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# Cowichan Bay and Tributaries: Water Quality Assessment and Recommended Objectives

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## EXECUTIVE SUMMARY

This report summarizes water and sediment quality data collected in 2012-13 for the freshwater tributaries to Cowichan Bay, as well as at sites within the bay, to determine if local activities are impacting water uses within the watershed. Water uses to be protected in the Cowichan Bay marine areas include: aquatic life – shellfish harvesting, and recreation (primary and secondary contact). Water uses to be protected in the Tributaries to Cowichan Bay (freshwater) include: aquatic life, drinking water, wildlife, recreation and irrigation. Potential sources of contamination associated with urban and rural households and agricultural activities (such as runoff, septic fields, fertilizers and pesticides) as well as commercial and industrial uses, including forestry related activities, may impact water quality in the Cowichan Bay study area. Overall, the findings from this study indicate that water quality in the watershed were generally good, with periodic water quality impairments usually associated with rainfall events. Tributary streams showed occasional elevated turbidity, TSS, total copper, total zinc, dissolved aluminum, total and dissolved iron, total phosphorus and *E. coli*. The marine portion of the study area showed occasional elevated enterococci and fecal coliforms. Microbial source tracking showed some of the microbiological results had anthropogenic sources. Further investigation should occur to better identify specific sources of water quality contaminants.

*Recommended Water Quality Objectives for the Cowichan Bay and tributaries.*

| Variable | Objective | Applies to | Objective adopted from: |
|---|---|---|---|
| Enterococci | ≤ 4 CFU/100 mL (median) | Marine water | BC WQG |
| Fecal coliforms | ≤ 14 CFU/100 mL (median) | Marine water | BC WQG |

[1]Unless otherwise specified, all statistics are to be calculated based on five weekly samples in 30 days.

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# 1. INTRODUCTION

## 1.1 Program Background

The British Columbia (BC) Ministry of Environment and Climate Change Strategy (ENV) is conducting a program to assess water quality in priority watersheds. The purpose of this program is to accumulate the baseline data necessary to assess both the current state of water quality and long-term trends, and to propose ambient water quality objectives on a watershed specific basis.

Water quality objectives provide goals that need to be met to ensure protection of designated water uses. The inclusion of water quality objectives into planning initiatives can help protect watershed values, mitigate impacts of land-use activities, and protect water quality in the context of both acute and chronic impacts to human and aquatic ecosystem health. Water quality objectives provide direction for resource managers, serve as a guide for issuing permits, licenses, and orders by ENV, and establish benchmarks for assessing the Ministry's performance in protecting water quality. Water quality objectives and attainment monitoring results are reported out both to local stakeholders and on a province wide basis through forums such as State of the Environment reporting.

Vancouver Island's topography is such that the many watersheds on Vancouver Island are generally small (<500 $km^2$). As a result, the stream response times can be relatively short and opportunities for dilution or settling are often minimal. Rather than developing water quality objectives for these watersheds on an individual basis, an ecoregion approach has been implemented. The ecoregion areas are based on the ecosections developed by Demarchi (1996). However, for ease of communication with a wide range of stakeholders the term "ecoregion" has been adopted by Vancouver Island ENV regional staff. Thus, Vancouver Island has been split into six terrestrial ecoregions, based on similar climate, geology, soils and hydrology (Figure 1).

Fundamental baseline water quality should be similar in all streams and all lakes throughout each ecoregion. However, the underlying physical, chemical and biological differences between streams and lakes must be recognized. Representative lake and stream watersheds within each ecoregion are selected (initially stream focused) and a three-year monitoring program is implemented to collect water quality and quantity data, as well as biological data. Standard base monitoring programs have been established for use in streams and lakes to maximize data comparability between watersheds and among ecoregions, regardless of location. Water quality objectives will be developed for each of the representative lake and stream watersheds, and these objectives will also be applied on an interim basis to the remaining lake and stream watersheds within that ecoregion. Over time, other priority watersheds within each ecoregion will be monitored for one year to verify the validity of the objectives developed for each ecoregion and to determine whether the objectives are being met for individual watersheds.


*Figure 1. Map of Vancouver Island Ecoregions.*

Partnerships formed between the ENV, local municipalities, other stakeholders and stewardship groups are a key component of the water quality network. Water quality sampling conducted by the public works departments of local municipalities and stewardship groups has enabled the Ministry to significantly increase the number of watersheds studied. These partnerships have allowed the Ministry to study watersheds over a greater geographic range and in more ecoregions across Vancouver Island, have resulted in strong relationships with local government and interest groups, provided valuable input and local support and, ultimately, resulted in a more effective monitoring program.

## 1.2 Site Specific Background

The estuary of the Cowichan and Koksilah rivers is in Cowichan Bay, near the City of Duncan and about 40 kilometers north of Victoria, on Vancouver Island. Numerous small tributaries that are part of ten major (1:50 000 mapping) watersheds also drain into the bay (DataBC, 2015a). The area near the Cowichan Estuary is the traditional land of the Cowichan people. European settlement began in the late 1800’s and fishing, agriculture and logging have been the primary land uses within the Cowichan Bay study area (CCLT, 2004).

The demand for industrial use in the estuary and bay has conflicted with concerns to protect the environmental resources in the area. The Cowichan Estuary is valued for rearing salmon and overwintering water birds due to the high quality of fish and wildlife habitat (Lambertsen, 1987). Diking for agriculture, filling for industrial and commercial uses, log handling, and water pollution by waste discharges, sewage disposal, and agricultural runoff has caused the loss and degradation of habitat in the estuary (Lambertsen, 1987).

The Cowichan Bay study area has high recreational and fisheries values, with cutthroat trout, coho salmon, and chum salmon present in some freshwater tributaries at some point during the year (Habitat Wizard, 2015), and opportunities for fishing, prawning and crabbing in the marine areas. Marine waters of Cowichan Bay contain shellfish beds (historically harvested) that have been closed since the 1970's due to forestry-related impacts, agriculture and sewage discharge from urban development (DFO, 2019; CERCA, 2015). Cowichan Bay is also used for boating, with a marina located within the Bay, and Hecate Park is a 6.2-acre waterfront park located on the southern portion of the Bay (CVRD, 2015).

Private land is bound by general laws such as the *Drinking Water Protection Act, the Fisheries Act, Water Act, Wildlife Act*, and the *Private Managed Forest Land Act*. The ENV relies on such legislation and uses tools (including Water Quality Objectives) to ensure that all watersheds and /or water supplies are managed in a consistent manner and to protect water quality within these watersheds.

The study area does not include community watersheds, as defined under the *Forest Practices Code of British Columbia Act* ("the drainage area above the downstream point of diversion and which are licensed under the *Water Act* for waterworks purposes") (DataBC, 2015b).

The BC *Drinking Water Protection Act* (administered by the Ministry of Health and implemented by Regional Health Authorities) sets minimum disinfection requirements for all surface supplies as well as requiring drinking water to be potable. Island Health (previously called the Vancouver Island Health Authority; VIHA) determines the level of treatment and disinfection required based on both the source and end-of-tap water quality. As such, VIHA requires all surface water supply systems to provide two types of treatment processes (VIHA, 2010). There is a community water system, operated by the Cowichan Bay Waterworks Improvement District, which is the largest purveyor of water services in the area and is responsible for ensuring that water quality meets the Canadian Drinking Water Guidelines (CVRD, 2013). The source of this water is not from surface waters within the study area. VIHA continues to allow the CVRD to provide drinking water treated by disinfection (chlorination) only, with the understanding that the CVRD is working towards implementing a second step of treatment (Doyle-Yamaguchi, *pers. comm.*, 2014).

Where community water service is not provided (rural residential, agricultural, and First Nations Reserves) domestic water is mainly drawn from groundwater aquifers (CVRD, 2013) (see Section 3.5). Domestic water licenses for the various tributaries are issued to individuals, who are responsible for treating their own drinking water prior to consumption.

Anthropogenic land uses within the study area have included residential development, agriculture, recreation, commercial/industrial, fishing and logging (CCLT, 2004). These activities, as well as natural erosion and the presence of wildlife, all potentially affect the water quality in the freshwater and marine areas of the Cowichan Bay study area.

Maintenance of the microbiological quality and safety of waterbodies for recreational use and shellfish harvesting is essential to prevent risks to human health and economic losses due to shellfish harvesting closures. A stringent standard for shellfish growing water is necessary due to the filter feeding mechanism of bivalve shellfish that can concentrate bacteria (Warrington, 2001). A sanitary closure to bivalve shellfish harvesting in Cowichan Bay is currently in place (DFO, 2019).

There is a high level of community involvement and awareness regarding the value of the estuarine and marine environment and there have been numerous government and non-government organizations actively involved with projects related to estuarine habitat enhancement. The following organizations are actively involved in protecting the ecological integrity of the area: Cowichan Estuary Preservation Society, Cowichan Estuary Restoration and Conservation Association, Cowichan Estuary Nature Centre, Cowichan Tribes, Cowichan Land Trust. The Cowichan Estuary Environmental Management Plan (CEEMP) was developed through the late 1970's and was completed in 1987 to provide a framework for future management of the estuary. The management plan area encompasses multiple jurisdictions and land-uses: Village of Cowichan Bay; First Nations traditional lands; industrial leases of Crown lands; parcels under the management of the municipality of North Cowichan; the Cowichan Valley Regional District; national and international conservation organizations and; private landholders.

The ENV Environmental Protection Division worked in partnership with the CVRD, Island Health, Cowichan Tribes, Cowichan Land Trust and Cowichan Watershed Board 2012 and 2013 to collect marine and freshwater monitoring data in the Cowichan Bay study area. This report examines the existing water quality (2012 – 2013) of the Cowichan Bay study area (Cowichan Bay marine areas and tributaries to the Bay) and recommends water quality objectives based on potential impacts and water quality parameters of concern.

## 1.3 Water Quality Objectives

Water quality objectives are prepared for specific bodies of fresh, estuarine, and coastal marine surface waters of BC as part of ENV's mandate to manage water quality. Objectives are prepared only for those waterbodies and water quality characteristics that may be affected by human activity now or in the future.

Water quality objectives are based on scientific guidelines (BC ENV water quality guidelines available at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html) that are safe limits of the physical, chemical or biological characteristics of water, biota (plant and animal life) or sediment, which protect water use. Objectives are established in BC for waterbodies on a site-specific basis. They are derived from the guidelines by considering local water quality, water uses, water movement, and waste discharges.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. For marine waters, designated uses include: aquatic life and wildlife; shellfish harvesting; and recreation and aesthetics. For freshwater, designated uses include: aquatic life and wildlife; drinking water; livestock watering; industrial use; and irrigation. By protecting the most sensitive water use for a given water quality parameter, all designated uses for a given waterbody are also protected.

Water quality objectives have no legal standing at this time and are not directly enforced. However, they do provide policy direction for resource managers for the protection of water uses in specific waterbodies. Objectives guide the evaluation of water quality, the issuing of permits, licenses and orders, and the management of fisheries and the province's land base. They also provide a reference against which the state of water quality in a particular water body can be checked and help to determine whether area wide water quality studies should be initiated. Water quality objectives are also a standard for assessing the Ministry's performance in protecting water uses and can be integrated into an overall fundamental water protection program.

Monitoring is undertaken to determine if all the designated water uses are being protected. The monitoring usually takes place at one or more critical periods during the year, when the water quality objectives may not be met, that is generally determined as part of the water quality objective setting exercise. It is assumed that if all designated water uses are protected at the critical time(s), then they will also be protected at other times when the threat is less. For practical reasons, the monitoring usually takes place during a five-week period, which allows the specialists to measure extremes and variability in the water, and allows the calculation of statistics (including means, $90^{th}$ percentiles, etc.). For some waterbodies, the monitoring period and frequency may vary, depending upon the nature of the problem, severity of threats to designated water uses, and the way the objectives are expressed (e.g., mean and/or maximum values).

# 2. WATERSHED PROFILE AND HYDROLOGY

## 2.1 Basin Profile

The Cowichan Bay study area is approximately 80.3 $km^2$ in area, located on southern Vancouver Island (Figure 2). It is comprised of the marine areas of Cowichan Bay, as well as the numerous small freshwater tributaries flowing into the bay (listed in section 5.0). A small portion of the study includes the south-western portion of Salt Spring Island (largely undeveloped park land, including some environmentally sensitive areas (Islands Trust, 2010)). For the purposes of this report, the study area is defined as the watershed boundary shown in Figure 2.

The Cowichan Estuary (the common estuary of the Koksilah and Cowichan Rivers) is located at the west end of Cowichan Bay (Figure 2). The Koksilah River begins at Waterloo Mountain, south of the Cowichan Valley and the Cowichan River originates at Cowichan Lake. These two rivers provide most of the freshwater inflow to Cowichan Bay, thus greatly influence water quality in the bay. As these systems are so large, and have their own water quality objectives, monitoring data from 2012-2014 from these systems are presented separately in a water quality objectives attainment report (Smorong & Saso, 2021a).

The shallow water, marshes and tidal flats of the Cowichan Estuary provide some of the most biologically productive habitat in BC, essential to migrating waterfowl, anadromous fish and other species.

Carmack *et al.* (2014) have been involved in an ongoing study of the oceanography of Cowichan Bay, for which no report is yet available. However, findings of this work should be considered in future understanding of water quality observed in the bay. G3 Consulting (2020a) summarizes historical oceanographic information from several sources in detail as part of a 2018 Environmental Impact Study in Cowichan Bay. Based on their summary, currents in Cowichan Bay are a combination of marine tidal influences and estuarine circulation resulting from river inputs at the head of the bay. Water depth in the bay is fairly uniform around 50 m in the center of the bay, getting shallower closer to shore. Around Boatswain Bank depths are around 10 m, while at Separation Point depths are up to 135 m and in Satellite Channel depths are greater than 80 m. On an ebb tide, surface waters tend to flow out of the bay along the south shore (due to a back eddy at Separation Point) while deep water flows into the bay; on a flood tide the opposite occurs.

The Cowichan Bay study area falls within the Coastal Douglas-fir biogeoclimatic zone (CDFmm), characterized by a variety of tree species such as coastal Douglas-fir, grand fir, western red-cedar, Garry oak, western flowering dogwood, arbutus, hemlock, red alder and big leaf maple. The watershed falls within the Nanaimo Lowland (NAL) ecoregion (Figure 1).

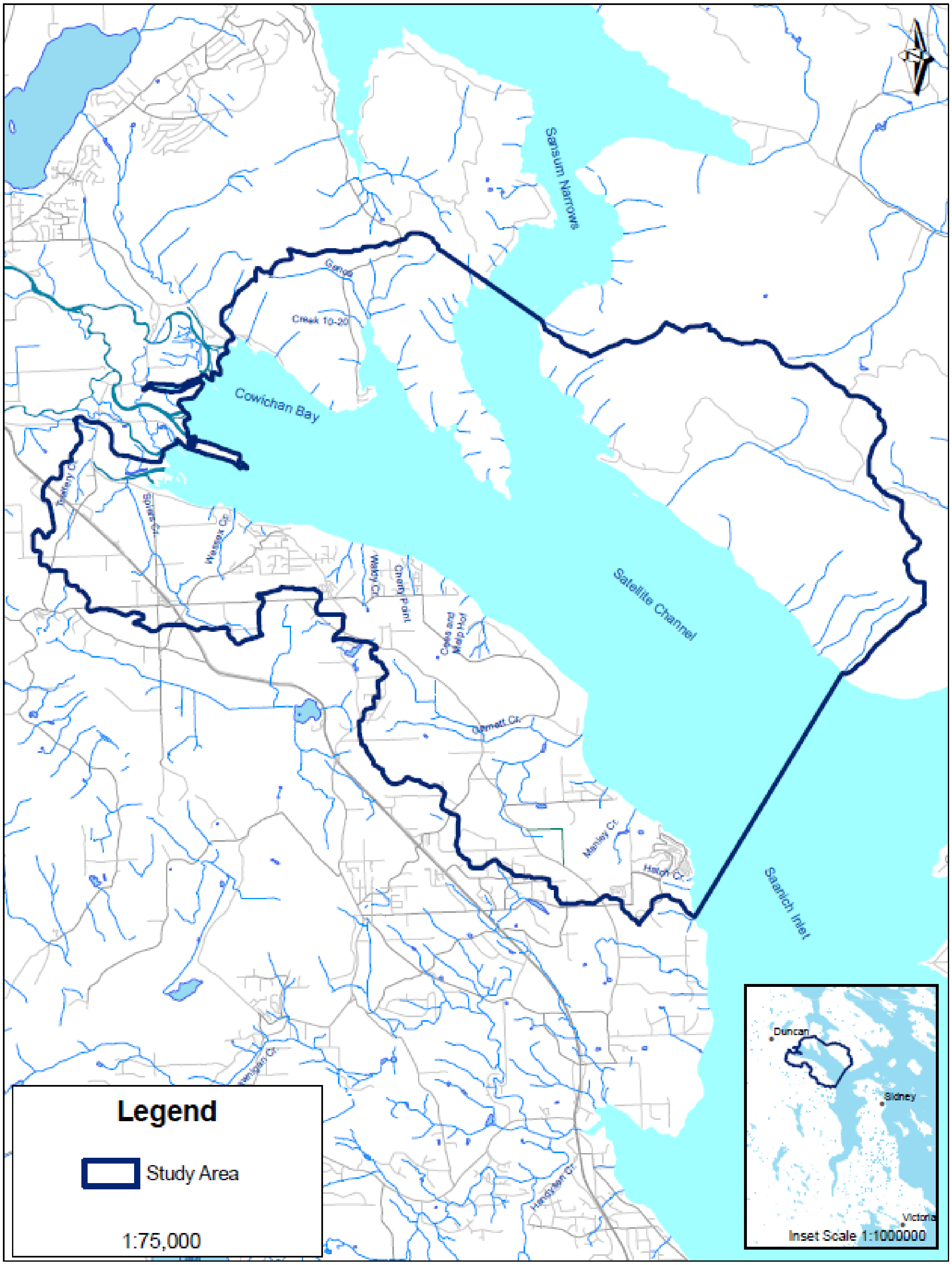



*Figure 2. Map showing the boundary of the Cowichan Bay study area.*

There are three different classes of underlying geology in the study area. The area west and south of the bay (west of Tzouhalem Creek) is described as the Nanaimo Group. It is composed of undivided sedimentary rocks from the Cretaceous period, and is described as boulder, cobble and pebble conglomerate, coarse to fine sandstone, siltstone, shale, coal (Santonian to Maastrichtian) (DataBC, 2015c). The north-east side of the Bay (east of Tzouhalem Creek and on Salt Spring Island) includes two different geological classifications. One is described as the Sicker Group. It is composed of volcaniclastic rocks from the Middle Devonian to Upper Devonian period and is described as thickly bedded tuffite and lithic tuffite, breccia, tuff, feldspar and quartz-feldspar crystal tuff, lapilli tuff, rhyolite, dacite, laminated tuff, jasper, chert, hematite-chert iron formation (DataBC, 2015c). The other is described as the Buttle Lake Group. It is composed of chert, siliceous argillite, siliciclastic rocks from the Carboniferous period, and is described as ribbon chert, cherty tuff, graphitic argillite, thinly bedded intercalated sandstone-siltstone-argillite, volcanic sandstone and conglomerate, interbedded argillite and crinoidal limestone, massive and pillowed basalt with intercalated cherty sed (DataBC, 2015c).

## 2.2 Hydrology and Precipitation

The nearest climate stations to the watershed for which climate normal data were available were the North Cowichan stations (elevation 44.80 m: Environment Canada Climate Stations 1015628 and 1015630). Average daily temperatures in 2014 ranged from 2.0°C in February to 19.7°C in July and August. Average total annual precipitation between 1981 and 2010 was 1,153 mm, with 4% of this falling as snow. Most precipitation (863 mm, or 75%) fell between October and March (Government of Canada, 2015; Figure 3).

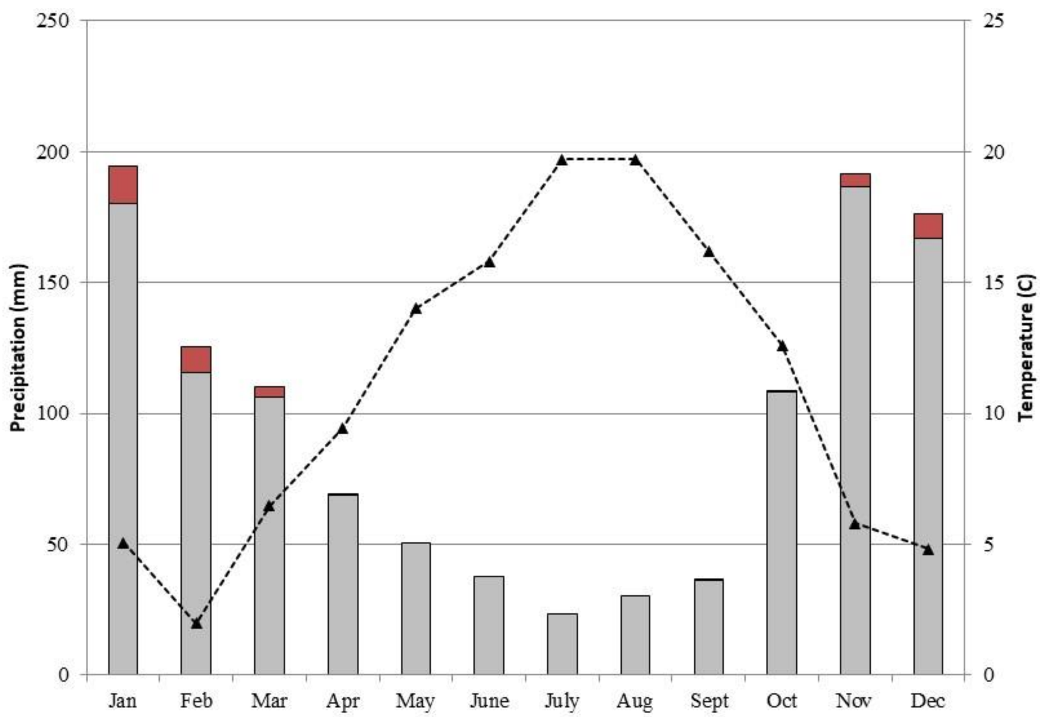



*Figure 3. Precipitation data (1981 – 2010) for North Cowichan (Environment Canada Climate Station 1015628) and temperature data (2014) for North Cowichan (Environment Canada Climate Station 1015630). Gray shading represents rainfall, red shading is snowfall.*

There are no hydrometric stations operated by the Water Survey Canada (WSC) on any of the smaller tributaries to Cowichan Bay. The Cowichan and Koksilah rivers are the largest sources of freshwater directly entering Cowichan Bay. These river systems have extremely low flows during the months of August and September and have very low flow from May through July. Figure 4 shows the minimum, maximum and average discharges between 1960 and 2016 for WSC Station 08HA011 (Cowichan River near Duncan; WSC, 2018). Peak flows measured in this period were approximately 550 $m^3/s$, while minimum flows approached 0 $m^3/s$ (Figure 4). Peak flows occur between October and January because of high rainfall, with a secondary spring peak resulting from snowmelt in the upper watershed.

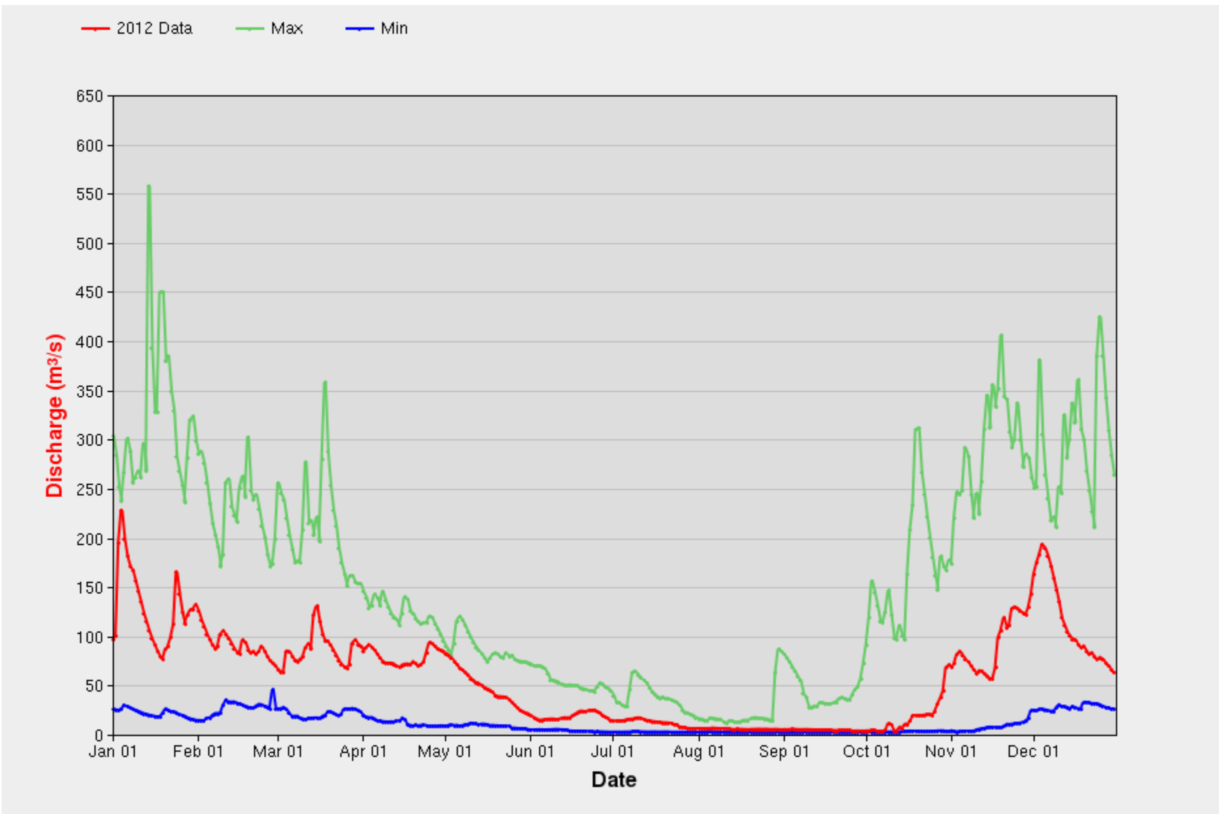



*Figure 4. Minimum, maximum and 2012 daily discharge data for Cowichan River near Duncan (Water Survey Canada Station 08HA011) between 1960 and 2016 (WSC, 2018).*

## 3. <u>WATER USES</u>

### 3.1 Water Licenses

In the study area there are 48 current and/or applications for points of diversion on 19 (including five on Salt Spring Island) surface water courses (Table 1) (DataBC, 2015d; BC MFLNRO, 2015), not including licenses for springs. The licenses for water extraction allow 752 $m^3$/day for domestic use, irrigation (551 $m^3$/day or about 73% of water licensed) or other purposes, and 290 $m^3$/day for water storage. Though domestic licenses are generally for small amounts of water and may not all be actively in use at any given time, the licenses are considered current; thus, drinking water is also a designated use.

*Table 1. Licensed domestic water withdrawals and storage volumes ($m^3$/day) for the Cowichan Bay study area (DataBC, 2015d).*

| Site | Number of licenses | Domestic | Irrigation | Other* | Storage |
|---|---|---|---|---|---|
| ***Vancouver Island*** | | | | | |
| Collings Creek | 1 | 2.3 | | | |
| Denise Brook | 1 | | | 18.6 | |
| Dewey Creek | 2 | | 33.7 | 2.5 | 38.9 |
| Garnett Creek | 1 | | 2.3 | | |
| Girtin Pond | 1 | 4.5 | 5.1 | | |
| Gravelle Slough | 1 | | | 68.6 | |
| Manley Creek | 5 | 2.3 | 72.1 | | |
| Ordano Brook | 3 | 6.8 | 10.1 | | |
| Sender Brook | 1 | | 27.0 | | 27.0 |
| Shearing Creek | 7 | 9.1 | 304.1 | | 135.2 |
| Spears Creek | 2 | 6.8 | | | |
| Stevenson Brook | 1 | | 40.6 | | 40.6 |
| Treffery Creek | 4 | 18.2 | | | |
| Whittaker Creek | 1 | | 33.7 | | 38.9 |
| **Total** | **31** | **50.0** | **528.7** | **89.7** | **280.6** |
| ***Salt Spring Island*** | | | | | |
| Arnold Creek | 10 | 38.6 | 20.3 | | 8.2 |
| Dowling Brook | 2 | 4.5 | | | |
| Eis Brook | 1 | 2.3 | | | |
| MacAlpine Brook | 1 | 4.5 | | | |
| Trench Creek | 3 | 11.4 | 1.7 | | |
| **Total** | **17** | **61.4** | **22.0** | **0.0** | **8.2** |
| **Grand Total** | **48** | **111.4** | **550.6** | **89.7** | **288.7** |

*Other includes land improvement, fire protection, processing, or waterworks local authority.

## 3.2 Fisheries

The Cowichan Bay study area provides a good recreational fishery and fishing is an attraction to the area. The following fish species are reported as being present at some point during the year in Garnett Creek, Speirs Creek, and Treffery Creek: cutthroat trout (*O. clarki*), coho salmon (*O. kisutch*) and chum salmon (*O. keta*). In addition to the species listed above, steelhead (*O. mykiss*), chinook salmon (*O. tshawytsha*), brown trout (*Salmo trutta*) and Atlantic salmon (*S. salar*) have been reported as being present at some point in the year in the Cowichan River (provides information on the fish residing in the area) (HabitatWizard, 2015). The estuary provides important habitat for anadromous fish that spawn in the Cowichan and Koksilah rivers. There are no reported fish stocking events within the Cowichan Bay study area (FFSBC, 2015).

The marine areas of Cowichan Bay offer opportunities for fishing, crabbing and prawning. Several shellfish species are found in the inlet/harbor and basin. The area has been closed for direct harvesting of bivalves since 1973 (Figure 5; DFO, 2019). The direct harvesting closure is in place due to identified pollution sources such as septic seepage, urban and agricultural runoff and wildlife. The shellfish harvesting closure has had critical and long-lasting impacts for First Nations, as shellfish has had food, social and ceremonial value for generations (CVRD, 2013).

Land and water-based activities in the Cowichan Estuary have threatened this area, which is recognized as one of the world's most biologically important areas for fish, waterfowl and wildlife. Species such as chinook salmon, shellfish, water birds and eelgrass are dependent on the habitat provided in the estuary (CVRD, 2013). Chinook salmon are relied upon as a food source by southern resident killer whales (Hanson *et al*., 2021) (listed as endangered by the Committee on the Status of Endangered Wildlife (COSWIC) and the Species at Risk Act; and red listed by the BC Conservation Data Centre), which emphasizes the importance of protecting chinook and their habitat. The CVRD Official Community Plan for Electoral Area D recognizes these habitat values and "seeks to restore, protect and enhance the Cowichan Estuary so that fish and shellfish can be safely harvested, and the coastal environment can be enjoyed for social, cultural and recreational purposes" (CVRD, 2013).

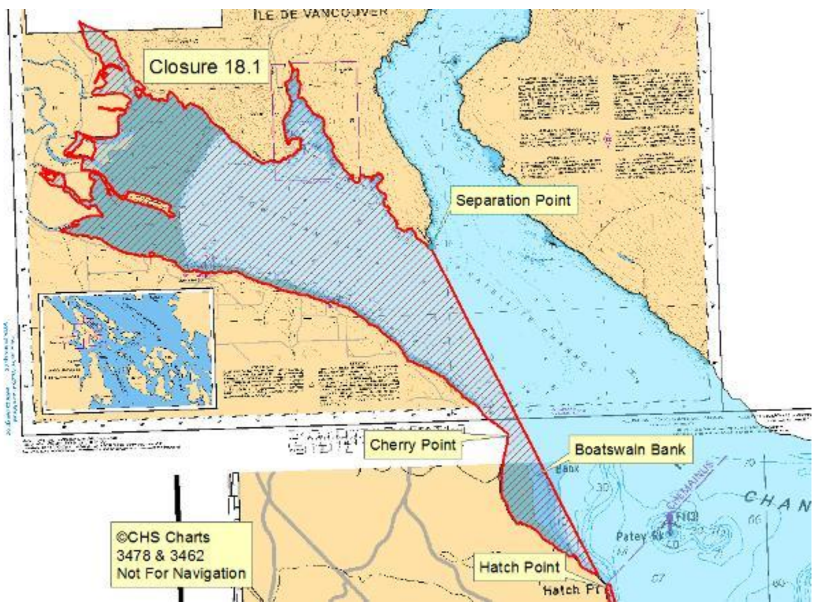



*Figure 5. Map of Area 18.1: Sanitary Shellfish Closures (DFO, 2019).*

### 3.3 Recreation

The Cowichan Bay area provides numerous outdoor recreational opportunities including boating, kayaking, diving, birding, whale watching and ecotours, golf, wineries, hiking, cycling, swimming, horseback riding and fishing. Boating and fishing are very popular activities in this oceanfront area. The Dungeness Marina is located on the south side of Cowichan Bay and offers full services, including transient moorage. The study area includes several regional or community parks, comprised of 14 hectares of parks, six trails and two formal beach access points (CVRD, 2013). There are no provincial parks within the study area.

