Location	Site Code	Latitude; Longitude
E291128	Cowichan Bay above Lambourn Holdings	**CBM1** *(10P3)**	48.7391; -123.5852
0150360	Cowichan Bay shoreline at PE1538 outfall	**CBM2** *(1P3)**	48.7437; -123.6227
E291134	Genoa Bay head	**CBM3** *(CB001)**	48.7684; -123.5979
E291124	Cowichan Bay out from Botwood Lane storm drain	**CBM4** *(CB039)**	48.741; -123.614
E291369	Genoa Bay, 150 m north of marina	**CBM5** *(CB057)**	48.7609; -123.5975
E294495	Cowichan Bay Marina Floating Home 1	**CBM6** *(CB062)**	48.7411; -123.6229
E294496	Cowichan Bay Marina Floating Home 2	**CBM7** *(CB063)**	48.7413; -123.6222
E294497	Cowichan Bay Marina Floating Home 3	**CBM8** *(CB064)**	48.7414; -123.6206
E294498	Cowichan Bay Marina Floating Home 4	**CBM9** *(CB065)**	48.7407; -123.6181

**Sites codes used by Smorong, D., Phippen, B. and Barlak, R. 2021. Cowichan Bay and Tributaries: Water Quality Assessment and Recommended Objectives. Environmental Quality Series. Prov. B.C., Victoria B.C.*

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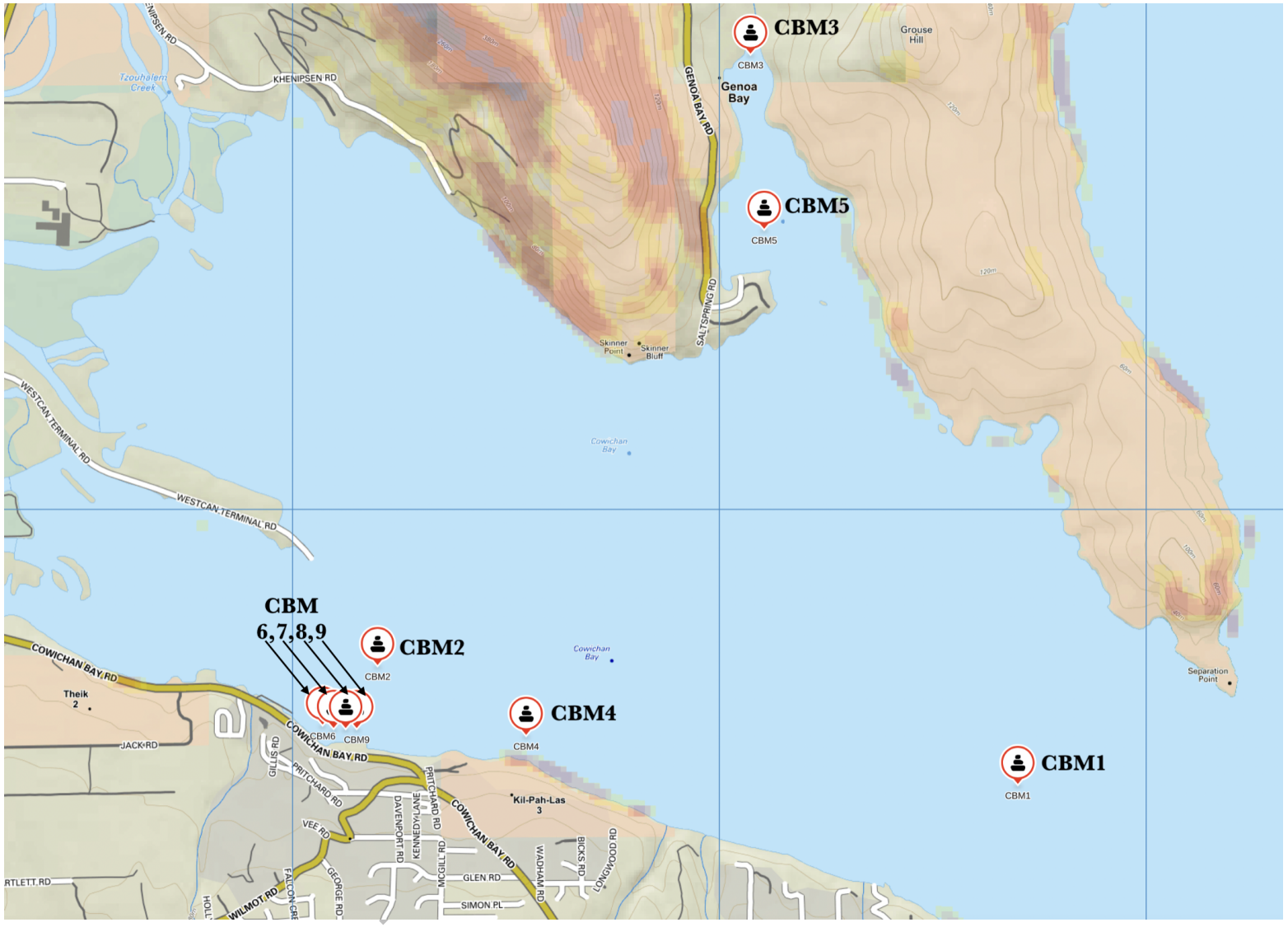

Figure 3. *Map illustrating the location of the Cowichan Bay marine sampling sites. Map is based upon Gaia GPS Topo map that uses OpenStreetMap data.*

3.0. WATER QUALITY OBJECTIVES

3.1. Koksilah River Basin

The original water quality objectives were established by McKean, 1989. These objectives were revised by Obee, 2011 and by Smorong and Saso, 2021. The current water quality objectives for the lower Koksilah River Basin are presented in **Table 4**.

Table 4. Koksilah River Basin Water Quality Objectives*

E. coli	≤10 CFUs/100 mL (90th percentile) based on 5 weekly measurements in 30 days
Dissolved Oxygen	June to September: ≥8 mg/L, mean of weekly measurements October to May: ≥11.2 mg/L, mean of weekly measurements
Temperature	17° C is maximum weekly mean temperature
Turbidity	May to September ≤2 NTU (maximum) October to April: ≤5 NTU (maximum)
Total Suspended Solids (TSS)†	≤27 mg/L (maximum for any sample – acute toxicity) ≤7 mg/L (mean of 5 samples collected over 30 days – chronic toxicity)
Ammonia-N	May to September: ≤0.49 mg/L (mean); ≤3.61 mg/L (maximum) October to April: ≤1.31 mg/L (mean); 6.83 mg/L (maximum)
Total Phosphorus	May to September: ≤5 µg/L (mean); ≤7 µg/L (maximum)
Total Copper	≤2 µg/L (mean); ≤4 µg/L (maximum)
Total Lead	≤4 µg/L (mean); ≤11 µg/L (maximum)
Total Zinc	≤7.5 µg/L (mean); ≤33 µg/L (maximum)

**Objectives are based upon Obee, 2011 and Smorong and Saso, 2021. †As funds for sampling were limited, a decision was made to sample only one of turbidity and TSS, as there is commonly a relationship between the two.*

3.2. Cowichan Bay Tributaries

The Cowichan Bay tributaries water quality objectives are provisional (**Table 5**) and described in the 2023 document by the Province of BC entitled "Water Quality Objectives for Cowichan Bay and Tributary Streams." The objectives for *E. coli,* turbidity, total copper, total lead, and total zinc are the same as for the Koksilah River Basin. The mean total phosphorus is identical to the Koksilah River Basin but the maximum is ≤10 µg/L rather than the ≤7 µg/L for the Koksilah River Basin. Dissolved oxygen objectives are also different in that the mean dissolved oxygen at any time of the year should be ³8 mg/L and never lower than 5 mg/L.

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Table 5. Cowichan Bay Tributaries Provisional Water Quality Objectives*

E. coli	≤10 CFUs/100 mL (90th percentile) based on 5 weekly measurements in 30 days
Dissolved Oxygen	≥8 mg/L mean of weekly measurements ≥5 mg/L (minimum concentration at any given time)
Turbidity	≤2 NTU (maximum May 1 to September 30) based on 5 weekly measurements in 30 days ≤5 NTU (maximum October 1 to April 30) based on 5 weekly measurements in 30 days
Total Suspended Solids†	≤27 mg/L (maximum for any sample) ≤7 mg/L (mean) based on 5 weekly measurements in 30 days
Total Phosphorus	≤5 µg/L mean from May through September with a maximum ≤10 µg/L at any one time based on 5 weekly measurements in 30 days No fall objectives
Total Copper	≤2 µg/L (mean); ≤4 µg/L (maximum) based on 5 weekly measurements in 30 days
Total Zinc	≤7.5 µg/L (mean); ≤33 µg/L (maximum) based on 5 weekly measurements in 30 days

**Provisional objectives given in: Province of British Columbia. 2023. Water Quality Objectives for Cowichan Bay and Tributary Streams. Water Quality Objective Series, WQO-07. Prov. B.C., Victoria B.C.*
†As funds for sampling were limited, a decision was made to sample only one of turbidity and TSS, as there is commonly a relationship between the two.

3.3. Cowichan Bay Marine

The Cowichan Bay marine water quality objectives are provisional (**Table 6**) and described in the 2023 document by the Province of BC entitled: Water Quality Objectives for Cowichan Bay and Tributary Streams.

Table 6. Cowichan Bay Marine Sites Water Quality Objectives and Guidelines†

Bivalve Shellfish Harvesting	**Objectives**
Fecal Coliforms	≤14 MPN* / 100 mL, median (or geometric mean) of 5 in 30 samples **Or** ≤43 MPN/100 mL of 5 in 30 samples (90th percentile)
Enterococci	≤4 MPN / 100 mL, median of 5 in 30 samples **Or** ≤11 MPN/100 mL of 5 in 30 samples (90th percentile)
Recreational & Cultural Activities	**Guidelines**
Enterococci	≤35 MPN / 100 mL, geometric mean of 5 in 30 samples OR ≤70 MPN/100 mL, single sample

*†Provisional objectives given in: Province of British Columbia. 2023. Water Quality Objectives Cowichan Bay and Tributary Streams. Water Quality Objective Series, WQO-07. Prov. B.C., Victoria B.C. and Smorong et al. 2021. *or CFU*

4.0. METHODS AND SCOPE OF WORK

4.1. Overview

Sampling was carried out in three areas: Koksilah River Basin, Cowichan Bay Tributaries and Cowichan Bay Marine.

As noted in Section 2.1, the Koksilah river was sampled at the Trans-Canada Highway, at Bright Angel Park and at Koksilah Road. The Koksilah River tributaries sampled were Patrolas Creek, Norrie Creek, Kelvin Creek and Glenora Creek.

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As noted in Section 2.2, the streams that entered Cowichan Bay that were sampled were Treffery Creek (2 sites), Speirs Creek (2 sites), Wessex Creek, Waldy Creek, Garnett Creek and Manley Creek. In addition, a storm drain at Botwood Lane and a storm drain at Cherry Point Marina were sampled.

As noted in Section 2.3, a total of nine marine sites were sampled: five locations in Cowichan Bay/Genoa Bay as well as four locations adjacent to floating homes in Cowichan Bay.

The sampling was done over the course of five weeks during August and September capturing the summer low flow for the river and tributaries and over the course of five weeks during the fall rainy season from the end of October through November. One aim of the fall sampling was to get samples during the fall's first fall flush. During the same period the Cowichan Bay marine sites were sampled. The year 2022 was unusual in that rainfall was well below normal and the normal distinct fall flush was not seen. The sampling dates in 2022 were identical for all the sites except one day for the Cowichan Bay Marine sites, which was sampled on September 20th rather than the 19th when the other sites were sampled (**Table 7**).

Table 7. Sampling Dates in 2022

Koksilah River Basin & Cowichan Bay Tributaries Sampling Dates	Cowichan Bay Marine Sampling Dates
August 22	August 22
August 29	August 29
September 5	September 5
September 12	September 12
September 19	September 20
October 31	October 31
November 7	November 7
November 14	November 14
November 21	November 21
November 28	November 28

Volunteers were trained by ENV staff to sample following provincial standards as per the BC Field Sampling Manual on Friday, July 29, 2022, at Bright Angel Park on the Koksilah River. A handout was also given out on proper sampling procedures (**Appendix 1**)

On August 15 and August 18, 2022, Ms. Elodie Roger and volunteers drove to all the Koksilah River Basin as well as the Cowichan Bay Tributary sites respectively, to become familiar with these sampling sites. Ms Elodie also met with Mr. Tim Kulchyski (RPBio) and other Cowichan Tribes volunteers on July 29th, 2022 to view and become familiar with the Cowichan Bay marine sites. The goals of this review were to receive feedback from a biological and cultural perspectives on the marine sites' selection, and to train the crew on site access and sampling procedures. The sites selected for summer and fall sampling reflected the Cowichan Tribes' inputs.

Prior to sampling, volunteers were instructed on special safety considerations and given a paper version of the Ministry of Environment and Climate Change 'Surface Water Quality Stewardship Toolbox Field Safety guideline – see **Appendix 2**. No adverse weather conditions and associated safety concerns were encountered during the entire sampling period which cannot be taken for granted, especially during fall sampling. Also, no high water-levels/flows were encountered by the field crew volunteers. A list of volunteers is provided in **Appendix 3**.

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4.2. Parameters Sampled at The Specific Areas

4.2.1. Koksilah River Basin

In addition to measuring temperature, dissolved oxygen and specific conductivity the Koksilah River Basin, summer samples were collected for: *E. coli*, turbidity, and total phosphorus. At one site (KRB3: Koksilah River at the Koksilah Road) summer samples were collected for total metals and dissolved organic carbon. As noted above, samples were collected in the fall for analyses for *E. coli*, turbidity, total ammonia nitrogen, total nitrate-nitrogen, total phosphorus as well as total and dissolved metals.