## 3.4 Flora and Fauna

The Cowichan Bay estuary provides valuable habitat to a wide variety of species including coastal birds such as the belted kingfisher (*Megaceryle alcyon*), marine mammals such the northern river otter (*Lontra canadensis pacifica*) and sea lions (*Zalophus californianus* and *Eumetophias jubatus*), and a variety of estuarine/marine invertebrates (e.g., sea stars, sea urchins, clams, and shrimp) (CENC, 2015). A key habitat species in the Cowichan Estuary is eelgrass (*Zostera marina*) (Carmack *et al*., 2014) which provides critical habitat for commercially and ecologically important species such as salmon and Dungeness crab (*Metacarcinus magister*). Eelgrass beds provide cover from desiccation during low tide, provide refuge from predators and are a food source for a variety of species (Hemmera, 2013).

The BC Conservation Data Centre reports the presence of 23 red- or blue-listed plant and animal species within the study area (Table 2; BC CDC, 2015).

*Table 2. Summary of red- and blue-listed plant and animal species in the Cowichan Bay study area (BC CDC, 2015)*.*

| Name Category/Class | Species Level | Scientific Name | English Name | BC List |
|---|---|---|---|---|
| Fungus | fungus | *Ramalina subleptocarpha* | continuous ribbon | Blue |
| Invertebrate Animal | insects | *Anarta edwardsii* | Edwards' Beach Moth | Red |
| Invertebrate Animal | insects | *Erynnis propertius* | Propertius Duskwing | Red |
| Invertebrate Animal | insects | *Speyeria zerene bremnerii* | Zerene Fritillary, bremnerii subspecies | Red |
| Vascular Plant | dicots | *Epilobium densiflorum* | dense spike-primrose | Red |
| Vascular Plant | dicots | *Idahoa scapigera* | scalepod | Red |
| Vascular Plant | dicots | *Meconella oregana* | white meconella | Red |
| Vascular Plant | dicots | *Pyrola aphylla* | NR | Red |
| Vascular Plant | dicots | *Sanicula bipinnatifida* | purple sanicle | Red |
| Vascular Plant | dicots | *Sidalcea hendersonii* | Henderson's checker-mallow | Blue |
| Vascular Plant | dicots | *Silene scouleri ssp. Scouleri* | coastal Scouler's catchfly | Red |
| Vascular Plant | dicots | *triteleia howellii* | Howell's triteleia | Red |
| Vascular Plant | dicots | *Viola praemorsa ssp. Praemorsa* | yellow montane violet | Red |
| Vascular Plant | dicots | *Yabea microcarpa* | California hedge-parsley | Blue |
| Vascular Plant | ferns | *Woodwardia fimbriata* | giant chain fern | Blue |
| Vascular Plant | monocots | *Carex interrupta* | green-fruited sedge | Red |
| Vascular Plant | monocots | *Cephalanthera austiniae* | phantom orchid | Red |
| Vascular Plant | monocots | *Melica harfordii* | Harford's melic | Blue |
| Vertebrate Animal | amphibians | *Rana aurora* | Northern Red-legged Frog | Blue |
| Vertebrate Animal | birds | *Megascops kennicottii kennicottii* | Western Screech-Owl, kennicottii subspecies | Blue |
| Vertebrate Animal | birds | *Progne subis* | Purple Martin | Blue |
| Vertebrate Animal | mammals | *Mustela erminea anguinae* | Ermine, anguinae subspecies | Blue |
| Vertebrate Animal | reptiles | *Contia tenuis* | Sharp-tailed Snake | Red |

*This list was generated using the BC Conservation Data Centre's GIS-based CDC iMap theme 'species and ecosystems at risk', and geographically selecting the Cowichan Bay study area.

There are a number of invasive plant species of concern on Southern Vancouver Island (Infrastructure & Environment, 2009), including:

- European Beachgrass and Japanese Weed in marine shoreline areas;
- Eurasian watermilfoil, Reed Canary Grass, and Purple Loosestrife in freshwater and wetland areas, and;
- Scotch Broom, Himalayan Blackberry, Orchard Grass, Common Holly, English Ivy, Laurel-leafed Daphne, Gorse, Canada Thistle, Sweet Vernalgrass, and Hedgehod Dogtail in upland areas.

The land base within the study area is characterized by fragmented landscapes, which are particularly susceptible to invasive species such as English ivy, Scotch broom, giant hogweed, American bullfrogs, European starlings and grey squirrels (CVRD, 2013).

## 3.5 Groundwater

Groundwater is a valuable drinking water resource in Cowichan Bay study area and there are six aquifers that have boundaries within the watershed (DataBC, 2015e; Table 3). The aquifers are classified (class IA being most at-risk and IIIC being least at-risk) to provide information on their level of development, vulnerability to contaminants and water quality, but do not consider the existing type of land use, nature of potential contaminants or other risks (Bernardinucci and Ronneseth, 2002). Vulnerability is defined as the potential for an aquifer to be degraded by contaminants, based on the aquifer's hydrogeological characteristics. Cobble Hill/Mill Bay is classified IIB (low-moderate development, moderate aquifer vulnerability), and as such is the most at-risk of the six in the study area. Aquifers in this category may be able to support additional withdrawals; however, until site specific studies are undertaken, they require care and attention for development activities that could affect water quality of quantity (Bernardinucci and Ronneseth, 2002).

*Table 3. Aquifers and their classifications within the Cowichan Bay study area.*

| Aquifer Number | Descriptive Location | Classif-ication | Size ($km^2$) | Productivity | Vulnerability | Demand | Material | Use |
|---|---|---|---|---|---|---|---|---|
| 0176 | East Duncan - Maple Bay | IIIA | 15.5 | Low | High | Low | Bedrock | Domestic |
| 0177 | East Duncan - Maple Bay | IIIA | 7.7 | Low | High | Low | Bedrock | Domestic |
| 0197 | Cowichan Bay/Cobble Hill | IIC | 39.5 | Moderate | Low | Moderate | Sand and Gravel | Multiple |
| 0198 | Cowichan Station/Duncan | IIIC | 6.2 | Low | Low | Low | Bedrock | Domestic |
| 0204 | Cobble Hill/Mill Bay | IIB | 16.6 | Moderate | Moderate | Moderate | Bedrock | Multiple |
| 0723 | Saltspring Island | IIIB | 51.3 | Low | Moderate | Low | Bedrock | Domestic |

There are over 400 wells constructed in the Cowichan Bay study area (Data BC, 2015f), which provides an indication of the level of groundwater use in this area. Liggett *et al.* (2011) used the South Cowichan area in a report that demonstrates the use of intrinsic aquifer vulnerability mapping in land use planning and source water protection. A series of hydro-geographical reporting requirements were developed to direct new development permits and zoning applications.

The CVRD Official Community Plan for Electoral Area D identifies access to groundwater as a key concern, as many residents and farm operators are heavily dependent on groundwater as their supply of drinking and domestic water and for agricultural irrigation (CVRD, 2013). Water is abundant during wet winter months, but it is not uncommon for private wells to run dry during summer months (CVRD, 2013). With potential changes to seasonal precipitation, there is the potential for aquifers to be depleted more quickly than they are recharged or for contamination of groundwater resources to occur.

The *Water Sustainability Act* came into force in 2016 and included the *Groundwater Protection Regulation*. This regulation provides protective provisions relating to well construction, identification, operation and maintenance, as well as registration and qualification of drillers and pump installers. Under the *Water Sustainability Act* a water license is required for groundwater use for any non-domestic purpose (e.g., irrigation, industrial use, waterworks, etc); however, there is a transition period of bringing existing non-domestic groundwater users into the current water licensing system.

## 3.6 Agriculture

The lands within the study area have a high capacity for food production, with approximately 70% of the land in Electoral Area D located within the Agricultural Land Reserve, and approximately 50% of this land base is under active agricultural production (CVRD, 2013). Local food production and retention of the agricultural landscape is important to the community, but due to challenges with the economic viability of farming, there is a threat for farmland to be converted to non-agricultural uses. Between 1986 and 2006, 5700 hectares of farmland became inactive, and the average farm size decreased by 50% (from 31 hectares to 17 hectares; CVRD, 2013). To support agricultural activities, several water licenses have been issued for freshwater streams for which the designated use is irrigation (see Table 1).

## 3.7 Designated Water Uses

Designated water uses are those identified for protection in a specific watershed or waterbody. Water quality objectives are designed for the substances or conditions of concern in a watershed so that attainment of the objectives will protect the most sensitive designated uses.

The preceding discussion demonstrates that water uses to be protected in the Cowichan Bay marine areas should include: aquatic life – shellfish harvesting, and recreation (primary and secondary contact). The most sensitive use is shellfish harvesting and consumption by humans. Human health also needs to be considered with people spending time in or on the water, swimming, boating or fishing. The water should also be protected for aquatic life and wildlife.  Protecting the shellfish resources would protect all other marine water uses in the area.

The preceding discussion demonstrates that water uses to be protected in the tributaries to Cowichan Bay (freshwater) should include: aquatic life, drinking water, wildlife, recreation and irrigation. The most sensitive uses of the freshwater streams are aquatic life or drinking water (see Section 3.1), depending on which water quality parameter is being considered; protecting for aquatic life or drinking water (as applicable) would protect all the other freshwater uses in the watersheds. As the streams flow directly into the marine areas, protecting the freshwater streams for the uses in the marine areas (i.e., shellfish, in addition to those listed above) is also important.

# 4. INFLUENCES ON WATER QUALITY

## 4.1 Land Ownership and Use

The study area falls within the CVRD Electoral Area D (see Figure 2 and Figure 6) which supports a population of 3243 people (an 8.4% increase relative to the 2011 population) (2016 Census; CVRD, 2016). Electoral Area D is located within the traditional lands of the Cowichan Tribes and there are six traditional villages that remain inhabited today (Cowichan Tribes Reserves 1, 2, 3 and 9) and constitute approximately 1400 hectares (1/3 of the area within Electoral Area D) (CVRD, 2013). Apart from the Mt. Tzouhalem area, the landscape has been extensively cleared either for agricultural production or urban development, resulting in little remaining habitat for fish, birds and wildlife (CVRD, 2013).

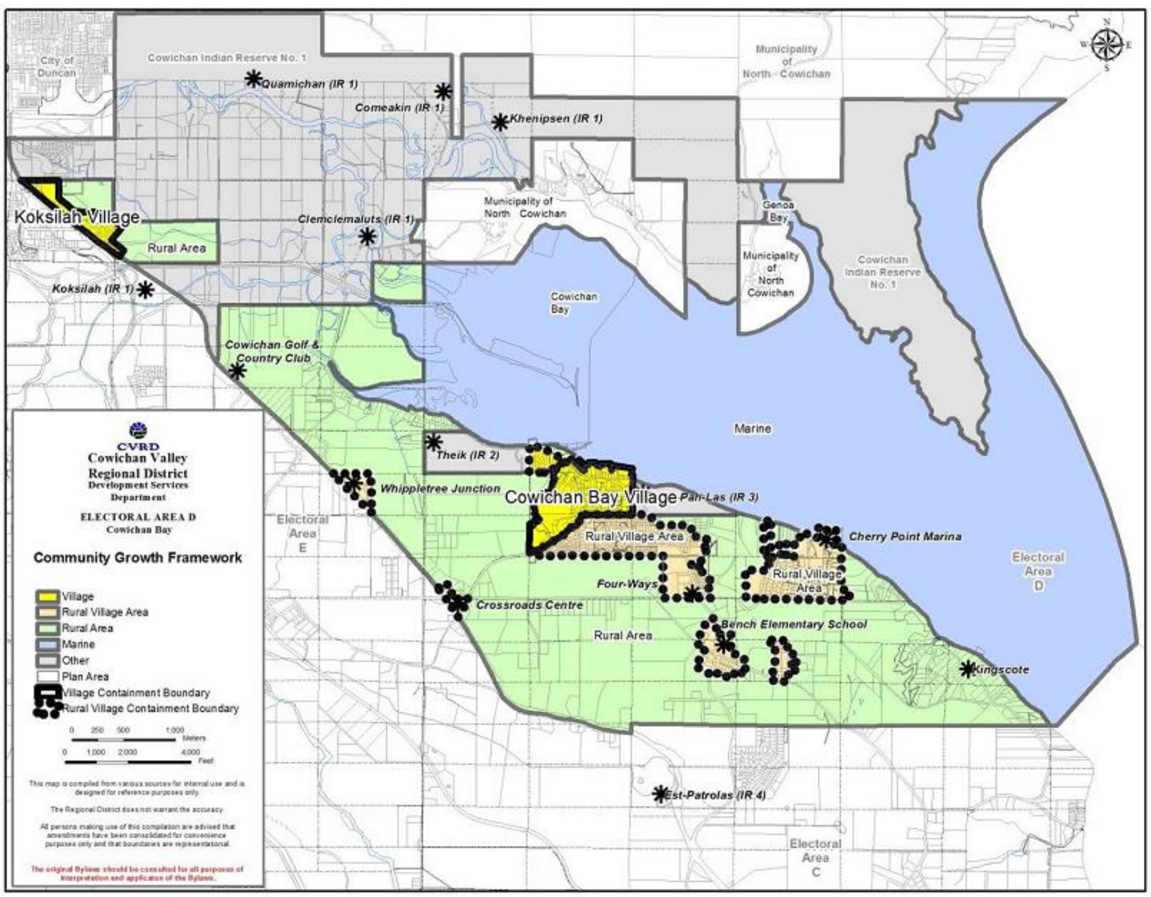



*Figure 6. Electoral Area D (Cowichan Bay), showing major land uses (CVRD, 2013).*

Figure 6 shows the locations of the major land use categories in Electoral Area D. The majority (70%) of the area within Electoral Area D falls within the Agricultural Land Reserve (ALR), with just over 50 percent classified as active farmland. Residential uses, outside First Nations reserves and the ALR, occupied 25 percent of the land base. Commercial uses occupy 3% of the land base, located in Cowichan Bay (Marine) Village, Koksilah Village, Whippletree Junction, Crossroads Centre, and minor commercial uses at Four-Ways and Cherry Point. Industrial uses represent 2% of the land base, including the gravel extraction and processing uses at Cowichan Bay Road and Shearing Road, (Westcan) log sorting/storage marine terminal in Cowichan Bay, and the wood processing facilities on Hillbank Road (CVRD, 2013).

Virtually all the land within the Cowichan Bay study area has been developed residentially or for agricultural or park use. Thus, potential sources of contamination associated with households and farming activities (such as runoff, septic fields, fertilizers and pesticides), as well as commercial and industrial uses, may impact water quality in the Cowichan Bay study area.

## 4.2 *Environmental Management Act* Authorized Effluent Discharges

There are seven active permits for authorized effluent discharge within the Cowichan Bay study area (Table 4). The CVRD has three authorized effluent discharge permits, including one that discharges directly to the marine waters of Cowichan Bay.

*Table 4. Authorized effluent discharge permits for the Cowichan Bay study area.*

| FID | Authorization Number | Authorization Type | Client Name | State | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 47 | 103748 | Municipal Wastewater Regulation | CVRD | Active | 48.7367 | -123.587 |
| 133 | 7735 | Permit | CVRD | Active | 48.69 | -123.55 |
| 218 | 11630 | Permit | CVRD | Active | 48.6896 | -123.581 |
| 79 | 100377 | Code of Practice for Concrete and Concrete Products | Gravel Hill Supplies Ltd. | Active | 48.7195 | -123.602 |
| 17 | 6798 | Petroleum Storage and Distribution Facilities Storm Water Regulation | Chevron Canada Ltd. | Active | 48.6939 | -123.535 |
| 69 | 100310 | Vehicle Dismantling and Recycling Industry Environmental Planning Regulation | Blacky's Auto Recycling Ltd. | Active | 48.7466 | -123.663 |
| 24 | 7973 | Permit | Pacific Industrial & Marine Ltd. | Active | 48.7486 | -123.6264 |

There are three major sewer systems within the CVRD Electoral Area D: Cowichan Bay Sewer System and Eagle Heights Sewer System, which transport liquid waste to the Joint Utility Board sewage treatment plant operated by the Municipality of North Cowichan; and the Lambourn Sewer System Authorization # 103748, which is operated by the CVRD (CVRD, 2013) Authorization # 103748. The Lambourn Sewer System has been upgraded and now discharges advanced secondary effluent to Cowichan Bay. The Joint Utilities Board sewage outfall currently discharges under Operational Certificate 1497 into the Cowichan River about 5 km upstream from the point where Cowichan River enters the estuary, but outfall relocation to marine waters in Satellite Channel just outside of Cowichan Bay is currently under review by ENV. Comprehensive environmental impact studies occurred in 2018 and receiving environment monitoring will continue pre- and post-operation of the proposed Joint Utilities Board outfall (G3 Consulting Ltd., 2020a and 2020b). Onsite sewage treatment on Reserve lands is covered by Health Canada through the First Nations and Inuit Health Branch. The Joint Utilities Board provides some service to Cowichan Tribes.

Developments that are not connected to community sewer systems dispose of liquid waste through septic systems, which poses challenges due to the clay-based soil composition in the study area, which has low percolation rates and therefore are not conducive to ground sewer disposal (CVRD, 2013). Private septic systems are a dominant means of disposing of domestic effluent in the Cowichan Bay study area and are effective at treating household sewage if designed properly and maintained regularly. If the system is improperly located, constructed, or poorly maintained, it can fail, discharging untreated wastewater to nearby waterbodies. This can impact the suitability of the water for drinking, recreational activities, and aquatic life. This is particularly problematic where such systems are located close to watercourses, highly vulnerable aquifers, and the marine environment. Where private septic systems are near private wells there is a potential to contaminate drinking water resources, particularly for systems built prior to 1971 when land use regulations were first introduced (CVRD, 2013).

In the Cowichan Bay Village area, there are many floating homes and live-aboard vessels (CVRD, 2013), which are responsible for disposing of their sewage in accordance with the Canada Shipping Act Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals. However, control of these non-permitted discharges is limited. If marine vessels do not properly discharge sewage to a functioning marine pump-out, there may be direct effluent discharge to the marine environment. The CVRD initiated a study (Hemmera, 2013) to evaluate the status and issues associated with float home siting and usage in Cowichan Bay; this was done to consider study recommendations in the development and implementation of a float home management strategy consistent with long term environmental protection and sustainability goals.

## 4.3 Licensed Water Withdrawals

Water is withdrawn from surface water and groundwater sources in the Cowichan Bay study area to support many uses, including domestic use, irrigation, land improvement, and storage. Surface water withdrawals are likely to impact downstream flows in tributary streams during summer low-flow periods when water consumption is highest and natural flows are lowest. Groundwater withdrawals can also affect streamflow where groundwater/surface water interactions occur.

There are a variety of plans, regulations, and guidelines that affect and are relevant to water and watershed management in the Cowichan Bay study area (Urban Systems Ltd., 2014), as well as community land use plans. The present water governance structure in BC results in limitations to local governments' (i.e., CVRD) abilities to implement and enforce water use policies within their jurisdictions (Infrastructure & Environment, 2009).

The CVRD commissioned a study to assess agricultural water demand in the region (van der Gulik *et al.*, 2013), to better understand current agricultural water use and provide data for establishing water reserves for agricultural lands as the residential demand for water increases. The study found that uncontrolled water use for farming, cattle rearing, wineries, and new land development projects will place increasing pressure on existing water resources. These circumstances all highlight the need for conservation and the importance of considering future land use decisions as part of a sound water management strategy, to ensure that an adequate supply of water is available for all water users.

## 4.4 Forest Harvesting and Forest Roads

Forestry activities can impact water quality both directly and indirectly in several ways. The removal of trees can decrease water retention times within the watershed and result in a more rapid response to precipitation events and earlier and higher rain on snow events in spring. The improper construction of roads can change drainage patterns, destabilize slopes, and introduce high concentrations of sediment to streams. Potential impacts from forestry decrease as roads are deactivated and reclaimed, and as timber stands grow back in harvested areas.

Forest harvesting is not a current land use within the study area; however, forestry-related activities have historically been important there. The inter-tidal areas of the estuary have been extensively used for log storage/sorting by multiple companies, as well as for lumber storage, loading and shipping (Vis-à-vis Management Resources Inc, 2005) by the Western Stevedoring (formerly Westcan) port facility. Although a variety of commodities are delivered at the Western Stevedoring dock, the port facility has historically operated primarily to store and ship lumber to other domestic and foreign destinations (Lambertsen, 1987). The Canadian National Railway owns most of the intertidal portion of the estuary and leases the log handling and storage area. Lease companies have included BC Forest Products, Doman Industries, and MacMillan Bloedel.

Timber storage at the Western Stevedoring Terminal and shipping lumber from Cowichan Bay was largely phased out in the 2000’s, which has decreased ecological pressure on the estuary (CERCA, 2015). Reduction of log handling and the acquisition of lands for conservation purposes and restoration activities has resulted in substantial habitat protection and restoration; it has also been credited for the development and implementation of the Cowichan Estuary Environmental Management Plan (Vis-à-vis Management Resources, 2005).

## 4.5 Recreation

The Cowichan Bay study area experiences high levels of recreational activity, primarily during the summer months. Activities include swimming and sun-bathing, as well as boating, fishing, diving, and various other water-based activities. Recreational activities can affect water quality in several ways. Erosion associated with 4-wheel drive and ATV vehicles, direct contamination of water from vehicle fuel, combustion by-products from boats and vehicles, garbage left by recreationalists, and fecal contamination from human and domestic animal wastes (e.g., dogs or horses) are typical examples of potential effects. As no specific studies have been conducted on the rates of use or areas affected by recreation within the Cowichan Bay study area, the relative impacts of recreational activities cannot be specifically discussed. However, with the knowledge of the activities taking place (see Section 3.3), the proximity to population centres (Victoria and Nanaimo), the region’s scenic lakes, rivers and oceanfront, and the warm climate, it can be assumed that the watershed experiences significant recreational pressures.

### 4.6 Wildlife

Wildlife can influence water quality through the deposition of fecal material which may include pathogens such as *Giardia lamblia*, which causes giardiasis or “beaver fever”, and *Cryptosporidium* oocysts which cause the gastrointestinal disease, cryptosporidiosis (Health Canada, 2004). Microbiological indicators, such as *Escherichia coli,* are used to assess the risk of fecal contamination to human health. Fecal contamination of water by animals is generally considered to be less of a concern to human health than contamination by humans because there is less risk of inter-species transfer of pathogens. However, without specific source tracking methods, it is impossible to determine the origins of coliforms.

The Cowichan Bay study area contains valuable wildlife habitat and provides a home for a wide variety of warm-blooded species. Therefore, the risk of contamination from endemic wildlife exists. In addition, the marine waters are home to many marine mammals such as seals, otters and mink, as well as significant populations of waterfowl. Therefore, a risk of fecal contamination from natural wildlife populations within the area does exist.

### 4.7 Mining

Mining activities can potentially impact water quality through the introduction of metals and other contaminants to the watershed. The leaching of acidic waste rock or adit discharges can also impact downstream water quality. Mining activities generally include road construction and land-clearing, which can change water movement patterns and result in increased turbidity. There are currently no active mines identified in the study area but there are three mineral claims: two near the Trans-Canada highway by Dougan Lake and one on Salt Spring Island (MINFILE, 2015). The likelihood of these sites being developed for mining activities is not known, but any activities would have to undergo impact assessments to ensure that water quality is not impacted.

### 4.8 Highways and Transportation

Highways and transportation corridors can influence water quality through run-off of pollutants such as oil and gasoline, as well as alter flow patterns. The Cowichan Bay study area has a network of roads, and a major highway (Highway 1) transects the study area. If a vehicle transporting potential contaminants (such as a fuel truck) were to overturn on these roads near streams or the Bay, there is the potential for contaminants to impact water quality in the study area.

## 5. STUDY DETAILS AND METHODOLOGY

This study assessed water quality monitoring data collected in Cowichan Bay and its tributaries in 2012 and 2013 in order to recommend water quality objectives based on water uses, potential impacts and water quality parameters of concern. To complete the study, ENV partnered with the CVRD, Cowichan Land Trust, Cowichan Tribes, Cowichan Watershed Board and VIHA to assist with field work. The project consisted of four phases: collecting water quality data, gathering information on water use, determining land use activities that may influence water quality, and assessing the data to recommend water quality objectives.

Multiple water and sediment studies have been conducted in the freshwater and marine waters of the study area that focused on chlorinated phenolics (Envirochem Special Projects Inc., 1990a,b,c) and sources of coliforms and nutrients (Rideout *et al*., 2000 and Costa, 2003). There have also been several studies conducted on fish and waterfowl habitat, as well as the intertidal and marine environment (CCLT, 2004). In addition, Cowichan Tribes collected sediment and shellfish tissues samples at 11 sites in Cowichan Bay in 2013 (Laliberte and Kulchynski, 2013). These data, along with ongoing data collection by the CVRD and Environment Canada, are not summarized in this report, but information contained within the studies was considered in the development of recommended objectives for the Cowichan Bay study area. Recent and proposed monitoring work in Cowichan Bay associated with proposed relocation of the Joint Utilities Board sewage outfall (see section 4.2) (G3 Consulting Ltd., 2020a and 2020b) should be considered in future data assessments.

Water quality monitoring for the Cowichan area was conducted over three years (2012-2014) in a phased approach.

- Year 1 (2012) - Lower Cowichan and Koksilah rivers and Cowichan Bay. Maven Consulting (2013) summarized these data and identified areas of concern, actions required to rectify any problems (e.g. land use decisions, follow up inspections), and recommendations for additional sampling.
- Year 2 (2013) - Upper Cowichan River and Cowichan Lake watershed. Smorong and Epps (2014) summarized these data. Additional work as per recommendation from Year 1 completed in Cowichan Bay and tributaries.
- Year 3 (2014) - Cowichan and Koksilah Rivers, Cowichan Lake, and tributaries to Cowichan Lake. Smorong and Saso (2021a and 2021b) wrote Water Quality Objective attainment reports summarizing these data.

Another component of this project included inspections and compliance sampling of all permitted or authorized discharges within the Cowichan watershed in 2012. This included activities such as municipal discharges, golf courses, sawmills, the Chevron industrial site, concrete plants and other small businesses. The link between monitoring, compliance and inspections conducted during 2012 was maximized by coordinating all activities to take place during the summer low flow and fall high flow periods. Compliance activities included site inspections and both effluent and receiving environment monitoring (data not presented in this report), if warranted. The compliance monitoring was carried out by either ENV Environmental Protection Officers or by the authorization holder as part of their required monitoring programs. For a complete list of sites and activities conducted see Maven Consulting (2013).

## 5.1 Sampling Sites and Schedule

Figure 7 shows the locations of water quality monitoring sampling sites within the Cowichan Bay study area (2012-2013). The sites include freshwater sites on the tributaries to Cowichan Bay, and marine sites in Cowichan Bay (Table 5). Existing CVRD and Environment Canada sampling locations were used in this study to facilitate comparisons with historical data.

Most sampling was conducted between 2012 and 2013 during the summer low flow (May-September) and fall flush (October-April) periods; during each period five weekly samples were collected over 30 days (5-in-30 sampling). In the five sites done by VIHA (Table 5), samples were collected in three sequential 5-in-30 sets (May/June, June/July, and July/August). In September 2013 a large rainstorm event occurred that was not captured by monitoring and may have represented the first flush event; as little rain occurred in the weeks following, it is likely the 2013 fall flush sampling did not capture large rainstorm events as occurred in 2012. Table 6 summarizes the total number of sampling sites.

Note that during the 2012 sampling there were six sites in which only a single sample was collected for illustrative purposes at sites where it was considered likely that impacts to water quality had occurred: near float houses (“FH_1”, “FH_2”, “FH_3”, “FH_4”, and “GB@Creek”) and a storm drain near the breakwater (“OceanSD”). During 2013 sampling, the float house sites where single samples were collected in 2012 were re-sampled and re-named “CB062”, “CB063”, “CB064”, “CB065”, for which the requisite five samples within a 30-day period were collected.

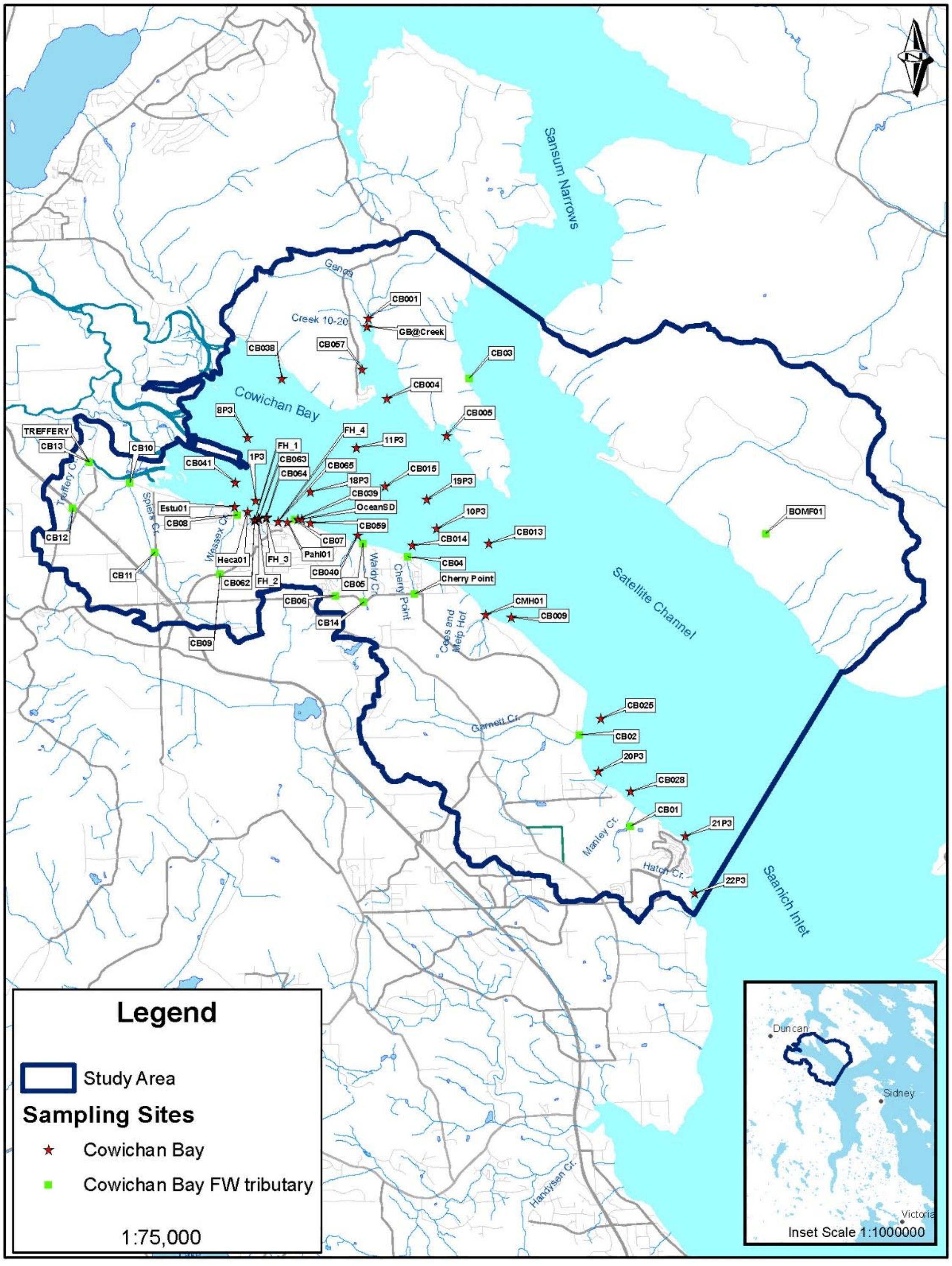



*Figure 7. Location of water quality sampling sites within the Cowichan Bay study area (2012-2013).*

*Table 5. List of water quality monitoring sites, including station descriptions, EMS ID Number, sampling agency, and years in which sampling occurred.*

| | | | | | Monitoring | |
|---|---|---|---|---|---|---|
| **Area *** | **Station ID** | **Station description**** | **EMS Number** | **Agency*** | **2012** | **2013** |
| M | 10P3 | CB above PE3893 - Lambourn STP | E291128 | CBMS | X | |
| M | 11P3 | CB south of Skinner Point | E291129 | CBMS | X | |
| M | 18P3 | CB north of Botswood Lane Site | E291130 | CBMS | X | |
| M | 19P3 | CB mid channel between CB014 and CB005 | E291131 | CBMS | X | |
| M | 1P3 | CB - Shoreline at PE1538 | 0150360 | CBMS | X | |
| M | 20P3 | CB at Boatswain Bank - mid beach | E291132 | CBMS | X | X |
| M | 21P3 | CB at Hatch Point | E291133 | CBMS | X | |
| M | 22P3 | CB south of Hatch Point | E291137 | CBMS | X | |
| M | 8P3 | CB north of Westcan Terminal | E291127 | CBMS | X | X |
| M | CB001 | CB - head of Genoa Bay | E291134 | CBMS | X | X |
| M | CB004 | CB off Genoa Bay | E219326 | CBMS | X | |
| M | CB005 | CB at cove east of Genoa Bay | E219323 | CBMS | X | X |
| M | CB009 | CB 1km east of satellite channel | E291121 | CBMS | X | |
| M | CB013 | CB mouth | E219324 | CBMS | X | |
| M | CB014 | CB at Cherry Point Marina | E219325 | CBMS | X | X |
| M | CB015 | CB between Skinner and Cherry Pt | E291122 | CBMS | X | |
| M | CB025 | CB out from Garnett Creek | E291136 | CBMS | X | X |
| M | CB028 | CB out from Manley Creek | E291135 | CBMS | X | |
| M | CB038 | CB N of dolphins at Skinner Point | E291123 | CBMS | X | X |
| M | CB039 | CB - by Botwood Ln storm drain | E291124 | CBMS | X | X |
| M | CB040 | CB off creek west of Cherry Point Marina | E291125 | CBMS | X | X |
| M | CB041 | CB S Westcan Terminal, mid channel | E291126 | CBMS | X | X |
| M | CB057 | Genoa Bay - 150m north of marina | E291369 | CBMS | X | X |
| M | CB059 | CB 400m S rock barrier at marina | E291193 | CBMS | X | |
| M | FH_1/CB062 | Float Home #1/CB Marina #1 | E294495 | CBMS | X | X |
| M | FH_2/CB063 | Float Home #2/CB Marina #2 | E294496 | CBMS | X | X |
| M | FH_3/CB064 | Float Home #3/CB Marina #3 | E294497 | CBMS | X | X |
| M | FH_4/CB065 | Float Home #4/CB Marina #4 | E294498 | CBMS | X | X |
| M | GB@Creek | Genoa Bay at Creek 10-20 | NA | CBMS | X | |
| M | OceanSD | Oceanfront storm drain 10-2 | NA | CBMS | X | |
| M | BOMF01 | Bomford Trail | NA | VIHA | | X |
| M | CMH01 | Cees and Meip Hof | NA | VIHA | | X |
| M | Estu01 | Estuary Nature Centre Beach | NA | VIHA | | X |
| M | Heca01 | Hecate Park Boat Launch | NA | VIHA | | X |
| M | Pahl01 | Pah Las Reserve Beach | NA | VIHA | | X |

| | | | | | Monitoring | |
|---|---|---|---|---|---|---|
| **Area*** | **Station ID** | **Station description**** | **EMS Number** | **Agency*** | **2012** | **2013** |
| FW | Cherry Pt | Cherry Point Road | NA | CVRD | X | |
| FW | Treffery | Treffery Creek at Cowichan Bay Road | E291163 | CVRD | X | |
| FW | CB01 | Manley Creek at Manley Creek park | E291149 | CBFWS | X | |
| FW | CB02 | Garnett Creek at Cherry Point Beach | E291150 | CBFWS | X | X |
| FW | CB03 | Garnett Creek at Telegraph Road | E291151 | CBFWS | X | X |
| FW | CB04 | Storm Drain at Cherry Point Marina | E291152 | CBFWS | X | X |
| FW | CB05 | Waldy Creek at Foreshore | E291153 | CBFWS | X | X |
| FW | CB06 | Longwood Ravine at Waldy Road | E291154 | CBFWS | X | |
| FW | CB07 | Storm Drain at Botwood Lane | E291155 | CBFWS | X | X |
| FW | CB08 | Wessex Creek at Wessex Inn | E291158 | CBFWS | X | X |
| FW | CB09 | Wessex Creek at Wilmot Road | E291159 | CBFWS | X | X |
| FW | CB10 | Spiers Creek at Cowichan Bay Road | E291160 | CBFWS | X | X |
| FW | CB11 | Spiers Creek at Hillbank Road | E291161 | CBFWS | X | X |
| FW | CB12 | Treffery Creek at Hwy Crossing | E291162 | CBFWS | X | X |
| FW | CB13 | Treffery Creek at Cowichan Bay Road | E291163 | CBFWS | X | X |
| FW | CB14 | Waldy Creek at Cherry Point Road | E295430 | CBFWS | | X |

*M – Marine; FW - Freshwater

**CB = Cowichan Bay; CBMS = Cowichan Bay marine sampling partnership; CBFWS = Cowichan Bay freshwater sampling partnership; VIHA = Island Health

*Table 6. Total number of sampling sites and samples by area and season.*

| | | 2012 | | 2013 | |
|---|---|---|---|---|---|
| **Area** | **Season** | **# of Sampling Sites** | **# of Samples** | **# of Sampling Sites** | **# of Samples** |
| Cowichan Bay | Fall | 30 | 125 | 15 | 71 |
| | Summer | 0 | 0 | 17 | 135 |
| | | | | | |
| Cowichan Bay FW tributary | Fall | 15 | 66 | 12 | 59 |
| | Summer | 1 | 1 | 0 | 0 |
| | **Total** | **46** | **192** | **44** | **265** |

Based on current knowledge of potential anthropogenic impacts to the watershed (generally associated with agriculture and human land-use), the following water quality parameters were measured in water samples collected from the freshwater tributaries to Cowichan Bay and marine sites in Cowichan Bay, during year one (2012) and year two (2013) sampling:

Year one (2012) water quality monitoring included the following sampling activities:

- 5-in-30 sampling for microbiological indicators in Cowichan Bay (fall only; 24 sites);
- Single samples for microbiological indicators in Cowichan Bay (fall only; 6 sites);
- 5-in-30 sampling for conventional parameters (turbidity and TSS) and nutrients (total phosphorous and ammonia) in the freshwater tributaries to Cowichan Bay (fall only; 11 sites; 2 sites sampled by CVRD);
- Sampling for dissolved and total metals in the freshwater tributaries to Cowichan Bay (13 sites; one to three samples collected within a 30-day period in the fall);
- Dissolved Oxygen (DO) and temperature field sampling in freshwater tributaries in fall 2012 only (2 sites)
- Microbial Source Tracking (MST) samples collected at freshwater and marine sites during the last week of fall sampling.

The limited metals results for 2012 were considered preliminary to determine if further sampling was necessary. Though 2012 exceedances of total copper and zinc guidelines suggested that more intensive 5-in-30 metal sampling should be conducted in the Cowichan Bay freshwater tributaries, 2013 monitoring did not include metals sampling (cost prohibitive). The 2013 monitoring instead focused on identifying sources of microbiological contamination, with a plan to do more metals monitoring in future years.

Year two (2013) water quality monitoring included the following sampling activities:

- Fall and summer 5-in-30 sampling in Cowichan Bay (15 sampling stations) – enterococci and fecal coliforms;
- Fall 5-in-30 sampling in freshwater tributaries to Cowichan Bay (12 sampling stations) – *E. coli* only;
- Summer sampling for fecal coliforms in Cowichan Bay (5 shoreline sampling stations), sampled by VIHA;
- MST samples collected at all sites on the last week of fall sampling, however only a limited number of samples had the required levels of fecal coliforms (>40 CFU/100 ml) to be further analyzed.

Summary statistics were calculated on all available data, and geometric means, maximum values, 30-day averages and 90$^{th}$ percentiles were calculated using data from a minimum of five weekly samples in 30 consecutive days for each site, as required for comparison to water quality guidelines. Data are summarized in Appendix I.

If four samples were collected over a 30-day period, these data were included in the analysis, but it was noted that the statistical calculations were based on only four samples. In 2012, this situation occurred for several Cowichan Bay tributary sites (CB04, CB05, CB06, CB07, CB08, CB09, CB11, CB12, and Treffery Creek) due to insufficient flow to collect samples during the first week of fall sampling (October 15$^{th}$, 2012). On November 5, 2013, this situation occurred at four Cowichan Bay sites (20P3, 8P3, CB039, CB040) when sampling did not occur due to a communication break-down amongst staff, and at site CB14 (freshwater tributary to Cowichan Bay), because there was insufficient flow to collect samples.

If three or fewer samples were collected over a 30-day period, these data were excluded from the analysis. The exception to this convention was for dissolved oxygen and temperature, for which all results were included in the analysis. In addition, metals were typically measured in only one to four samples over a 30-day period. Metals levels are typically not elevated unless there is a known source; as such, metals were measured in fewer samples as a cost-saving measure.

Surface water samples were collected by hand using applicable bottles provided by the analytical laboratory, and water column samples were collected using a Van Dorn bottle, then transferred to plastic bottles. Samples were collected and analyzed in strict accordance with Resource Inventory Standards Committee (RISC) standards (BC MOE, 2013; Cavanagh *et al.*, 1997) by trained personnel, including BC ENV and CVRD staff. Water chemistry parameters (including microbiological) analyses were conducted by Maxxam Analytics Inc. in Burnaby, BC (2012, 2013) Microbial source tracking (MST) analysis were conducted by the Pacific Environmental Science Centre (PESC) or the University of Victoria laboratory. All samples were shipped on ice to the laboratory for analysis. Field data for temperature, specific conductance and dissolved oxygen were collected using a YSI Pro Plus handheld meter.

## 5.2 Data Interpretation

Data from different sources (e.g., ENV, CVRD) were compiled in a Microsoft Access database. Each station and sample in the database was associated with an area (i.e., Cowichan Bay or tributary to Cowichan Bay) and the sampling season (i.e., fall or summer), to expedite summarizing and analyzing the results.

Results for field duplicate samples were averaged following these calculation rules:

- if one result was below the analytical detection limit (DL) and the other was above the DL, the DL and measured result were averaged, and the resulting value reported;
- if both results were below the DL, the DLs were averaged and reported as below the DL; and,
- if both results were above the detection limit, the results were averaged.

Results below the DL were included in calculations using the reported DL.

## 5.3 Quality Assurance/Quality Control

Field duplicate samples were collected in accordance with BC ENV standards that specify a minimum of 10% of samples should be collected in duplicate on each sampling date. Duplicate grab samples at randomly selected sample sites were collected by filling two sample bottles at as close to the same time as possible (one right after the other) at a monitoring location.

In addition, the analytical laboratories prepared and analyzed a variety of Quality Assurance/Quality Control (QA/QC) samples (e.g., matrix spike, spiked blank, method blank) and all QC data were reviewed and validated prior to delivery to the BC ENV.

The maximum acceptable percentage difference between duplicate samples is 25% (RISC, 1997). However, this interpretation only holds true if the results are at least 10 times the detection limits for a given parameter, as the accuracy of a result close to the detection limit shows more variability than results well above detection limits. As well, some parameters (notably bacteriological indicators and chlorophyll *a*) are not homogeneous throughout the water column and therefore we expect to see more variability between replicate samples.

Results of the QA/QC analyses are summarized in Appendix II. For the 2012 freshwater sites, three duplicate pairs of grab samples were collected for dissolved and total metals. Of the results that were greater than 10 times the applicable detection limits, 12 duplicate sample/metal pairs had a relative percent difference greater than 25% (Appendix II). Most of these results occurred on the same two dates (October 15 and 29, 2012), coinciding with the first fall flush sampling events, and most of these results only marginally exceeded the threshold (with RPD values ranging from 25% to 35%). Higher relative percent difference values were observed for dissolved lead and dissolved selenium on the October 15$^{th}$, 2012 sampling date and for total selenium on the October 29$^{th}$, 2012 sampling date.

As microbiological analyses measure constantly changing concentrations of living organisms, the results are inherently variable. Twenty-one sets of duplicate samples were collected for enterococci and fecal coliforms during the 2012 and 2103 marine sampling program, as well as an additional six sets of duplicate samples for enterococci only during the fall 2013 sampling (Appendix II). Fifteen of the 21 sets of duplicate samples collected had greater than 25% relative difference. Six of the duplicate sets of samples showed greater than 25% difference for enterococci only (i.e., fecal coliforms were within the acceptable limit). In these instances, contamination may have occurred during collection or analysis, but it is more likely the result of environmental conditions that were highly variable, as both these analyses (fecal coliform and enterococci) were conducted on water from the same bottle. This suggests that there are many non-fecal coliforms that contribute to the fecal coliform results. Five sets of duplicate samples had relative percent difference values greater than 25% for both enterococci and fecal coliforms.

*E. coli* was measured in duplicate for four of the freshwater samples collected in 2013, with three exceedances of the acceptable limit of 25% difference observed.

Variability noted in all duplicate samples was within the expected range for the parameters measured and the concentrations at which these were present. Based on these samples, the data are within acceptable limits for data quality.

## 6. WATER QUALITY ASSESSMENT AND RECOMMENDED OBJECTIVES

The following sections describe the characteristics considered in assessing the water quality of Cowichan Bay and its tributaries. Following the ecoregion approach (see Section 1.1), water quality objectives for the Cowichan and Koksilah rivers (Obee and Epps, 2011) were applied to monitoring data collected from the freshwater tributaries to Cowichan Bay (Table 7) and should continue to be in the future. For this reason, no objectives are recommended for the Cowichan Bay tributaries, though some discussion is provided if the Cowichan and Koksilah River objectives may not be applicable for a certain parameter. Only objectives for the marine waters of Cowichan Bay are recommended.

*Table 7. Summary of the water quality objectives for Cowichan and Koksilah rivers (Obee and Epps, 2011).*

| **Variable** | **Revised Objectives (2011)** | |
|---|---|---|
| | **Site** | **Objective** |
| Temperature | All | ≤ 17 °C (weekly mean) |
| Dissolved Oxygen | All (Oct to May)<br>All (June to Sept) | ≥ 11.2 mg/L<br>≥ 8 mg/L |
| Non-filterable Residue (Total Suspended Solids) | All | ≤ 7 mg/L (mean)<br>≤ 27 mg/L (max) |
| Turbidity | All (Oct to Apr)<br>All (May to Sept) | ≤ 5 NTU (max)<br>≤ 2 NTU (max) |
| Ammonia | All (Oct to Apr)<br><br>All (May to Sept) | ≤ 1.31 mg/L (mean)<br>≤ 6.83 mg/L (max)<br>≤ 0.49 mg/L (mean)<br>≤ 3.61 mg/L (max) |
| Total Phosphorus | All (May to Sept) | ≤ 5 µg/L (mean)<br>≤ 7 µg/L (max) |
| Chlorophyll a | d/s of PE-247 and PE-1497 | ≤ 5.0 µg/m$^2$ |
| Total Copper* ** | All | ≤ 2 µg/L (mean)<br>≤ 4 µg/L (max) |
| Total Lead* ** | All | ≤ 4 µg/L (mean)<br>≤ 11 µg/L (max) |
| Total Zinc* ** | All | ≤ 7.5 µg/L (mean)<br>≤ 33 µg/L (max) |
| *Escherichia coli* | All | ≤ 10 CFU/100 mL* |

*90th percentile
**geometric mean

## 6.1 Temperature

Water quality guidelines for temperature have been developed for several water uses (see Oliver and Fidler, 2001). For drinking water supplies, it is recommended that water temperature be less than 15°C to protect the aesthetic quality of the water. For the protection of aquatic life in streams, the allowable change in temperature is +/-1°C from naturally occurring levels. The optimum temperature ranges for salmonids are based on species and specific life history stages such as incubation, rearing, migration and spawning. Cutthroat trout, coho and chum salmon are present in the Cowichan Bay tributaries (HabitatWizard, 2015). Of the species present in the Cowichan Bay tributaries, chum salmon are the most sensitive salmonid to warmer temperatures (12 – 14°C for rearing) (Oliver and Fidler, 2001). Chum juveniles, however, are not present during the summer months. The water quality objectives for the Cowichan and Koksilah rivers is that the average weekly temperature at any location in the river should not exceed 17°C for the protection oftrout and juvenile salmonids, particularly coho (Obee and Epps, 2011).

In the tributaries to Cowichan Bay, water temperatures were not measured at enough sites or with enough frequency during the critical summer months; therefore no assessment of water temperature can be made. In the future, water temperature should be measured in the tributaries throughout the summer months, prioritizing those with lower flows or less canopy cover and/or higher fisheries values, to determine if water temperature is a concern.

## 6.2 Dissolved Oxygen

Dissolved oxygen (DO) levels are important for the survival of aquatic organisms, especially species sensitive to low oxygen levels such as salmonids. Oxygen becomes dissolved in water on the surface of waterbodies because of diffusion from the atmosphere, as well as from photosynthetic activity from plants and algae. When deeper waters no longer mix with surface waters due to stratification or restricted circulation, concentrations of DO can decrease below levels necessary to sustain aquatic life (including fish). The solubility of oxygen in water is temperature-dependent – the warmer the water, the less oxygen it can hold. In streams, low flows and/or high water temperatures can result in lower oxygen levels in the water. In marine waters with restricted circulation, such as some inlets, deep waters can remain anoxic. Low oxygen can also occur from decomposition of organic materials in the water body. If the euphotic zone lies above the thermocline, no photosynthesis occurs in deeper waters, and therefore oxygen depletion occurs because of decomposition.

Local land use, including stormwater and agricultural runoff, aging septic systems and land development, which are prevalent in the Cowichan Bay watershed, may also play a role by increasing the nutrient load, and thus productivity, in the streams. The resulting plant and algal growth can deplete oxygen levels when it dies and begins to decompose, as well as during periods of low productivity when plants consume oxygen (i.e., at night and during the winter under ice cover).

The aquatic life guideline is a minimum instantaneous DO concentration ≥ 5 mg/L and a 30-day mean ≥ 8 mg/L (BC ENV, 1997). This level represents the minimum concentration required to avoid stress to salmonids and will also protect other species present which tend to be more tolerant of lower DO concentrations (e.g. smallmouth bass; Rieberger, 2007). The DO objective for the Cowichan and Koksilah rivers is based on the minimum requirement for eyed or hatched fish eggs (≥ 11.2 mg/L October to May) or alevins and juvenile fish (≥ 8 mg/L June to September) (McKean, 1989; Obee and Epps, 2011), originally based on criteria outlined in Davis (1975).

DO was only measured at two freshwater tributary locations (NO EMS ID Cherry Point (n=5) and E291163 Treffery Creek (n=4)) and only in the 2012 fall 5-in-30 sample period. At both locations, the minimum DO concentrations (9.16 mg/L and 10.28 mg/L, respectively) did not meet the water quality objective for the Cowichan and Koksilah rivers but did meet the BC water quality guidelines. These results are similar to DO levels observed during the fall months (2004 -2008 data) in the Cowichan and Koksilah rivers (Obee and Epps, 2011).

As there is potential for freshwater streams in the Cowichan Bay study area to experience very low flows, and since there are little data for DO levels in the freshwater tributaries to Cowichan Bay, it is recommended to measure DO in future monitoring programs. Given the smaller size of the tributaries relative to the larger Cowichan and Koksilah Rivers, the DO objective for the rivers may not be appropriate for the tributaries, thus DO data should be assessed relative to the BC ENV guidelines of a minimum instantaneous DO concentration ≥ 5 mg/L and a 30-day mean ≥ 8 mg/L (BC ENV, 1997).

## 6.3 Turbidity

Turbidity is a measure of the clarity or cloudiness of water and is measured by the amount of light scattered by the particles in the water as nephelometric turbidity units (NTU). Elevated turbidity levels can decrease the efficiency of disinfection, allowing microbiological contaminants to enter the water system. As well, there are aesthetic concerns with cloudy water, and particulate matter can clog water filters and leave a film on plumbing fixtures. Turbidity events can result from non-point sources such as runoff from roads, ditches, and farmland, as well as from landslides (both natural and those resulting from anthropogenic impacts such as timber harvesting or road construction).

*The BC guideline for drinking water that does not receive treatment to remove turbidity is an induced turbidity over background of 1 NTU when background is less than 5 NTU and a maximum change from background of 5 NTU (during turbid flow periods) (Caux et al., 1997). While the Cowichan Bay Waterworks District relies on groundwater, several of the freshwater tributaries are licensed for domestic water use (which includes drinking water) (see*

Table 1 above). VIHA's goal for surface source drinking water quality for systems that do not receive filtration, such as domestic use licenses, is that it demonstrate 1 NTU turbidity or less (95% of days) and not above 5 NTU on more than 2 days in a 12 month period (min. four hour frequency of monitoring) when sampled immediately before disinfection (BC ENV, 2012; BC ENV, 2013; VIHA, 2010). The water quality objective for the Cowichan and Koksilah rivers is that turbidity should not exceed 5 NTU during the high-flow period (October to April), and should not exceed 2 NTU the remainder of the year during low flows (May – September) (Obee and Epps, 2011).

In the freshwater tributaries to Cowichan Bay no turbidity samples were collected during the summer low-flow season, but turbidity data was collected at 15 sampling sites during the fall-flush season of 2012; nine of which had only four samples collected over a 30-day period due to low flows preventing sampling the first sample week. The freshwater tributaries to Cowichan Bay have known turbidity sources and all sites exceeded fall water quality objectives for the Cowichan and Koksilah rivers (Table 8, Figure 8, Map 1). Highest maximum values were observed at the E291150 Garnett Creek at Cherry Point

Beach (CB02) and E291163 Treffery Creek at Cowichan Bay Road sites, while highest average values were seen at E291153 Waldy Creek at Foreshore (CB05) and E291151 Garnett Creek at Telegraph Road (CB03).

*Table 8. Summary of turbidity values (NTU) for water samples collected from tributaries to Cowichan Bay during the 2012 fall 5-in-30 sample period.*

| EMS ID | Site name | Minimum | Maximum | Mean | No. of samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 4.3 | 17.6 | 9.1 | 5 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 1.5 | 68.4 | 19.5 | 5 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 12.8 | 48.7 | 22.8 | 5 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 1.7 | 6.7 | 4.4 | 4 |
| E291153 | Waldy Creek at Foreshore (CB05) | 2.8 | 41.2 | 24.2 | 4 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 9.4 | 16.4 | 13.3 | 4 |
| E291155 | Storm Drain at Botwood Lane (CB07) | 6.9 | 15.0 | 11.0 | 4 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 10.4 | 15.3 | 13.2 | 4 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 12.6 | 34.8 | 20.8 | 4 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 2.6 | 24.6 | 11.3 | 5 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 9.8 | 22.2 | 14.5 | 4 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 4.7 | 18.9 | 9.3 | 4 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 3.3 | 39.1 | 14.7 | 5 |
| NA | Cherry Point | 5.0 | 34.0 | 11.7 | 5 |
| E291163 | Treffery Creek at Cowichan Bay Road | 5.4 | 50.0 | 18.5 | 4 |

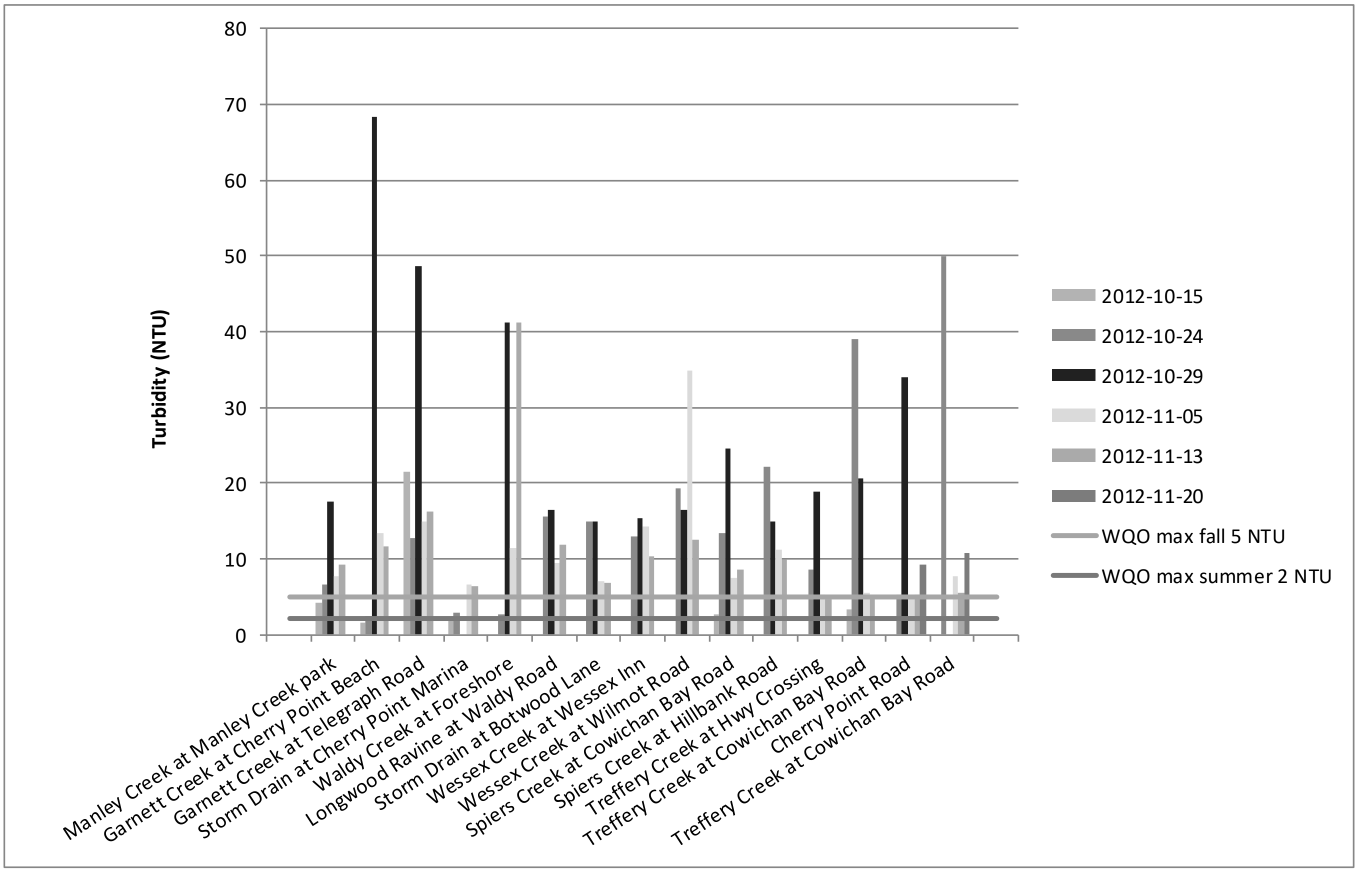
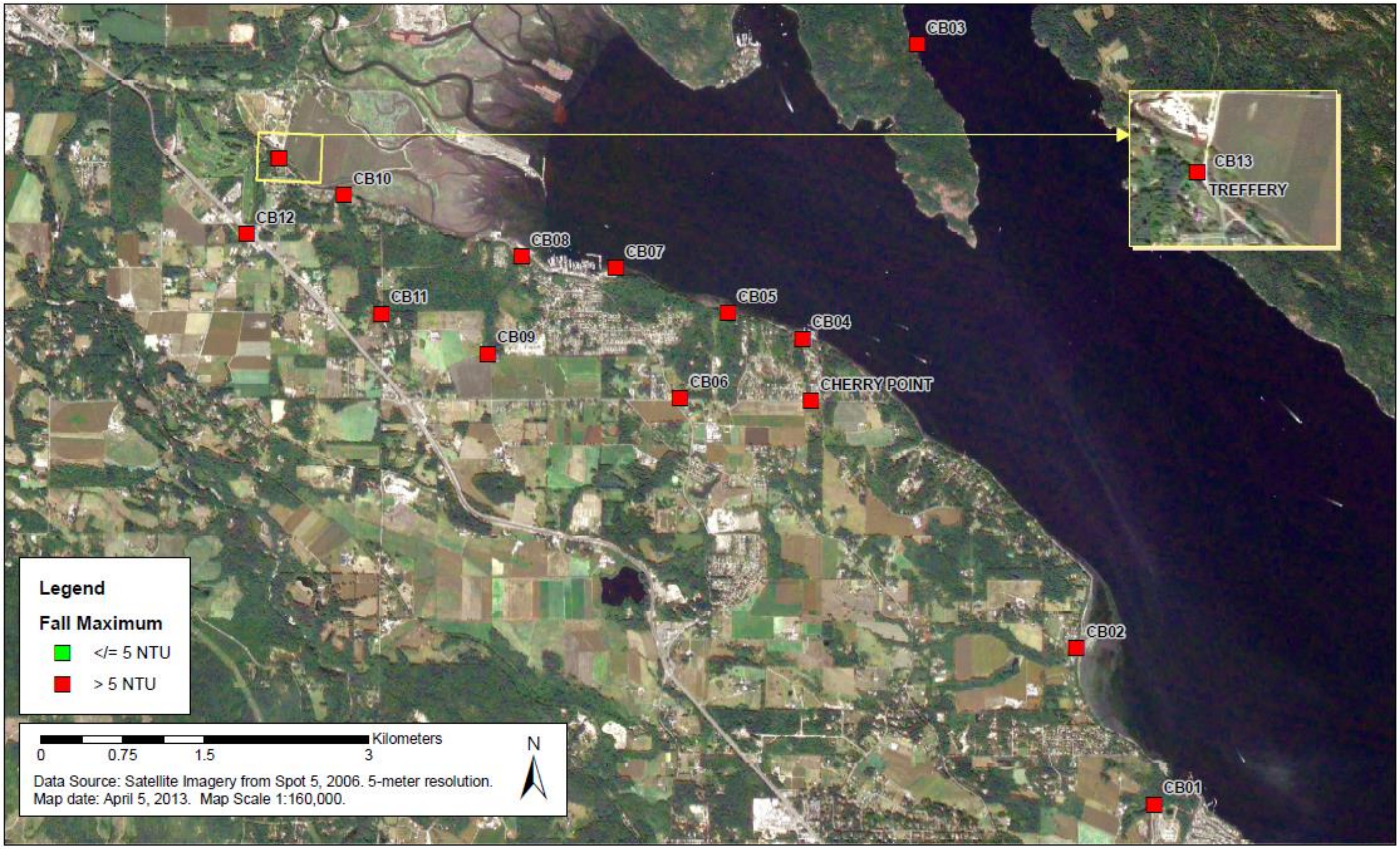



*Figure 8. Fall 2012 turbidity sample results from tributaries to Cowichan Bay, relative to the water quality objectives for Cowichan and Koksilah rivers.*




*Map 1. Map of the freshwater tributaries to Cowichan Bay, showing locations where the Cowichan and Koksilah rivers water quality objectives for turbidity (NTU) were exceeded in fall 2012 water samples collected.*

To protect water quality entering Cowichan Bay, future data from the Cowichan Bay tributaries should continue to be assessed relative to the objectives developed for the Cowichan and Koksilah Rivers. It should be noted that turbidity values above 2 NTU are considered likely to affect disinfection in a chlorine-only system (Anderson, *pers. comm.*, 2006). An alternative to the average objective of 2 NTU would be to treat the raw water prior to chlorination to remove some of the turbidity and increase chlorine efficiency.