4.2.2. Cowichan Bay Tributaries

In addition to measuring temperature, dissolved oxygen and specific conductivity, the Cowichan Bay Tributaries summer samples were analyzed for *E. coli*, turbidity and total phosphorus. Samples collected in the fall were analyzed for *E. coli*, also analyzed for total ammonia-nitrogen, total nitrate-nitrogen, dissolved organic carbon as well as total and dissolved metals.

4.2.3. Cowichan Bay Marine

The Cowichan Bay Marine sites were sampled and analyzed for enterococci and fecal coliforms.

5.0. RESULTS

5.1. Rainfall

There was essentially no rain during the summer sampling period as shown in **Figure 4** where the data were taken from the North Cowichan Weather Station. Sampling days are indicated by the open circles in this figure. There was less than normal rainfall in the fall. As a comparison, **Figure 5** shows rainfall over a similar period in 2017. The summer of 2017 had little rainfall during the sampling period, whereas the fall of 2017 had a more normal pattern of rainfall.

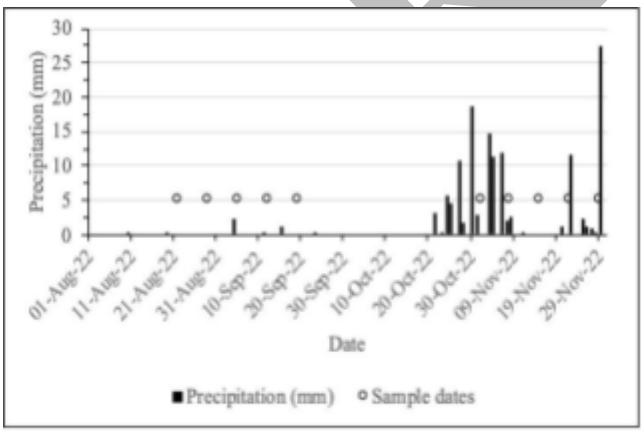

***Figure 4**. Daily precipitation at North Cowichan Environment Canada Station and sample dates (open circles) in the summer and fall of 2022.*

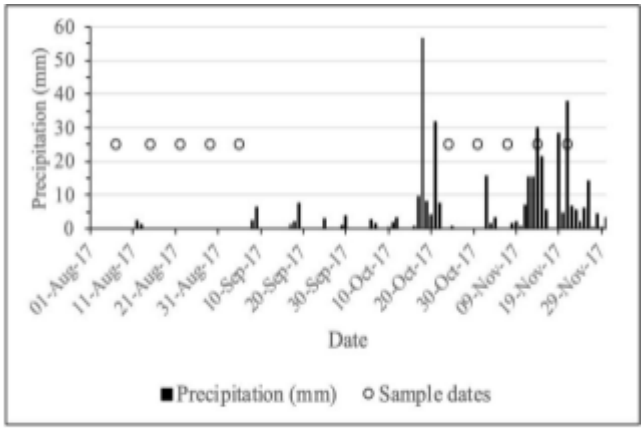

***Figure 5.** Daily precipitation at North Cowichan Environment Canada Station and sample dates (open circles) in the summer and fall of 2017.*

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5.2. Koksilah River Basin

5.2.1. Microbiology

All sites sampled had *E. coli* values greater than 10 CFU/100 mL (**Table 8**). *E. coli* results were similar, with a few exceptions, to those reported for 2012 by Smorong and Saso, 2021) and for 2017 by Preikshot, 2018.

Table 8. *E. coli* values for the Koksilah River Basin Sampling Sites, 2022. Shaded areas exceed the objectives.

Site	*E. coli* (CFU/100 mL)			
	90th percentile (objective £10 CFU/100 mL		Geometric mean (No objective)	
	Summer*	Fall	Summer*	Fall
KRB1	80.2	210.8	45.7	72.8
KRB2	255.4	198	110.5	22.9
KRB3	110.9	130	26.9	44.1
KRB4	ND	ND	ND	ND
KRB5	45.8	68	25.0	35.2
KRB6	44.2	104	23.5	62.1
KRB7	1512	140	843.4	38
KRB8	ND	ND	ND	ND
KRB9	137.2	76	66	9.4

**Includes MPNs/100 mL for August 22, 2022*

The lower Koksilah River Basin was sampled for *E. coli* in the fall of 2012 & 2013 (Smorong and Saso, 2021), 2017 (Preikshot, 2018) and 2022 (present study). In addition, there was a sampling at KRB3 (Koksilah River at Koksilah Road) in the fall of 2014 (Smorong and Saso, 2021). **Table 9** compares the geometric means of *E. coli* levels over these years. Compared to 2012, all sites sampled in 2022 had lower *E. coli* geometric means than in 2012. The 2022 sample results were either very similar to those of 2017 or were much lower (KRB2, KRB6, KRB7 and KRB9).

Note that **Table 9** provides rounded-off values for the *E. coli* geometric means for the summers of 2012, 2017 and 2022 for the lower Koksilah River Basin. The 2017 values were taken from Preikhot's Figures 2-5; hence, they are estimates of the values represented in these figures and are likely correct to the nearest 10. Because of this slight uncertainty in the 2017 values, all the other values are rounded off to the nearest 10. What particularly stands out is KRB7 (Kelvin Creek at the Koksilah Road) where the geometric means are much higher in 2012 and 2022 than in 2017.

The BC recreational water quality guidelines (British Columbia Ministry of Environment and Climate Change Strategy, 2019) state that for primary contact (where bodies can become immersed) *E. coli* levels should be ≤200 cells/100 mL, geometric mean of 5 in 30 samples with a single sample maximum of ≤400 cells/100 mL. Obee (2011) writes that the *E. coli* guidelines for recreation the geometric mean should ≤77 CFU/100 mL for primary contact and ≤385 CFU/100 mL for secondary contact (where bodies do not become immersed). Only one of the sites exceeds the provincial guideline for *E. coli*: KRB7 (Kelvin Creek at Koksilah Road). The Koksilah River at Bright Angel Park which is heavily used in the summer for recreation had a geometric mean for *E. coli* of 25 CFU/100 mL, well within the recreation guideline.

Table 9. Geometric Means (rounded-off) in CFU/100 mL) for *E. coli* Values for the Summers of 2012, 2017 & 2022

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Site	Summer 2012	Summer 2017	Summer 2022
KRB1	60	80	50
KRB2	150	120	110
KRB3	50	50	30
KRB4	ND*	100	ND*
KRB5	ND*	20	30
KRB6	30	170	20
KRB7	**700**	**120**	**840†**
KRB8	80	80	ND*
KRB9	70	110	70

**No data †Exceeds recreational objective*

5.2.2. Temperature

The water temperatures are given in **Figure 6.** In the summer or 2022, only two sites very slightly exceeded the Water Quality Objectives. These were KRB3 (Koksilah River at Koksilah Road) and KRB5 (Koksilah River at Bright Angel Park). The tributaries of the Koksilah River sampled all met the Objectives. In the fall all sites met the Objectives.

The Koksilah River is rather broad and shallow at these two sites with little shade. The fact that the tributaries met the temperature objectives was likely due to the tributaries had shade and that cool ground water was supplying the tributaries. Water temperatures were not reported in 2012 nor in 2017.

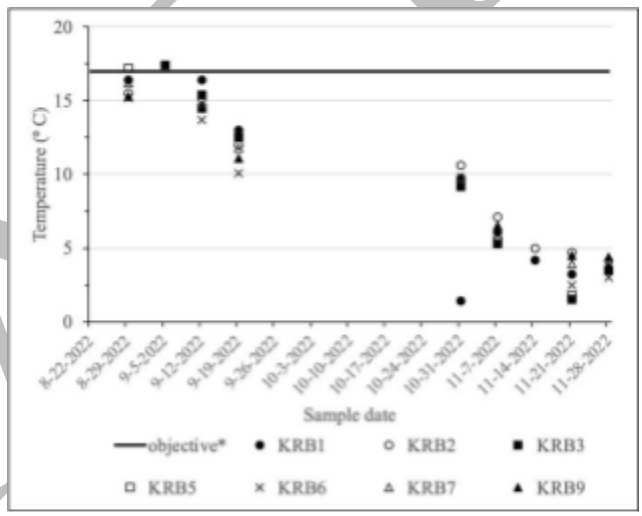

Figure 6. *Summer and fall water temperatures of the Koksilah River Basin sampling sites, 2022*

5.2.3. Dissolved Oxygen

The dissolved oxygen objectives are based upon the oxygen needs for hatched salmonoids or alevins (≥ 11.2 mg/L) and juvenile fish (≥8 mg/L) – see McKean, 1989. The data are given in **Figure 7**. For the summer sampling period dissolved oxygen measurements were reported during only three of the five sampling days, although data were collected for all five sampling days. For the three sampling days, KRB1 (Koksilah River at the TCH) was below ≤8 mg/L while KRB6 (Norrie Creek at the Koksilah Road) was below ≤8 mg/L two of the sampling days while KRB5 (Koksilah River at Bright Angel Park) & KRB7 (Kelvin Creek at Koksilah Road) was below ≤8 mg/L on one of the sampling days. There were no dissolved oxygen data reported during the summer sampling period of 2012.

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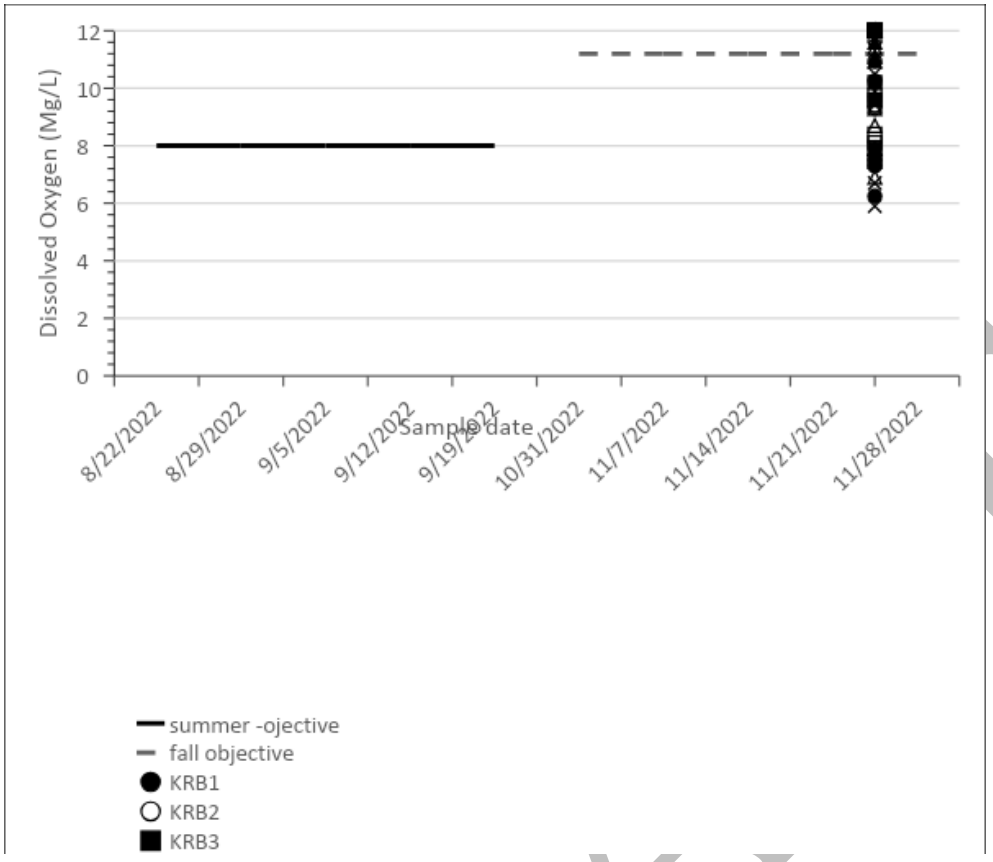

Figure 7. *Dissolved oxygen concentrations (mg/L) in the waters of the Koksilah River Basin sites during the summer and fall sampling periods.*

For the Fall sampling period, there are missing data for the November 14 sampling day. The data were obtained and this must be a transcribing error. KRB5 dissolved oxygen was below ≥11.2 mg/L on the October 31st sampling day, KRB6 was below ≥11.2 mg/L during the first two sampling days, while KRB7 was below ≥11.2 mg/L on the second and fourth sampling days (Smorong, 2021). KRB2 and KRB9 were just slightly below ≥11.2 mg/L on the second sampling day.

In 2012, only two of the present sampling sites were measured for dissolved oxygen in the fall of 2012: KRB3 and KRB7. KRB3 (Koksilah River at Koksilah Road) met the fall objective whereas KRB7 (Kelvin Creek at Koksilah Road) did not (Smorong et al 2021).

No dissolved oxygen data are reported in 2017 (Preikshot, 2018).

5.2.4. Turbidity

Figure 8 illustrates the turbidity levels at the Koksilah River Basin Sites. The horizontal lines indicate the Water Quality Objective maximums for summer (solid line) and fall (dished line). It can be seen that KRB2 (Petrolas Creek at Moss Road) and KRB6 Norrie Creek at Koksilah Road) did not meet the Summer Water Quality Objective of maximums no greater than 2 NTUs while all sites met the Fall Water Quality Objectives.