## 6.4 Total Suspended Solids

Total suspended solids (TSS), or non-filterable residue or (NFR), include all the undissolved particulate matter in a sample. TSS is typically correlated with turbidity; however, unlike turbidity, it is not measured by optics. Instead, a quantity of the sample is filtered, and the residue is dried and weighed so that a weight of residue per volume is determined. No provincial guideline has been established for drinking water sources at this time. For the protection of aquatic life, the maximum concentration allowed is an induced TSS concentration over background of 25 mg/L at any one time in 24 hours when background is less than or equal to 25 mg/L (clear flows) and an induced TSS concentration of 5 mg/L over background concentrations at any one time for a duration of 30 days (clear flows). Initially, less frequent monitoring may be appropriate to determine the need for more extensive monitoring (Caux *et al.* 1997).

The water quality objectives for the Cowichan and Koksilah rivers (Obee and Epps, 2011) is that TSS should not exceed 27.0 mg/L at any time and the mean of five weekly samples in 30 days in this period should not exceed 7.0 mg/L. These objectives were based on the observation that occasional high concentrations of TSS can occur, and the objective is meant to apply to situations which are not natural but may have been triggered by human activities (Obee and Epps, 2011).

In the freshwater tributaries to Cowichan Bay, TSS was measured at 15 sampling sites during the fall-flush season; nine of which had only four samples collected over a 30-day period because low flows prevented sampling during the first week of fall sampling. No samples were collected during the summer low-flow season. Concentrations of TSS at all sites ranged from below detection limits (<5 mg/L) at sites sampled by the CVRD (Cherry Point and Treffery Creek) to 121 mg/L at the Waldy Creek at Foreshore site (Table 9; Map 2). The mean water quality objective established for the Cowichan and Koksilah Rivers ($\leq$ 7 mg/L) was exceeded at most locations, with a maximum of 121 mg/L at the Waldy Creek at Foreshore site.

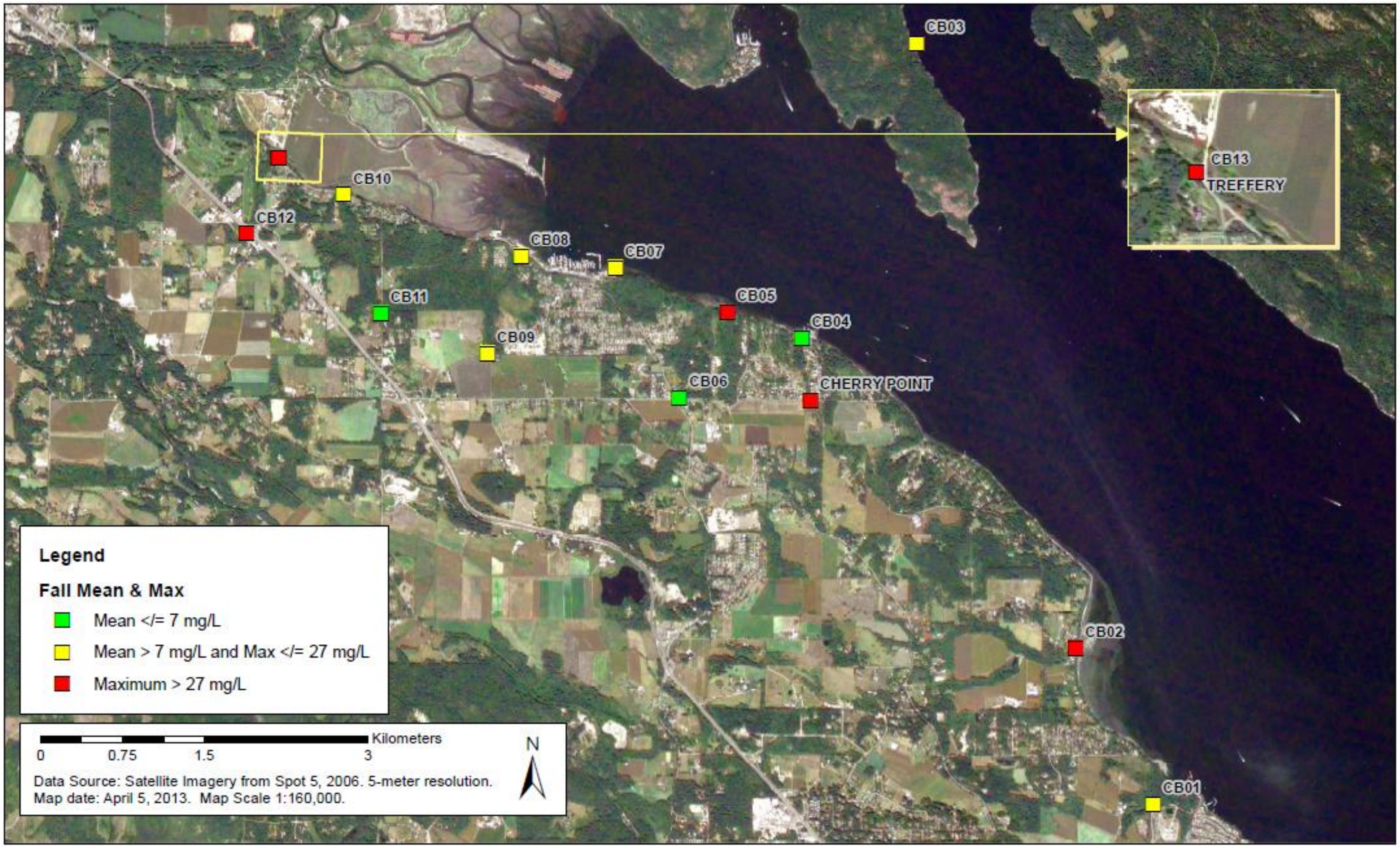
It is evident that high concentrations of TSS can occur in the tributaries; given the known activities occurring in the watershed, these are likely anthropogenically sourced. For this reason, the Cowichan and Koksilah Rivers objectives for TSS should continue to be used to assess water quality in the Cowichan Bay tributaries.

*Table 9. Summary of TSS concentrations (mg/L) for water samples collected at freshwater tributaries during the fall of 2012.*

| EMS ID | Station Name | Minimum | Maximum[1] | Mean[2] | No. of samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 3.8 | 26.5 | 9.6 | 5 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 1 | 81.4 | 19.3 | 5 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 4 | 20.1 | 10.5 | 5 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 1 | 3.9 | 3.0 | 4 |
| E291153 | Waldy Creek at Foreshore (CB05) | 2.6 | 121 | 43.6 | 4 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 1.3 | 4.5 | 3.0 | 4 |
| E291155 | Storm Drain at Botwood Lane (CB07) | 2.7 | 12.9 | 8.3 | 4 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 4.2 | 11.8 | 7.7 | 4 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 6.2 | 10.8 | 8.1 | 4 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 2.1 | 22.9 | 9.9 | 5 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 2.8 | 8.2 | 5.5 | 4 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 2.2 | 86.6 | 38.4 | 4 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 2 | 29.3 | 14.5 | 5 |
| NA | Cherry Point | <5 | 30 | 11.3 | 4 |
| E291163 | Treffery Creek at Cowichan Bay Road | <5 | 42 | 14.3 | 4 |

[1] Dark grey highlighted maximum values exceed the Cowichan and Koksilah River water quality objectives for TSS of < 27 mg/L

[2] Light grey highlighted mean values exceed the Cowichan and Koksilah River water quality objectives for TSS of < 7 mg/L.




*Map 2. Map of Cowichan Bay showing locations where the Cowichan and Koksilah rivers water quality objectives for TSS objective were exceeded in fall 2012 water samples collected.*

## 6.5 Nutrients

The concentrations of nitrogen (including nitrate and nitrite) and phosphorus are important parameters since they tend to be the limiting nutrients in biological systems. Productivity is therefore directly proportional to the availability of these parameters. Nitrogen is usually the limiting nutrient in terrestrial systems, while phosphorus tends to be the limiting factor in freshwater aquatic systems. In watersheds where drinking water is a priority, it is desirable that nutrient levels in surface water remain low to avoid algal blooms and foul-tasting water. Similarly, to protect aquatic life, nutrient levels should not be too high or the resulting plant and algal growth can deplete oxygen levels when it dies and begins to decompose, as well as during periods of low productivity when plants consume oxygen (i.e., at night and during the winter under ice cover) (Nordin, 2001).

Ammonia and total phosphorus were the only nutrient parameters sampled in 2012 and 2013. Given the results presented below for phosphorus, which is indicative of widespread nutrient contamination in the study area, it would be prudent to assess if there are any elevated nitrate levels by including nitrate sampling in future attainment monitoring.

### *6.5.1 Ammonia*

The ammonia objective for the Cowichan and Koksilah rivers was based on the ammonia guideline tables, which considers water temperature and pH. The toxicity of ammonia increases with both pH and temperature. To reflect the possible worst-case scenario, maximum temperature and pH values obtained from the Cowichan and Koksilah River sampling sites for the 2002-2008 summer and fall periods were used to determine appropriate objective levels. The water quality objectives for the Cowichan and Koksilah Rivers is that ammonia should not exceed a maximum of 6.83 mg/L from October to April and the mean of five weekly samples in 30 days in this period should not exceed 1.31 mg/L; ammonia should not exceed a maximum of 3.61 mg/L from May to September and the mean of five weekly samples in 30 days in this period should not exceed 0.49 mg/L.

In the freshwater tributaries to Cowichan Bay, ammonia was measured at 15 sampling sites during the fall-flush season; at nine of these sites only four samples were collected over a 30-day period (Table 10). Both the maximum and average water quality objectives for ammonia were met at all of the sampling locations. No samples were collected during the summer low-flow season. Future data should continue to be compared to Cowichan River and Koksilah River water quality objectives.

*Table 10. Summary of total ammonia concentrations (mg/L) for Cowichan Bay tributaries fall 2012.*

| EMS Number | Station | Min | Max | Mean | No. of samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 0.0206 | 0.0409 | 0.0306 | 5 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 0.0313 | 0.762 | 0.1888 | 5 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 0.0144 | 0.0538 | 0.0300 | 5 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 0.0101 | 0.0484 | 0.0199 | 4 |
| E291153 | Waldy Creek at Foreshore (CB05) | 0.0179 | 0.251 | 0.0850 | 4 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 0.0134 | 0.0301 | 0.0178 | 4 |
| E291155 | Storm Drain at Botwood Lane (CB07) | 0.0066 | 0.0088 | 0.0079 | 4 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 0.015 | 0.0358 | 0.0244 | 4 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 0.0172 | 0.608 | 0.2579 | 4 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 0.0076 | 0.202 | 0.0745 | 5 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 0.0089 | 0.0129 | 0.0109 | 4 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 0.0233 | 0.0379 | 0.0305 | 4 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 0.0211 | 0.0408 | 0.0295 | 5 |
| NA | Cherry Point | 0.015 | 0.11 | 0.0380 | 5 |
| E291163 | Treffery Creek at Cowichan Bay Road | 0.028 | 0.048 | 0.0385 | 4 |

### *6.5.2 Total Phosphorous*

There are no BC water quality guidelines for phosphorous in streams, as various factors (including suitable water velocity, substrate, light, temperature and grazing pressures) influence whether phosphorus is the limiting factor in biological growth in streams (Nordin, 2001). However, BC ENV has phosphorus guidance for Vancouver Island. This guidance takes into consideration the fact that elevated phosphorus is primarily a concern during the summer low flow period when elevated nutrient levels are most likely to lead to deterioration in aquatic life habitat and aesthetic problems. The total phosphorus guidance applies from May to September and is an average of 0.005 mg/L and a maximum of 0.010 mg/L, based on a minimum of five monthly samples (BC ENV, 2014).

This report compares data to the Vancouver Island phosphorus guidance, as opposed to the phosphorus water quality objectives for the Cowichan and Koksilah rivers (which were based on a draft of the Vancouver Island phosphous guidance, differing in that the maximum was 0.007 mg/L not 0.010 mg/L) (Obee and Epps, 2011).

Total phosphorus was not measured in the freshwater tributaries to Cowichan Bay during the summer in 2012 or 2013, but only during the fall, and so an accurate assessment of the potential for guidance exceedance cannot be made. Instead, individual fall measurements were compared to the 10 µg/L maximum guideance (Table 11). In all instances, observed values were higher than the guidance, with concentrations ranging from 28.6 µg/L to a maximum of 761 µg/L. Elevated phosphorus values were associated with elevated turbidity and TSS values that have likely anthropogenic sources.

*Table 11. Summary of total phosphorus concentrations (µg/L) for freshwater tributaries to Cowichan Bay in fall 2012.*

| EMS ID | Station | Minimum | Maximum | Average | No. of Samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 195 | 354 | 260 | 5 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 28.6 | 655 | 200 | 5 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 113 | 318 | 215 | 5 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 63.8 | 103 | 80 | 4 |
| E291153 | Waldy Creek at Foreshore (CB05) | 80.2 | 489 | 241 | 4 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 72.6 | 119 | 97 | 4 |
| E291155 | Storm Drain at Botwood Lane (CB07) | 56.3 | 101 | 82 | 4 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 129 | 217 | 173 | 4 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 104 | 761 | 394 | 4 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 117 | 202 | 146 | 5 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 86.5 | 125 | 103 | 4 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 93.6 | 349 | 184 | 4 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 144 | 404 | 253 | 5 |
| NA | Cherry Point | 54.9 | 472 | 148 | 5 |
| E291163 | Treffery Creek at Cowichan Bay Road | 146 | 299 | 198 | 4 |

Because total phosphorus in the tributaries to Cowichan Bay are extremely elevated during the fall periods, and that lower flows in the summer can concentrate phosphorus and result in higher levels than seen in fall, continued monitoring of phosphorus is recommended at monthly frequency from May through December. Data should continue to be compared to the Vancouver Island phosphorus guidance. As there is a BC WQG for chlorophyll *a* (biomass of naturally growing periphytic algae), this parameter should be included in future sampling.

## 6.6 Metals

In the freshwater tributaries to Cowichan Bay, total and dissolved metals were measured at 12 sampling sites during the fall flush season only. As metals were not collected with the requisite frequency of five weekly samples in 30 days to compare with chronic guidelines, only maximum metals guidelines were considered. A screening analysis was conducted to determine if there were elevated levels of metals relative to the associated BC ENV approved or working water quality guideline (Appendix III).

Water quality objectives for the Cowichan and Koksilah Rivers were established for total copper, total lead and total zinc. As the guideline for many metals depends on water hardness, the objectives were calculated based on the lowest observed water hardness in historical sampling activities in the Cowichan and Koksilah rivers (20 mg/L). This lowest observed value represents the worst-case scenario and thus results in the most protective guideline value (Obee and Epps, 2011). Obee and Epps (2011) note that since metal objectives are based on water hardness, the objectives may need to be adjusted based on water hardness levels at the time of future attainment monitoring.

Total hardness was measured in 18 samples collected from 12 sites in the tributaries to Cowichan Bay in the fall of 2012. Values ranged from 30 mg/L to 130 mg/L (Table 12).

*Table 12. Summary of total hardness (mg/L) in water samples collected at freshwater sites in the tributaries to Cowichan Bay, fall 2012.*

| EMS Number | Station | Minimum | Maximum | Average | No. of Samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 56 | 68 | 64 | 3 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 97 | 97 | 97 | 2 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 66 | 96 | 81 | 2 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 89 | 89 | 89 | 1 |
| E291153 | Waldy Creek at Foreshore (CB05) | 57 | 57 | 57 | 1 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 52 | 52 | 52 | 1 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 60 | 60 | 60 | 1 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 59 | 59 | 59 | 1 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 39 | 122 | 81 | 2 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 30 | 30 | 30 | 1 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 65 | 65 | 65 | 1 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 58 | 130 | 94 | 2 |

### *6.6.1 Total Copper*

The water quality objective for the Cowichan and Koksilah rivers is that total copper should not exceed 4 µg/L at any time and the mean of five weekly samples in 30 days should not exceed 2 µg/L (Obee and Epps, 2011).

Total copper concentrations in the freshwater tributaries to Cowichan Bay were consistently above both the mean and maximum objectives, based on samples collected during the fall months (Table 13). The sampling frequency was insufficient (no 5-in-30-days sampling was conducted) to accurately assess the mean objective, but individual concentrations ranged from 0.838 µg/L to 14.45 µg/L. Elevated values were associated with high turbidity. As total copper concentrations were 1.2 to 2.9 times higher than the dissolved copper concentrations, a significant portion of the copper was likely associated with suspended sediments (and therefore not bioavailable).

Given that total copper concentrations were elevated in all the tributaries to Cowichan Bay, it is recommended that monitoring for total copper in the Cowichan Bay tributaries continue. Monitoring should occur at a frequency of five weekly samples in 30 days to enable comparison to the existing objective for the Cowichan and Koksilah Rivers.

*Table 13. Summary of total copper concentrations (µg/L) in freshwater tributaries to Cowichan Bay in October 2012.*

| EMS Number | Station | Minimum | Maximum | Average | No. of Samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 2.09 | 4.69 | 2.99 | 3 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 0.84 | 14.45 | 7.64 | 2 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 6.10 | 8.42 | 7.26 | 2 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 3.44 | 3.44 | 3.44 | 1 |
| E291153 | Waldy Creek at Foreshore (CB05) | 9.21 | 9.21 | 9.21 | 1 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 8.88 | 8.88 | 8.88 | 1 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 3.90 | 3.90 | 3.90 | 1 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 6.23 | 6.23 | 6.23 | 1 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 3.20 | 7.06 | 5.13 | 2 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 7.18 | 7.18 | 7.18 | 1 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 8.52 | 8.52 | 8.52 | 1 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 3.45 | 8.71 | 6.08 | 2 |

### *6.6.2 Total Zinc*

The water quality objective for the Cowichan and Koksilah Rivers is that total zinc concentrations should not exceed 33 µg/L at any time and the mean of five weekly samples in 30 days should not exceed 7.5 µg/L (Obee and Epps, 2011; Natgpal, 1999).

Total zinc concentrations in the tributaries to Cowichan Bay ranged from 0.6 µg/L to 28.8 µg/L (Table 14). All concentrations were below the maximum guideline, but if values consistently stayed at the observed levels, the mean guideline could potentially be exceeded at seven of the 12 locations. However, sampling frequencies were insufficient to allow an accurate assessment of the mean guideline. Total zinc concentrations were 1.2 to 4.3 times greater than the dissolved zinc concentrations, suggesting that a significant portion of the zinc was associated with particulate matter and therefore not bioavailable.

As total zinc concentrations were elevated in most of the tributaries to Cowichan Bay, it is recommended that monitoring for total zinc in the Cowichan Bay tributaries continue. Monitoring should occur at a frequency of five weekly samples in 30 days to enable comparison to the existing objective for the Cowichan and Koksilah Rivers.

*Table 14. Summary of total zinc concentrations (µg/L) in freshwater tributaries to Cowichan Bay in October 2012.*

| EMS Number | Station | Minimum | Maximum | Average | No. of Samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 1.7 | 4.6 | 2.7 | 3 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 0.6 | 28.8 | 14.7 | 2 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 16.2 | 21.5 | 18.9 | 2 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 3.1 | 3.1 | 3.1 | 1 |
| E291153 | Waldy Creek at Foreshore (CB05) | 15.5 | 15.5 | 15.5 | 1 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 11.3 | 11.3 | 11.3 | 1 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 2.7 | 2.7 | 2.7 | 1 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 11.2 | 11.2 | 11.2 | 1 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 1.1 | 8.1 | 4.6 | 2 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 10.1 | 10.1 | 10.1 | 1 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 14.3 | 14.3 | 14.3 | 1 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 1.9 | 11.7 | 6.8 | 2 |

### *6.6.3 Total Lead*

The water quality objective for the Cowichan and Koksilah rivers is that total lead should not exceed 11 µg/L at any time and the mean of five weekly samples in 30 days in this period should not exceed 4 µg/L (Obee and Epps, 2011; Nagpal, 1987). These objectives are consistent with the BC water quality guidelines.

Concentrations of total lead were very low and well below the objectives for all sites that were sampled in the freshwater tributaries to Cowichan Bay (Table 15).

*Table 15. Summary of total lead concentrations (µg/L) in freshwater tributaries to Cowichan Bay in October 2012.*

| EMS Number | Station | Minimum | Maximum | Average | No. of Samples |
|---|---|---|---|---|---|
| E291149 | Manley Creek at Manley Creek park (CB01) | 0.068 | 0.28 | 0.1425 | 3 |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 0.028 | 0.394 | 0.211 | 2 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 0.28 | 0.44 | 0.36 | 2 |
| E291152 | Storm Drain at Cherry Point Marina (CB04) | 0.042 | 0.042 | 0.042 | 1 |
| E291153 | Waldy Creek at Foreshore (CB05) | 0.567 | 0.567 | 0.567 | 1 |
| E291154 | Longwood Ravine at Waldy Road (CB06) | 0.399 | 0.399 | 0.399 | 1 |
| E291158 | Wessex Creek at Wessex Inn (CB08) | 0.195 | 0.195 | 0.195 | 1 |
| E291159 | Wessex Creek at Wilmot Road (CB09) | 0.218 | 0.218 | 0.218 | 1 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 0.075 | 0.496 | 0.2855 | 2 |
| E291161 | Spiers Creek at Hillbank Road (CB11) | 0.359 | 0.359 | 0.359 | 1 |
| E291162 | Treffery Creek at Hwy Crossing (CB12) | 0.259 | 0.259 | 0.259 | 1 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 0.1 | 0.492 | 0.296 | 2 |

### *6.6.4 Other Metals*

In addition to the metals listed above, average and/or maximum concentrations for 21 other metals were compared to the BC ENV approved or working water quality guidelines (Table 16). For those parameters where concentrations were above detection limits, the values were generally below BC ENV's approved or working (BC ENV, 2015) guidelines, or there were no guidelines available. Exceptions to this were for dissolved aluminum and total iron.

*Table 16. Summary of the BC water quality guidelines for metals (µg/L).*

| Metal | 30-day average | Maximum | Note |
|---|---|---|---|
| Dissolved Aluminum | 50 | 100 | Protection of FW aquatic life; pH > than 6.5 |
| Dissolved Cadmium | 0.127 | 0.288 | Protection of FW aquatic life |
| Dissolved Iron | | 350 | Protection of FW aquatic life |
| Total Aluminum | | 5000 | Protection of wildlife/livestock/irrigation |
| Total Antimony | 9 | | |
| Total Arsenic | | 5 | Protection of FW aquatic life (DW protection is 25 µg/L) |
| Total Barium | 1000 | | |
| Total Beryllium | 0.13 | | |
| Total Boron | | 1200 | Protection of FW aquatic life |
| Total Chromium | 8.9 | | |
| Total Cobalt | 4 | 110 | Protection of FW aquatic life |
| Total Iron | | 1000 | Protection of FW aquatic life |
| Total Manganese | 700 | 800 | Protection of FW aquatic life |
| Total Mercury (Hg) | 0.00125 | 1 | Max - Protection of drinking water, primary contact rec, and food processing; Avg. - most conservative FW aquatic life guideline |
| Total Molybdenum | 1000 | 50 | Max - Protection of wildlife; Avg. - Protection of FW aquatic life |
| Total Nickel | 25 | | |
| Total Selenium | | 1 | This is the ALERT concentration for protection of aquatic life (FW and marine); actual guideline is 2 µg/L |
| Total Silver | 0.05 | 0.1 | Protection of FW aquatic life |
| Total Thallium | 0.8 | | |
| Total Uranium | 8.5 | | |

The approved guideline for the protection of aquatic life for dissolved aluminum is a maximum of 100 µg/L and an average of 50 µg/L (Butcher, 1988). The maximum guideline was exceeded in two different samples collected from the E291154 Longwood Ravine at Waldy Road (CB06) sampling site (107 and 123 µg/L). Note that pH levels were not assessed, which is recommended in the guideline document (i.e., it was assumed that pH levels in the tributaries to Cowichan Bay are greater than or equal to 6.5). Although exceedances of the maximum guideline were observed at only one site (suggesting a site-specific condition affecting a localized area), the dissolved aluminum concentrations were elevated (but below the guideline) at other sites as well (77 µg/L at E2191151 Garnett Creek at Cherry Point Beach (CB03); 87 µg/L at E291161

Spiers Creek at Hillbank Road (CB11); 97 µg/L at E291162 Treffery Creek at Hwy Crossing (CB12)). If these values stayed consistently high, there is potential for exceedance of the average guideline. Other areas of Vancouver Island have shown elevated aluminum levels in reference condition areas ((Barlak *et al*. 2010; Barlak, 2019), so there could be some natural contribution to observed aluminum levels. However, data from less impacted sites in the Cowichan and Koksilah Rivers show only occasional elevated levels in fall flush events (Obee and Epps, 2011), and do not appear to have elevated background aluminum. To properly assess dissolved aluminum relative to water quality guidelines, it is recommended that dissolved aluminum, as well as pH to ensure correct application of guidelines, should continue to be monitored in the tributaries to Cowichan Bay.

The approved WQG for the protection of aquatic life for iron is that the maximum concentration should not exceed 1000 µg/L total iron and 350 µg/L dissolved iron. Concentrations of total iron exceeded the guideline in eight samples collected from five different sites in the freshwater tributaries to Cowichan Bay (E291149 Manley Creek at Manley Creek park (CB01), E291150 Garnett Creek at Cherry Point Beach (CB02), E291151 Garnett Creek at Telegraph Road (CB03), E291153 Waldy Creek at Foreshore (CB05), and E291160 Spiers Creek at Cowichan Bay Road (CB10)), with values ranging from 1010 µg/L to 2130 µg/L. The guideline for dissolved iron was also exceeded at two of these sites (E291149 Manley Creek at Manley Creek park (CB01) and E291153 Waldy Creek at Foreshore (CB05)), with exceedances ranging from 439 µg/L to 518 µg/L.

At three of the sites (E291150 Garnett Creek at Cherry Point Beach (CB02), E291151 Garnett Creek at Telegraph Road (CB03), and E291160 Spiers Creek at Cowichan Bay Road (CB10)) where total iron was greater than the guideline, dissolved iron was below the guideline. Total iron concentrations can be elevated due to natural causes, whereas this is not the case for dissolved iron (Phippen *et al.*, 2008). Thus, total iron at these three sites may be due to natural causes (total iron associated with suspended materials during high flow conditions when there is a high load of suspended material in water). The exceedances of the guideline for total iron at these sites were only observed in the samples collected on the October 29$^{th}$ date, and rainfall over the preceding seven days ranged from 0.2 to 8.6 mm (as measured at the nearby North Cowichan climate station, Environment Canada Climate ID 1015628). Turbidity measurements are also elevated in the samples collected on October 24$^{th}$ and 29$^{th}$.

At the other two sites (E291149 Manley Creek at Manley Creek park (CB01) and E291153 Waldy Creek at Foreshore (CB05)), both total iron and dissolved iron exceeded the guidelines. Furthermore, elevated dissolved iron concentrations exceeding the guidelines were observed in all samples collected at each of these sites (at 'CB01' n=3 and at 'CB05' n=2). It is possible natural iron levels could play a role in observed exceedances at some sites, while anthropogenic impacts are likely influencing those with high dissolved iron. To properly assess total and dissolved iron in the study area, iron levels should continue to be monitored in the tributaries to Cowichan Bay.

## 6.7 Microbiological Indicators

The microbiological quality of marine waters used for recreating and harvesting of seafood, as well as freshwaters used for drinking and recreating, is imperative, as contamination of these systems can result in high risks to human health, as well as significant economic losses due to closure of beaches and shellfish harvesting areas (Scott *et al*., 2002). Water contaminated with human feces is generally regarded as a greater risk to human health, as the water is more likely to contain human-specific enteric pathogens, including *Salmonella enterica*, *Shigella* spp., Hepatitis A virus, and Norwalk-group viruses. The direct measurement and monitoring of pathogens in water, however, is difficult due to their low numbers, intermittent and generally unpredictable occurrence, and specific growth requirements (Krewski et al., 2004; Ishii and Sadowsky, 2008). To assess risk of microbiological contamination from fecal matter, resource managers commonly measure fecal indicator bacteria levels (Field and Samadpour, 2007; Ishii and Sadowsky, 2008).

There are a number of characteristics that suitable indicator organisms should possess. They should be present in the intestinal tracts of warm-blooded animals, not multiply outside the animal host, be nonpathogenic and have similar survival characteristics to the pathogens of concern. They should also be strongly associated with the presence of pathogenic microorganisms, be present only in contaminated samples and be detectable and quantifiable by easy, rapid, and inexpensive methods (Scott *et al*., 2002; Field and Samadpour, 2007; Ishii and Sadowsky, 2008). The most commonly used indicator organisms for assessing the microbiological quality of water are the total coliforms, fecal coliforms (a subgroup of the total coliforms more appropriately termed thermotolerant coliforms as they can grow at elevated temperatures), *Escherichia coli* (a thermotolerant coliform considered to be specifically of fecal origin (Edberg *et al*., 2000; Kloot *et al*., 2006), and enterococcus, a subgroup of the fecal streptococci, normally found in the gastrointestical tract of warm-blooded animals (Yates, 2007).

Fecal coliforms have been used extensively for many years as indicators for determining the sanitary quality of surface, recreational, and shellfish growing waters. However, research in recent years has shown that there are many differences between the coliforms and the pathogenic microorganisms that they are a surrogate for, which limits the use of coliforms as an indicator of fecal contamination (Scott *et al*., 2002). For example, many pathogens (such as enteric viruses and parasites) are not as easily inactivated by water and wastewater treatment processes as coliforms are. As a result, disease outbreaks can occur when indicator bacteria counts are at acceptable levels (Yates, 2007; Haack *et al*., 2009). Additionally, some members of the coliform group (such as *Klebsiella*) can originate from non-fecal sources (Ishii and Sadowsky, 2008) adding a level of uncertainty when analyzing data. Waters contaminated with human feces are generally regarded as a greater risk to human health, as they are more likely to contain human-specific enteric pathogens (Scott *et al*., 2002). Measurement of total and fecal coliforms does not indicate the source of contamination, which can make the actual risk to human health uncertain; therefore, it is not always clear where to direct management efforts. Therefore, additional microbes such as *E. coli* and enterococci have been suggested for use as alternative indicators (Griffin *et al*., 2001). Studies have shown that *E. coli*, a component of the fecal coliforms group, is the main thermotolerant coliform species present in human and animal fecal samples (94%) (Tallon *et al*., 2005) and at contaminated bathing beaches (80%) (Davis *et al.*, 2005). Enterococci are considered especially reliable as indicators of health risk in marine environments (Cabelli, 1983).

It should be noted that Environment Canada still bases their shellfish harvesting designations on fecal coliform measurements. The monitoring programs of the BC ENV have traditionally measured total coliforms, fecal coliforms, *E. coli* and enterococci, either alone or in combination, depending on the specific program. In cases where fecal coliform counts were greater than *E. coli*, we can assume a high likelihood of contributions from non-fecal sources. Thus, the value-added benefit of measuring both groups is limited. Given the uncertainty in linking thermotolerant (i.e., fecal) coliforms to human sources of sewage, we recommend using *E. coli* as the microbiological indicator for freshwater in the Cowichan Bay study area.

The BC ENV water quality guidelines were used to assess water quality in Cowichan Bay and the tributaries to Cowichan Bay based on the designated water uses, i.e., Cowichan Bay: aquatic life – shellfish harvesting, and recreation (primary and secondary contact); tributaries to Cowichan Bay: aquatic life – shellfish harvesting, recreation (secondary contact), aquatic life, drinking water, wildlife and irrigation (Warrington, 2001; Table 17). Primary contact refers to direct contact with water over most of the body's surface, to the point of complete submergence, or where there is substantial risk of ingestion or intimate contact with eyes, ears, nose, mouth or groin, such as swimming and scuba diving. Secondary contact refers to an activity where a person would have very limited direct contact with the water, usually only the feet and hands, and little risk of complete immersion, such as boating, kayaking, canoeing, and fishing. These water quality guidelines are set at levels intended to prevent health problems in healthy adults. Children, seniors and domestic animals may be more susceptible to illness. As small pieces of fecal matter in a sample can skew the overall results for a site, the 90$^{th}$ percentiles (for drinking water) and geometric means (for recreation) of at least five weekly samples collected in a 30-day period are generally used to determine if the water quality guideline is exceeded, as extreme values would have less effect on the data. Though in 2017 BC ENV adopted the Health Canada guidelines for recreational uses (BC ENV, 2019), replacing the primary and secondary recreation guidelines it can still be useful to consider the specific types of recreation uses in an area.

*Table 17. Summary of BC ENV Approved Water Quality Guideline for Microbiological Indicators (colony forming units (CFU)/100 mL) (Warrington, 2001; BC ENV, 2019; BC ENV, 2020). Medians, geometric means and 90th percentiles are calculated from at least five samples in a 30-day period.*

| **Water Use** | ***E. Coli*** **(freshwater only)** | **Enterococci** | **Fecal coliforms** |
|---|---|---|---|
| Drinking Water Sources | less than or equal to 10/100 mL (90th percentile) | less than or equal to 3/100 mL (90th percentile) | None applicable |
| Aquatic life - shellfish harvesting | less than or equal to 14/100 mL (median) | less than or equal to 4/100 mL (median) | less than or equal to 14/100 mL (median) |
| Aquatic life - shellfish harvesting | less than or equal to 43/100 mL (90th percentile) | less than or equal to 11/100 mL (90th percentile) | less than or equal to 43/100 mL (90th percentile) |
| Recreation | less than or equal to 200/100 mL (geometric mean); less than or equal to 400/100 mL (single sample) | less than or equal to 35/100 mL (geometric mean); less than or equal to 70/100 mL (single sample) | None applicable |

### *6.7.1 Freshwater - E. coli*

*E. coli* was measured during the fall-flush season at 14 sites in 2012 (six of these sites had only four samples collected over a 30-day period) and 11 sites in 2013 (one of these sites had only four samples collected over a 30-day period). In summer, most of the creeks are dry, so no samples were collected during the summer low-flow season in 2012 or 2013 (Table 18).

In samples collected in the fall of 2012, *E. coli* concentrations ranged from 11 CFU/100 mL to a maximum of 56000 CFU/100 mL (Table 18). Geometric mean values were highest at E291158 Wessex Creek at Wessex Inn (CB08): 4217 CFU/100 mL. Geometric means at all but two sites sampled in 2012 exceeded the BC water quality guideline for recreation ($\leq$ 200 CFU/100 mL). The 90$^{th}$ percentiles exceeded guidelines for drinking water receiving disinfection only ($\leq$ 10 CFU/100 mL) and shellfish harvesting ($\leq$ 43 CFU/100mL) at all sites. Median values exceeded shellfish harvesting guidelines ($\leq$ 14CFU/100ml) at all sites sampled. Note that the 2012 sampling program targeted fall samples to be collected during rainstorm events; thus, 2012 results are representative of the worst-case scenario for *E. coli* levels.

The 2013 sampling program also focused on collecting samples during fall rainstorm events but, as no major rainstorm events occurred during the 2013 fall sampling period, the worst-case scenario was not captured. Fall 2013 *E. coli* results, while still high, were markedly lower than fall 2012 results. Levels ranged from below detectable limits (< 1 CFU/100 mL) to a maximum of 1700 CFU/100 mL (Table 18). Geometric mean values were highest at E291162 Treffery Creek at Hwy Crossing (CB12): 228 CFU/100 mL. Geometric means at only one of the sites sampled in 2013 exceeded the BC water quality guideline for recreation. The 90$^{th}$ percentiles exceeded the guideline for drinking water receiving disinfection only (≤ 10 CFU/100 mL) and for shellfish harvesting (≤ 43 CFU/100mL) at all sites. Median values exceeded shellfish harvesting guidelines (≤ 14CFU/100ml) at all but one site.

In both 2012 and 2013 all sites exceeded the *E. coli* objective for the Cowichan and Koksilah Rivers of a 90$^{th}$ percentile value of ≤ 10 CFU/100 mL.

*Table 18. Summary of* E. coli *concentrations (CFU/100 mL) in freshwater tributaries to Cowichan Bay 2012*, 2013**. Grey highlighting indicates BC water quality guideline exceedances.*

| **EMS ID** | **Station** | **2012 fall** | | | **2013 fall** | | |
|---|---|---|---|---|---|---|---|
| | | **Geo-mean** | **Median** | **90$^{th}$ %ile** | **Geo-mean** | **Median** | **90$^{th}$ %ile** |
| E291149 | Manley Creek at Manley Creek park (CB01) | 520 | 1100 | 2610 | -- | -- | -- |
| E291150 | Garnett Creek at Cherry Point Beach (CB02) | 175 | 250 | 1008 | 30 | 14 | 912 |
| E291151 | Garnett Creek at Telegraph Road (CB03) | 971 | 600 | 13400 | 163 | 110 | 448 |
| E291152 | Storm Drain at Cherry Point Marina (CB04)** | *551* | *420* | *1740* | 12 | 19 | 49 |
| E291153 | Waldy Creek at Foreshore (CB05) | *974* | *890* | *11792* | 51 | 90 | 370 |
| E291154 | Longwood Ravine at Waldy Road (CB06)* | *117* | *204* | *512* | -- | -- | -- |
| E291155 | Storm Drain at Botwood Lane (CB07)* | *448* | *730* | *1790* | 34 | 39 | 74 |
| E291158 | Wessex Creek at Wessex Inn (CB08)* | *4217* | *2900* | *40430* | 12 | 15 | 67 |
| E291159 | Wessex Creek at Wilmot Road (CB09)* | *1242* | *1065* | *22970* | 35 | 35 | 1080 |
| E291160 | Spiers Creek at Cowichan Bay Road (CB10) | 464 | 750 | 1330 | 31 | 30 | 181 |
| E291161 | Spiers Creek at Hillbank Road (CB11)* | *1596* | *2340* | *15930* | 121 | 64 | 580 |
| E291162 | Treffery Creek at Hwy Crossing (CB12)* | *2623* | *1385* | *29300* | 228 | 180 | 1096 |
| E291163 | Treffery Creek at Cowichan Bay Road (CB13) | 660 | 900 | 1760 | 55 | 38 | 350 |
| NA | Cherry Point | 749 | 145 | 16000 | -- | -- | -- |

* **italicized values calculated from fewer than five samples in 30 days. If fewer than four samples in 30 days, no comparison to guidelines was made

As bivalves are filter feeders and concentrate pathogens, the concentration of coliforms in the meat on a per 100 g basis can be expected to be 10 to 100 times the concentration in 100 mL of the water in which they grow (Warrington, 2001). For this reason, concentrations of coliforms in growing water must be very low. While shellfish harvesting is not occurring in the freshwater environments, the shellfish harvesting guidelines were applied to the freshwater inputs as they are potential sources of fecal contamination into Cowichan Bay. Exceedances of shellfish guidelines outlined above illustrate the potential for upland sources to contribute to fecal contamination in the marine environment.

Clearly there are issues with microbiological contamination in the freshwater tributaries to Cowichan Bay and these streams are contributing microbiological concentrations higher than the shellfish harvesting guidelines to the marine waters. Recreational water users need also to use caution given the extensive recreation guideline exceedances. While these are likely only a risk in the warmer summer season, higher fall values should not be overlooked, particularly regarding pet waste sources. The presence of a few domestic licenses on the tributaries to Cowichan Bay emphasizes the need for consideration of exceedances of drinking water guidelines and the need for disinfection prior to consumption, where applicable. For all these reasons, it is recommended that microbiological parameters continue to be monitored in the Cowichan Bay tributaries, and that results should be compared to the *E. coli* objective existing for Cowichan and Koksilah Rivers of ≤ 10 CFU/100 mL.

### *6.7.2 Cowichan Bay marine areas - Fecal coliforms and Enterococci*

As part of the 2012 monitoring at marine sites in Cowichan Bay, fecal coliforms and enterococci were sampled at 30 sites. At 23 of these sites the requisite five weekly samples collected in a 30-day period was achieved. At one site E291369 Genoa Bay – 150m north of marina (CB057), only four weekly samples were collected over a 30-day period. The remaining six sites were sampled only once, as they were likely highly impacted sites (near float houses 'FH_1', 'FH_2', 'FH_3', 'FH_4', and 'GB@Creek' and at a storm drain near the breakwater ('OceanSD')); of these the four float house sites were renamed and resampled in 2013. During the 2013 monitoring period, enterococci was sampled at 15 sites and fecal coliforms were sampled at 20 sites. There were four sites sampled in the fall where only four weekly samples were collected over a 30-day period. Statistics were calculated and included for sites based on only four samples, as it was apparent that the data was indicative of trends in the bay. The enterococci and fecal coliform results from the Cowichan Bay marine sites were compared to the BC water quality guidelines for recreation and aquatic life (shellfish harvesting) (Table 17).

In 2012, the enterococci guideline for shellfish harvesting (median ≤4 CFU/100 mL) was exceeded in every site that was sampled in Cowichan Bay (Table 19); the guideline for recreation (geomean ≤35 CFU/100 mL) was exceeded at approximately one third of the sites. Concentrations of enterococci at sampling sites in Cowichan Bay, based on 2012 sampling, were highest clustered around the Dungeness Marina area; moderate levels were found in areas further out from the marina and the E291134 CB – Head of Genoa Bay (CB001) site (mouth of Manley Creek), and the lowest levels were found in open water areas of the Bay.

In 2013, the enterococci guideline for shellfish harvesting (median ≤4 CFU/100 mL) was exceeded in all but three of the sites sampled in Cowichan Bay (Table 19). The guideline for recreation (geomean ≤35 CFU/100 mL) was exceeded at two sites (both float homes). Comparison of fall and summer sampling results shows that enterococci levels tended to be more elevated in the fall months. Like 2012 results, 2013 results show the highest levels of enterococci were clustered around the Dungeness Marina area and at site E291369 Genoa Bay – 150m north of marina (CB057); lower levels were found in areas farther out from the marina, and the lowest levels were found farther down the eastern coastline of the Bay.

The fecal coliform guideline for shellfish harvesting (median ≤14 CFU/100 mL) was exceeded in all but five sites sampled in Cowichan Bay in samples collected in 2012 (Table 20), with median values ranging from 8 MPN/100 mL at E291152 Storm Drain at Cherry Point Marina (CB04) to 130 MPN/100 mL at the 0150360 Cowichan Bay - Shoreline at PE1538 (IP3). The concentrations of fecal coliforms were higher at the float home locations, ranging from 70 MPN/100 mL to 350 MPN/100 mL.

For samples collected in 2013, the fecal coliform guideline for shellfish harvesting (median ≤14 CFU/100 mL) was exceeded in four of the 11 sites sampled in the fall, and one of the 17 sites sampled in the summer (Table 20). At the five Cowichan Bay shoreline sites sampled by Island Health during the summer of 2013, most showed exceedances of the guideline for shellfish harvesting, and generally showed a pattern of having higher concentrations than the open water sites (which were sampled by the other partnership agencies). These higher concentrations could be due to collection methods (sampling from shore versus collecting them from a boat near the shoreline); regardless, these shore sites were sampled as they are known locations for recreational activities to occur.

The various levels of fecal coliform contamination generally followed the same spatial pattern as those seen with enterococci. The highest concentrations were seen around the Dungeness Marina and there were fewer exceedances of the guideline at sites farther into the Bay and farther south along the coastline. In addition, comparison of the fall and summer sampling results shows that fecal coliform levels tended to be higher in the fall months.

Microbiological data from the 2012 and 2013 sampling demonstrate that Cowichan Bay marine areas are clearly subject to bacteriological contamination, particularly in the area near Dungeness Marina. Most elevated levels occurred in association with rainfall events either during typically rainy seasons (e.g., fall vs. summer) or during years with more storm events (e.g., 2012 vs. 2013). These results were consistent with earlier studies (Envirochem Special Projects Inc., 1990a). It is also apparent that there is microbial input to Cowichan Bay from the freshwater tributaries to the Bay. Recreational water users need to use caution given recreation guideline exceedances; though these are likely only a risk in the warmer summer season, higher fall values should not be overlooked.

*Table 19. Summary of enterococci concentrations (CFU/100 mL) at Cowichan Bay marine sites 2012 and 2013.*

| EMS ID | Station | **2012 -Fall** | | | | **2013 -Fall** | | | | **2013 - Summer** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Median[1] | Geomean[2] | Max | Min | Median[1] | Geomean[2] | Max | Min | Median[1] | Geomean[2] | Max |
| E291128 | Cowichan Bay above PE3893 - Lambourn STP (10P3) | 1 | 38 | 17 | 122 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291129 | Cowichan Bay south of Skinner Point (11P3) | 3 | 18 | 19 | 85 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291130 | Cowichan Bay north of Botswood Lane Site (18P3) | 29 | 57 | 71 | 210 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291131 | Cowichan Bay mid channel between CB014 and CB005 (19P3) | 1 | 27 | 13 | 106 | -- | -- | -- | -- | -- | -- | -- | -- |
| 0150360 | Cowichan Bay - Shoreline at PE1538 (1P3) | 56 | 395 | ***228*** | 560 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291132** | Cowichan Bay at Boatswain Bank - mid beach (20P3) | 1 | 31 | 15 | 93 | <1 | 1 | 2 | 24 | <1 | 1 | 1 | 3 |
| E291133 | Cowichan Bay at Hatch Point (21P3) | 1 | 8 | 8 | 46 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291137 | Cowichan Bay south of Hatch Point (22P3) | 3 | 7 | 11 | 39 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291127** | Cowichan Bay north of Westcan Terminal (8P3) | 19 | 65 | 65 | 310 | 7 | 22 | 18 | 42 | -- | -- | -- | -- |
| E291134 | Cowichan Bay - head of Genoa Bay (CB001) | 6 | 20 | 22 | 73 | 1 | 8 | 7 | 36 | <1 | 2 | 3 | 11 |
| E219326 | Cowichan Bay off Genoa Bay (CB004) | 1 | 8 | 10 | 60 | -- | -- | -- | -- | -- | -- | -- | -- |
| E219323 | Cowichan Bay at cove east of Genoa Bay (CB005) | 5.5 | 13 | 18 | 71 | 1 | 3 | 4 | 13 | <1 | 1 | 1 | 4 |
| E291121 | Cowichan Bay 1km east of satellite channel (CB009) | 1 | 35 | 15 | 135 | -- | -- | -- | -- | -- | -- | -- | -- |
| E219324 | Cowichan Bay mouth (CB013) | 2 | 23 | 16 | 109 | -- | -- | -- | -- | -- | -- | -- | -- |
| E219325 | Cowichan Bay at Cherry Point Marina (CB014) | 1 | 58.5 | 44 | 1220 | <1 | 6 | 6 | 37.5 | <1 | 1 | 1 | 7 |
| E291122 | Cowichan Bay between Skinner and Cherry Point (CB015) | 1 | 31 | 13 | 114 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291136 | Cowichan Bay out from Garnett Creek (CB025) | 1 | 37 | 11 | 88 | 1 | 3 | 4 | 27 | <1 | 1 | 1 | 3 |
| E291135 | Cowichan Bay out from Manley Creek (CB028) | 1 | 16 | 15 | 121 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291123 | Cowichan Bay N of dolphins at Skinner Point (CB038) | 7 | 34 | 36 | 168 | 2 | 8 | 9 | 31 | 1 | 5 | 3 | 10 |
| E291124** | Cowichan Bay - out from Botwood Lane storm drain (CB039) | 39 | 120 | 94 | 147 | 1 | 11 | 9 | 67 | -- | -- | -- | -- |
| E291125** | Cowichan Bay off creek west of Cherry Point Marina (CB040) | 1 | 64 | 28 | 190 | 8 | 13 | 13 | 23 | -- | -- | -- | -- |
| E291126 | Cowichan Bay south Westcan Terminal, mid channel (CB041) | 42 | 86 | ***115*** | 840 | 6 | 7 | 9 | 15 | <1 | 3 | 5 | 30 |
| E291369* | Genoa Bay - 150m north of marina (CB057) | 5 | 15 | 16 | 59 | 3 | 16 | ***30*** | 2750 | <1 | 3.5 | 5 | 279 |
| E291193 | Cowichan Bay 400m south rock barrier at marina (CB059) | 2 | 68 | 54 | 450 | -- | -- | -- | -- | -- | -- | -- | -- |
| NA***/ E294495 | Float Home #1/ Cowichan Bay Marina #1 (FH/1/CB062) | 690 | -- | -- | 690 | 14 | 180 | ***131*** | 1000 | 5 | 11 | 14 | 35 |
| NA***/ E294496 | Float Home #2/ Cowichan Bay Marina #2 (FH/2/CB063) | 580 | -- | -- | 580 | 14 | 35 | ***55*** | 310 | 2 | 14 | 11 | 29 |
| NA***/ E294497 | Float Home #3/ Cowichan Bay Marina #3 (FH/3/CB064) | 130 | -- | -- | 130 | 4 | 21 | 19 | 74 | 12 | 20 | ***33*** | 142 |
| NA***/ E294498 | Float Home #4/ Cowichan Bay Marina #4 (FH/4/CB065) | 710 | -- | -- | 710 | 5 | 16 | 16 | 52 | 1 | 6 | 7 | 38 |
| NA*** | Genoa Bay at Creek 10-20 (GB@creek) | 39 | -- | -- | 39 | -- | -- | -- | -- | -- | -- | -- | -- |
| NA*** | Oceanfront storm drain 10-2 (OceanSD) | 290 | -- | -- | 290 | -- | -- | -- | -- | -- | -- | -- | -- |

*Based on 4 weekly samples in 30 days (2012 fall sampling); **Based on 4 weekly samples in 30 days (2013 fall sampling). ***Based on a single sample in 2012 and do not have requisite frequency to be compared to guidelines in 2012; [1]Light grey highlighted median values exceed the enterococci guideline for shellfish harvesting of < 4 CFU/100 mL; [2]Light grey highlighted geometric mean values exceed enterococci guideline for recreation of < 35 CFU/100 mL

*Table 20. Summary of fecal coliform concentrations (CFU/100 mL) at Cowichan Bay marine sites 2012 and 2013.*

| EMS ID | Station | ***2012 -Fall*** | | | | ***2013 -Fall*** | | | | ***2013 - Summer*** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Min** | **Median[1]** | **Geomean[2]** | **Max** | **Min** | **Median[1]** | **Geomean[2]** | **Max** | **Min** | **Median[1]** | **Geomean[2]** | **Max** |
| E291128 | Cowichan Bay above PE3893 - Lambourn STP (10P3) | 2 | 46 | 18 | 130 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291129 | Cowichan Bay south of Skinner Point (11P3) | 2 | 33 | 22 | 79 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291130 | Cowichan Bay north of Botswood Lane Site (18P3) | 11 | 49 | 43 | 110 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291131 | Cowichan Bay mid channel between CB014 and CB005 (19P3) | 2 | 31 | 19 | 110 | -- | -- | -- | -- | -- | -- | -- | -- |
| 0150360 | Cowichan Bay - Shoreline at PE1538 (1P3) | 49 | 130 | 115 | 260 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291132** | Cowichan Bay at Boatswain Bank - mid beach (20P3) | 5 | 33 | 24 | 79 | <1 | 3 | 4 | 33 | <1 | 1 | 2 | 5 |
| E291133 | Cowichan Bay at Hatch Point (21P3) | 5 | 8 | 17 | 130 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291137 | Cowichan Bay south of Hatch Point (22P3) | 2 | 13 | 14 | 79 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291127** | Cowichan Bay north of Westcan Terminal (8P3) | 23 | 33 | 50 | 110 | 24 | 60 | 75 | 360 | -- | -- | -- | -- |
| E291134 | Cowichan Bay - head of Genoa Bay (CB001) | 2 | 33 | 22 | 130 | <1 | 1 | 1 | 1 | <1 | 5 | 5 | 55 |
| E219326 | Cowichan Bay off Genoa Bay (CB004) | 5 | 8 | 11 | 79 | -- | -- | -- | -- | -- | -- | -- | -- |
| E219323 | Cowichan Bay at cove east of Genoa Bay (CB005) | 3.5 | 17 | 30 | 540 | 1 | 3 | 3 | 9 | <1 | 1 | 2 | 9 |
| E291121 | Cowichan Bay 1km east of satellite channel (CB009) | 2 | 13 | 12 | 79 | -- | -- | -- | -- | -- | -- | -- | -- |
| E219324 | Cowichan Bay mouth (CB013) | 2 | 23 | 17 | 220 | -- | -- | -- | -- | -- | -- | -- | -- |
| E219325 | Cowichan Bay at Cherry Point Marina (CB014) | 4 | 38 | 38 | 540 | <1 | 9 | 8 | 58 | <1 | 2 | 2. | 3 |
| E291122 | Cowichan Bay between Skinner and Cherry Point (CB015) | 2 | 22 | 17 | 240 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291136 | Cowichan Bay out from Garnett Creek (CB025) | 2 | 17 | 21 | 350 | 3 | 8 | 9 | 23 | <1 | 1 | 1 | 6 |
| E291135 | Cowichan Bay out from Manley Creek (CB028) | 2 | 11 | 18 | 140 | -- | -- | -- | -- | -- | -- | -- | -- |
| E291123 | Cowichan Bay N of dolphins at Skinner Point (CB038) | 13 | 49 | 66 | 240 | 6 | 19 | 16 | 36 | 4 | 8 | 8 | 26 |
| E291124** | Cowichan Bay - out from Botwood Lane storm drain (CB039) | 33 | 79 | 75 | 130 | 2 | 24 | 16 | 63 | -- | -- | -- | -- |
| E291125** | Cowichan Bay off creek west of Cherry Point Marina (CB040) | 5 | 33 | 26 | 130 | 7 | 18 | 20 | 76 | -- | -- | -- | -- |
| E291126 | Cowichan Bay south Westcan Terminal, mid channel (CB041) | 24 | 49 | 76 | 350 | 7 | 13 | 14 | 27 | <1 | 5 | 5 | 50 |
| E291369* | Genoa Bay - 150m north of marina (CB057) | 11 | 25 | 29 | 110 | 1 | 9 | 7 | 49 | 2 | 4 | 8 | 83 |
| E291193 | Cowichan Bay 400m south rock barrier at marina (CB059) | 2 | 49 | 39 | 350 | -- | -- | -- | -- | -- | -- | -- | -- |
| NA***/ E294495 | Cowichan Bay Marina #1 | 350 | 350 | ***350*** | 350 | -- | -- | -- | -- | 3 | 6 | 7 | 44 |
| NA***/ E294496 | Cowichan Bay Marina #2 | 280 | 280 | ***280*** | 280 | -- | -- | -- | -- | 3 | 8 | 9 | 27 |
| NA***/ E294497 | Cowichan Bay Marina #3 | 70 | 70 | 70 | 70 | -- | -- | -- | -- | 5 | 16 | 23 | 110 |
| NA***/ E294498 | Cowichan Bay Marina #4 | 220 | 220 | ***220*** | 220 | -- | -- | -- | -- | 2 | 6 | 5 | 10 |
| NA*** | Genoa Bay at Creek 10-20 | 79 | 79 | 79 | 79 | -- | -- | -- | -- | -- | -- | -- | -- |
| NA*** | Oceanfront storm drain 10-2 | 79 | 79 | 79 | 79 | -- | -- | -- | -- | -- | -- | -- | -- |

| EMS ID | Station | 2012 -Fall | | | | 2013 -Fall | | | | 2013 - Summer | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Median[1] | Geomean[2] | Max | Min | Median[1] | Geomean[2] | Max | Min | Median[1] | Geomean[2] | Max |
| ***Cowichan Bay (samples collected by VIHA)[2]*** | | | | | | | | | | | | | |
| NA | Bomford Trail (BOMF01) | -- | -- | -- | -- | -- | -- | -- | -- | 5 | 25 | 27 | 100 |
| NA | Bomford Trail (BOMF01 | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 18 | 17 | 75 |
| NA | Bomford Trail (BOMF01 | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 9 | 27 | 1250 |
| NA | Cees and Meip Hof (CMH01) | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 5 | 10 | 75 |
| NA | Cees and Meip Hof (CMH01) | -- | -- | -- | -- | -- | -- | -- | -- | 5 | 30 | 21 | 64 |
| NA | Cees and Meip Hof (CMH01) | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 5 | 7 | 25 |
| NA | Estuary Nature Centre Park (Estu01) | -- | -- | -- | -- | -- | -- | -- | -- | 30 | 36 | 37 | 55 |
| NA | Estuary Nature Centre Park (Estu01) | -- | -- | -- | -- | -- | -- | -- | -- | 5 | 40 | 37 | 150 |
| NA | Estuary Nature Centre Park (Estu01) | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 20 | 21 | 55 |
| NA | Hecate park Boat Launch (Heca01) | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 10 | 14 | 50 |
| NA | Hecate park Boat Launch (Heca01) | -- | -- | -- | -- | -- | -- | -- | -- | 5 | 30 | 42 | 1050 |
| NA | Hecate park Boat Launch (Heca01) | -- | -- | -- | -- | -- | -- | -- | -- | 5 | 20 | 20 | 160 |
| NA | Pah Las Reserve Beach (Pahl01) | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 32 | 22 | 73 |
| NA | Pah Las Reserve Beach (Pahl01) | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 25 | 36 | 105 |
| NA | Pah Las Reserve Beach (Pahl01) | -- | -- | -- | -- | -- | -- | -- | -- | <5 | 15 | 15 | 75 |

*Based on 4 weekly samples in 30 days (2012 fall sampling).

**Based on 4 weekly samples in 30 days (2013 fall sampling).

*** Based on a single sample in 2012 and do not have requisite frequency to be compared to guidelines in 2012.

[1]Light grey highlighted median values exceed the fecal coliform guideline for shellfish harvesting of < 14 CFU/100 mL

[2]Note that VIHA collected 15 samples from 5 sites over the summer months. Statistics were calculated based on groups of 5 samples collected sequentially, resulting in 3 results for each site.

While shellfish harvesting is closed in the inlet and surrounding area, it is a designated water use that local shellfish harvesters and residents would like to see re-established. Therefore, water quality objectives are recommended for both fecal coliforms and enterococci based on future shellfish harvesting. While fecal coliforms do have their limitations as indicators (see Section 6.7), they were chosen in addition to enterococci due to their use in the Environment Canada shellfish regulations. Objectives established for shellfish harvesting may only be applicable to portions of the Bay, as the area could potentially be opened for harvesting through options such as conditional management plans, seasonal openings or depuration. However, any future shellfish harvesting would be dependent on the success of measures taken to reduce bacteriological contamination. ***Thus, the recommended water quality objective is that the median of a minimum of five weekly samples collected within a 30-day period must not exceed 4 CFU/100 mL for enterococci and must not exceed 14 CFU/100 mL for fecal coliforms at all sites within Cowichan Bay (shellfish harvesting guideline).***

## 6.8 Microbial Source Tracking

While elevated levels of fecal indicator bacteria can indicate a potential risk to human health and provide evidence of fecal pollution, they cannot identify the source of contamination. When this is unknown, the actual risk to human health is uncertain and it is not always clear where to direct management efforts. Over the last decade, researchers have developed a range of microbial source tracking (MST) tools that can be used to distinguish human-sourced fecal contamination from that of animals (Ahmed *et al*., 2010). Some methods include ribotyping, pulse-field gel electrophoresis, denaturing-gradient gel electrophoresis, repetitive DNA sequences (Rep-PCR), host-specific 16S rDNA genetic markers (Bacteroides), and antibiotic resistance analysis (Scott *et al.*, 2002; Meays *et al.*, 2004). Each method appears to have distinct advantages and disadvantages and currently there is no standard method that has been adopted for source tracking (Meays *et al.*, 2004). Determining which method or combination of methods to use for any given situation will depend on several factors including: the goal of the project; the level of detail required (broad scale results -human /non-human versus detailed results – human, livestock species, wildlife species); availability of resources; time constraints; and access to a lab with expertise to analyze the samples.

To identify the potential source(s) of fecal contamination in the Cowichan Bay watershed, the MST technique used in this study combined the measurements of fecal indicator bacteria (i.e., fecal coliform) with the detection of human specific markers for Bacteroides. This technique can be used to discriminate and identify the source of contamination if it is human, ruminant (including deer), horse, pig, or dog. This MST technique provides a presence/absence result and cannot quantify the amount of contamination from each source identified. Other considerations for selecting this method included the ability to use the Pacific Environmental Services Centre (PESC) laboratory in North Vancouver, which specializes in this technique. Only samples with fecal coliform counts of 40 colony forming units (CFU)/100 mL or higher were submitted for Bacteroides analysis.

In the 2012 sampling, 33 of the 52 samples collected for MST analysis were analyzed by PESC, as they met the required fecal coliform results (≥40 CFU/100ml). The breakdown of samples analyzed by location were as follows: one out of eight Cowichan River sites; seven out of nine Koksilah River sites (not within the Cowichan Bay study area); 14 (plus two duplicates) out of 24 Cowichan Bay marine sites and 11 (plus one duplicate) out of 11 Cowichan Bay freshwater sites. The results for the 2012 MST analysis can be found in Appendix IVa. Human markers were identified at all sites within Cowichan Bay. There were six other human markers identified from the Cowichan Bay freshwater sites. The human sources are likely due to freshwater inputs from aging and poorly maintained septic systems, as well as marine activity, including float homes and boating. Ruminant (e.g., cattle, sheep, goats and deer) markers were found in all of the Cowichan Bay marine sites, and in 10 of the 12 freshwater sites which drain into Cowichan Bay. The only two Cowichan Bay freshwater sites that did not contain ruminant markers were Manley Creek and the storm drain at Botwood Lane. Coincidently these two sites did not have human markers either. Pig markers were found at two sites in Cowichan Bay and seven sites in the Cowichan Bay freshwater tributaries. The level of confidence in a positive pig result is not as high as any of the other organisms because pig primers for one of the markers have been noted to cross-prime with ruminant animals (PESC personnel communication, 2013).

Of the 65 sites sampled for MST analysis in 2013, only two samples from the study area were analyzed through PESC (the remaining samples did not meet the fecal coliforms threshold of at least 40 CFU/100 ml) (note sites from outside of the study area are seen in the results presented in the Appendix). The low concentration of fecal coliforms is likely due to lower rainfall in 2013. The samples analyzed for MST were E291151 Garnett Creek at Telegraph Road (CB03), E291161 Spiers Creek at Hillbank Road (CB11). The results of the MST analysis can be found in Appendix IVb. Only the E291151 Garnett Creek at Telegraph Road (CB03) site had any markers identified, these were for human and ruminant (e.g. cow, sheep, goat or deer).

For the 2013 sampling, some microbiological samples shipped to the University of Victoria (UVIC) Water Research lab, in addition to the MST work conducted by the PESC lab. The UVIC lab has developed a DNA library for the Shawnigan watershed from various sources of scat in the area from which the test samples can be compared to verify the source of contamination. Samples were submitted from the Cowichan Lake watershed to determine whether the Shawnigan watershed library would provide matches. The UVIC MST method can identify a broader range of sources than the PESC Bacteroides method. The specific methods used for microbial source tracking can be found in Mazumber (2011). As funding was limited, only 10 samples were sent to UVIC from sites that previously had concentrations of bacteria (five from Cowichan Bay freshwater tributaries and five from Cowichan Bay marine sites).
All 10 samples sent to the UVIC lab had sufficient concentrations of *E. coli* that one or more sources of bacteria were identified in each sample. This process was able to identify various types of wildlife (including black bear, coyote, and marmot) as well as human and domestic animal sources. As coyotes are not present on Vancouver Island, it appears that the methodology may need some refinement; samples identified as coyote are likely from domestic dogs. Samples from two sites had *E. coli* from wildlife sources only (E294495

Cowichan Bay -Marina #1 (FH_1/CB062) and E291163 Treffery Creek at Hwy (Treffery)) and samples from four sites contained *E. coli* from human, wildlife and cow/horse sources: E294496 Cowichan Bay -Marina #2 (FH_2/CB063), E291126 Cowichan Bay- S of Westcan Terminal, mid channel (CB041), E291124 Cowichan Bay by Botwood Stormdrain (CB039), and E291151 Garnett Creek at Telegraph Road (CB03). The E291136 Cowichan Bay at Garnett Creek (CB025) site had only ruminant (cow) markers identified, and the remaining three sites had wildlife and cow/horse markers. The results of the MST analysis can be found in Appendix IVc.

Results from both studies indicate that human sources of bacteriological contamination occur in the watershed, as evidenced by human markers found in the Bay and tributaries to the Bay. It is recommended that another set of samples be analyzed for microbial source tracking to confirm the sites that pose a high risk to human health and pinpoint the sources of contamination. Once identified, appropriate actions should be initiated to work towards removing these inputs.