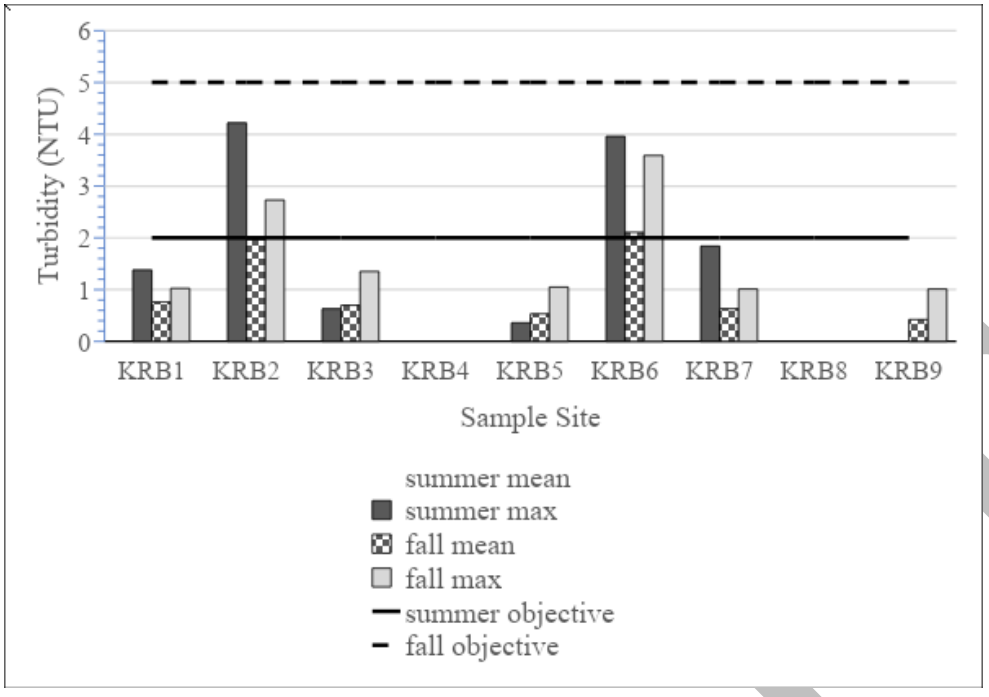

Figure 8. *Turbidity levels in the Koksilah River Basin sites sampled during the summer and fall of 2022. The summer and fall objectives are maximum levels. The means are included to give an indication of the mean relative to the maximum values.*

In the summer sampling period of 2012, KRB2, KRB6 and KRB9 did not meet the Water Quality Objective. In the fall of 2012, only one site met the objective: KRB3 (Koksilah River at Koksilah Road). In 2017, not one of the Koksilah River Basin sites met the Summer Water Quality Objective. Furthermore, in the fall only one site met the Fall Water Quality Objective (KRB3). One explanation for why all the Fall Water Quality Objective was met in the fall of 2022 is that there was very little rain.

5.2.5. Nutrients

5.2.5.1. Ammonia-N

*A*mmonia-N was only measured in the fall of 2022. **Figure 9** illustrates the fall ammonia levels. All sites met the Fall Water Quality Objective for Ammonia-N. In 2012, fall ammonia levels met the objective as well. Ammonia also met the summer objective during the summer sampling period of 2012.

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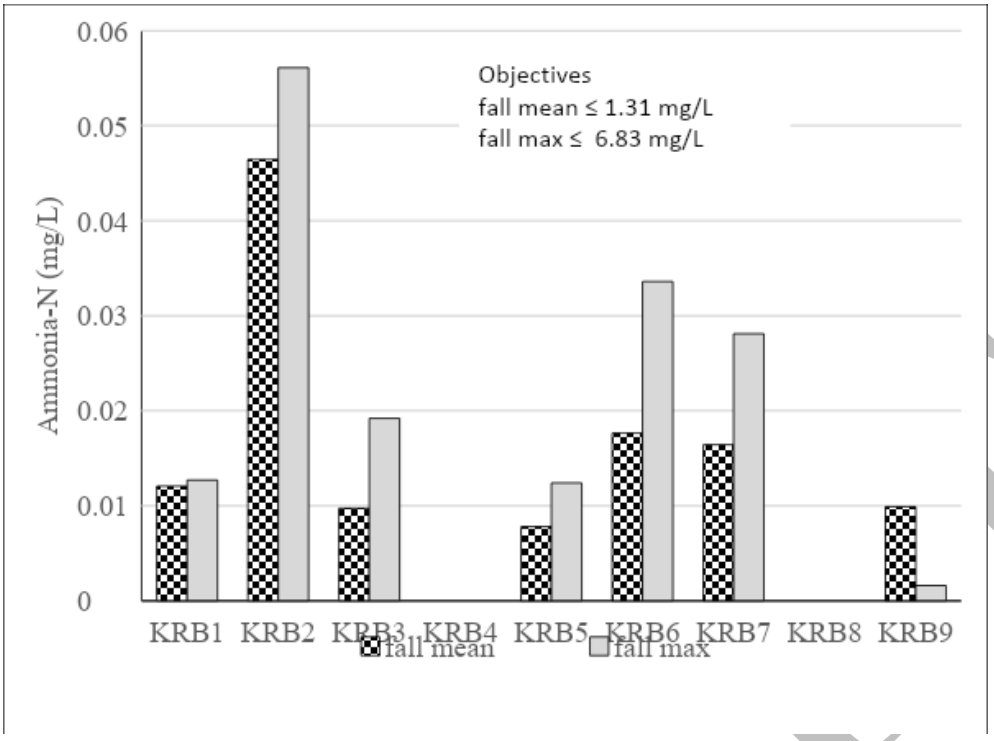

Figure 9. *Fall ammonia-**N** levels at the Koksilah River Basin sites sampled in 2022.*

5.2.5.2. Nitrate-N

There are no nitrate-N objectives for the Koksilah River; however, nitrate-N levels were measured in the fall of 2022 and fell within the water quality guidelines for freshwater aquatic life (Figure 10).

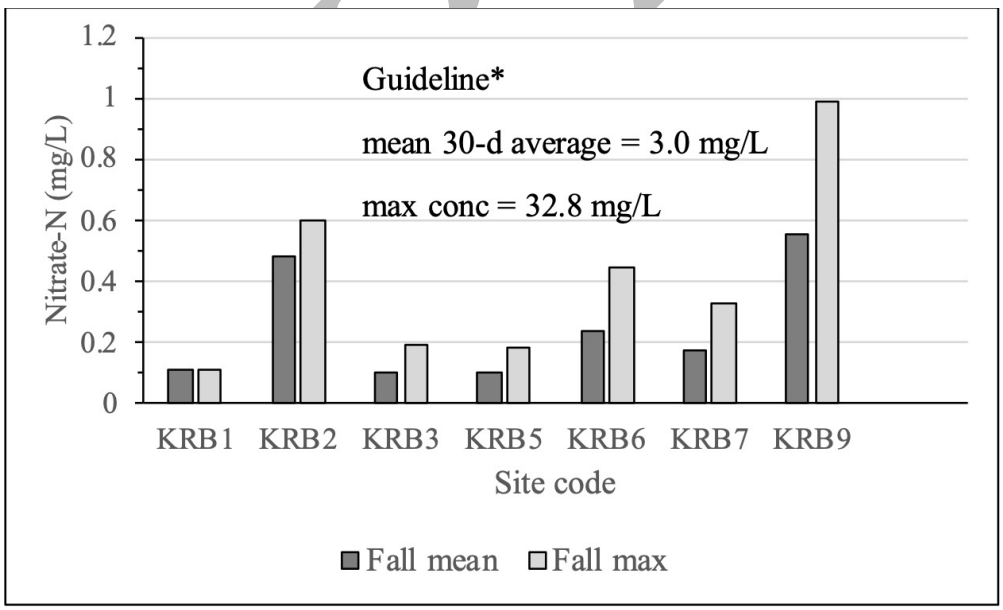

Figure 10. *Fall mean and maximum concentration of nitrate-N at seven sites along the Koksilah River Basin in 2022. There are no data for KRB 4 and KRB8. *Guideline is to protect aquatic life.*

5.2.5.3. Total Phosphorus

During the summer sampling period all Koksilah River Basin sites exceeded the Total Phosphorus Water Quality Objectives (**Figure 11**). Total phosphorus levels were lower in the fall than in the summer. Only KRB5 (Koksilah River at Bright Angel Park) did not exceed the fall objective. Especially high values were seen at: KRB2 (Petrolas Creek at Moss Road), KRB6 (Norrie Creek at Koksilah road) and KRB9 (Glenora Creek at Doupe Road).

Higher total phosphorus levels in the summer compared to the fall suggests that the streams are being fed with high phosphorus groundwater. The high levels of groundwater phosphorus may be due to agricultural activities.

The high concentrations of total phosphorus at KRB2 and KRB6 correspond to high turbidity levels suggesting the phosphorus may be adsorbed and not available. It is noted that ammonia-N and nitrate-N were also high at these two sites (as well as KRB9), and they are dissolved and available.

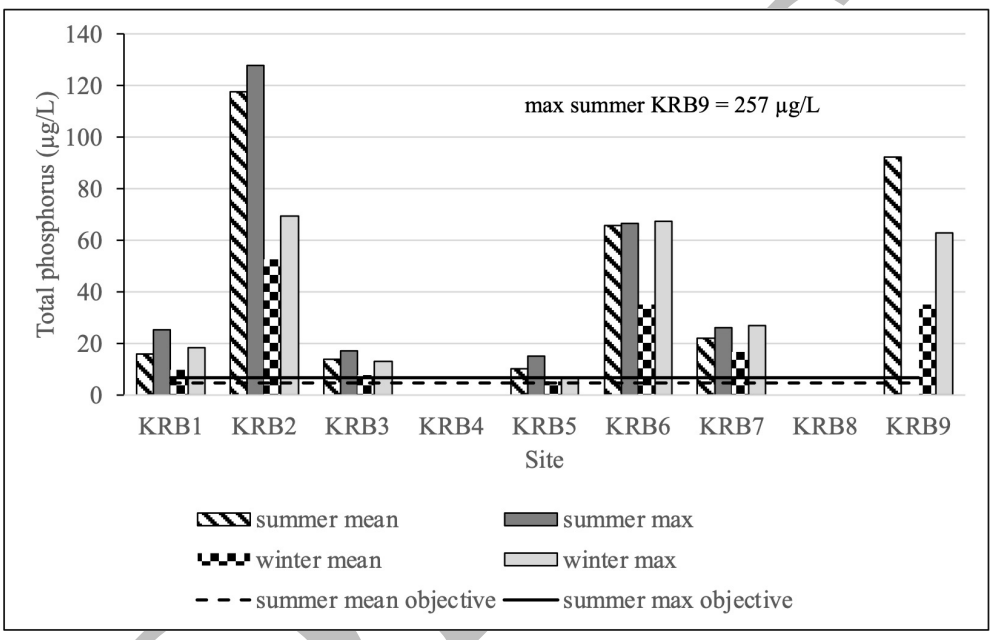

Figure 11. *Summer and Fall Total Phosphorus Levels in the Koksilah River Basin Sampling Sites, 2022.*

5.2.6. Metals

5.2.6.1. Copper

Total copper levels met the Fall Water Quality Objective (**Figure 12)**. In 2012, KRB3 (Koksilah River at Koksilah Road) exceeded the copper objective. Copper was not reported in the 2017 sampling period. Whatever, the cause of high fall copper levels at KRB3, it appeared to be transient. Of course, we did not have the normal fall flush in 2022 and this may account for the copper meeting the water quality objectives.

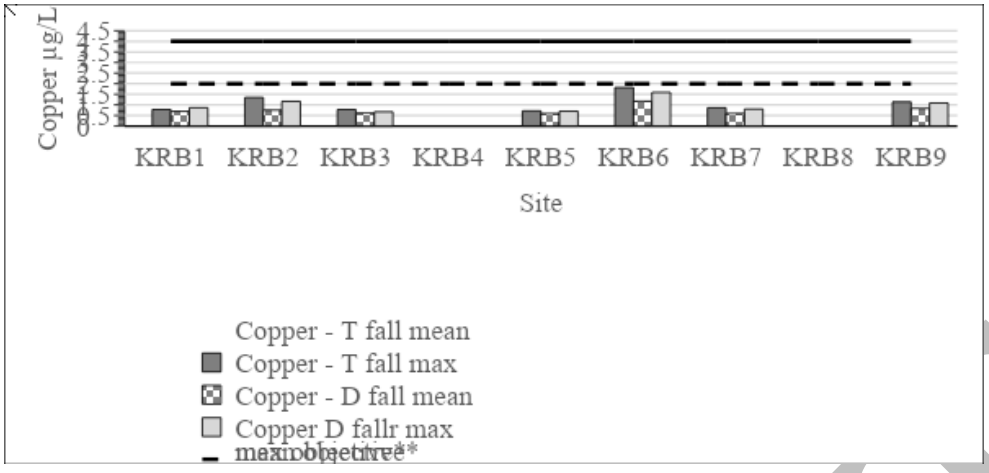

Figure 12. *Fall Total (T) and Dissolved (D) Copper in the Koksilah River Basin sampling sites in 2022.*

5.2.6.2. Lead

All Koksilah River Basin sampling sites in the fall met the Water Quality Objectives for Lead (**Figure 13**). The last time lead was analyzed for was in the fall of 2012 and one site (KRB3) in 2014. At that time all the samples also met the objective.

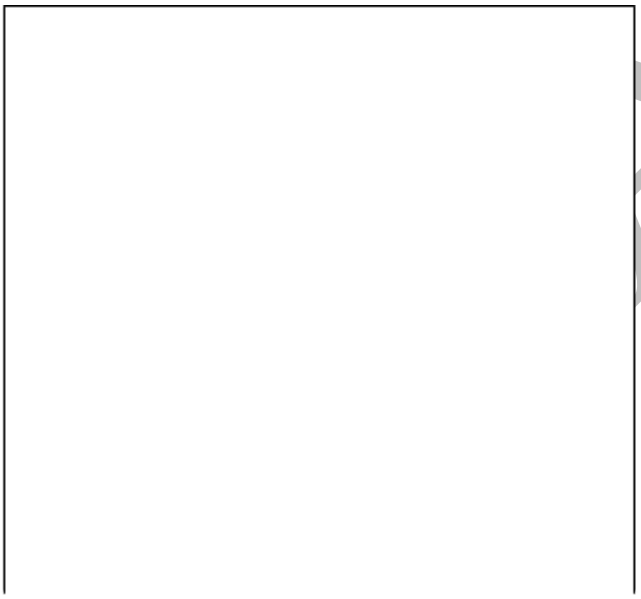

Figure 13. *Fall Total (T) and Dissolved (D) Lead in the Koksilah River Basin sampling sites, 2022.*

5.2.6.3. Total Zinc

Total Zinc levels at all the sites in the fall sampling period of 2022 met the Water Quality Objective (**Figure 14**). In the fall of 2012, total zinc slightly exceeded the Water Quality Objective at KRB3 (Koksilah River at Koksilah Road).