## 7. SUMMARY OF RECOMMENDED WATER QUALITY OBJECTIVES AND MONITORING SCHEDULE

In BC, water quality objectives are generally based on approved or working water quality guidelines. These guidelines are established to prevent specified detrimental effects from occurring with respect to a designated water use. Designated water uses for the freshwater streams in the Cowichan Bay study area that are sensitive and should be protected include aquatic life, aquatic life (shellfish harvesting), wildlife, drinking water, irrigation and secondary contact recreation. Designated water uses for the marine areas of the Cowichan Bay study area that are sensitive and should be protected include aquatic life (shellfish harvesting) and recreation. The water quality objectives recommended in this document (summarized in Table 21) apply only to the marine waters of Cowichan Bay. It is recommended that the Cowichan Bay freshwater tributaries be compared to the water quality objectives in place for the Cowichan and Koksilah Rivers, except for dissolved oxygen (compare to BC water quality guidelines) and total phosphorus (compare to Vancouver Island Phosphorus Guidance) (summarized in Table 22).

Recommended objectives for Cowichan Bay consider background conditions, impacts from current land use, contributions from the tributary streams and any known potential future impacts that may arise within the watershed. These recommended objectives should be periodically reviewed and revised to reflect any future improvements or technological advancements in water quality assessment and analysis.

*Table 21. Summary of recommended Water Quality Objectives for Cowichan Bay.*

| Variable | Objective | Applies to | Objective adopted from: |
|---|---|---|---|
| Enterococci | ≤ 4 CFU/100 mL (median) | Marine water | BC WQG |
| Fecal coliforms | ≤ 14 CFU/100 mL (median) | Marine water | BC WQG |

[1]Unless otherwise specified, all statistics are to be calculated based on five samples in 30 days.

*Table 22. Summary of parameters and associated BC water quality guidelines or Cowichan and Koksilah Rivers Water Quality Objectives for consideration in Cowichan Bay tributaries.*

| Variable | Objective | Applies to | Objective adopted from: |
|---|---|---|---|
| Dissolved Oxygen | ≥ 5 mg/L (min) | Freshwater | BC WQG |
| | ≥ 8 mg/L (average) | | |
| Turbidity | ≤ 5 NTU (max) | Freshwater (Oct to Apr) | Cowichan/Koksilah River Water Quality Objectives |
| | ≤ 2 NTU (max) | Freshwater (May to Sept) | |
| Non-filterable Residue/Total Suspended Solids (TSS) | ≤ 7 mg/L (mean) | Freshwater | Cowichan/Koksilah River Water Quality Objectives |
| | ≤ 27 mg/L (max) | | |
| Total Phosphorus[2] | ≤ 5 µg/L (mean) | Freshwater (May to Sept) | Vancouver Island Phosphorus Guidance document |
| | ≤ 10 µg/L (max) | | |
| Total Copper | ≤ 2 µg/L (mean) | Freshwater | Cowichan/Koksilah River Water Quality Objectives |
| | ≤ 4 µg/L (max) | | |
| Total Zinc | ≤ 7.5 µg/L (mean) | Freshwater | Cowichan/Koksilah River Water Quality Objectives |
| | ≤ 33 µg/L (max) | | |
| *Escherichia coli* | ≤ 10 CFU/100 mL ($90^{th}$ percentile) | Freshwater | Cowichan/Koksilah River Water Quality Objectives |

[1]Unless otherwise specified, all statistics are to be calculated based on five weekly samples in 30 days.
[2]Guidance is to be applied to the total phosphorus average, with samples collected monthly.

The recommended water quality monitoring program for Cowichan Bay study area is summarized in Table 23. It is recommended that future attainment monitoring occur once every 5 years based on staff and funding availability, and whether activities (such as agriculture or development) change significantly within the study area. Water quality parameters to monitor include some that are supplemental to core water quality objectives monitoring.

*Table 23. Recommended schedule for future water quality monitoring for the Cowichan Bay study area.*

| Sampling area | Timing | Parameters |
|---|---|---|
| Freshwater streams | 5-in-30 sampling summer and fall | Total and dissolved metals, total hardness<br>**Nutrients**: total P, total N, total nitrate, total nitrite<br>**Conventional parameters:** turbidity, TSS, temperature, DO, pH, conductivity<br>**Microbiology**: *E. coli* |
| Freshwater streams | Monthly (growing season only) | Total phosphorus, chlorophyll *a* |
| Cowichan Bay marine areas | 5-in-30 sampling summer and fall | Enterococci, fecal coliforms |

Monitoring consisting of at least 5 samples collected within a 30-day period should be conducted during the summer dry period (between August and September) and the fall freshet period (October and November) at all sites (freshwater and marine). Samples collected during the winter months should coincide with rain events whenever possible. In this way, the two critical periods (maximum residence time/minimum dilution during low-flow and maximum turbidity during freshet), will be monitored. An additional 5 in 30 monitoring period during spring manure spreading (March/April) in the tributaries only may provide useful information on nutrient sources to the streams. The samples in the tributaries should be analyzed for total and dissolved metals and hardness, nutrients, conventional parameters and *E. coli*. The samples collected in the marine areas should be analyzed for microbiological parameters (enterococci and fecal coliforms).

It is recommended that monitoring for *E. coli* in the tributaries to Cowichan Bay should specifically target hot spots identified in Sections 6.7 and 6.8 of this report and sites in the upper portion of the tributaries, to provide information on contamination patterns along the streams (from headwaters to where the stream flows into the Bay). This sampling should be done in conjunction with or following remediation activities or improved changes to land use activities (such as manure spreading and storage).

Summer sampling may not be required for enterococci (except for the marina area), since the 2013 sampling results indicate that summer concentrations are lower than those observed in the fall. However, if budgets permit, it is recommended that summer sampling commence for at least one additional year to confirm this temporal pattern. Cowichan Bay shoreline sites (VIHA sampling sites) should be targeted for microbiological sampling, as these sites showed a pattern of being generally higher than the open water sites sampled by the other partnership agencies.

It is recommended that suitable reference sites for microbial indicators should be identified and sampled, to allow comparison to the sites sampled within the Bay.

It is recommended that microbial source tracking (MST) sampling occur during future attainment monitoring, to provide additional information for identifying sources of microbiological contaminants, and to determine if there are any changes in the sources of microbiological contaminants.

Monthly field sampling should occur during the growing season at the freshwater sites to measure total phosphorous and chlorophyll *a*. Chlorophyll *a* should be measured as the biomass of naturally growing periphytic algae, which will allow direct comparison to the Cowichan and Koksilah Rivers objective.

It is recommended that some limited marine sediment sampling be included during future attainment monitoring sampling at key sites (sites in the estuary, near the Westcan terminal, and near the marina). Many toxic and bioaccumulative substances can accumulate to elevated levels in sediment, although they may be found only in trace amounts in water. Contaminants enter water systems from industrial and municipal discharges, urban and agricultural runoff and atmospheric deposition, and due to the physical and chemical properties of these contaminants, many tend to accumulate in sediments. Sediments provide sinks for many chemicals and may also serve as a source of pollutants to the water column (MacDonald and Ingersoll, 2003). Monitoring completed and proposed by G3 Consulting Ltd (2020a and 2020b) associated with the proposed movement of the Joint Utilities Boards sewage outfall includes valuable sediment data that should be considered, together with data collected from Cowichan Tribes (Laliberte and Kulchynski, 2013) in future assessments of Cowichan Bay.

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# APPENDIX I. SUMMARY OF WATER QUALITY DATA

*Table 24. Raw water quality data for sites in Cowichan Bay (2012 sampling).*

| Site | Collection Date | Collection Season | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) | Site | Collection Date | Collection Season | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) | Site | Collection Date | Collection Season | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10P3 | 20121015 | Fall | <1 | <2 | 8P3 | 20121015 | Fall | 69 | 110 | CB025 | 20121015 | Fall | <1 | 8 |
| 10P3 | 20121024 | Fall | 3 | <2 | 8P3 | 20121024 | Fall | 19 | 33 | CB025 | 20121024 | Fall | 1 | 2 |
| 10P3 | 20121029 | Fall | 114 | 130 | 8P3 | 20121029 | Fall | 310 | 110 | CB025 | 20121029 | Fall | 88 | 350 |
| 10P3 | 20121105 | Fall | 38 | 46 | 8P3 | 20121105 | Fall | 44 | 33 | CB025 | 20121105 | Fall | 37 | 46 |
| 10P3 | 20121113 | Fall | 122 | 79 | 8P3 | 20121113 | Fall | 65 | 23 | CB025 | 20121113 | Fall | 52 | 17 |
| 11P3 | 20121015 | Fall | 3 | <2 | CB001 | 20121015 | Fall | 14.5 | 130 | CB028 | 20121015 | Fall | 9 | 7 |
| 11P3 | 20121024 | Fall | 11 | 13 | CB001 | 20121024 | Fall | 6 | <2 | CB028 | 20121024 | Fall | 1 | 2 |
| 11P3 | 20121029 | Fall | 85 | 79 | CB001 | 20121029 | Fall | 40.5 | 33 | CB028 | 20121029 | Fall | 121 | 140 |
| 11P3 | 20121105 | Fall | 46 | 79 | CB001 | 20121105 | Fall | 20 | 17 | CB028 | 20121105 | Fall | 44 | 79 |
| 11P3 | 20121113 | Fall | 18 | 33 | CB001 | 20121113 | Fall | 73 | 33 | CB028 | 20121113 | Fall | 16 | 11 |
| 18P3 | 20121015 | Fall | 34 | 33 | CB004 | 20121015 | Fall | <1 | 8 | CB038 | 20121015 | Fall | 7 | 13 |
| 18P3 | 20121024 | Fall | 29 | 11 | CB004 | 20121024 | Fall | 5 | 5 | CB038 | 20121024 | Fall | 34 | 33 |
| 18P3 | 20121029 | Fall | 149 | 110 | CB004 | 20121029 | Fall | 60 | 79 | CB038 | 20121029 | Fall | 168 | 240 |
| 18P3 | 20121105 | Fall | 57 | 49 | CB004 | 20121105 | Fall | 8 | 5 | CB038 | 20121105 | Fall | 54 | 49 |
| 18P3 | 20121113 | Fall | 210 | 79 | CB004 | 20121113 | Fall | 37 | 11 | CB038 | 20121113 | Fall | 29 | 240 |
| 19P3 | 20121015 | Fall | <1 | <2 | CB005 | 20121015 | Fall | 8 | 17 | CB039 | 20121015 | Fall | 147 | 130 |
| 19P3 | 20121024 | Fall | 3 | 8 | CB005 | 20121024 | Fall | 5.5 | 3.5 | CB039 | 20121024 | Fall | 39 | 33 |
| 19P3 | 20121029 | Fall | 106 | 110 | CB005 | 20121029 | Fall | 71 | 130 | CB039 | 20121029 | Fall | 139 | 55 |
| 19P3 | 20121105 | Fall | 27 | 31 | CB005 | 20121105 | Fall | 43 | 540 | CB039 | 20121105 | Fall | 78 | 79 |
| 19P3 | 20121113 | Fall | 51 | 49 | CB005 | 20121113 | Fall | 13 | 6 | CB039 | 20121113 | Fall | 120 | 130 |
| 1P3 | 20121015 | Fall | 110 | 70 | CB009 | 20121015 | Fall | 2 | <2 | CB040 | 20121015 | Fall | 1 | 5 |
| 1P3 | 20121024 | Fall | 56 | 49 | CB009 | 20121024 | Fall | <1 | <2 | CB040 | 20121024 | Fall | 13 | 8 |
| 1P3 | 20121029 | Fall | 560 | 130 | CB009 | 20121029 | Fall | 135 | 70 | CB040 | 20121029 | Fall | 190 | 130 |
| 1P3 | 20121105 | Fall | 450 | 170 | CB009 | 20121105 | Fall | 35 | 13 | CB040 | 20121105 | Fall | 64 | 33 |
| 1P3 | 20121113 | Fall | 395 | 260 | CB009 | 20121113 | Fall | 81 | 79 | CB040 | 20121113 | Fall | 107 | 70 |
| 20P3 | 20121015 | Fall | 1 | 8 | CB013 | 20121015 | Fall | 3 | <2 | CB041 | 20121015 | Fall | 86 | 49 |
| 20P3 | 20121024 | Fall | 6 | 5 | CB013 | 20121024 | Fall | 2 | <2 | CB041 | 20121024 | Fall | 42 | 24 |
| 20P3 | 20121029 | Fall | 93 | 79 | CB013 | 20121029 | Fall | 109 | 220 | CB041 | 20121029 | Fall | 840 | 170 |
| 20P3 | 20121105 | Fall | 31 | 33 | CB013 | 20121105 | Fall | 23 | 23 | CB041 | 20121105 | Fall | 53.5 | 36 |
| 20P3 | 20121113 | Fall | 38 | 79 | CB013 | 20121113 | Fall | 78 | 79 | CB041 | 20121113 | Fall | 123 | 350 |
| 21P3 | 20121015 | Fall | 2 | 6 | CB014 | 20121015 | Fall | 1 | 4 | CB057 | 20121024 | Fall | 5 | 11 |
| 21P3 | 20121024 | Fall | <1 | 5 | CB014 | 20121024 | Fall | 20 | 13 | CB057 | 20121029 | Fall | 14 | 110 |
| 21P3 | 20121029 | Fall | 46 | 130 | CB014 | 20121029 | Fall | 1220 | 540 | CB057 | 20121105 | Fall | 16 | 17 |
| 21P3 | 20121105 | Fall | 42 | 49 | CB014 | 20121105 | Fall | 58.5 | 38 | CB057 | 20121113 | Fall | 59 | 33 |
| 21P3 | 20121113 | Fall | 8 | 8 | CB014 | 20121113 | Fall | 112 | 79 | CB059 | 20121015 | Fall | 2 | 2 |
| 22P3 | 20121015 | Fall | 6 | 13 | CB015 | 20121015 | Fall | <1 | <2 | CB059 | 20121024 | Fall | 49 | 33 |
| 22P3 | 20121024 | Fall | 3 | 17 | CB015 | 20121024 | Fall | 3 | 2 | CB059 | 20121029 | Fall | 450 | 79 |
| 22P3 | 20121029 | Fall | 7 | <2 | CB015 | 20121029 | Fall | 114 | 240 | CB059 | 20121105 | Fall | 68 | 49 |
| 22P3 | 20121105 | Fall | 37 | 79 | CB015 | 20121105 | Fall | 35 | 22 | CB059 | 20121113 | Fall | 152 | 350 |
| 22P3 | 20121113 | Fall | 39 | 13 | CB015 | 20121113 | Fall | 31 | 64 | FH_1 | 20121105 | Fall | 690 | 350 |
| | | | | | | | | | | FH_2 | 20121105 | Fall | 580 | 280 |
| | | | | | | | | | | FH_3 | 20121105 | Fall | 130 | 70 |
| | | | | | | | | | | FH_4 | 20121105 | Fall | 710 | 220 |
| | | | | | | | | | | GB@Cree | 20121029 | Fall | 39 | 79 |
| | | | | | | | | | | OceanSD | 20121029 | Fall | 290 | 79 |

*Table 25.. Raw water quality data for sites in Cowichan Bay (2013 sampling).*

| Site | Collection Date | Collection Season | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) |
|---|---|---|---|---|
| 20P3 | 20130730 | Summer | <1 | 1 |
| 20P3 | 20130806 | Summer | 1 | <1 |
| 20P3 | 20130813 | Summer | <1 | 1 |
| 20P3 | 20130820 | Summer | 3 | 3 |
| 20P3 | 20130827 | Summer | <1 | 5 |
| 20P3 | 20131105 | Fall | | |
| 20P3 | 20131112 | Fall | 24 | 33 |
| 20P3 | 20131119 | Fall | 1 | <1 |
| 20P3 | 20131127 | Fall | 1 | 5 |
| 20P3 | 20131203 | Fall | <1 | <1 |
| 8P3 | 20131105 | Fall | | |
| 8P3 | 20131112 | Fall | 9 | 68 |
| 8P3 | 20131119 | Fall | 35.5 | 52.5 |
| 8P3 | 20131127 | Fall | 42 | 360 |
| 8P3 | 20131203 | Fall | 7 | 24 |
| BOMF01 | 20130521 | Summer | | 15 |
| BOMF01 | 20130529 | Summer | | 100 |
| BOMF01 | 20130603 | Summer | | 5 |
| BOMF01 | 20130610 | Summer | | 25 |
| BOMF01 | 20130617 | Summer | | 70 |
| BOMF01 | 20130624 | Summer | | 10 |
| BOMF01 | 20130701 | Summer | | <5 |
| BOMF01 | 20130708 | Summer | | 75 |
| BOMF01 | 20130715 | Summer | | 18 |
| BOMF01 | 20130722 | Summer | | 20 |
| BOMF01 | 20130729 | Summer | | 1250 |
| BOMF01 | 20130805 | Summer | | 50 |
| BOMF01 | 20130812 | Summer | | <5 |
| BOMF01 | 20130827 | Summer | | <5 |
| BOMF01 | 20130828 | Summer | | 9 |
| CB001 | 20130730 | Summer | <1 | <1 |
| CB001 | 20130806 | Summer | <1 | <1 |
| CB001 | 20130813 | Summer | 5 | 10 |
| CB001 | 20130820 | Summer | 11 | 55 |
| CB001 | 20130827 | Summer | 2 | 5 |
| CB001 | 20131105 | Fall | 21 | <1 |
| CB001 | 20131112 | Fall | 2 | 1 |
| CB001 | 20131119 | Fall | 36 | 1 |
| CB001 | 20131127 | Fall | 1 | <1 |
| CB001 | 20131203 | Fall | 8 | <1 |
| CB005 | 20130730 | Summer | <1 | <1 |
| CB005 | 20130806 | Summer | 1 | <1 |
| CB005 | 20130813 | Summer | 1 | <1 |
| CB005 | 20130820 | Summer | 4 | 9 |
| CB005 | 20130827 | Summer | 1 | 3 |
| CB005 | 20131105 | Fall | 13 | 9 |
| CB005 | 20131112 | Fall | 3 | 7 |
| CB005 | 20131119 | Fall | 7 | 3 |
| CB005 | 20131127 | Fall | 2 | 1 |
| CB005 | 20131203 | Fall | 1 | 1 |
| CB014 | 20130730 | Summer | <1 | 3 |
| CB014 | 20130806 | Summer | <1 | 2 |
| CB014 | 20130813 | Summer | 7 | 2 |
| CB014 | 20130820 | Summer | <1 | 3 |
| CB014 | 20130827 | Summer | <1 | <1 |
| CB014 | 20131105 | Fall | <1 | <1 |
| CB014 | 20131112 | Fall | 8 | 3 |
| CB014 | 20131119 | Fall | 37.5 | 58 |
| CB014 | 20131127 | Fall | 6 | 9 |
| CB014 | 20131203 | Fall | 5 | 17 |
| CB025 | 20130730 | Summer | <1 | 1 |
| CB025 | 20130806 | Summer | <1 | <1 |
| CB025 | 20130813 | Summer | <1 | <1 |
| CB025 | 20130820 | Summer | 3 | 1 |
| CB025 | 20130827 | Summer | 1 | 6 |
| CB025 | 20131105 | Fall | 27 | 19 |
| CB025 | 20131112 | Fall | 8.5 | 22.5 |
| CB025 | 20131119 | Fall | 2.5 | 8 |
| CB025 | 20131127 | Fall | 3 | 7 |
| CB025 | 20131203 | Fall | 1 | 3 |
| CB038 | 20130730 | Summer | 1 | 5 |
| CB038 | 20130806 | Summer | 1 | 8 |
| CB038 | 20130813 | Summer | 5 | 4 |
| CB038 | 20130820 | Summer | 10 | 26 |
| CB038 | 20130827 | Summer | 5 | 9 |
| CB038 | 20131105 | Fall | 31 | 6 |
| CB038 | 20131112 | Fall | 5 | 36 |
| CB038 | 20131119 | Fall | 29 | 25 |
| CB038 | 20131127 | Fall | 8 | 11 |
| CB038 | 20131203 | Fall | 2 | 19 |
| CB039 | 20131105 | Fall | | |
| CB039 | 20131112 | Fall | 9 | 18 |
| CB039 | 20131119 | Fall | 67 | 63 |
| CB039 | 20131127 | Fall | 1 | 2 |
| CB039 | 20131203 | Fall | 12 | 29 |
| CB040 | 20131105 | Fall | | |
| CB040 | 20131112 | Fall | 8 | 12 |
| CB040 | 20131119 | Fall | 23 | 23 |
| CB040 | 20131127 | Fall | 8 | 7 |
| CB040 | 20131203 | Fall | 17.5 | 75.5 |
| CB041 | 20130730 | Summer | <1 | <1 |
| CB041 | 20130806 | Summer | 3 | 10 |
| CB041 | 20130813 | Summer | 16 | <1 |
| CB041 | 20130820 | Summer | 30 | 50 |
| CB041 | 20130827 | Summer | 3 | 5 |
| CB041 | 20131105 | Fall | 15 | 26.5 |
| CB041 | 20131112 | Fall | 7 | 19 |
| CB041 | 20131119 | Fall | 6 | 13 |
| CB041 | 20131127 | Fall | 13 | 10 |
| CB041 | 20131203 | Fall | 7 | 7 |
| CB057 | 20130730 | Summer | <1 | 2 |
| CB057 | 20130806 | Summer | <1 | 2 |
| CB057 | 20130813 | Summer | 4 | 4 |
| CB057 | 20130820 | Summer | 3.5 | 22 |
| CB057 | 20130827 | Summer | 279 | 83 |
| CB057 | 20131105 | Fall | 16 | 1 |
| CB057 | 20131112 | Fall | 20 | 4 |
| CB057 | 20131119 | Fall | 9 | 9 |
| CB057 | 20131127 | Fall | 2750 | 48.5 |
| CB057 | 20131203 | Fall | 3 | 11 |
| CB062 | 20130730 | Summer | 35 | 44 |
| CB062 | 20130806 | Summer | 11 | 9 |
| CB062 | 20130813 | Summer | 5 | 3 |
| CB062 | 20130820 | Summer | 31 | 6 |
| CB062 | 20130827 | Summer | 8 | 3 |
| CB062 | 20131105 | Fall | 180 | |
| CB062 | 20131112 | Fall | 74 | |
| CB062 | 20131119 | Fall | 210 | |
| CB062 | 20131127 | Fall | 1000 | |
| CB062 | 20131203 | Fall | 14 | |

| Site | Collection Date | Collection Season | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) |
|---|---|---|---|---|
| CB063 | 20130730 | Summer | 29 | 27 |
| CB063 | 20130806 | Summer | 14 | 15 |
| CB063 | 20130813 | Summer | 2 | 3 |
| CB063 | 20130820 | Summer | 20 | 8 |
| CB063 | 20130827 | Summer | 11 | 5 |
| CB063 | 20131105 | Fall | 310 | |
| CB063 | 20131112 | Fall | 14 | |
| CB063 | 20131119 | Fall | 200 | |
| CB063 | 20131127 | Fall | 35 | |
| CB063 | 20131203 | Fall | 17 | |
| CB064 | 20130730 | Summer | 142 | 110 |
| CB064 | 20130806 | Summer | 20 | 16 |
| CB064 | 20130813 | Summer | 12 | 5 |
| CB064 | 20130820 | Summer | 20 | 9 |
| CB064 | 20130827 | Summer | 59.5 | 75.5 |
| CB064 | 20131105 | Fall | 26.5 | |
| CB064 | 20131112 | Fall | 21 | |
| CB064 | 20131119 | Fall | 74 | |
| CB064 | 20131127 | Fall | 4 | |
| CB064 | 20131203 | Fall | 15 | |
| CB065 | 20130730 | Summer | 1 | 3 |
| CB065 | 20130806 | Summer | 6 | 2 |
| CB065 | 20130813 | Summer | 4 | 8 |
| CB065 | 20130820 | Summer | 13 | 10 |
| CB065 | 20130827 | Summer | 38 | 6 |
| CB065 | 20131105 | Fall | 10 | |
| CB065 | 20131112 | Fall | 5 | |
| CB065 | 20131119 | Fall | 52 | |
| CB065 | 20131127 | Fall | 26 | |
| CB065 | 20131203 | Fall | 16 | |
| CMH01 | 20130521 | Summer | | <5 |
| CMH01 | 20130529 | Summer | | 10 |
| CMH01 | 20130603 | Summer | | 5 |
| CMH01 | 20130610 | Summer | | <5 |
| CMH01 | 20130617 | Summer | | 75 |
| CMH01 | 20130624 | Summer | | 40 |
| CMH01 | 20130701 | Summer | | 10 |
| CMH01 | 20130708 | Summer | | 64 |
| CMH01 | 20130715 | Summer | | 30 |
| CMH01 | 20130722 | Summer | | 5 |
| CMH01 | 20130729 | Summer | | 25 |
| CMH01 | 20130805 | Summer | | <5 |
| CMH01 | 20130812 | Summer | | <5 |
| CMH01 | 20130827 | Summer | | <5 |
| CMH01 | 20130828 | Summer | | 5 |
| Estu01 | 20130521 | Summer | | 30 |
| Estu01 | 20130529 | Summer | | 55 |
| Estu01 | 20130603 | Summer | | 30 |
| Estu01 | 20130610 | Summer | | 36 |
| Estu01 | 20130617 | Summer | | 40 |
| Estu01 | 20130624 | Summer | | 85 |
| Estu01 | 20130701 | Summer | | 5 |
| Estu01 | 20130708 | Summer | | 27 |
| Estu01 | 20130715 | Summer | | 40 |
| Estu01 | 20130722 | Summer | | 150 |
| Estu01 | 20130729 | Summer | | 50 |
| Estu01 | 20130805 | Summer | | 55 |
| Estu01 | 20130812 | Summer | | <5 |
| Estu01 | 20130827 | Summer | | 20 |
| Estu01 | 20130828 | Summer | | 15 |
| Heca01 | 20130521 | Summer | | 5 |
| Heca01 | 20130529 | Summer | | 36 |
| Heca01 | 20130603 | Summer | | <5 |
| Heca01 | 20130610 | Summer | | 10 |
| Heca01 | 20130617 | Summer | | 50 |
| Heca01 | 20130624 | Summer | | 30 |
| Heca01 | 20130701 | Summer | | 5 |
| Heca01 | 20130708 | Summer | | 45 |
| Heca01 | 20130715 | Summer | | 1050 |
| Heca01 | 20130722 | Summer | | 18 |
| Heca01 | 20130729 | Summer | | 35 |
| Heca01 | 20130805 | Summer | | 20 |
| Heca01 | 20130812 | Summer | | 160 |
| Heca01 | 20130827 | Summer | | 5 |
| Heca01 | 20130828 | Summer | | 5 |
| Pahl01 | 20130521 | Summer | | 9 |
| Pahl01 | 20130529 | Summer | | 73 |
| Pahl01 | 20130603 | Summer | | <5 |
| Pahl01 | 20130610 | Summer | | 32 |
| Pahl01 | 20130617 | Summer | | 45 |
| Pahl01 | 20130624 | Summer | | 65 |
| Pahl01 | 20130701 | Summer | | 23 |
| Pahl01 | 20130708 | Summer | | 105 |
| Pahl01 | 20130715 | Summer | | 15 |
| Pahl01 | 20130722 | Summer | | 25 |
| Pahl01 | 20130729 | Summer | | 25 |
| Pahl01 | 20130805 | Summer | | 75 |
| Pahl01 | 20130812 | Summer | | 15 |
| Pahl01 | 20130827 | Summer | | 5 |
| Pahl01 | 20130828 | Summer | | <5 |

*Table 26.. Raw water quality data for sites in freshwater tributaries to Cowichan Bay (2012 sampling).*

| | | | Microbiological parameters | | | | Conventional parameters | | | | | | Nutrients | | | Metals | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Collection Date** | **Collection Season** | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) | *E. coli* (CFU/100 mL) | Chlorophyll a (ug/cm $^2$) | DO (mg/L) | Total Hardness (mg/L) | pH | Temp (C) | Turbidity (NTU) | TSS/NFR (mg/L) | Ammonia (N; mg/L) | Total N (mg/L) | Total P (mg/L) | Total Copper (ug/L) | Total Lead (ug/L) | Total Zinc (ug/L) | Total PAH (ug/L) |
| CB01 | 20121015 | Fall | | | 3150 | | | 67.6 | | | 4.29 | 5.9 | 0.0374 | | 0.223 | 2.195 | 0.0795 | 1.885 | |
| CB01 | 20121024 | Fall | | | 66 | | | 67.3 | | | 6.7 | 7.1 | 0.0409 | | 0.212 | 2.09 | 0.0680 | 1.74 | |
| CB01 | 20121029 | Fall | | | 1100 | | | 55.7 | | | 17.6 | 26.5 | 0.0279 | | 0.354 | 4.69 | 0.280 | 4.57 | |
| CB01 | 20121105 | Fall | | | 92 | | | | | | 7.6 | 3.8 | 0.0264 | | 0.315 | | | | |
| CB01 | 20121113 | Fall | | | 1800 | | | | | | 9.18 | 4.6 | 0.0206 | | 0.195 | | | | |
| CB02 | 20121015 | Fall | | | 59 | | | 97.1 | | | 1.53 | 1.7 | 0.0313 | | 0.0359 | 0.838 | 0.0280 | 0.60 | |
| CB02 | 20121024 | Fall | | | 11 | | | | | | 2.38 | 1 | 0.051 | | 0.0286 | | | | |
| CB02 | 20121029 | Fall | | | 870 | | | 97.25 | | | 68.4 | 81.4 | 0.762 | | 0.655 | 14.45 | 0.394 | 28.8 | |
| CB02 | 20121105 | Fall | | | 250 | | | | | | 13.4 | 6.6 | 0.0684 | | 0.172 | | | | |
| CB02 | 20121113 | Fall | | | 1100 | | | | | | 11.7 | 5.7 | 0.0314 | | 0.106 | | | | |
| CB03 | 20121015 | Fall | | | 2000 | | | 95.7 | | | 21.5 | 20.1 | 0.0366 | | 0.229 | 6.10 | 0.280 | 16.2 | |
| CB03 | 20121024 | Fall | | | 67 | | | | | | 12.8 | 4 | 0.0144 | | 0.113 | | | | |
| CB03 | 20121029 | Fall | | | 21000 | | | 65.8 | | | 48.7 | 16 | 0.0538 | | 0.266 | 8.42 | 0.440 | 21.5 | |
| CB03 | 20121105 | Fall | | | 510 | | | | | | 14.9 | 5.2 | 0.0186 | | 0.318 | | | | |
| CB03 | 20121113 | Fall | | | 600 | | | | | | 16.3 | 7.3 | 0.0268 | | 0.151 | | | | |
| CB04 | 20121015 | Fall | | | 420 | | | 88.5 | | | 1.68 | 1 | 0.0484 | | 0.103 | 3.44 | 0.0420 | 3.08 | |
| CB04 | 20121024 | Fall | | | 1500 | | | | | | 2.83 | 3.6 | 0.0101 | | 0.0762 | | | | |
| CB04 | 20121105 | Fall | | | 170 | | | | | | 6.65 | 3.5 | 0.0104 | | 0.0771 | | | | |
| CB04 | 20121113 | Fall | | | 250 | | | | | | 6.3 | 3.9 | 0.0106 | | 0.0638 | | | | |
| CB05 | 20121024 | Fall | | | 330 | | | | | | 2.75 | 2.6 | 0.0246 | | 0.0802 | | | | |
| CB05 | 20121029 | Fall | | | 19000 | | | 57.3 | | | 41.2 | 38.8 | 0.251 | | 0.489 | 9.21 | 0.567 | 15.5 | |
| CB05 | 20121105 | Fall | | | 160 | | | | | | 11.5 | 11.8 | 0.0464 | | 0.18 | | | | |
| CB05 | 20121113 | Fall | | | 980 | | | | | | 41.2 | 121 | 0.0179 | | 0.213 | | | | |
| CB06 | 20121024 | Fall | | | 375 | | | | | | 15.5 | 3.7 | 0.0134 | | 0.117 | | | | |
| CB06 | 20121029 | Fall | | | 570 | | | 52.1 | | | 16.4 | 4.5 | 0.0301 | | 0.119 | 8.88 | 0.399 | 11.3 | |
| CB06 | 20121105 | Fall | | | 33 | | | | | | 9.42 | 1.3 | 0.0139 | | 0.0781 | | | | |
| CB06 | 20121113 | Fall | | | 27 | | | | | | 11.8 | 2.4 | 0.0138 | | 0.0726 | | | | |
| CB07 | 20121024 | Fall | | | 1300 | | | | | | 15 | 12.9 | 0.0088 | | 0.101 | | | | |
| CB07 | 20121029 | Fall | | | 1300 | | | | | | 15 | 12.9 | 0.0088 | | 0.101 | | | | |
| CB07 | 20121105 | Fall | | | 160 | | | | | | 7.02 | 2.7 | 0.0066 | | 0.0694 | | | | |
| CB07 | 20121113 | Fall | | | 97 | | | | | | 6.87 | 4.7 | 0.0072 | | 0.0563 | | | | |
| CB08 | 20121024 | Fall | | | 56000 | | | | | | 12.9 | 11.8 | 0.0158 | | 0.129 | | | | |
| CB08 | 20121029 | Fall | | | 1700 | | | 59.9 | | | 15.3 | 9.8 | 0.015 | | 0.132 | 3.90 | 0.195 | 2.73 | |
| CB08 | 20121105 | Fall | | | 4100 | | | | | | 14.2 | 4.9 | 0.0308 | | 0.217 | | | | |
| CB08 | 20121113 | Fall | | | 810 | | | | | | 10.4 | 4.2 | 0.0358 | | 0.212 | | | | |