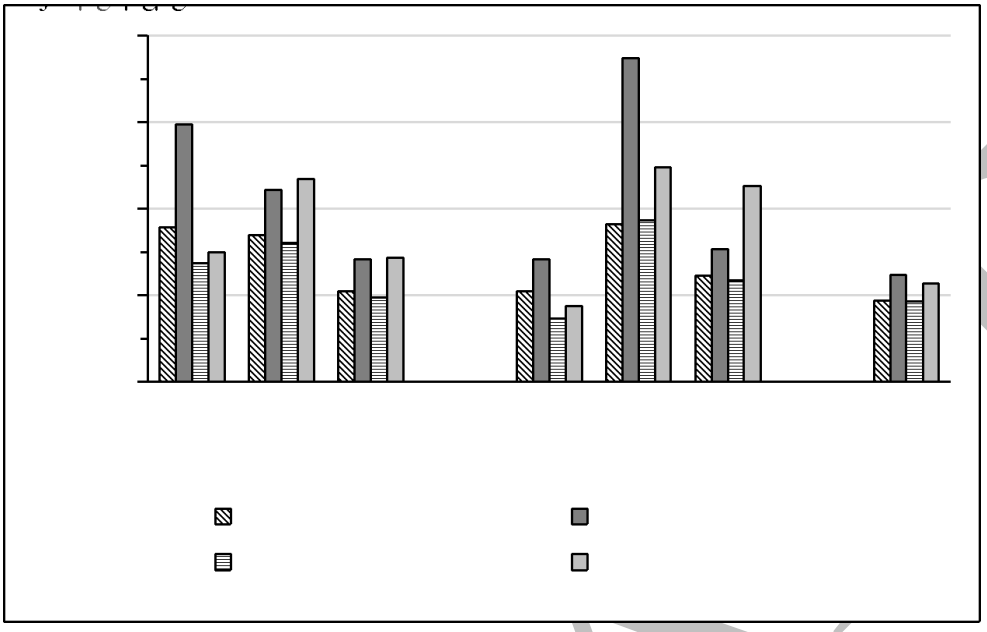

Figure 14. *Fall Total (T) and Dissolved (D) Zinc levels in the Koksilah River Basin sampling sites, 2022.*

5.2.7. Overview of Which Water Quality Standards Were Met

Table 10 outlines which Parameters met the Summer Water Quality Objectives.

Table 10. The KRB Sites That Met (Y) Or Did Not Meet (N) the Summer Water Quality Objectives in 2022

Summer	KRB1	KRB2	KRB3	KRB5	KRB6	KRB7	KRB9
E. coli	**N**	**N**	**N**	**N**	**N**	**N***	**N**
Oxygen	**N**	Y	Y	**N**	**N**	**N**	Y
Temperature	Y	Y	**N**	**N**	Y	Y	Y
Turbidity	Y	**N**	Y	Y	**N**	Y	Y
Phosphorus	**N**	**N**	**N**	**N**	**N**	**N**	**N**

**Did not meet recreational level guideline*

Table 11 outlines which Parameters met the fall Water Quality Objectives.

Table 11. The KRB Sites That Met (Y) Or Did Not Meet (N) the Fall Water Quality Objectives in 2022

Fall	KRB1	KRB2	KRB3	KRB5	KRB6	KRB7	KRB9
E. coli	**N**	**N**	**N**	**N**	**N**	**N**	**N**
Oxygen	Y	**N**	Y	**N**	**N**	**N**	Y
Temperature	Y	Y	Y	Y	Y	Y	Y
Turbidity	Y	**N**	Y	Y	**N**	Y	Y

Fall	KRB1	KRB2	KRB3	KRB5	KRB6	KRB7	KRB9
Ammonia	Y	Y	Y	Y	Y	Y	Y
Phosphorus	**N**	**N**	**N**	**N**	**N**	**N**	**N**
Copper	Y	Y	Y	Y	Y	Y	Y
Lead	Y	Y	Y	Y	Y	Y	Y
Zinc	Y	Y	Y	Y	Y	Y	Y

5.3. Cowichan Bay Tributaries

5.3.1. Microbiology

Not one of the Cowichan Bay tributaries sampled met the Water Quality Objective for *E. coli* (**Table 12**). This objective, based upon raw water being chlorinated for drinking water, is that the 90th percentile based upon five weekly samples over thirty days should not exceed 10 CFU/100 mL. We have also included the geometric mean to demonstrate the serious contamination of the tributary waters with *E. coli*. Note that the geometric means are mainly well above 10 CFU/100 mL. The only other summer samples taken was in 2017 (Preikshot, 2018). **Table 13** compares the geometric means (CFU/100 mL) of sites sampled in 2017 with those in sampled in 2022. Where there are data for the same site, it can be seen that there are somewhat lower *E. coli* geometric means in 2022 compared to 2017.

Table 12. *E. coli* levels at the 90th percentile and the geometric means in CFU/100 mL in the Cowichan Bay Tributaries, 2022. Shaded cells indicate exceedances.

Site code	***E. coli*** (CFU/ 100 mL)[1]			
	90th percentile (Summer)	**90th percentile (Fall)**	**Geometric mean (Summer)**	**Geometric mean (Fall)**
CBT1	176.2	520	72.0	51.4
CBT2	78.2	158.4	48.5	13.3
CBT3	ND[4]	167.6	ND[4]	17.1
CBT4	ND[2]	ND[2]	ND[2]	ND[2]
CBT5	51.6	164	28.1	46.2
CBT6	ND[2]	ND[2]	ND[2]	ND[2]
CBT7	ND[3]	ND[3]	ND[3]	ND[3]
CBT8	ND[4]	INC	ND[4]	INC
CBT9	130.4	104	55.9	33.7
CBT10	38.3	90	16.1	24.0
CBT11	173.9	434	63.0	121.3
CBT12	718	678	143.6	148.4
CBT13	INC	121.6	INC	16.9

1. *One summer sample is MPN/100 mL*
2. *No water flowing*
3. *No water course*
4. *No explanation for no data*

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Table 13. Comparison of the Summer Values for *E. coli* Geometric Means (CFU/100 mL) Between 2017 and 2022

Site	Summer 2017	Summer 2022
CBT1	160*	70
CBT2	150	50
CBT3	50	ND
CBT4	ND	ND
CBT5	ND	30
CBT6	ND	ND
CBT7	ND	ND
CBT8	ND	ND
CBT9	120	60
CBT10	ND	20
CBT11	80	60
CBT12	ND	140
CBT13	ND	INC

**Note that the geometric means are rounded to the nearest 10. The reason for this is that the values for 2017 were taken off Figure 2 from Preikshot, 2018, and only approximate values were determined.*

The 2012 and 2013 sampling for *E. coli* in the Cowichan Bay tributaries were performed only in the fall (Smorong *et al.* 2021). No summer samples were taken. The samples taken in the fall of 2012 were very high to extremely high in *E. coli* with the 90th percentile values ranging from 1008 to 40,430. In the 2022 sampling period the fall *E. coli* 90th percentile values ranged from 90 to 678. The 90th percentile *E. coli* values in 2022 for CBT9 (Garnett Creek at Cherry Point Beach), CBT10 (Garnett Creek at Telegraph Road) and CBT13 (Treffery Creek at the TCH) were more than five-fold lower in the fall of 2022 compared to the values in 2013. Smorong *et al.* (2021) point out that there was little rainfall in the fall of 2013 when samples were being collected, a situation similar to the fall of 2022. On the other hand, the *E. coli* 90th percentile values for CBT3 Wessex Creek at Wessex Inn) and CBT5 (storm drain at Botwood Lane) were more than two times higher in 2022 than in 2013.

The *E. coli* geometric means in the fall of 2012 generally were very high ranging from a low of 175 CFU/100 mL to 4217 CFUs/100 mL (**Table 14)**. The 2013 fall geometric means were similar to those found in 2022, ranging from 12 to 228 CFU/100 mL; however, two sites had geometric means lower than in 2013: CBT10 (Garnett Creek at Telegraph Road) and CBT13 (Treffery Creek at the TCH). In comparison, the geometric means for *E. coli* values in 2022 ranged from 13 to 148 CFU/100 mL, similar to the values seen in 2013. Only a few sites were sampled for *E. coli* in 2017.

Overall. There has been a large improvement in *E. coli* levels since the fall of 2012 and a few sites had improvement over 2013.

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Table 14. Comparison of the Geometric Means of *E. coli* levels (CFU/100 mL) in the Cowichan Bay Tributaries Over the Past Decade

Site	Fall 2012	Fall 2013	Fall 2017	Fall 2022
CBT1	660*	60	ND	50
CBT2	460	30	200	10
CBT3	4200	10	40	20
CBT4	1240	40	ND	ND
CBT5	450	30	ND	50
CBT6	ND†	ND	ND	ND
CBT7	ND	ND	ND	ND
CBT8	550	10	ND	INC
CBT9	180	30	140	30
CBT10	**970**	**160**	ND	**20**
CBT11	520	ND	40	120
CBT12	1600	120	ND	150
CBT13	**2620**	**230**	ND	**20**

**Note that the geometric means are rounded to the nearest 10. The reason for this is that the values for 2017 were taken off Figure 3 from Preikshot, 2018, and only approximate values were taken.*
†No data

In summary, in 2022, the fall 90th percentile values for *E. coli* tended to be 2-3 times higher than in the summer sampling period, with the major exceptions being CBT9 (Garnett Creek at Cherry Point Beach) and CBT12 (Speirs Creek at Hill Bank Road) where summer values were slightly higher than the fall values. In general, the geometric means of the summer and fall sampling were similar with some summer values being somewhat higher than the fall values and *vice versa*.

5.3.2. Temperature

There are no water temperature objectives for the Cowichan Bay Tributaries. This is because of the small size of the tributaries relative to the mainstem rivers and thus it could not be assumed that the objectives would apply (Barlak, pers. comm). However, the results were compared to the Cowichan/Koksilah temperature objectives, i.e., mean weekly temperatures equal to or less than 17° C (Province of BC, 2023). Note that not all tributaries had temperatures measured for the full 5 in 30 period. All tributaries that were measured in the summer met the Cowichan/Koksilah objective and all tributaries measured in the fall met the Cowichan/Koksilah objective (**Figure 15**).

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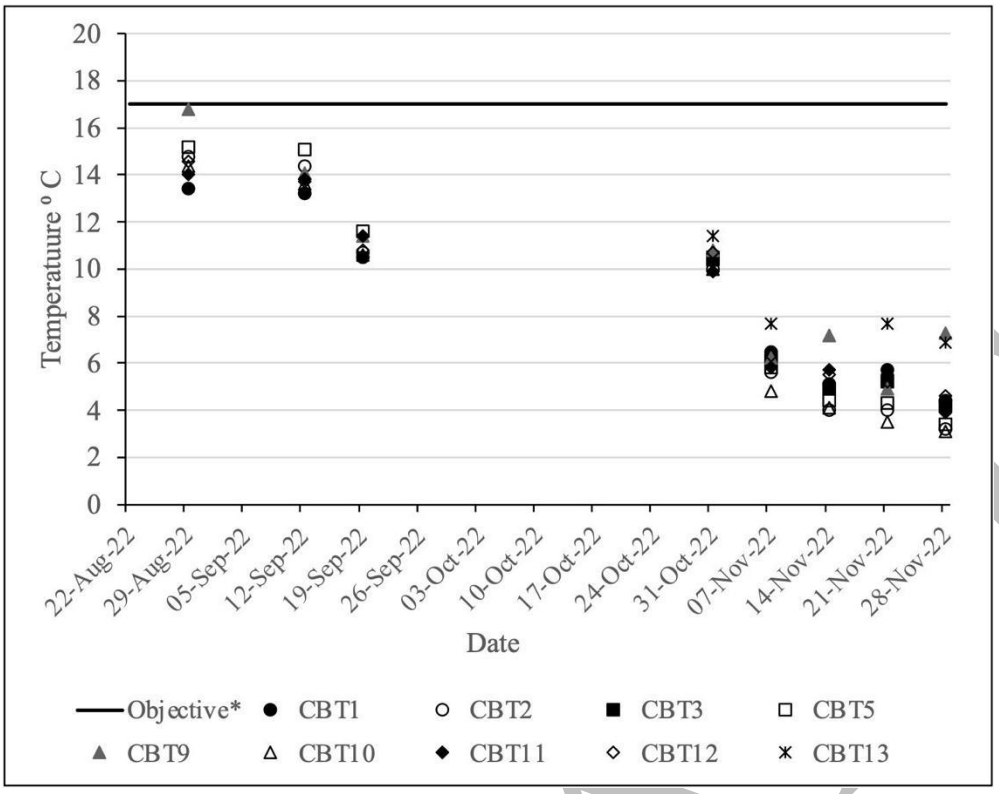

Figure 15. *Water temperature in 9 tributaries to Cowichan Bay in the summer and fall of 2022. There are no data for CBT4, CBT6 and CBT7 and only two dates for CBT8 (not included).*

5.3.3. Dissolved Oxygen

In the summer of 2022, on only 3 sampling days was dissolved oxygen reported (**Figure 16**). It should be noted that the provisional objective is for a weekly mean to be equal to or greater than 8 mg dissolved oxygen/L with no sample falling below 5 mg/L. Note that there was only one measurement taken each week.

Four sites had dissolved oxygen levels below 5 mg/L: CBT5 (Storm drain at Botwood Lane), CBT9 (Garnett Creek at Cherry Point Beach), CBT10 (Garnett Creek at Telegraph Road), and CBT12 (Spiers Creek at Hillbank Road) of not having dissolved oxygen fall below 5 mg/L. Furthermore, CBT5, CBT9 and CBT10 had dissolved oxygen levels below 8 mg/L objective. In the fall all five sampling days measured for dissolved oxygen (**Figure 16**) and all sites had dissolved oxygen above the 5 mg/L minimum level however, two sites fell below the 8 mg/L level: CBT9 and CBT10.