| | | | Microbiological parameters | | | | Conventional parameters | | | | | | Nutrients | | | Metals | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Collection Date** | **Collection Season** | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) | *E. coli* (CFU/100 mL) | Chlorophyll a (ug/cm $^2$) | DO (mg/L) | Total Hardness (mg/L) | pH | Temp (C) | Turbidity (NTU) | TSS/NFR (mg/L) | Ammonia (N; mg/L) | Total N (mg/L) | Total P (mg/L) | Total Copper (ug/L) | Total Lead (ug/L) | Total Zinc (ug/L) | Total PAH (ug/L) |
| CB09 | 20121024 | Fall | | | 230 | | | | | | 19.3 | 6.2 | 0.0172 | | 0.137 | | | | |
| CB09 | 20121029 | Fall | | | 170 | | | 59.0 | | | 16.5 | 6.8 | 0.0383 | | 0.104 | 6.23 | 0.218 | 11.2 | |
| CB09 | 20121105 | Fall | | | 32000 | | | | | | 34.8 | 10.8 | 0.608 | | 0.761 | | | | |
| CB09 | 20121113 | Fall | | | 1900 | | | | | | 12.6 | 8.4 | 0.368 | | 0.574 | | | | |
| CB10 | 20121015 | Fall | | | 350 | | | 122 | | | 2.56 | 2.1 | 0.0234 | | 0.126 | 3.20 | 0.0750 | 1.11 | |
| CB10 | 20121024 | Fall | | | 1000 | | | | | | 13.3 | 16.3 | 0.0076 | | 0.159 | | | | |
| CB10 | 20121029 | Fall | | | 750 | | | 39.1 | | | 24.6 | 22.9 | 0.202 | | 0.202 | 7.06 | 0.496 | 8.05 | |
| CB10 | 20121105 | Fall | | | 53 | | | | | | 7.45 | 4.8 | 0.0403 | | 0.127 | | | | |
| CB10 | 20121113 | Fall | | | 1550 | | | | | | 8.66 | 3.2 | 0.0992 | | 0.117 | | | | |
| CB11 | 20121024 | Fall | | | 580 | | | | | | 22.2 | 8.2 | 0.0106 | | 0.0961 | | | | |
| CB11 | 20121029 | Fall | | | 21000 | | | 29.7 | | | 15 | 7.4 | 0.0089 | | 0.125 | 7.18 | 0.359 | 10.1 | |
| CB11 | 20121105 | Fall | | | 130 | | | | | | 11.1 | 2.8 | 0.0112 | | 0.0865 | | | | |
| CB11 | 20121113 | Fall | | | 4100 | | | | | | 9.83 | 3.5 | 0.0129 | | 0.103 | | | | |
| CB12 | 20121024 | Fall | | | 770 | | | | | | 8.59 | 62.4 | 0.0379 | | 0.186 | | | | |
| CB12 | 20121029 | Fall | | | 41000 | | | 65.0 | | | 18.9 | 86.6 | 0.037 | | 0.349 | 8.52 | 0.259 | 14.3 | |
| CB12 | 20121105 | Fall | | | 750 | | | | | | 5.2 | 2.2 | 0.0233 | | 0.106 | | | | |
| CB12 | 20121113 | Fall | | | 2000 | | | | | | 4.68 | 2.3 | 0.0237 | | 0.0936 | | | | |
| CB13 | 20121015 | Fall | | | 160 | | | 130 | | | 3.25 | 23 | 0.0408 | | 0.404 | 3.45 | 0.100 | 1.89 | |
| CB13 | 20121024 | Fall | | | 900 | | | | | | 39.1 | 29.3 | 0.0211 | | 0.254 | | | | |
| CB13 | 20121029 | Fall | | | 2000 | | | 58.3 | | | 20.7 | 14.5 | 0.0297 | | 0.3 | 8.71 | 0.492 | 11.7 | |
| CB13 | 20121105 | Fall | | | 310 | | | | | | 5.47 | 2 | 0.0294 | | 0.164 | | | | |
| CB13 | 20121113 | Fall | | | 1400 | | | | | | 4.89 | 3.7 | 0.0266 | | 0.144 | | | | |
| CHERRY P( | 20120823 | Summer | | | 33 | | | | 7.9 | 10.9 | | <5 | 0.036 | | 0.160 | | | | |
| CHERRY P( | 20121024 | Fall | | | >28000 | | 9.29 | | | 9.1 | 5.2 | <5 | 0.020 | | 0.0549 | | | | |
| CHERRY P( | 20121029 | Fall | | | 4000 | | 9.16 | | | 11.3 | 34.0 | 30 | 0.11 | | 0.472 | | | | |
| CHERRY P( | 20121105 | Fall | | | 100 | | 9.36 | | | 11.7 | 5.0 | <7 | 0.026 | | 0.0726 | | | | |
| CHERRY P( | 20121113 | Fall | | | 140 | | 10 | | | 9.5 | 5.2 | <5 | 0.015 | | 0.0594 | | | | |
| CHERRY P( | 20121120 | Fall | | | 150 | | 9.56 | | | 8.9 | 9.2 | <5 | 0.019 | | 0.0810 | | | | |
| TREFFERY | 20121024 | Fall | | | 720 | | 10.69 | | | 8.5 | 50 | 42 | 0.046 | | 0.299 | | | | |
| TREFFERY | 20121105 | Fall | | | 330 | | 10.28 | | | 10.8 | 7.7 | <5 | 0.032 | | 0.162 | | | | |
| TREFFERY | 20121113 | Fall | | | 550 | | 10.81 | | | 8.5 | 5.4 | <5 | 0.028 | | 0.146 | | | | |
| TREFFERY | 20121120 | Fall | | | 1000 | | 10.3 | | | 8.6 | 10.8 | <5 | 0.048 | | 0.185 | | | | |

*Table 27.. Raw water quality data for sites in freshwater tributaries to Cowichan Bay (2013 sampling).*

| **Site** | **Collection Date** | **Collection Season** | Enterococci (CFU/100 mL) | Fecal coliforms (CFU/100 mL) | *E. coli* (CFU/100 mL) |
|---|---|---|---|---|---|
| CB02 | 20131105 | Fall | | | 1200 |
| CB02 | 20131112 | Fall | | | 14 |
| CB02 | 20131120 | Fall | | | 480 |
| CB02 | 20131126 | Fall | | | <1 |
| CB02 | 20131203 | Fall | | | 3 |
| CB03 | 20131105 | Fall | | | 550 |
| CB03 | 20131112 | Fall | | | 71 |
| CB03 | 20131120 | Fall | | | 295 |
| CB03 | 20131126 | Fall | | | 110 |
| CB03 | 20131203 | Fall | | | 91 |
| CB04 | 20131105 | Fall | | | 61 |
| CB04 | 20131112 | Fall | | | 16.5 |
| CB04 | 20131120 | Fall | | | 21 |
| CB04 | 20131126 | Fall | | | 3 |
| CB04 | 20131203 | Fall | | | 1 |
| CB05 | 20131105 | Fall | | | 550 |
| CB05 | 20131112 | Fall | | | 99 |
| CB05 | 20131120 | Fall | | | 90 |
| CB05 | 20131126 | Fall | | | 7 |
| CB05 | 20131203 | Fall | | | 10 |
| CB07 | 20131105 | Fall | | | 71 |
| CB07 | 20131112 | Fall | | | 30 |
| CB07 | 20131120 | Fall | | | 39 |
| CB07 | 20131126 | Fall | | | 76 |
| CB07 | 20131203 | Fall | | | 7 |
| CB08 | 20131105 | Fall | | | 92 |
| CB08 | 20131112 | Fall | | | 29 |
| CB08 | 20131120 | Fall | | | 15 |
| CB08 | 20131126 | Fall | | | <1 |
| CB08 | 20131203 | Fall | | | 6 |
| CB09 | 20131105 | Fall | | | 1700 |
| CB09 | 20131112 | Fall | | | 150 |
| CB09 | 20131120 | Fall | | | 35 |
| CB09 | 20131126 | Fall | | | 2 |
| CB09 | 20131203 | Fall | | | 3 |
| CB10 | 20131105 | Fall | | | 48 |
| CB10 | 20131112 | Fall | | | 270 |
| CB10 | 20131120 | Fall | | | 30 |
| CB10 | 20131126 | Fall | | | 4 |
| CB10 | 20131203 | Fall | | | 19 |
| CB11 | 20131105 | Fall | | | 550 |
| CB11 | 20131112 | Fall | | | 29 |
| CB11 | 20131120 | Fall | | | 600 |
| CB11 | 20131126 | Fall | | | 42 |
| CB11 | 20131203 | Fall | | | 64 |
| CB12 | 20131105 | Fall | | | 940 |
| CB12 | 20131112 | Fall | | | 180 |
| CB12 | 20131120 | Fall | | | 1200 |
| CB12 | 20131126 | Fall | | | 120 |
| CB12 | 20131203 | Fall | | | 25 |
| CB13 | 20131105 | Fall | | | 430 |
| CB13 | 20131112 | Fall | | | 38 |
| CB13 | 20131120 | Fall | | | 230 |
| CB13 | 20131126 | Fall | | | 10 |
| CB13 | 20131203 | Fall | | | 13 |
| CB14 | 20131105 | Fall | | | |
| CB14 | 20131112 | Fall | | | 40 |
| CB14 | 20131120 | Fall | | | 12 |
| CB14 | 20131126 | Fall | | | 1 |
| CB14 | 20131203 | Fall | | | 9 |

# APPENDIX II. RESULTS OF QA/QC DUPLICATE ANALYSIS

*Table 28. Results of QAQC duplicate analyses for Cowichan Bay and tributaries data.*

| Station | Sample Collection Date (YYYYMMDD) | Chemical | Units | Result - regular | Qualifier - regular | Result - replicate | Qualifier - replicate | Relative Percent Difference |
|---|---|---|---|---|---|---|---|---|
| E291149 | 2012-10-15 9:40 | Dissolved Aluminum (Al) | ug/L | 19.7 | | 20.1 | | 2.01 |
| E291149 | 2012-10-15 9:40 | Dissolved Antimony (Sb) | ug/L | 0.066 | | 0.055 | | 18.18 |
| E291149 | 2012-10-15 9:40 | Dissolved Arsenic (As) | ug/L | 0.732 | | 0.634 | | 14.35 |
| E291149 | 2012-10-15 9:40 | Dissolved Barium (Ba) | ug/L | 7.62 | | 7.64 | | 0.26 |
| E291149 | 2012-10-15 9:40 | Dissolved Beryllium (Be) | ug/L | 0.01 | < | 0.01 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Bismuth (Bi) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Boron (B) | ug/L | 50 | < | 50 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Cadmium (Cd) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Chromium (Cr) | ug/L | 0.44 | | 0.49 | | 10.75 |
| E291149 | 2012-10-15 9:40 | Dissolved Cobalt (Co) | ug/L | 0.163 | | 0.147 | | 10.32 |
| E291149 | 2012-10-15 9:40 | Dissolved Copper (Cu) | ug/L | 1.45 | | 1.49 | | 2.72 |
| E291149 | 2012-10-15 9:40 | Dissolved Iron (Fe) | ug/L | 510 | | 518 | | 1.56 |
| E291149 | 2012-10-15 9:40 | Dissolved Lead (Pb) | ug/L | 0.0900 | | 0.0230 | | ***118.58*** |
| E291149 | 2012-10-15 9:40 | Dissolved Lithium (Li) | ug/L | 0.5 | < | 0.5 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Manganese (Mn) | ug/L | 49.0 | | 46.2 | | 5.88 |
| E291149 | 2012-10-15 9:40 | Dissolved Molybdenum (Mo | ug/L | 0.087 | | 0.078 | | 10.91 |
| E291149 | 2012-10-15 9:40 | Dissolved Nickel (Ni) | ug/L | 0.426 | | 0.419 | | 1.66 |
| E291149 | 2012-10-15 9:40 | Dissolved Selenium (Se) | ug/L | 0.122 | | 0.04 | < | ***101.23*** |
| E291149 | 2012-10-15 9:40 | Dissolved Silver (Ag) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Strontium (Sr) | ug/L | 66.6 | | 68.1 | | 2.23 |
| E291149 | 2012-10-15 9:40 | Dissolved Thallium (Tl) | ug/L | 0.002 | < | 0.002 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Tin (Sn) | ug/L | 0.2 | < | 0.2 | < | 0 |
| E291149 | 2012-10-15 9:40 | Dissolved Uranium (U) | ug/L | 0.0110 | | 0.0080 | | ***31.58*** |
| E291149 | 2012-10-15 9:40 | Dissolved Vanadium (V) | ug/L | 0.98 | | 1.02 | | 4 |
| E291149 | 2012-10-15 9:40 | Dissolved Zinc (Zn) | ug/L | 1.06 | | 0.97 | | 8.87 |
| E291149 | 2012-10-15 9:40 | Dissolved Magnesium (Mg) | ug/L | 6720 | | 6810 | | 1.33 |
| E291149 | 2012-10-15 9:40 | Total Aluminum (Al) | ug/L | 98.1 | | 102 | | 3.9 |
| E291149 | 2012-10-15 9:40 | Total Antimony (Sb) | ug/L | 0.062 | | 0.060 | | 3.28 |
| E291149 | 2012-10-15 9:40 | Total Arsenic (As) | ug/L | 0.860 | | 0.874 | | 1.61 |
| E291149 | 2012-10-15 9:40 | Total Barium (Ba) | ug/L | 10.4 | | 9.92 | | 4.72 |
| E291149 | 2012-10-15 9:40 | Total Beryllium (Be) | ug/L | 0.01 | < | 0.01 | < | 0 |
| E291149 | 2012-10-15 9:40 | Total Bismuth (Bi) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291149 | 2012-10-15 9:40 | Total Boron (B) | ug/L | 50 | < | 50 | < | 0 |
| E291149 | 2012-10-15 9:40 | Total Cadmium (Cd) | ug/L | 0.0070 | | 0.0050 | | ***33.33*** |
| E291149 | 2012-10-15 9:40 | Total Chromium (Cr) | ug/L | 0.63 | | 0.62 | | 1.6 |
| E291149 | 2012-10-15 9:40 | Total Cobalt (Co) | ug/L | 0.311 | | 0.267 | | 15.22 |
| E291149 | 2012-10-15 9:40 | Total Copper (Cu) | ug/L | 2.30 | | 2.09 | | 9.57 |
| E291149 | 2012-10-15 9:40 | Total Iron (Fe) | ug/L | 1020 | | 1010 | | 0.99 |
| E291149 | 2012-10-15 9:40 | Total Lead (Pb) | ug/L | 0.0910 | | 0.0680 | | ***28.93*** |
| E291149 | 2012-10-15 9:40 | Total Lithium (Li) | ug/L | 0.55 | | 0.57 | | 3.57 |
| E291149 | 2012-10-15 9:40 | Total Manganese (Mn) | ug/L | 141 | | 129 | | 8.89 |
| E291149 | 2012-10-15 9:40 | Total Molybdenum (Mo) | ug/L | 0.117 | | 0.094 | | 21.8 |
| E291149 | 2012-10-15 9:40 | Total Nickel (Ni) | ug/L | 0.546 | | 0.523 | | 4.3 |
| E291149 | 2012-10-15 9:40 | Total Selenium (Se) | ug/L | 0.096 | | 0.087 | | 9.84 |

| Station | Sample Collection Date (YYYYMMDD) | Chemical | Units | Result - regular | Qualifier - regular | Result - replicate | Qualifier - replicate | Relative Percent Difference |
|---|---|---|---|---|---|---|---|---|
| E291149 | 2012-10-15 9:40 | Total Silver (Ag) | ug/L | 0.0050 | | 0.005 | < | 0 |
| E291149 | 2012-10-15 9:40 | Total Strontium (Sr) | ug/L | 73.7 | | 72.7 | | 1.37 |
| E291149 | 2012-10-15 9:40 | Total Thallium (Tl) | ug/L | 0.002 | < | 0.002 | < | 0 |
| E291149 | 2012-10-15 9:40 | Total Tin (Sn) | ug/L | 0.67 | | 0.52 | | ***25.21*** |
| E291149 | 2012-10-15 9:40 | Total Uranium (U) | ug/L | 0.0150 | | 0.0130 | | 14.29 |
| E291149 | 2012-10-15 9:40 | Total Vanadium (V) | ug/L | 1.11 | | 1.12 | | 0.9 |
| E291149 | 2012-10-15 9:40 | Total Zinc (Zn) | ug/L | 2.03 | | 1.74 | | 15.38 |
| E291149 | 2012-10-15 9:40 | Total Calcium (Ca) | mg/L | 15.3 | | 15.3 | | 0 |
| E291149 | 2012-10-15 9:40 | Total Magnesium (Mg) | mg/L | 7.22 | | 7.04 | | 2.52 |
| E291150 | 2012-10-29 9:50 | Dissolved Aluminum (Al) | ug/L | 57.3 | | 51.3 | | 11.05 |
| E291150 | 2012-10-29 9:50 | Dissolved Antimony (Sb) | ug/L | 0.067 | | 0.069 | | 2.94 |
| E291150 | 2012-10-29 9:50 | Dissolved Arsenic (As) | ug/L | 0.739 | | 0.761 | | 2.93 |
| E291150 | 2012-10-29 9:50 | Dissolved Barium (Ba) | ug/L | 9.01 | | 9.13 | | 1.32 |
| E291150 | 2012-10-29 9:50 | Dissolved Beryllium (Be) | ug/L | 0.01 | < | 0.01 | < | 0 |
| E291150 | 2012-10-29 9:50 | Dissolved Bismuth (Bi) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291150 | 2012-10-29 9:50 | Dissolved Boron (B) | ug/L | 50 | < | 50 | < | 0 |
| E291150 | 2012-10-29 9:50 | Dissolved Cadmium (Cd) | ug/L | 0.0280 | | 0.0300 | | 6.9 |
| E291150 | 2012-10-29 9:50 | Dissolved Chromium (Cr) | ug/L | 0.29 | | 0.32 | | 9.84 |
| E291150 | 2012-10-29 9:50 | Dissolved Cobalt (Co) | ug/L | 0.279 | | 0.253 | | 9.77 |
| E291150 | 2012-10-29 9:50 | Dissolved Copper (Cu) | ug/L | 4.94 | | 5.04 | | 2 |
| E291150 | 2012-10-29 9:50 | Dissolved Iron (Fe) | ug/L | 149 | | 144 | | 3.41 |
| E291150 | 2012-10-29 9:50 | Dissolved Lead (Pb) | ug/L | 0.0430 | | 0.0440 | | 2.3 |
| E291150 | 2012-10-29 9:50 | Dissolved Lithium (Li) | ug/L | 0.62 | | 0.88 | | ***34.67*** |
| E291150 | 2012-10-29 9:50 | Dissolved Manganese (Mn) | ug/L | 11.2 | | 9.64 | | 14.97 |
| E291150 | 2012-10-29 9:50 | issolved Molybdenum (Mc | ug/L | 0.342 | | 0.399 | | 15.38 |
| E291150 | 2012-10-29 9:50 | Dissolved Nickel (Ni) | ug/L | 0.571 | | 0.604 | | 5.62 |
| E291150 | 2012-10-29 9:50 | Dissolved Selenium (Se) | ug/L | 0.122 | | 0.138 | | 12.31 |
| E291150 | 2012-10-29 9:50 | Dissolved Silver (Ag) | ug/L | 0.0100 | | 0.0110 | | 9.52 |
| E291150 | 2012-10-29 9:50 | Dissolved Strontium (Sr) | ug/L | 85.7 | | 94.4 | | 9.66 |
| E291150 | 2012-10-29 9:50 | Dissolved Thallium (Tl) | ug/L | 0.0110 | | 0.0090 | | 20 |
| E291150 | 2012-10-29 9:50 | Dissolved Tin (Sn) | ug/L | 0.2 | < | 0.2 | < | 0 |
| E291150 | 2012-10-29 9:50 | Dissolved Uranium (U) | ug/L | 0.0400 | | 0.0390 | | 2.53 |
| E291150 | 2012-10-29 9:50 | Dissolved Vanadium (V) | ug/L | 2.31 | | 2.51 | | 8.3 |
| E291150 | 2012-10-29 9:50 | Dissolved Zinc (Zn) | ug/L | 7.24 | | 7.25 | | 0.14 |
| E291150 | 2012-10-29 9:50 | Dissolved Magnesium (Mg) | ug/L | 9090 | | 10300 | | 12.48 |
| E291150 | 2012-10-29 9:50 | Total Aluminum (Al) | ug/L | 865 | | 967 | | 11.14 |
| E291150 | 2012-10-29 9:50 | Total Antimony (Sb) | ug/L | 0.066 | | 0.078 | | 16.67 |
| E291150 | 2012-10-29 9:50 | Total Arsenic (As) | ug/L | 0.926 | | 1.01 | | 8.68 |
| E291150 | 2012-10-29 9:50 | Total Barium (Ba) | ug/L | 14.5 | | 14.9 | | 2.72 |
| E291150 | 2012-10-29 9:50 | Total Beryllium (Be) | ug/L | 0.022 | | 0.023 | | 4.44 |
| E291150 | 2012-10-29 9:50 | Total Bismuth (Bi) | ug/L | 0.0050 | | 0.0060 | | 18.18 |
| E291150 | 2012-10-29 9:50 | Total Boron (B) | ug/L | 50 | < | 50 | < | 0 |
| E291150 | 2012-10-29 9:50 | Total Cadmium (Cd) | ug/L | 0.140 | | 0.144 | | 2.82 |

| Station | Sample Collection Date (YYYYMMDD) | Chemical | Units | Result - regular | Qualifier - regular | Result - replicate | Qualifier - replicate | Relative Percent Difference |
|---|---|---|---|---|---|---|---|---|
| E291150 | 2012-10-29 9:50 | Total Chromium (Cr) | ug/L | 1.38 | | 1.65 | | 17.82 |
| E291150 | 2012-10-29 9:50 | Total Cobalt (Co) | ug/L | 0.884 | | 1.01 | | 13.31 |
| E291150 | 2012-10-29 9:50 | Total Copper (Cu) | ug/L | 14.1 | | 14.8 | | 4.84 |
| E291150 | 2012-10-29 9:50 | Total Iron (Fe) | ug/L | 1540 | | 1290 | | 17.67 |
| E291150 | 2012-10-29 9:50 | Total Lead (Pb) | ug/L | 0.353 | | 0.435 | | 20.81 |
| E291150 | 2012-10-29 9:50 | Total Lithium (Li) | ug/L | 1.25 | | 1.57 | | 22.7 |
| E291150 | 2012-10-29 9:50 | Total Manganese (Mn) | ug/L | 80.5 | | 94.7 | | 16.21 |
| E291150 | 2012-10-29 9:50 | Total Molybdenum (Mo) | ug/L | 0.339 | | 0.472 | | ***32.8*** |
| E291150 | 2012-10-29 9:50 | Total Nickel (Ni) | ug/L | 1.68 | | 1.82 | | 8 |
| E291150 | 2012-10-29 9:50 | Total Selenium (Se) | ug/L | 0.260 | | 0.147 | | ***55.53*** |
| E291150 | 2012-10-29 9:50 | Total Silver (Ag) | ug/L | 0.0400 | | 0.0400 | | 0 |
| E291150 | 2012-10-29 9:50 | Total Strontium (Sr) | ug/L | 86.4 | | 94.8 | | 9.27 |
| E291150 | 2012-10-29 9:50 | Total Thallium (Tl) | ug/L | 0.0170 | | 0.0180 | | 5.71 |
| E291150 | 2012-10-29 9:50 | Total Tin (Sn) | ug/L | 0.42 | | 0.54 | | ***25*** |
| E291150 | 2012-10-29 9:50 | Total Uranium (U) | ug/L | 0.0790 | | 0.0820 | | 3.73 |
| E291150 | 2012-10-29 9:50 | Total Vanadium (V) | ug/L | 4.51 | | 5.32 | | 16.48 |
| E291150 | 2012-10-29 9:50 | Total Zinc (Zn) | ug/L | 28.2 | | 29.4 | | 4.17 |
| E291150 | 2012-10-29 9:50 | Total Calcium (Ca) | mg/L | 26.2 | | 18.7 | | ***33.41*** |
| E291150 | 2012-10-29 9:50 | Total Magnesium (Mg) | mg/L | 9.23 | | 10.9 | | 16.59 |
| E291154 | 2012-10-24 | Dissolved Aluminum (Al) | ug/L | 112 | | 102 | | 9.35 |
| E291154 | 2012-10-24 | Dissolved Antimony (Sb) | ug/L | 0.125 | | 0.112 | | 10.97 |
| E291154 | 2012-10-24 | Dissolved Arsenic (As) | ug/L | 0.378 | | 0.372 | | 1.6 |
| E291154 | 2012-10-24 | Dissolved Barium (Ba) | ug/L | 6.59 | | 6.09 | | 7.89 |
| E291154 | 2012-10-24 | Dissolved Beryllium (Be) | ug/L | 0.01 | < | 0.01 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Bismuth (Bi) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Boron (B) | ug/L | 50 | < | 50 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Cadmium (Cd) | ug/L | 0.005 | < | 0.005 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Chromium (Cr) | ug/L | 0.58 | | 0.58 | | 0 |
| E291154 | 2012-10-24 | Dissolved Cobalt (Co) | ug/L | 0.107 | | 0.101 | | 5.77 |
| E291154 | 2012-10-24 | Dissolved Copper (Cu) | ug/L | 9.86 | | 8.95 | | 9.68 |
| E291154 | 2012-10-24 | Dissolved Iron (Fe) | ug/L | 180 | | 169 | | 6.3 |
| E291154 | 2012-10-24 | Dissolved Lead (Pb) | ug/L | 0.179 | | 0.160 | | 11.21 |
| E291154 | 2012-10-24 | Dissolved Lithium (Li) | ug/L | 0.5 | < | 0.5 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Manganese (Mn) | ug/L | 2.23 | | 2.17 | | 2.73 |
| E291154 | 2012-10-24 | issolved Molybdenum (Mc | ug/L | 0.127 | | 0.133 | | 4.62 |
| E291154 | 2012-10-24 | Dissolved Nickel (Ni) | ug/L | 0.624 | | 0.596 | | 4.59 |
| E291154 | 2012-10-24 | Dissolved Selenium (Se) | ug/L | 0.149 | | 0.108 | | ***31.91*** |
| E291154 | 2012-10-24 | Dissolved Silver (Ag) | ug/L | 0.0240 | | 0.0220 | | 8.7 |
| E291154 | 2012-10-24 | Dissolved Strontium (Sr) | ug/L | 37.7 | | 34.8 | | 8 |
| E291154 | 2012-10-24 | Dissolved Thallium (Tl) | ug/L | 0.002 | < | 0.002 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Tin (Sn) | ug/L | 0.2 | < | 0.2 | < | 0 |
| E291154 | 2012-10-24 | Dissolved Uranium (U) | ug/L | 0.0080 | | 0.0080 | | 0 |
| E291154 | 2012-10-24 | Dissolved Vanadium (V) | ug/L | 1.29 | | 1.13 | | 13.22 |

| Station | Sample Collection Date (YYYYMMDD) | Chemical | Units | Result - regular | Qualifier - regular | Result - replicate | Qualifier - replicate | Relative Percent Difference |
|---|---|---|---|---|---|---|---|---|
| E291154 | 2012-10-24 | Dissolved Zinc (Zn) | ug/L | 2.71 | | 2.74 | | 1.1 |
| E291154 | 2012-10-24 | Dissolved Magnesium (Mg) | ug/L | 3310 | | 3360 | | 1.5 |
| E219193/E | 2012-10-15 | Enterococcus | CFU/100ml | 3 | | 1 | < | ***100*** |
| E291134 | 2012-10-15 | Enterococcus | CFU/100ml | 16 | | 13 | | 20.69 |
| E219323 | 2012-10-24 | Enterococcus | CFU/100ml | 5 | | 6 | | 18.18 |
| E291135 | 2012-10-24 | Enterococcus | CFU/100ml | 1 | < | 1 | | 0 |
| E291124 | 2012-10-29 | Enterococcus | CFU/100ml | 141 | | 137 | | 2.88 |
| E291134 | 2012-10-29 | Enterococcus | CFU/100ml | 45 | | 36 | | 22.22 |
| E219325 | 2012-11-05 | Enterococcus | CFU/100ml | 69 | | 48 | | ***35.9*** |
| E291126 | 2012-11-05 | Enterococcus | CFU/100ml | 41 | | 66 | | ***46.73*** |
| 0150360 | 2012-11-13 | Enterococcus | CFU/100ml | 420 | | 370 | | 12.66 |
| E291122 | 2012-11-13 | Enterococcus | CFU/100ml | 35 | | 27 | | ***25.81*** |
| E219193/E | 2012-10-15 | Fecal Coliforms | CFU/100ml | 2 | | 2 | | 0 |
| E291134 | 2012-10-15 | Fecal Coliforms | CFU/100ml | 130 | | 130 | | 0 |
| E219323 | 2012-10-24 | Fecal Coliforms | CFU/100ml | 5 | | 2 | | ***85.71*** |
| E291135 | 2012-10-24 | Fecal Coliforms | CFU/100ml | 2 | < | 2 | | 0 |
| E291124 | 2012-10-29 | Fecal Coliforms | CFU/100ml | 79 | | 31 | | ***87.27*** |
| E291134 | 2012-10-29 | Fecal Coliforms | CFU/100ml | 33 | | 33 | | 0 |
| E219325 | 2012-11-05 | Fecal Coliforms | CFU/100ml | 33 | | 43 | | ***26.32*** |
| E291126 | 2012-11-05 | Fecal Coliforms | CFU/100ml | 49 | | 23 | | ***72.22*** |
| 0150360 | 2012-11-13 | Fecal Coliforms | CFU/100ml | 280 | | 240 | | 15.38 |
| E291122 | 2012-11-13 | Fecal Coliforms | CFU/100ml | 49 | | 79 | | ***46.88*** |
| E291151 | 2013-11-20 11:05 | E Coli | CFU/100mL | 270 | | 320 | | 16.95 |
| E291152 | 2013-11-12 14:10 | E Coli | CFU/100mL | 22 | | 11 | | ***66.67*** |
| E291152 | 2013-11-26 1:05 | E Coli | CFU/100mL | 2 | | 4 | | ***66.67*** |
| E291158 | 2013-12-03 15:05 | E Coli | CFU/100mL | 7 | | 5 | | ***33.33*** |
| E219325 | 2013-11-19 13:05 | Enterococcus | CFU/100mL | 42 | | 33 | | 24 |
| E291124 | 2013-11-19 13:30 | Enterococcus | CFU/100mL | 42 | | 92 | | ***74.63*** |
| E291125 | 2013-12-03 12:12 | Enterococcus | CFU/100mL | 21 | | 14 | | ***40*** |
| E291126 | 2013-11-05 9:30 | Enterococcus | CFU/100mL | 28 | | 2 | | ***173.33*** |
| E291127 | 2013-11-19 10:45 | Enterococcus | CFU/100mL | 32 | | 39 | | 19.72 |
| E291136 | 2013-11-12 11:30 | Enterococcus | CFU/100mL | 14 | | 3 | | ***129.41*** |
| E291136 | 2013-11-19 12:55 | Enterococcus | CFU/100mL | 2 | | 3 | | ***40*** |
| E291369 | 2013-11-27 9:25 | Enterococcus | CFU/100mL | 2500 | | 3000 | | 18.18 |
| E294495 | 2013-11-19 13:00 | Enterococcus | CFU/100mL | 210 | | 210 | | 0 |
| E294495 | 2013-12-03 9:54 | Enterococcus | CFU/100mL | 9 | | 19 | | ***71.43*** |
| E294497 | 2013-11-05 10:00 | Enterococcus | CFU/100mL | 26 | | 27 | | 3.77 |
| E294497 | 2013-11-12 13:54 | Enterococcus | CFU/100mL | 24 | | 18 | | ***28.57*** |
| E294497 | 2013-11-27 12:25 | Enterococcus | CFU/100mL | 3 | | 5 | | ***50*** |
| E219325 | 2013-11-19 13:05 | Fecal coliforms | CFU/100mL | 54 | | 62 | | 13.79 |
| E291124 | 2013-11-19 13:30 | Fecal coliforms | CFU/100mL | 69 | | 57 | | 19.05 |
| E291125 | 2013-12-03 12:12 | Fecal coliforms | CFU/100mL | 72 | | 79 | | 9.27 |
| E291126 | 2013-11-05 9:30 | Fecal coliforms | CFU/100mL | 18 | | 35 | | ***64.15*** |
| E291127 | 2013-11-19 10:45 | Fecal coliforms | CFU/100mL | 58 | | 47 | | 20.95 |
| E291136 | 2013-11-12 11:30 | Fecal coliforms | CFU/100mL | 22 | | 23 | | 4.44 |
| E291136 | 2013-11-19 12:55 | Fecal coliforms | CFU/100mL | 4 | | 12 | | ***100*** |
| E291369 | 2013-11-27 9:25 | Fecal coliforms | CFU/100mL | 34 | | 63 | | ***59.79*** |
| E294495 | 2013-08-06 0:00 | Enterococcus | CFU/100mL | 11 | | 11 | | 0 |
| E294495 | 2013-08-06 0:00 | Fecal Coliforms | CFU/100mL | 12 | | 6 | | ***66.67*** |
| E294497 | 2013-08-27 0:00 | Enterococcus | CFU/100mL | 85 | | 34 | | ***85.71*** |
| E294497 | 2013-08-27 0:00 | Fecal Coliforms | CFU/100mL | 75 | | 76 | | 1.32 |
| E291369 | 2013-08-20 0:00 | Enterococcus | CFU/100mL | 5 | | 2 | | ***85.71*** |
| E291369 | 2013-08-20 0:00 | Fecal Coliforms | CFU/100mL | 22 | | 22 | | 0 |