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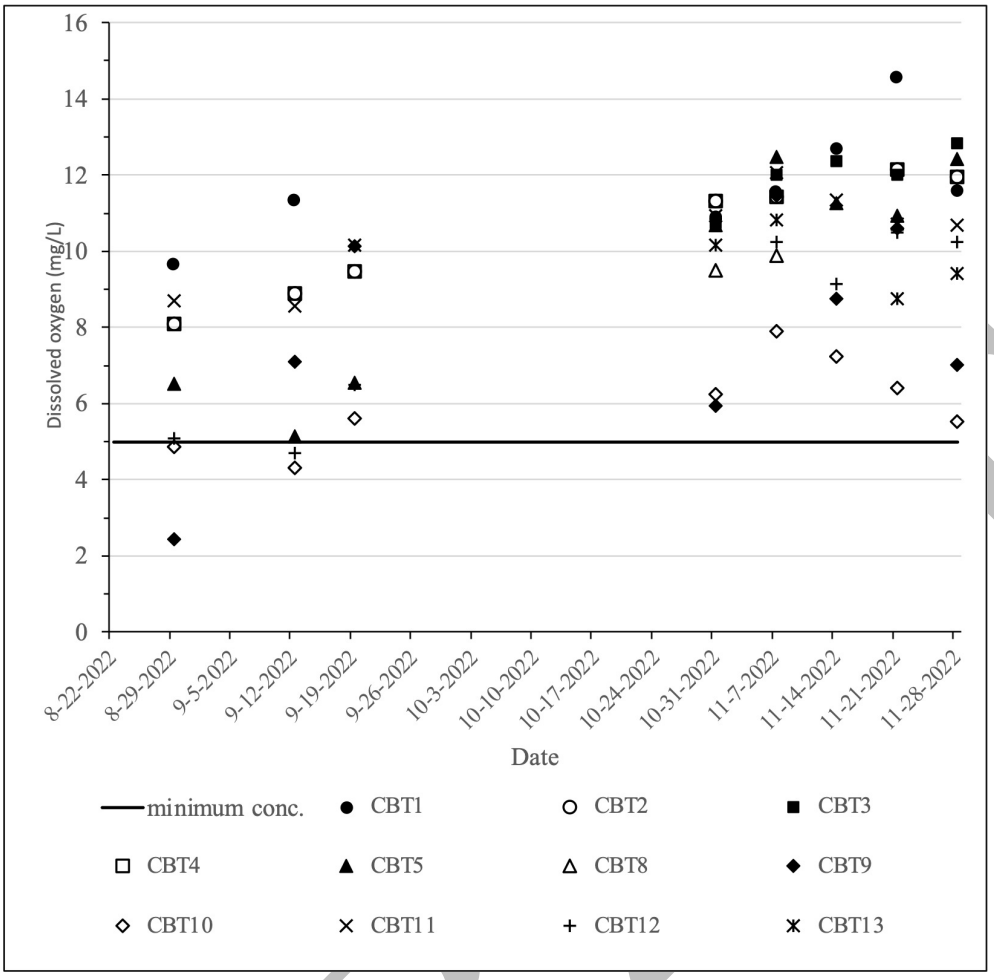

Figure 16. *Dissolved oxygen concentrations (mg/L) in the waters of 11 tributaries to Cowichan Bay in the summer (22-Aug-22 to 19-Sept-22) and fall (31-Oct-22 to 28-Nov-22) of 2022. The minimum objectives for summer and fall are indicated by the horizontal line. Since there were only three sampling days, no indication of the objectives for the mean of five sampling dates is indicated.*

5.3.4. Turbidity

The turbidity objectives are provisional (Province of BC, 2023. Only CBT2 (Speirs Creek at Cowichan Bay Road) met the provisional objectives throughout the summer period. CBT5 met the objectives for the first four summer sampling periods while CBT1 met the provisional objective in only three of the five sampling periods (**Figure 17**).

During the fall sampling period only CBT1 (Treffery Creek at Cowichan Bay Road), CBT2, CBT9 and CBT11 met the provisional objectives for turbidity.

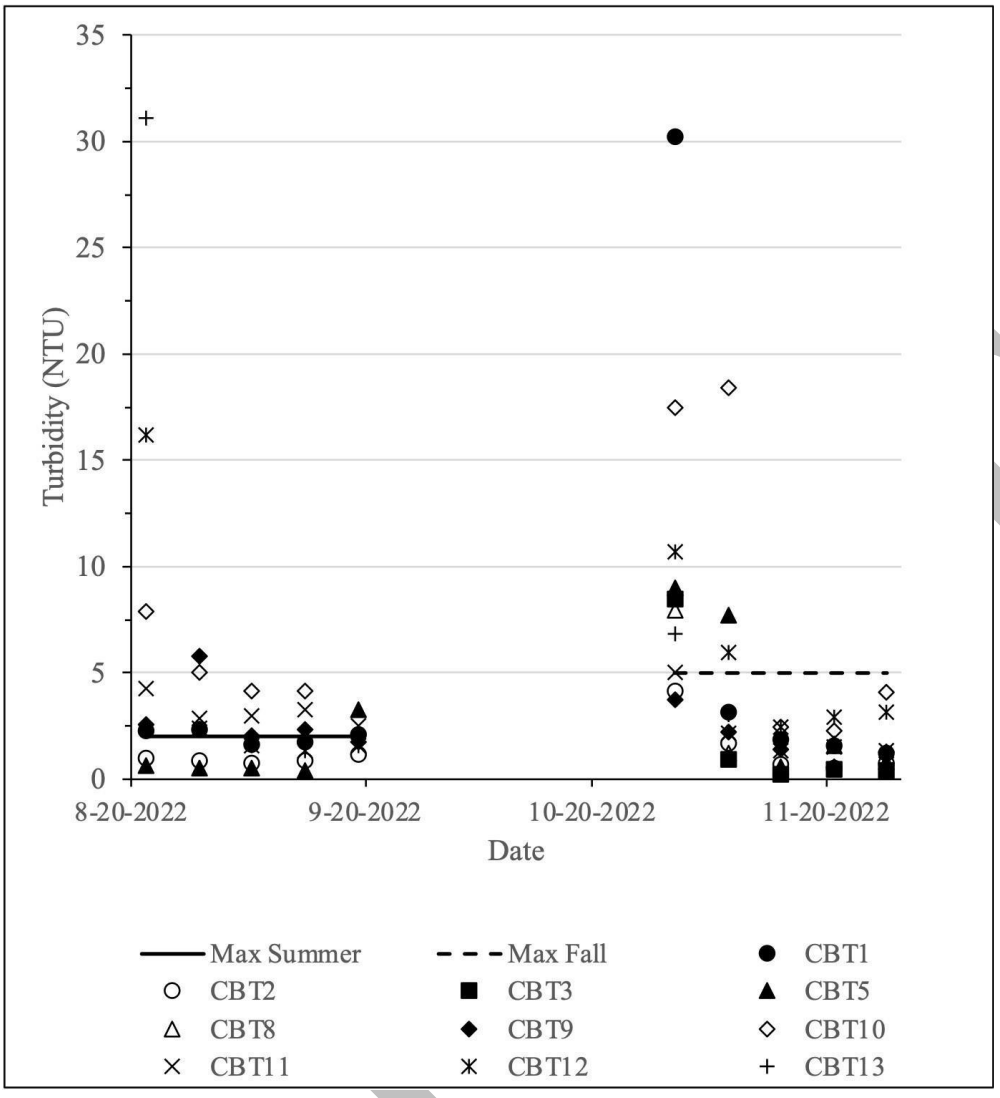

Figure 17. *Turbidity (NTU) in 10 tributaries to Cowichan Bay in summer (22-Aug-22 to 19-Sept-22) and fall (31-Oct-22) to 28-Nov-22). The maximum objectives for summer and fall are given as horizontal lines. Note: There are no data for CBT4, only summer data for CBT3 and CBT13 and only 31-Oct-22 and 07-Nov-22 for CBT8.*

5.3.5. Nutrients

5.3.5.1. Ammonia-nitrogen (N)

There are no water quality objectives for ammonia-N; however, the samples were analyzed for ammonia-N since Smorong *et al.*, 2021 suggest that ammonia-N should be examined and compared to the Cowichan and Koksilah objectives of a 5 in 30 mean objective of 1.31 mg/L and no sample higher than 8.85 mg/L. The Cowichan Bay tributaries met these objectives (**Figure 18**).

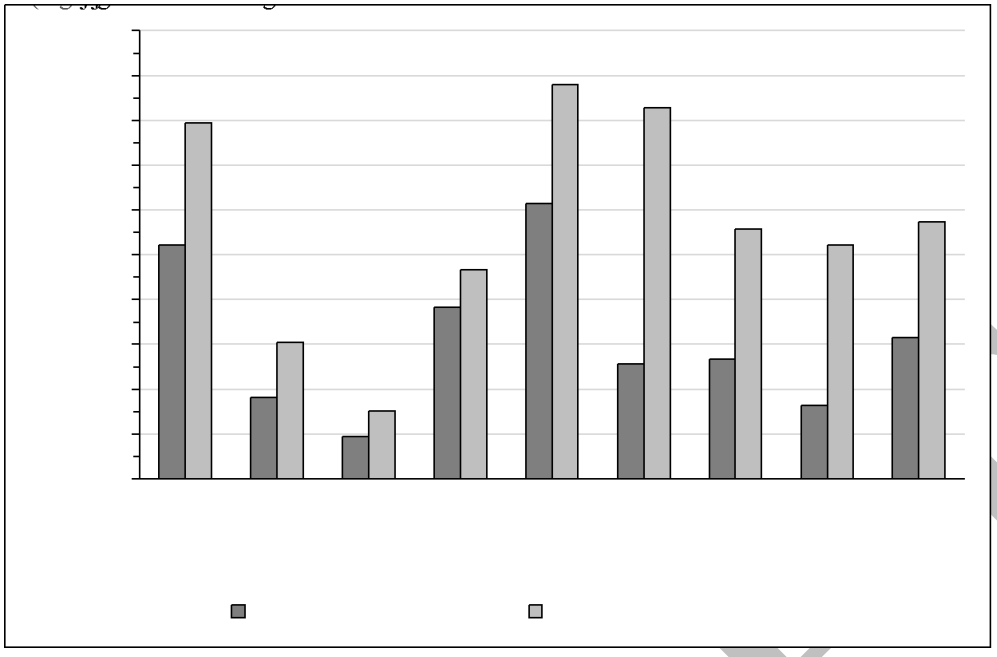

Figure 18. *The mean and maximum values for the 5 samples taken in the fall (31/10/22 – 28/11/22) over 30 days.*

5.3.5.2. Nitrate-nitrogen (N)

There are no provisional objectives for nitrate-N. The provincial water quality guideline for aquatic life is a weekly mean no greater than 3.0 mg nitrate-N/L and maximum value of 32.8 mg nitrate-N/L. All CBT sites had fall nitrate-N levels within the provincial water quality guidelines for aquatic life (**Figure 19**).

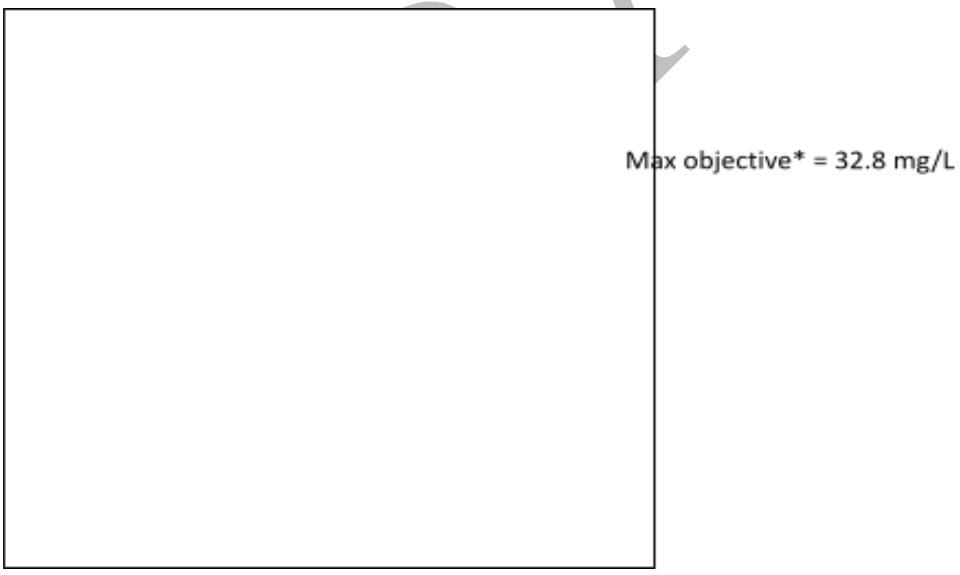

Figure 19. *5 in 30-day average nitrate-N, the 30 day average objective and the max concentration in nine tributaries to Cowichan Bay. There are no data CBT 4, CBT6 and CBT7 and only two sample times for CBT8 (not included). The max guideline is 32.8 mg/mL is in the text box. *These objectives are the BC Guidelines to protect freshwater aquatic life.*

5.3.5.3. Total Phosphorus

There are no stated fall objectives for total phosphorus in the Cowichan Bay tributaries. The provisional summer objective is ≤5 µg/L (mean of 5 samples taken over 30 days), with no sample being higher than 10 µg/L. Not one of the Cowichan Bay tributaries met the provisional summer objectives of ≤5 µg/L (**Table 15**). As noted, there are no fall objectives defined for the tributaries; however, all the tributaries had total phosphorus levels greater than 5 µg/L. The total phosphorus values for the majority of tributaries in the fall were lower than in the summer: the exceptions were CBT5 (Storm drain at Botwood Lane), CBT9 (Garnett Creek at Cherry Point Beach) and CBT10 (Garnett at Telegraph Road).

Table 15. The mean, minimum and maximum concentrations of total phosphorus at the sites on the tributaries to Cowichan Bay for the five samples in summer (22-Aug-22 to 19-Sept-22) and in fall (31-Oct-22 to 28-Nov-22). Shaded cells indicate sites that failed to meet the summer objective. See text for details.

Site code	**Summer – objective below table**			**Fall – no objective (All exceed summer objective)**		
	Mean (µg/L)	Min (µg/L)	Max (µg/L)	Mean (µg/L)	Min (µg/L)	Max (µg/L)
CBT1	430.4	427	437	332	298	358
CBT2	96.74	88.5	104	76.52	47.6	137.5
CBT3	ND	ND	ND	68.27	61	144
CBT5	90.44	82.4	98.5	121.12	87.2	199
CBT6	ND	ND	ND	ND	ND	ND
CBT7	ND	ND	ND	ND	ND	ND
CBT8	INC (2)	INC (2)	INC (2)	ND	ND	ND
CBT9	67.84	38	194	81.3	30.8	204
CBT10	163.4	151	191	211.46	28.3	481
CBT11	135.8	117	167	77.78	50.3	121
CBT12	86.02	76.1	96.8	49.84	25.1	103
CBT13	INC (1)	INC (1)	INC (1)	60.46	20	148

ND = no data, INC = incomplete data. The values that exceed objectives are shaded.

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5.3.6. Metals

5.3.6.1. Copper

Only CBT2 (Speirs Creek at Cowichan Bay Road), CBT3 (Wessex Creek at Wessex Inn), CBT9 (Garnett Creek at Cherry Point Beach) and CBT11 (Manley Creek at the end of Hatch Point Road) met the summer and fall provisional mean and maximum objectives for copper (**Figure 20**). CBT5, CBT10, CBT12 and CBT13 failed to meet the summer provisional mean objective for copper. CBT1, CBT5, CBT10, CBT12 and CBT13 also failed to meet the summer and fall maximum provisional objectives.

One possible reason for the high copper levels is that the unconsolidated and bedrock materials that underlie Cowichan Bay have high levels of copper (Barroso and Melnechenko, 2019). The unconsolidated materials had a mean groundwater level of dissolved copper of 1.65 µg/L ranging from 0.05 to 8.61 µg/L. The bedrock had a mean groundwater dissolved copper level of 1.36 µg/L, ranging from 0.15 to 5.15 µg/L.

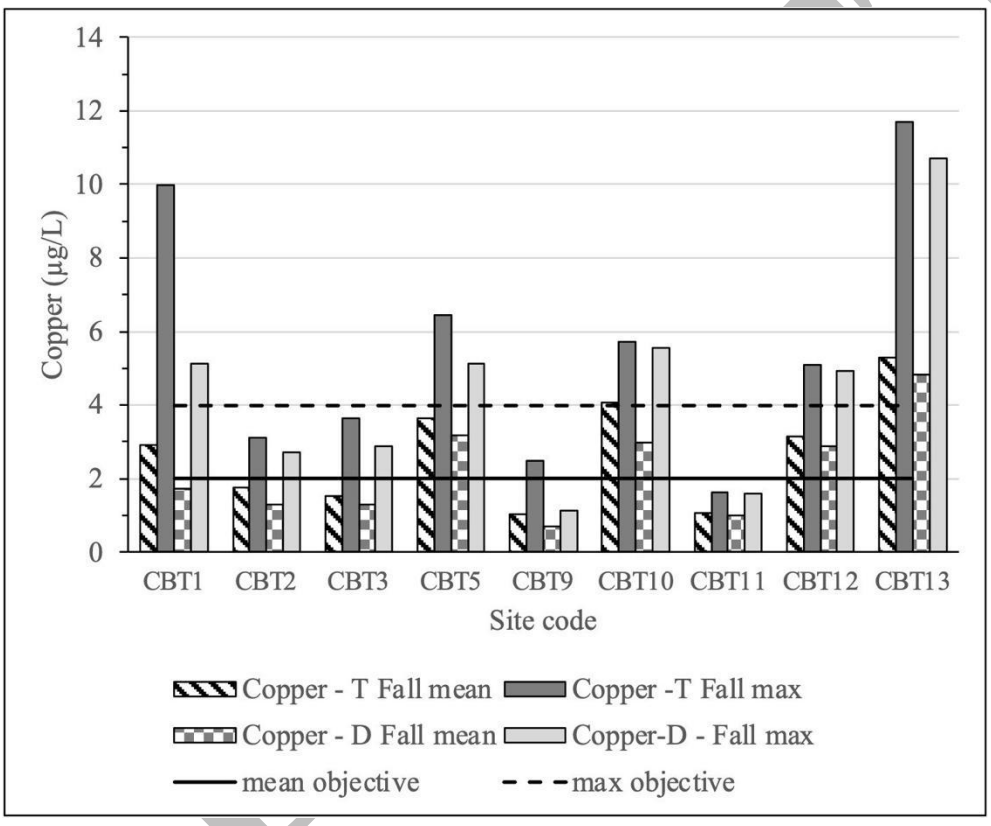

***Figure 20**. Mean and maximum concentrations of total (T) and dissolved (D) copper in Fall (31-Oct-22 to 28-Nov-22) at 10 sites on tributaries to Cowichan Bay. The objectives for the mean (≤ 2 µg/L) and maximum (≤4 µg/L) concentrations are the horizontal lines.*

5.3.6.2. Lead

There are no objectives for lead for the Cowichan Bay tributaries. We do point out that all sites sampled in the summer and fall met the Cowichan and Koksilah River's objectives for lead (**Figure 21**).

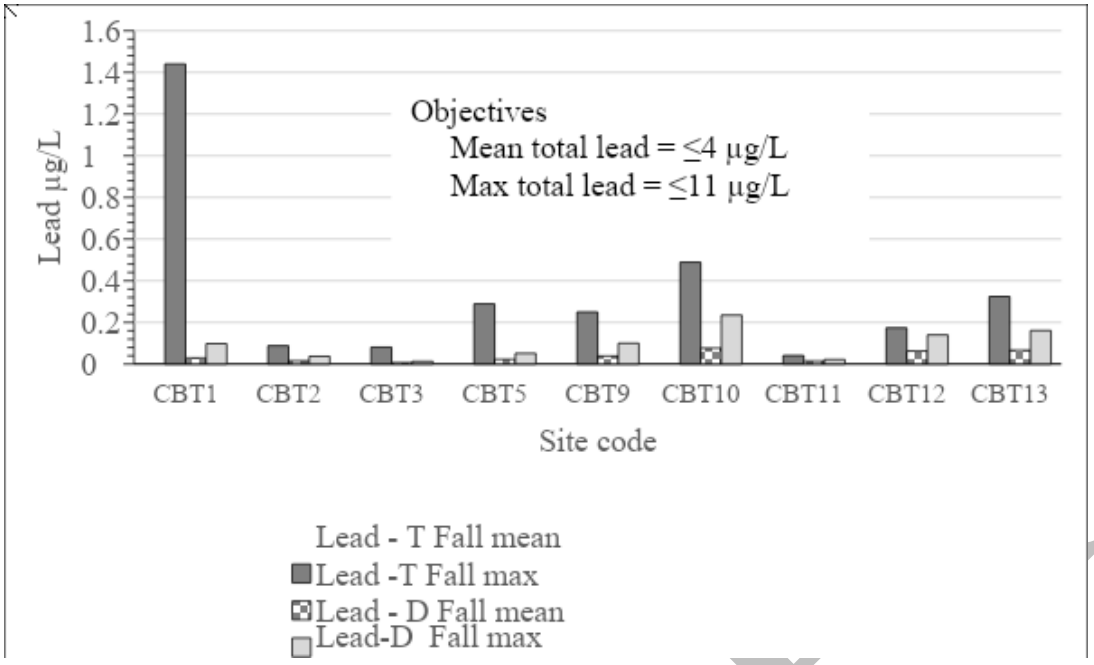

Figure 21. *Mean and maximum concentrations of total (T) and dissolved (D) lead (µg/L) in 10 tributaries to Cowichan Bay, 2022. The objectives for total lead are given as text in the Figure.*

5.3.6.3. Zinc

CBT1, CBT10 and CBT 13 failed to meet the summer mean and maximum provisional objectives for zinc (**Figure 22**). CBT9 and CBT 12 failed to meet the provisional maximum objective. As to the fall provisional objectives CBT13 failed to meet the mean and maximum provisional objective while CBT10 failed to meet the provisional maximum objective.

The only tributaries that met all provisional objectives for the summer and fall were CBT2 (Speirs Creek at Cowichan Bay Road), CBT3 (Wessex Creek at Wessex Inn), CBT5 (Storm drain at Botwood Lane) and CBT11 Manley Creek at the end of Hatch Point Road).

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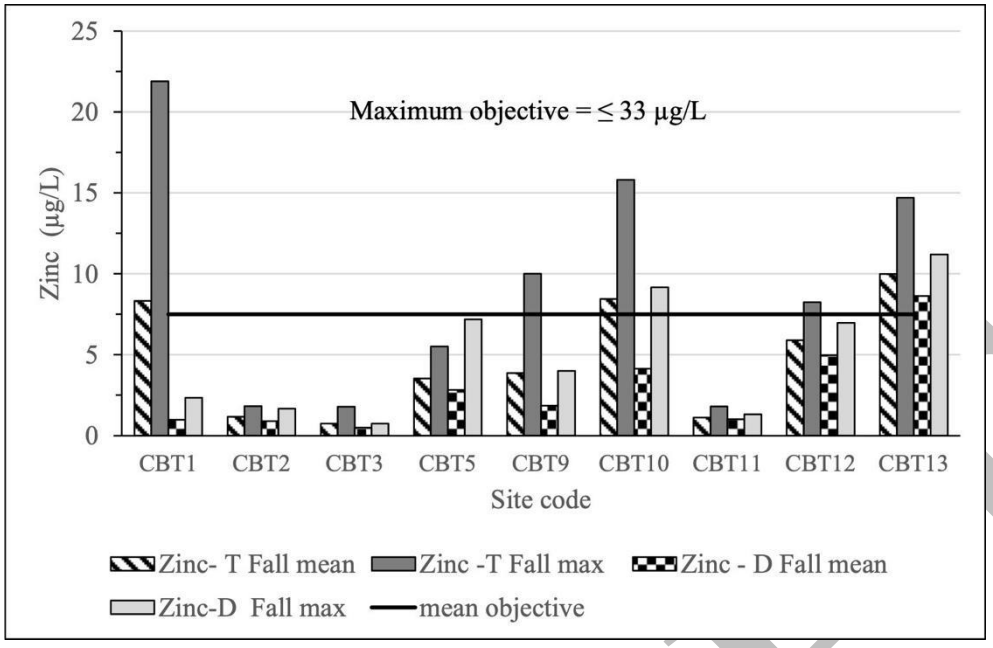

Figure 22. *Mean and maximum concentrations of total (T) and dissolved (D) zinc (µg/L) in 10 tributaries to Cowichan Bay, 2022.*

One possible reason for the high zinc levels may is that the unconsolidated and bedrock materials that underlie Cowichan Bay have high levels of zinc (Barroso and Melnechenko, 2019). The unconsolidated materials had a mean groundwater level of dissolved zinc of 15.3µg/L ranging from 2.8 to 219 µg/L. The bedrock had a mean groundwater dissolved zinc level of 74.7 µg/L, ranging from 6.4 to 680 µg/L.

5.3.7 Overview of Which Water Quality Objectives Were Met

Table 16 indicates which Water Quality (Provisional) Objectives have been met by the Cowichan Bay tributaries.

Table 16. Summary of the parameters at the sites in the tributaries to Cowichan Bay that did (Y) and did not (N) meet the provisional objectives in the summer and fall samples of 2022.

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Summer	CBT1	CBT2	CBT3	CBT4	CBT5	CBT6	CBT7	CBT8	CBT9	CBT10	CBT11	CBT12	CBT13
E. coli	N	N	ND	ND	N	ND	ND	ND	N	N	N	N	INC
DO	Y	Y	Y	ND	N	ND	ND	INC	N	N	Y	N	INC
Turbidity	N	Y	ND	ND	Y	ND	ND	ND	N	N	N	N	INC
Phosphorus -T	N	N	ND	ND	N	ND	ND	INC	N	N	N	N	INC
Copper - T	No Data												
Lead - T	No Data												
Zinc - T	No Data												
Fall	**CBT1**	**CBT2**	**CBT3**	**CBT4**	**CBT5**	**CBT6**	**CBT7**	**CBT8**	**CBT9**	**CBT10**	**CBT11**	**CBT12**	**CBT13**
E. coli	N	N	N	ND	N	ND	ND	INC	N	N	N	N	N
DO	Y	Y	Y	ND	Y	ND	ND	Y	N	N	Y	N	Y
Turbidity	N	Y	N	ND	N	ND	ND	INC	Y	N	N	N	N
Phosphorus -T	N	N	N	ND	N	ND	ND	ND	N	N	N	N	N
Copper - T	N	N	N	ND	N	ND	ND	ND	N	N	N	N	N
Lead - T	Y	Y	Y	ND	Y	ND	ND	ND	Y	Y	Y	Y	Y
Zinc - T	N	Y	Y	ND	?	ND	ND	ND	N	N	Y	N	N

ND = No Data, INC = Incomplete data. The sites that did not meet the objectives (N) are shaded. Summer is 22-Aug-22 to 19-Sept-22 and Fall is 31-Oct-22 to 28-Nov-22.

? = problem with the COA with total zinc 4.33 micrograms/L while dissolved is 7.17 micrograms / L

5.4. Cowichan Bay Marine

5.4.1. Microbiology

Both fecal coliforms and enterococci were analyzed for the Cowichan Bay marine sites. Because of the greater ability of enterococci to withstand high salt concentrations, it is considered that enterococci are more reliable indicators of fecal contamination in marine environments than *E. coli* and fecal coliforms (Byappanahali *et al.* 2012).

5.4.1.1. Fecal Coliforms

Table 17 outlines the analyses for fecal coliforms in the Cowichan Bay marine sites. The highest levels in the summer were CBM6-8 (floating home sites) and in the fall were seen at CBM4 (near Botwood Lane storm drain) and CBM6-9 (floating home sites).

Table 17. The geometric mean (GM) for fecal coliforms sampled in Cowichan Bay on five dates in summer (22-Aug-22 to 20-Sept-22) and fall (31-Oct-22 to 28-Nov-22). Shaded cells failed to meet objectives.

Site Code	CFU/100mL*	
	GM - Summer	GM - Fall
CBM1	3	7
CBM2	8	7
CBM3	15	4
CBM4	4	34

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CBM5	16	8
CBM6	32	30
CBM7	24	36
CBM8	37	163
CBM9	14	47

**The objective for bivalve harvesting is a geometric mean ≤ 14 MPN/100 mL (or ≤ 14 CFU/100 mL). Values that exceed the limit are shaded.*

There are some data for the summer fecal coliforms for the Cowichan Bay marine sites in 2013 but not in 2012. Fecal coliform levels in 2022 are generally 2-4 times higher than for the sites for which there are 2013 fecal coliform data (**Table 18)**.

Table 18. Comparison of the Geometric Means of the Summer Fecal Coliform Data for 2013 and 2022 for the Cowichan Bay Marine Sites

Site	Summer 2013	Summer 2022
CBM1	ND*	3
CBM2	ND	8
CBM3	5	15
CBM4	ND	4
CBM5	8	16
CBM6	7	32
CBM7	9	24
CBM8	23	37
CBM9	5	14

**No data*

Fecal coliforms at the various Cowichan Bay marine sites in the fall generally are improved in 2022 compared to 2013 (**Table 19**) with one exception, CBM8 (Floating Home #3). Note that in the fall of 2012, not one marine site met the Water Quality Objective of a geometric mean of 14 or fewer fecal coliforms per 100 mL. In the fall of 2013, only three sites were sampled, of which two met the objectives. In the fall of 2022, five of the nine sites did not meet the objective.

Table 19. Comparison of Geometric Means of Fecal Coliforms for the Cowichan Bay Marine Sites for the Fall of 2012, 2013 and 2022

Site	Fall 2012	Fall 2013	Fall 2022
CBM1	18	ND*	7
CBM2	115	ND	7
CBM3	22	1	4

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Site	Fall 2012	Fall 2013	Fall 2022
CBM4	75	16	34
CBM5	29	7	8
CBM6	350	ND	30
CBM7	280	ND	36
CBM8	70	ND	163
CBM9	220	ND	47

**No data*

5.4.1.2. Enterococci

The geometric mean and median values (CFU/100 mL) of enterococci for Cowichan Bay marine sites are given in **Table 20.** All values are based on N = 5.

The objective for shellfish harvesting is a median (or geometric mean) of 4 or fewer CFU/100 mL. In the summer CBM2 (Cowichan Bay shoreline at PE1538 outfall) and CBM6-9 (floating homes) did not meet the objectives. Not one of the nine sites met the objectives in the fall.

The guideline for recreational and cultural use is a geometric mean of ≤35 CFU/100mL. One site exceeded the guideline (CBM8) in the summer while four did not meet the guideline in the fall (CBM6-9). All these sites are adjacent to floating home.

Table 20. The geometric mean (GM) and median (M) for *Enterococci* levels (CFU/100mL) for the summer 22-Aug-22 to 20-Sep-22) and fall samples (31-Oct-22 to 28-Nov-22) at the nine sites in Cowichan Bay in 2022. The CFU/100mL guideline for recreational and cultural use is a geometric mean ≤ 35 CFU/100mL.

The cells (GM – Summer & GM – Fall) that are shaded exceed the guideline for recreational and cultural use. The objective from Smorong et al. 2021 for shellfish harvesting is a median of ≤ 4 CFU/100mL) The cells (M – Summer & M – Fall) for values that exceed the objective for shellfish harvesting are shaded. The maximum provisional objective for recreational and cultural use for a single sample of enterococci is ≤70 CFU/100 mL.

	Recreation & Cultural Use.		Shellfish harvesting	
Site code	GM -Summer	GM - Fall	M - Summer	M - Fall
CBM1	2	10	1	13
CBM2	3	19	6	20
CBM3	2	26	1	20
CBM4	2	36	2	42
CBM5	5	9	4	9
CBM6	33	37	39	38
CBM7	19	59	50	53
CBM8	54	108	64	116
CBM9	21	37	25	31

Table 21 gives the enterococci data for single sample values for Cowichan Bay marine sites. It can be seen that sites CBM3 to CBM8 failed to meet the recreational and cultural guideline on one or more times to meet this guideline.

Table 21. *Enterococci* data for the 9 sites in Cowichan Bay in 2022 The maximum guideline – recreational and cultural use - for a single sample is ≤ 70 CFU/100mL. Cells containing the data that exceed the guideline are shaded.

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Date	CBM1	CBM2	CBM3	CBM4	CBM5	CBM6	CBM7	CBM8	CBM9
22-Aug-22	1	6	1	9	73	59	50	56	4
29-Aug-22	1	7	1	2	10	10	1	9	4
05-Sep-22	3	1	1	1	1	158	77	105	25
12-Sep-22	1	1	14	1	4	10	10	140	200
20-Sep-22	8	12	1	3	1	30	69	64	57
31-Oct-22	57	28	110	129	101.5	81	108	111	210
07-Nov-22	16	55.5	20	64	16	56	42	52	31
14-Nov-22	1	7	20	20	2	20	55	200	30
21-Nov-22	9	12	10	10	2	20	50	120	10
28-Nov.22	6	18	10	40	4	460*	30	150	10

**This is the value given in the COA and excel file*

Table 22 is a comparison of geometric means of enterococci levels in Cowichan Bay marine sites from data collected in the fall of 2012, 2013 and 2022. Little has changed over the past decade. CBM2 (Cowichan Bay shoreline at PE1538 outfall) has improved over 2012 while CBM3 (Head of Genoa Bay), CBM8 (Floating Home #3) and CBM9 (Floating Home #4) are slightly worse off. In general, enterococci levels for Cowichan Bay marine sites were either similar to a decade ago with CBM2 (Cowichan Bay shoreline at PE1538 outfall) improving substantially and CBM8 (Floating Home 3) being worse. We also saw similar trends with the fecal coliform data.

Table 22. Enterococci Geometric Means for Cowichan Bay Marine Sites for the Fall of 2012, 2013 and 2022

Site	Fall 2012	Fall 2013	Fall 2022
CBM1	17	ND	18
CBM2	228	ND	20
CBM3	22	7	34
CBM4	94	9	53
CBM5	16	30	25
CBM6	ND*	131	127
CBM7	ND	55	57
CBM8	ND	19	127
CBM9	ND	16	58

**No data*

The geometric mean for the summer enterococci levels were generally somewhat higher in 2022 compared to 2013 for CBM5 to CBM9 sites as seen in **Table 23**

Table 23. Geometric Means of Enterococci Levels for Cowichan Bay Marine Sites for the Summers of 2013 and 2022

Site	Summer 2013	Summer 2022
CBM1	ND*	3
CBM2	ND	5
CBM3	3	4
CBM4	ND	3

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CBM5	5	18
CBM6	14	53
CBM7	11	41
CBM8	33	75
CBM9	7	58

**No data*

6.0. DISCUSSION OF RESULTS

6.1. Sampling Sites

Three areas were sampled in the summer (August/September) and fall (October/November) of 2022 for an assessment of water quality. These were seven sites in the lower Koksilah River and its tributaries, nine sites in the tributaries that run directly into Cowichan Bay and nine marine sites in Cowichan Bay. Of relevance to this report the following freshwater parameters were analyzed: *E. coli* levels, water temperature, dissolved oxygen, turbidity, the nutrients ammonia, nitrate and phosphorus, the metals copper, lead and zinc. Marine sites were analyzed for fecal coliforms and enterococci.

6.2. Rainfall

The year 2022 was an unusual sampling year in that both the summer, but particularly the fall, had very little rainfall.

6.3. Missing Data

Some of the data for dissolved oxygen and temperature are missing for the KRB sites (**Table 24**). Dissolved oxygen and temperature were taken during all the sampling dates in the summer and fall. What has happened to the field notes is unclear. We suggest that all field notes be copied and a copy kept in the Watershed Office and made accessible to report writers.

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Table 24. Summary of available (Y) and missing (N) data from the Koksilah River Basin sampling sites in summer (22-Aug-22 to 19-Sept-22) and fall (31-Oct-22 to 28-Nov-22).

Parameter	Summer Data	Fall Data
E. coli	Y	Y
Turbidity	Y	Y
Phosphorus - Total	Y	Y
Ammonia-N	N	Y
Nitrate-N	N	Y
Copper – Total	only KRB1	Y
Copper - Dissolved	only KRB1	Y
Lead – Total	N	Y
Lead – Dissolved	N	Y
Zinc - Total	N	Y
Zinc - Dissolved	N	Y
Dissolved Oxygen	No Aug 22 or Sept 5 data	No KRB7 & KRB9 Oct 31 No KRB3,5,6,7 &9 Nov 14
Temperature	No Aug 22 data No KRB 1,2,5,6,7,9 Aug 29 No KRB5 Sept 19	No KRB3,5,6,7 & 9 Nov 14

*There is missing data for the Cowichan Bay Tributary sites (**Table 25**).*

Table 25. Summary of available and missing data from the Cowichan Bay Tributary sampling sites in summer (22-Aug-22 to 19-Sept-22) and fall (31-Oct-22 to 28-Nov-22). Specific sites and dates are given where necessary.

Parameter	Summer Data	Fall Data
E. coli	No CBT3, 4, 7 & 8 CBT13 only 0n Aug 22	No CBT4, 6 & 7 CBT8 only on Oct 31 & Nov7
Turbidity		
Phosphorus - Total		
Nitrate - N	N	
Copper – Total	N	
Copper - Dissolved	N	
Lead - Total	N	
Lead - Dissolved	N	
Zinc – Total	N	
Zinc – Dissolved	N	
Dissolved oxygen	No data or incomplete	No data or incomplete
Temperature	No data or incomplete	No data or incomplete

N=No data

6.4. Microbiology

No freshwater sites sampled met the microbiological water quality objectives. The source(s) of *E. coli* is/are not known. In 2012, however, *E. coli* sources were determined (Smorong and Saso, 2021). Most of the 2012 Koksilah River Basin sites sampled had ruminants and pigs as the main source of *E. coli*; however, there was one exception, KRB2 (Petrolas Creek at Moss Road) that had *E. coli* of human source as well.

According to Appendix 1 of Smorong and Saso (2021), of the Cowichan Bay Tributary sites sampled in 2012, only CBT5 (Storm drain at Botwood Lane) and CBT11 (Manley Creek at the end of Hatchpoint Road) were negative for both human and ruminant *E. coli*. CBT1 (Treffery Creek at Cowichan Bay Road) and CBT13 (Treffery Creek at the TCH) were negative for human *E. coli* but contained ruminant *E. coli*. CBT3 (Wessex Creek at Wessex Inn), CBT8 (Storm drain at Cherry Point Marina), CBT10 (Garnett Creek at Telegraph Road) and CBT12 (Speirs Creek at Hillbank Road) had both human and ruminant-sourced *E. coli*.

Only two of the Cowichan Bay marine sites met the summer and fall water quality objectives for shellfish harvesting. Summer values for fecal coliforms in 2022 were generally higher than when sampled in 2013, whereas the fall values tend to be lower in 2022 compared to the fall of 2012. In 2022, only two sites met enterococci water quality guideline for recreational and cultural use during the entire sampling period. The source(s) of these fecal coliforms is/are not known; however, the fecal coliforms in the Cowichan Bay marine sites sampled in 2012 were identified as coming both from ruminants and humans (Smorong and Saso, 2021).

The Recreation and Cultural Use Water Quality Objective for enterococci is ≤35 CFU/100 mL geometric mean over five samples and no single sample being greater than 70 CFU/100 mL. CBM6, CBM7 and CBM8 failed to meet these objectives in the summer while CBM3-CBM9 failed to meet these objectives in the fall. Only CBM1 (Cowichan Bay above Lambourn Holdings) and CBM2 (Cowichan Bay shoreline at PE1538 outfall) met the objectives in both the summer and fall. Little has changed over the past decade.

We note that sites sampled near the floating homes tend to have the highest fecal coliforms and enterococci levels.

6.5. Water Temperature

During the summer sampling period, temperature was reported on only three of the five sampling dates, although taken on all five days. The Objective is a weekly mean of ≤17° C; however, only one temperature reading was done each week. We considered this one reading was representative of the week. Most freshwater sites met the summer water quality objective for temperature, the major exceptions being the Koksilah River at Bright Angel Park (KRB5) and also at Koksilah Road (KRB3). This is likely because the river is shallow and broad here with little shade and little flow. The fall temperature objective was met for the Koksilah River Basin sites.

The fall temperature objective was not met for the following Koksilah River Basin sites: KRB5 (Koksilah River at Bright Angel Park for one reading) KRB6 (Norrie Creek at Koksilah Road for two readings) KRB7 (Kelvin Creek at Koksilah Road for two readings) and KRB9 (Glenora Creek at Doupe Road for one reading). The failure to meet the fall temperature objective at these sites is likely due to an abnormally warm fall plus lack of normal fall rains.

Both the summer and fall water temperature objective was met by the Cowichan Bay Tributary sites.

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6.6. Dissolved Oxygen

Many of the Koksilah River Basin sites did not meet the objective for dissolved oxygen (weekly mean ≥8 mg/L) during many of the sampling periods in the summer. These sites included Koksilah River at the TCH, Norrie Creek at Koksilah Road, Kelvin Creek at the Koksilah Road and on one occasion the Koksilah River at Bright Angel Park. All these sites were characterized by being unshaded, shallow, and slow flowing or no flowing water. It is possible that the increased use of groundwater in the lower Koksilah River Basin has resulted in decreased flow in the Koksilah River Tributaries. The slow summer flow in the Koksilah River itself may be attributed in changes in the upper watershed.

Figure 22 shows that there has been increased flashiness of flow in the river over the past six decades. Note that total annual flow has changed little over time, but August flow has markedly decreased. Unless there are changes in the upper Koksilah River watershed, we will see that water temperature and dissolved oxygen content will likely worsen with climate change.

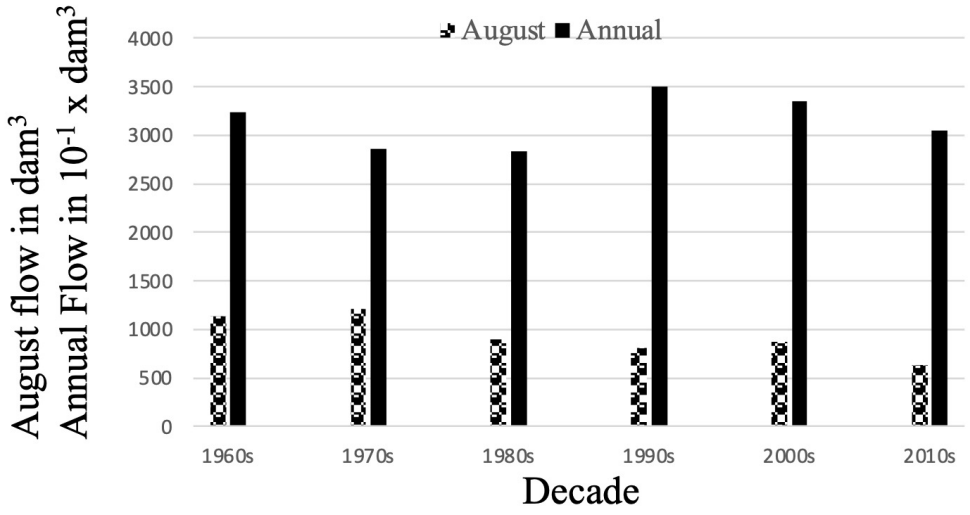

Figure 23. *Koksilah River mean annual decadal flow as well as mean August water flow at Cowichan Station. Data taken from Hydrometric Station 08HA003.*

The decreased August flow noted in Figure 22 correlates with the large loss of old growth forest in the Koksilah River watershed in the 1970s as noted in Pritchard *et al.* 2019.

Several Koksilah River Basin sites did not meet the fall dissolved oxygen objective (mean ≥11.2° C). These sites were: KRB5 (one time), KRB6 (two times), KRB7 (two times and KRB9 (one time). These are the same sites where the temperature objectives were not met; hence, the abnormally high October temperatures and low rainfall likely accounted for failure to meet the objectives.

Many, but not all Cowichan Bay Tributary sites met the provisional summer objectives for dissolved oxygen (weekly mean ≥8 mg/L). However, on two occasions the summer dissolved oxygen objective was not met for CBT10 (Garnett Creek at Telegraph Road) and on one occasion the objective was not met for CBT9 (Garnett Creek at Cherry Point Beach) and CBT11 (Manley Creek at the end of Hatchpoint Road). All but two Cowichan Bay Tributary sites met the fall dissolved oxygen provisional objectives (weekly mean ≥8 mg/L).

6.7. Turbidity

Only two Koksilah River Basin sites did not meet the turbidity objective: KRB2 (Petrolas Creek at Moss Road) and KRB6 Norrie Creek at Koksilah Road). The reason for this requires further investigation.

Only one Cowichan Bay Tributary site met the provisional objective for turbidity at all sampling dates, this was (CBT2 (Speirs Creek at Cowichan Bay Road). CBT5 (Storm drain at Botwood Lane) met the objectives for the first four sampling dates while CBT1 (Treffery Creek at Cowichan Bay Road) was just at the border of meeting and not meeting the objective during the summer sampling period. The remaining sites did not meet the objective. Without an onsite inspection of these sampling sites, it is difficult to account for the findings. No site in the fall met the provisional objectives for turbidity for all the sampling periods.

6.8. Nutrients

Although there are no objectives for nitrate-N, all Koksilah River Basin sites and all Cowichan Bay Tributary sites had nitrate-N below the BC guideline for the protection of freshwater aquatic life. Only the Koksilah River basin had a Water Quality Objective for ammonia-N for summer (0.49 mg ammonia-N/mL) and fall (3.61 mg ammonia-N/mL). Only the fall was tested for ammonia-N and all sites met the objective.

All Koksilah River Basin sites and all Cowichan Bay Tributary sites failed to meet the objective for total phosphorus. The source of this phosphorus is unclear but possible sources are agricultural practices. The total phosphorus is both organic and inorganic as well as adsorbed and available. Orthophosphate is the available form and was not measured. However, the sites with the highest concentrations of total phosphorus correspond to those with the highest turbidity suggesting that much of the phosphorus may be adsorbed.

6.9. Metals

The Koksilah River Basin sites all met the objectives for metals. In 2012, KBR3 (Koksilah River at Koksilah Road) did not meet the objectives for copper and zinc. There was no metal testing reported for 2017. The cause of the elevated copper and zinc in 2012 is not clear; however, this problem was no longer present in the fall of 2022.

Most of the Cowichan Bay Tributary sites did not meet the copper objective and many did not meet the zinc objective. These high metal values are likely accounted for by the high groundwater level for these metals (Barroso and Melnechenko, 2019).

7.0. RECOMMENDATIONS

1. The 2022 data had missing sample sites and missing parameters (Tables 24 & 25). The missing sites were in part due to lack of stream flow, but the missing parameters were not explained. We recommend that good field notes be included with the data so that any missing information is explained, and all data collected are recorded. We also recommend that a photocopy of the field notes be retained in the Cowichan Watershed Board office. **Note**: It seems that some of the field data were recorded, but somehow went missing. Detailed procedures for handling the data should be documented.
2. As a separate project the streams and river sites should be explored to determine potential point and non-point sources that may impact water quality. These inputs include small ditches, subsurface flows from the banks or cattle accessing stream, etc.

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3. The source of the high levels of *E. coli* should be determined using Microbial Source Tracking (MST). In 2012 MST found that the main sources in fresh water (Koksilah River and tributary streams to Cowichan Bay) were ruminants and pigs. Ruminants include domestic animals (e.g., cattle, sheep, and goats) as well as wild animals (e.g., deer). The *E. coli* may be from the animals on the fields adjacent to the freshwater streams and from manure applied to the agricultural land. Human *E. coli* are most probably from septic fields. Once the MST results are available, they can be used to recommend any remedial measures.
4. The source (human, other mammals, or birds) of the fecal coliforms and enterococci should be determined for the Cowichan Bay marine sites using Microbial Source Tracking. It is concerning that sites adjacent to the floating homes tend to be high in both fecal coliforms and enterococci.
5. It is recommended marine sampling sites to be also located in the western part and north-western part of Cowichan Bay, near the outflows of the branches of the Koksilah and Cowichan Rivers.
6. High concentrations of total phosphorus were found at all freshwater sites. Potential sources of phosphorus include fertilizer (synthetic and manure) and decomposition of organic materials such as leaf litter that may fall from riparian areas into the streams. The phosphorus can come from surface runoff and subsurface flow. Not all forms of phosphorus are available to autotrophs (plankton and algae) and the numerous forms of phosphorus are in dynamic equilibrium. Effort should be made to identify sources and initiate remedial measures. It is also recommended that orthophosphate, the form available to plankton and algae, be measured.
7. Suspended solids were not measured, and turbidity was used as a proxy. It is useful to note that sites with the highest phosphorus also had the highest turbidity. This suggests that much of the phosphorus was adsorbed and not available. Suspended solids should be included as a sample parameter. It is one of the objectives.

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APPENDICES

Appendix 1: Field Safety Instructions

SURFACE WATER QUALITY STEWARDSHIP TOOLBOX

Field Safety

Gear/supplies to have:

1. Sturdy non-slip footwear, appropriate clothing/protection for the weather
2. Gear for water conditions (e.g., life jacket, throw bag, wading staff)
3. Reflective vests
4. Cell phone and/or satellite location device
5. First-aid kit including emergency contact information
6. VHF radios if available for calling on active logging roads (programmed with necessary radio frequencies)
7. Hard hat (required on/near logging roads or when working near overhead hazards)
8. Map and directions, access agreement for private land access, permission from forestry company for logging road use, if applicable
9. Water, lunch

Conduct & Safety:

1. Be safety trained (forestry road use, basic first aid, bear aware, swift water awareness, etc.)
2. Always sample with a partner (buddy system)
3. Tell a responsible person where you are going (field trip plan), check-in times, and when you will be back. Follow your trip plan and check in as scheduled
4. Tailgate meetings - Assess weather or environmental hazards and how to mitigate them prior to conducting fieldwork
5. Park well off the side of the road. Use hazard lights and safety cones if close to road
6. Be familiar with site and surroundings
7. No smoking
8. No ATVs near streams
9. Be very careful around slippery rocks and high flows
10. Stay aware for both wildlife and human interactions. Follow appropriate wildlife safety procedures if applicable: https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/human-wildlife-conflict/staying-safe-around-wildlife
11. Never sample if you feel it is unsafe to do so

When on logging roads:

1. Understand standard radio and road use procedures on forestry roads. Radio frequencies and procedures for radio use on Forest Service Roads across the province can be found at: https://www2.gov.bc.ca/gov/content/industry/natural-resource-use/resource-roads/radio-communications. Training video: Radio Use and Road Calling Procedures - YouTube
2. Always follow road procedures recommended by the signage at the start of the mainline (posted by Province or forestry companies operating in the area)
3. Bring gate keys when necessary and inform companies when you will be on their roads if on private forest land

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4. Use extra caution
5. Turn headlights on
6. Observe signs of applicable radio frequency, set radio to appropriate frequency/channel and be aware of possible changes in frequency
7. Use radio to update position and listen for location of vehicles sharing the road. Example:
8. Call to advise of new vehicle entering logging road (e.g., “pick-up off of highway starting up Duncan Main”)
9. When passing kilometer markers, update location including truck description (pick-up), km mark (e.g., 2 km), road (e.g., Duncan Main), and direction (e.g., when km markers are counting up say ‘up’, when km markers are counting down say ‘down’)
10. Update the team when changing roads (e.g., “pick-up off of Duncan Main onto Pigeot Main”)
11. Give right-of-way to logging trucks, low-beds, commercial and emergency vehicles
12. Use pullout/pull over to the side of the road and come to a complete stop when trucks approaching. Announce if pulling off road and clear for oncoming traffic
13. Do not stop on blind corners
14. Use caution and drive to road conditions, do not depend entirely on the radio (MAX 80 km/hr or the speed posted)

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Appendix 2: Sampling Procedures

BRITISH COLUMBIA Ministry of Environment and Climate Change Strategy

SURFACE WATER QUALITY STEWARDSHIP TOOLBOX

Grab Sample Procedures

Sampling in fresh water often includes a current, so there are specific steps for collecting a sample to prevent contamination of the sample by the sampler.

The following steps will help preserve the quality of your samples:

- Prior to arrival at the site, ensure that any samples that require preservative are packed with the correct preservative. Additionally, ensure that enough ice is packed into the coolers.
- Put gloves on prior to working with water samples or preservatives to protect yourself from preservatives and to prevent contamination of samples.
- A sample bottle should only be opened to collect a sample to prevent contamination.
- Avoid entering the stream until after samples have been collected. If you need to cross the stream to reach the location, cross downstream of the sample site.
- If any information needs to be filled in on the label, fill the labels with pencil before collecting the sample. The wet labels are much harder to fill in.

The following are steps for collecting a sample.

1. Wearing gloves, orient yourself facing upstream holding the sample bottle.
2. Remove the lid from the bottle and dip it into the stream with the mouth of the bottle pointing upstream. The mouth of the bottle should be below the surface, and the bottom of the bottle should not touch the bottom of the stream.
3. Fill the bottle to the fill line or to the top. If you overfill a bottle that does not have preservative in it already, empty it onto the bank to prevent agitating the stream bottom and contaminating additional samples. If a bottle comes with preservative inside already (as a dry powder) you should do your best to fill to the fill line.
4. Replace the lid on the bottle. If any preservatives need to be added, add them to the bottle after the sample is collected. The bottle needs to be empty enough for the full volume of preservative to be added and mixed.
5. Repeat the collection procedures until all bottles are filled.

After all bottles are filled at a site, the bottles should be placed into the cooler with ice to be shipped to the lab. Once all sites have been sampled, the coolers should be sealed with packing or fiber tape with the Chain of Custody form enclosed and a shipping label attached to the lid, addressing the package to the analysis lab (ALS Global).

Appendix 3: Field team members' participation per week

Name / Week	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Date	**22-Aug**	**29-Aug**	**05-Sep**	**12-Sep**	**19-Sep**	**31-Oct**	**07-Nov**	**14-Nov**	**21-Nov**	**28-Nov**
Volunteer Team (freshwater)										
Alison Rimmer	x	x	x	x	x	x	x	x	0	x
John Lofto	x	x	x	0	0	0	0	0	0	0
Anna Scouten	0	0	x	x	x	x	x	0	0	0
Bernie Juurlink	x	x	x	x	x	x	x	x	x	x
Cliff Stainsby	x	x	x	x	x	x	x	x	x	x
Bill Lawrence	x	x	x	x	x	x	x	x	x	x
Scott Noble	0	0	0	0	0	x	x	x	x	x
Sarah Davies Long	0	0	0	0	0	x	0	x	x	x
Jill Thompson	0	0	0	0	0	0	0	x	0	0
Cowichan Tribes Team (marine)										
Tim Kulchyski	x	x	0	0	x	0	0	0	0	0
Audra Stacey	x	x	x	x	x	0	0	x	x	x
CT member 1 - name unknown	0	0	x	0	0	0	0	0	0	0
CT member 2 - name unknown	0	0	0	x	0	0	0	0	0	0
John Stewart	0	0	0	0	0	x	x	0	0	0
John Elliott	0	0	0	0	0	x	x	x	0	0
Clark Jonny	0	0	0	0	0	0	0	0	x	x

x = participated, 0 = did not participate

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