# APPENDIX III. SUMMARY OF TOTAL METALS (µG/L) COMPARED WITH BC ENV APPROVED OR WORKING WQGS

*Table 29. Summary statistics for total metals (µg/L) for water samples collected in 2012 at sites in the tributaries to Cowichan Bay during the fall (Oct-Apr) season, showing exceedances of the BC ENV approved or working Water Quality Guidelines.*

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291149 | CB01 | Manley Creek at Manley Creek park | Dissolved Aluminum | 3 | 19.9 | 38 | 26 | 10.39 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291149 | CB01 | Manley Creek at Manley Creek park | Dissolved Cadmium | 3 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Dissolved Iron | 3 | 500 | 518 | 510.67 | 9.45 | 350 | | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Dissolved Aluminum | 3 | 4.82 | 54.3 | 21.33 | 28.55 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Dissolved Cadmium | 3 | 0.005 | 0.029 | 0.01 | 0.01 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Dissolved Iron | 3 | 58.6 | 146.5 | 100.28 | 44.13 | 350 | | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Dissolved Aluminum | 3 | 28.7 | 76.6 | 47.8 | 25.38 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Dissolved Cadmium | 3 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Dissolved Iron | 3 | 127 | 282 | 202.33 | 77.59 | 350 | | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Dissolved Aluminum | 2 | 13.1 | 14.4 | 13.75 | 0.92 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Dissolved Cadmium | 2 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Dissolved Iron | 2 | 20.9 | 44.1 | 32.5 | 16.4 | 350 | | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Dissolved Aluminum | 2 | 10.5 | 73.1 | 41.8 | 44.26 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291153 | CB05 | Waldy Creek at Foreshore | Dissolved Cadmium | 2 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Dissolved Iron | 2 | 234 | 429 | 331.5 | 137.89 | 350 | | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Dissolved Aluminum | 2 | 107 | 123 | 115 | 11.31 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Dissolved Cadmium | 2 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Dissolved Iron | 2 | 124 | 174.5 | 149.25 | 35.71 | 350 | | Approved | Protection of FW aquatic life |
| E291155 | CB07 | Storm Drain at Botwood Lane | Dissolved Aluminum | 1 | 42.7 | 42.7 | 42.7 | 0 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291155 | CB07 | Storm Drain at Botwood Lane | Dissolved Cadmium | 1 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291155 | CB07 | Storm Drain at Botwood Lane | Dissolved Iron | 1 | 66.3 | 66.3 | 66.3 | 0 | 350 | | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Dissolved Aluminum | 2 | 25.9 | 59 | 42.45 | 23.41 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Dissolved Cadmium | 2 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Dissolved Iron | 2 | 49.4 | 107 | 78.2 | 40.73 | 350 | | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Dissolved Aluminum | 2 | 68.8 | 71.2 | 70 | 1.7 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Dissolved Cadmium | 2 | 0.005 | 0.01 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Dissolved Iron | 2 | 204 | 288 | 246 | 59.4 | 350 | | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Dissolved Aluminum | 3 | 11.2 | 73.5 | 35.43 | 33.37 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Dissolved Cadmium | 3 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Dissolved Iron | 3 | 175 | 204 | 188.67 | 14.57 | 350 | | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Dissolved Aluminum | 2 | 70.7 | 87.2 | 78.95 | 11.67 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Dissolved Cadmium | 2 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Dissolved Iron | 2 | 111 | 156 | 133.5 | 31.82 | 350 | | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Dissolved Aluminum | 2 | 46.6 | 96.5 | 71.55 | 35.28 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Dissolved Cadmium | 2 | 0.006 | 0.009 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Dissolved Iron | 2 | 137 | 142 | 139.5 | 3.54 | 350 | | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Dissolved Aluminum | 3 | 16.3 | 73.8 | 51.23 | 30.68 | 100 | 50 | Approved | Protection of FW aquatic life; pH greater than 6.5 |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Dissolved Cadmium | 3 | 0.005 | 0.011 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Dissolved Iron | 3 | 144 | 227 | 182 | 41.94 | 350 | | Approved | Protection of FW aquatic life |

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Aluminum | 3 | 100.05 | 483 | 228.35 | 220.54 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Antimony | 3 | 0.06 | 0.077 | 0.07 | 0.01 | | 9 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Arsenic | 3 | 0.867 | 1.21 | 0.98 | 0.2 | 5 | | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Barium | 3 | 9.92 | 14.5 | 11.53 | 2.58 | | 1000 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Beryllium | 3 | 0.01 | 0.014 | 0.01 | 0 | | 0.13 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Boron | 3 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Cadmium | 3 | 0.005 | 0.011 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Chromium | 3 | 0.62 | 1.31 | 0.85 | 0.4 | | 8.9 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Cobalt | 3 | 0.267 | 0.788 | 0.45 | 0.29 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Copper | 3 | 2.09 | 4.69 | 2.99 | 1.47 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Iron | 3 | 1010 | 2130 | 1385 | 645.19 | 1000 | | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Lead | 3 | 0.068 | 0.28 | 0.14 | 0.12 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Manganese | 3 | 129 | 344 | 202.67 | 122.44 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Molybdenum | 3 | 0.094 | 0.123 | 0.11 | 0.01 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Nickel | 3 | 0.523 | 1.26 | 0.77 | 0.42 | | 25 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Selenium | 3 | 0.087 | 0.243 | 0.14 | 0.09 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Silver | 3 | 0.005 | 0.012 | 0.01 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Thallium | 3 | 0.002 | 0.003 | 0 | 0 | | 0.8 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Uranium | 3 | 0.013 | 0.037 | 0.02 | 0.01 | | 8.5 | Working | |
| E291149 | CB01 | Manley Creek at Manley Creek park | Total Zinc | 3 | 1.74 | 4.57 | 2.73 | 1.59 | 33 | 7.5 | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Aluminum | 2 | 36.1 | 916 | 476.05 | 622.18 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Antimony | 2 | 0.02 | 0.072 | 0.05 | 0.04 | | 9 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Arsenic | 2 | 0.287 | 0.968 | 0.63 | 0.48 | 5 | | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Barium | 2 | 4.47 | 14.7 | 9.59 | 7.23 | | 1000 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Beryllium | 2 | 0.01 | 0.0225 | 0.02 | 0.01 | | 0.13 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Boron | 2 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Cadmium | 2 | 0.005 | 0.142 | 0.07 | 0.1 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Chromium | 2 | 0.15 | 1.515 | 0.83 | 0.97 | | 8.9 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Cobalt | 2 | 0.061 | 0.947 | 0.5 | 0.63 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Copper | 2 | 0.838 | 14.45 | 7.64 | 9.63 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Iron | 2 | 133 | 1415 | 774 | 906.51 | 1000 | | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Lead | 2 | 0.028 | 0.394 | 0.21 | 0.26 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Manganese | 2 | 11.2 | 87.6 | 49.4 | 54.02 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Molybdenum | 2 | 0.174 | 0.4055 | 0.29 | 0.16 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Nickel | 2 | 0.181 | 1.75 | 0.97 | 1.11 | | 25 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Selenium | 2 | 0.098 | 0.2035 | 0.15 | 0.07 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Silver | 2 | 0.005 | 0.04 | 0.02 | 0.02 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Thallium | 2 | 0.002 | 0.0175 | 0.01 | 0.01 | | 0.8 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Uranium | 2 | 0.016 | 0.0805 | 0.05 | 0.05 | | 8.5 | Working | |
| E291150 | CB02 | Garnett Creek at Cherry Point Beach | Total Zinc | 2 | 0.6 | 28.8 | 14.7 | 19.94 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Aluminum | 2 | 604 | 1650 | 1127 | 739.63 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Antimony | 2 | 0.114 | 0.135 | 0.12 | 0.01 | | 9 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Arsenic | 2 | 1.1 | 2.36 | 1.73 | 0.89 | 5 | | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Barium | 2 | 13 | 22.1 | 17.55 | 6.43 | | 1000 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Beryllium | 2 | 0.017 | 0.039 | 0.03 | 0.02 | | 0.13 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Boron | 2 | 50 | 71 | 60.5 | 14.85 | 1200 | | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Cadmium | 2 | 0.005 | 0.009 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Chromium | 2 | 1.06 | 2.61 | 1.84 | 1.1 | | 8.9 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Cobalt | 2 | 0.499 | 0.842 | 0.67 | 0.24 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Copper | 2 | 6.1 | 8.42 | 7.26 | 1.64 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Iron | 2 | 1030 | 1630 | 1330 | 424.26 | 1000 | | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Lead | 2 | 0.28 | 0.44 | 0.36 | 0.11 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Manganese | 2 | 36.2 | 51.1 | 43.65 | 10.54 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Molybdenum | 2 | 0.137 | 0.632 | 0.38 | 0.35 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Nickel | 2 | 1.43 | 2.31 | 1.87 | 0.62 | | 25 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Selenium | 2 | 0.08 | 0.111 | 0.1 | 0.02 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Silver | 2 | 0.014 | 0.027 | 0.02 | 0.01 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Thallium | 2 | 0.004 | 0.009 | 0.01 | 0 | | 0.8 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Uranium | 2 | 0.039 | 0.041 | 0.04 | 0 | | 8.5 | Working | |
| E291151 | CB03 | Garnett Creek at Telegraph Road | Total Zinc | 2 | 16.2 | 21.5 | 18.85 | 3.75 | 33 | 7.5 | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Aluminum | 1 | 55.5 | 55.5 | 55.5 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Antimony | 1 | 0.081 | 0.081 | 0.08 | 0 | | 9 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Arsenic | 1 | 0.346 | 0.346 | 0.35 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Barium | 1 | 9.44 | 9.44 | 9.44 | 0 | | 1000 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Beryllium | 1 | 0.01 | 0.01 | 0.01 | 0 | | 0.13 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Cadmium | 1 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Chromium | 1 | 0.23 | 0.23 | 0.23 | 0 | | 8.9 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Cobalt | 1 | 0.133 | 0.133 | 0.13 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Copper | 1 | 3.44 | 3.44 | 3.44 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Iron | 1 | 95.1 | 95.1 | 95.1 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Lead | 1 | 0.042 | 0.042 | 0.04 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Manganese | 1 | 3.7 | 3.7 | 3.7 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Molybdenum | 1 | 0.155 | 0.155 | 0.16 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Nickel | 1 | 0.641 | 0.641 | 0.64 | 0 | | 25 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Selenium | 1 | 0.065 | 0.065 | 0.07 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Silver | 1 | 0.005 | 0.005 | 0.01 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Thallium | 1 | 0.002 | 0.002 | 0 | 0 | | 0.8 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Uranium | 1 | 0.011 | 0.011 | 0.01 | 0 | | 8.5 | Working | |
| E291152 | CB04 | Storm Drain at Cherry Point Marina | Total Zinc | 1 | 3.08 | 3.08 | 3.08 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291153 | CB05 | Waldy Creek at Foreshore | Total Aluminum | 1 | 1410 | 1410 | 1410 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Antimony | 1 | 0.151 | 0.151 | 0.15 | 0 | | 9 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Arsenic | 1 | 0.982 | 0.982 | 0.98 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Barium | 1 | 19.2 | 19.2 | 19.2 | 0 | | 1000 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Beryllium | 1 | 0.026 | 0.026 | 0.03 | 0 | | 0.13 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Cadmium | 1 | 0.009 | 0.009 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Chromium | 1 | 2.34 | 2.34 | 2.34 | 0 | | 8.9 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Cobalt | 1 | 0.953 | 0.953 | 0.95 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Copper | 1 | 9.21 | 9.21 | 9.21 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Iron | 1 | 1710 | 1710 | 1710 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Lead | 1 | 0.567 | 0.567 | 0.57 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Manganese | 1 | 87 | 87 | 87 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Molybdenum | 1 | 0.419 | 0.419 | 0.42 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Nickel | 1 | 1.98 | 1.98 | 1.98 | 0 | | 25 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Selenium | 1 | 0.105 | 0.105 | 0.11 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Silver | 1 | 0.027 | 0.027 | 0.03 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Thallium | 1 | 0.009 | 0.009 | 0.01 | 0 | | 0.8 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Uranium | 1 | 0.06 | 0.06 | 0.06 | 0 | | 8.5 | Working | |
| E291153 | CB05 | Waldy Creek at Foreshore | Total Zinc | 1 | 15.5 | 15.5 | 15.5 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Aluminum | 1 | 652 | 652 | 652 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Antimony | 1 | 0.09 | 0.09 | 0.09 | 0 | | 9 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Arsenic | 1 | 0.486 | 0.486 | 0.49 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Barium | 1 | 14.1 | 14.1 | 14.1 | 0 | | 1000 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Beryllium | 1 | 0.023 | 0.023 | 0.02 | 0 | | 0.13 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Cadmium | 1 | 0.007 | 0.007 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Chromium | 1 | 1.09 | 1.09 | 1.09 | 0 | | 8.9 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Cobalt | 1 | 0.399 | 0.399 | 0.4 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Copper | 1 | 8.88 | 8.88 | 8.88 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Iron | 1 | 604 | 604 | 604 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Lead | 1 | 0.399 | 0.399 | 0.4 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Manganese | 1 | 42.7 | 42.7 | 42.7 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Molybdenum | 1 | 0.099 | 0.099 | 0.1 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Nickel | 1 | 1.15 | 1.15 | 1.15 | 0 | | 25 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Selenium | 1 | 0.178 | 0.178 | 0.18 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Silver | 1 | 0.025 | 0.025 | 0.03 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Thallium | 1 | 0.003 | 0.003 | 0 | 0 | | 0.8 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Uranium | 1 | 0.025 | 0.025 | 0.03 | 0 | | 8.5 | Working | |
| E291154 | CB06 | Longwood Ravine at Waldy Road | Total Zinc | 1 | 11.3 | 11.3 | 11.3 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Aluminum | 1 | 577 | 577 | 577 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Antimony | 1 | 0.117 | 0.117 | 0.12 | 0 | | 9 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Arsenic | 1 | 0.415 | 0.415 | 0.42 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Barium | 1 | 11.7 | 11.7 | 11.7 | 0 | | 1000 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Beryllium | 1 | 0.013 | 0.013 | 0.01 | 0 | | 0.13 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Cadmium | 1 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Chromium | 1 | 0.99 | 0.99 | 0.99 | 0 | | 8.9 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Cobalt | 1 | 0.315 | 0.315 | 0.32 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Copper | 1 | 3.9 | 3.9 | 3.9 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Iron | 1 | 604 | 604 | 604 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Lead | 1 | 0.195 | 0.195 | 0.2 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Manganese | 1 | 35.7 | 35.7 | 35.7 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Molybdenum | 1 | 0.134 | 0.134 | 0.13 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Nickel | 1 | 0.816 | 0.816 | 0.82 | 0 | | 25 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Selenium | 1 | 0.059 | 0.059 | 0.06 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Silver | 1 | 0.012 | 0.012 | 0.01 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Thallium | 1 | 0.003 | 0.003 | 0 | 0 | | 0.8 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Uranium | 1 | 0.028 | 0.028 | 0.03 | 0 | | 8.5 | Working | |
| E291158 | CB08 | Wessex Creek at Wessex Inn | Total Zinc | 1 | 2.73 | 2.73 | 2.73 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Aluminum | 1 | 615 | 615 | 615 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Antimony | 1 | 0.084 | 0.084 | 0.08 | 0 | | 9 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Arsenic | 1 | 0.527 | 0.527 | 0.53 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Barium | 1 | 12.7 | 12.7 | 12.7 | 0 | | 1000 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Beryllium | 1 | 0.012 | 0.012 | 0.01 | 0 | | 0.13 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Cadmium | 1 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Chromium | 1 | 1.04 | 1.04 | 1.04 | 0 | | 8.9 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Cobalt | 1 | 1.03 | 1.03 | 1.03 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Copper | 1 | 6.23 | 6.23 | 6.23 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Iron | 1 | 980 | 980 | 980 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Lead | 1 | 0.218 | 0.218 | 0.22 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Manganese | 1 | 397 | 397 | 397 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Molybdenum | 1 | 0.069 | 0.069 | 0.07 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Nickel | 1 | 1.05 | 1.05 | 1.05 | 0 | | 25 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Selenium | 1 | 0.045 | 0.045 | 0.05 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Silver | 1 | 0.017 | 0.017 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Thallium | 1 | 0.004 | 0.004 | 0 | 0 | | 0.8 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Uranium | 1 | 0.018 | 0.018 | 0.02 | 0 | | 8.5 | Working | |
| E291159 | CB09 | Wessex Creek at Wilmot Road | Total Zinc | 1 | 11.2 | 11.2 | 11.2 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Aluminum | 2 | 74.3 | 858 | 466.15 | 554.16 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Antimony | 2 | 0.058 | 0.18 | 0.12 | 0.09 | | 9 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Arsenic | 2 | 0.627 | 0.632 | 0.63 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Barium | 2 | 8.73 | 12.9 | 10.82 | 2.95 | | 1000 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Beryllium | 2 | 0.01 | 0.021 | 0.02 | 0.01 | | 0.13 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Boron | 2 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Cadmium | 2 | 0.005 | 0.006 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Chromium | 2 | 0.43 | 1.76 | 1.1 | 0.94 | | 8.9 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Cobalt | 2 | 0.099 | 0.513 | 0.31 | 0.29 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Copper | 2 | 3.2 | 7.06 | 5.13 | 2.73 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Iron | 2 | 328 | 1080 | 704 | 531.74 | 1000 | | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Lead | 2 | 0.075 | 0.496 | 0.29 | 0.3 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Manganese | 2 | 34.4 | 59.3 | 46.85 | 17.61 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Molybdenum | 2 | 0.181 | 0.413 | 0.3 | 0.16 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Nickel | 2 | 1.2 | 1.95 | 1.58 | 0.53 | | 25 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Selenium | 2 | 0.1 | 0.148 | 0.12 | 0.03 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Silver | 2 | 0.005 | 0.022 | 0.01 | 0.01 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Thallium | 2 | 0.002 | 0.005 | 0 | 0 | | 0.8 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Uranium | 2 | 0.044 | 0.24 | 0.14 | 0.14 | | 8.5 | Working | |
| E291160 | CB10 | Spiers Creek at Cowichan Bay Road | Total Zinc | 2 | 1.11 | 8.05 | 4.58 | 4.91 | 33 | 7.5 | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Aluminum | 1 | 721 | 721 | 721 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Antimony | 1 | 0.228 | 0.228 | 0.23 | 0 | | 9 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Arsenic | 1 | 0.575 | 0.575 | 0.58 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Barium | 1 | 13.1 | 13.1 | 13.1 | 0 | | 1000 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Beryllium | 1 | 0.021 | 0.021 | 0.02 | 0 | | 0.13 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Cadmium | 1 | 0.005 | 0.005 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Chromium | 1 | 1.56 | 1.56 | 1.56 | 0 | | 8.9 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Cobalt | 1 | 0.353 | 0.353 | 0.35 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Copper | 1 | 7.18 | 7.18 | 7.18 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Iron | 1 | 710 | 710 | 710 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Lead | 1 | 0.359 | 0.359 | 0.36 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Manganese | 1 | 23.1 | 23.1 | 23.1 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Molybdenum | 1 | 0.161 | 0.161 | 0.16 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Nickel | 1 | 1.11 | 1.11 | 1.11 | 0 | | 25 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Selenium | 1 | 0.058 | 0.058 | 0.06 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Silver | 1 | 0.026 | 0.026 | 0.03 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Thallium | 1 | 0.004 | 0.004 | 0 | 0 | | 0.8 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Uranium | 1 | 0.024 | 0.024 | 0.02 | 0 | | 8.5 | Working | |
| E291161 | CB11 | Spiers Creek at Hillbank Road | Total Zinc | 1 | 10.1 | 10.1 | 10.1 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS Number | Station | Station description | Chemical | Count | Min | Max | Mean | StDev | Maximum Guideline | Average Guideline | Approved or Working | Guideline Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Aluminum | 1 | 775 | 775 | 775 | 0 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Antimony | 1 | 0.083 | 0.083 | 0.08 | 0 | | 9 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Arsenic | 1 | 0.542 | 0.542 | 0.54 | 0 | 5 | | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Barium | 1 | 13.4 | 13.4 | 13.4 | 0 | | 1000 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Beryllium | 1 | 0.014 | 0.014 | 0.01 | 0 | | 0.13 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Boron | 1 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Cadmium | 1 | 0.01 | 0.01 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Chromium | 1 | 1.16 | 1.16 | 1.16 | 0 | | 8.9 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Cobalt | 1 | 0.503 | 0.503 | 0.5 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Copper | 1 | 8.52 | 8.52 | 8.52 | 0 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Iron | 1 | 633 | 633 | 633 | 0 | 1000 | | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Lead | 1 | 0.259 | 0.259 | 0.26 | 0 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Manganese | 1 | 33.5 | 33.5 | 33.5 | 0 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Molybdenum | 1 | 0.139 | 0.139 | 0.14 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Nickel | 1 | 1.23 | 1.23 | 1.23 | 0 | | 25 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Selenium | 1 | 0.147 | 0.147 | 0.15 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Silver | 1 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Thallium | 1 | 0.006 | 0.006 | 0.01 | 0 | | 0.8 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Uranium | 1 | 0.033 | 0.033 | 0.03 | 0 | | 8.5 | Working | |
| E291162 | CB12 | Treffery Creek at Hwy Crossing | Total Zinc | 1 | 14.3 | 14.3 | 14.3 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Aluminum | 2 | 96.4 | 892 | 494.2 | 562.57 | 5000 | | Approved | Protection of wildlife/livestock/irrigation |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Antimony | 2 | 0.124 | 0.191 | 0.16 | 0.05 | | 9 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Arsenic | 2 | 0.747 | 1.63 | 1.19 | 0.62 | 5 | | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Barium | 2 | 9.86 | 14.9 | 12.38 | 3.56 | | 1000 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Beryllium | 2 | 0.01 | 0.019 | 0.01 | 0.01 | | 0.13 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Boron | 2 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Cadmium | 2 | 0.005 | 0.01 | 0.01 | 0 | 0.288 | 0.127 | Approved | Protection of FW aquatic life; guideline is for dissolved Cd |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Chromium | 2 | 0.38 | 1.42 | 0.9 | 0.74 | | 8.9 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Cobalt | 2 | 0.145 | 0.573 | 0.36 | 0.3 | 110 | 4 | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Copper | 2 | 3.45 | 8.71 | 6.08 | 3.72 | 4 | 2 | Approved | Protection of FW aquatic life; Cow/Kok River WQO |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Iron | 2 | 478 | 927 | 702.5 | 317.49 | 1000 | | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Lead | 2 | 0.1 | 0.492 | 0.3 | 0.28 | 11 | 4 | Approved | Protection of FW aquatic life; based on hardness of 20 mg/L |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Manganese | 2 | 53.9 | 67.1 | 60.5 | 9.33 | 800 | 700 | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Molybdenum | 2 | 0.227 | 0.555 | 0.39 | 0.23 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Nickel | 2 | 0.433 | 1.47 | 0.95 | 0.73 | | 25 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Selenium | 2 | 0.046 | 0.165 | 0.11 | 0.08 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Silver | 2 | 0.006 | 0.025 | 0.02 | 0.01 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Thallium | 2 | 0.002 | 0.004 | 0 | 0 | | 0.8 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Uranium | 2 | 0.038 | 0.108 | 0.07 | 0.05 | | 8.5 | Working | |
| E291163 | CB13 | Treffery Creek at Cowichan Bay Road | Total Zinc | 2 | 1.89 | 11.7 | 6.8 | 6.94 | 33 | 7.5 | Approved | Protection of FW aquatic life |

## APPENDIX IVA. BACTERIAL SOURCE TRACKING (BST) RESULTS FROM PESC LABORATORY – 2012 SAMPLING

*Table 30. Cowichan Bay and tributaries bacterial source tracking (BST) results from PESC laboratory, 2012 sampling.*

Environment Canada, Environmental Toxicology Section, Pacific Environmental Science Centre

| Client and Sample Information: | |
|---|---|
| Name | Deb Epps |
| Affiliation | BCMOE |
| Project: | **Cowichan Bay** |
| Sampling Date: | 13-Nov-12 |

| | |
|---|---|
| Arrival at PESC: | 14-Nov-12 |
| Folder number: | 201200791,-793,-794,-795 |
| Analyst(s): | LB, MLS |
| Results checked by: | LB, MLS |
| Results updated: | 28May2013 - LB |

Legend:
- = absent
+ = all possible markers present (1 of 1 for pig, horse, dog, elk; 2 of 2 for human, ruminant animal; result is **bolded**)
*+ = 1 of 2 possible markers present
+f or *+f = faint
? = unsure (potentially present)

| PESC sample # | Client's Sample Description | Fecal Count (per 100mL) | Human | Ruminant Animal | Pig | Horse | Dog | Elk | General *Bacteroides* | Summary of fecal pollution source identification evidence by BST: |
|---|---|---|---|---|---|---|---|---|---|---|
| 257525 | 18P3 Cowichan Bay between CB039 and 11P3 10:10 | 79 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257526 | 19P3 Cowichan Bay between CB013 & Cb015 11:08 | 49 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257527 | 20P3 Cowichan Bay at Boatswain Bank 10:41 | 79 | *+ | *+ | - | - | - | - | + | human, ruminant animal, general *Bacteroides* |
| 257531 | CB059 Cowichan Bay 400m E of breakwater 10:13 | 350 | + | + | - | - | - | - | + | **human, ruminant animal**, general *Bacteroides* |
| 257537 | CB009 Cowichan Bay-small bay east of Genoa Bay 10:30 | 79 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257538 | CB013 Cowichan Bay mouth 11:04 | 79 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257539 | CB014 Cowichan Bay - Cherry Point Marina 10:22 | 79 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257540 | A CB015 Cowichan Bay - between Skinner and Cherry Points 11:13 | 49 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257541 | B CB015 Cowichan Bay - between Skinner and Cherry Points 11:14 | 79 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257542 | CB038 Cowichan Bay - N of dolphins at Skinner point 11:48 | 240 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257543 | CB039 Cowichan Bay - Botwood lane storm drain 10:07 | 130 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257544 | CB040 - Waldy Creek 10:17; CB040 Cow Bay @ Waldy Ck | 70 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257545 | CB041 - Cowichan Bay - S wescan terminal 11:58 | 350 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257546 | 1P3 - Cowichan Bay - out from boat launch A 10:00 | 280 | + | + | +f | - | - | - | + | **human, ruminant animal**, pig, general *Bacteroides* |
| 257547 | 1P3 - Cowichan Bay - out from boat launch A 10:01 | 240 | *+ | + | + | - | - | - | + | human, **ruminant animal, pig**, general *Bacteroides* |
| 257549 | 10P3 Cowichan bay - above Lambourne outfall 10:25 | 79 | + | *+ | +f | - | - | - | + | **human**, ruminant animal, pig, general *Bacteroides* |
| 257575 | Patrolas Creek at Moss Rd 12:05; E230098 | 1,300 | *+f | + | + | - | - | - | + | human, **ruminant animal, pig**, general *Bacteroides* |
| 257576 | Koksilah River at Koksilah Rd 12:15; E206976 | 95 | - | + | +f | - | - | - | + | **ruminant animal,** general *Bacteroides* |
| 257577 | Howie Creek at Koksilah Rd 12:40; E234128 | 71 | - | - | - | - | - | - | + | general *Bacteroides* |
| 257579 | Kelvin Creek at Koksilah Rd A 12:55; E207427 | 45 | - | *+ | - | - | - | - | + | ruminant animal, general *Bacteroides* |
| 257581 | Koksilah River d/s Kelvin Creek 1:20; E207433 | 85 | - | + | +f | - | - | - | + | **ruminant animal,** pig, general *Bacteroides* |

| PESC sample # | Client's Sample Description | Fecal Count (per 100mL) | Human | Ruminant Animal | Pig | Horse | Dog | Elk | General *Bacteroides* | Summary of fecal pollution source identification evidence by BST: |
|---|---|---|---|---|---|---|---|---|---|---|
| 257582 | Koksilah Rever at highway 1 1:35; 0123981 | 720 | - | + | + | - | - | - | + | **ruminant animal, pig**, general *Bacteroides* |
| 257583 | Ditch/stream across Bright Angel Park 12:30; E291189 | 1,100 | - | *+ | + | - | - | - | + | ruminant animal, **pig**, general *Bacteroides* |
| 257585 | Cowichan River 300 m u/s PE247 9:15; 0120808 | 180 | - | - | - | - | - | - | - | no *Bacteroides* detected |
| 257591 | Manley Creek at Manley Creek park 9:50; E291149 | 1,800 | - | - | - | - | - | - | + | general *Bacteroides* |
| 257592 | Garnett Creek at Cherry Point Beach 10:05; E291150 | 1,100 | - | + | +f | - | - | - | + | **ruminant animal**, pig, general *Bacteroides* |
| 257593 | Garnett Creek at Telegraph Road 10:16; E291151 | 600 | +f | + | +f | - | - | - | + | human, **ruminant animal**, pig, general *Bacteroides* |
| 257594 | Storm drain at Cherry Point Marina 10:30; E291152 | 250 | + | *+ | - | - | - | - | + | **human**, ruminant animal, general *Bacteroides* |
| 257595 | Waldy Creek foreshore end Waldy Rd 10:55; E291153 | 980 | *+f | + | - | - | - | - | + | human, **ruminant animal**, general *Bacteroides* |
| 257597 | Storm drain at Botwood Lane 11:22; E291155 | 97 | - | - | - | - | - | - | - | no *Bacteroides* detected |
| 257598 | Wessex Creek at Wessex Inn 11:35; E291158 | 810 | *+f | + | - | - | - | - | + | human, **ruminant animal**, general *Bacteroides* |
| 257599 | Wessex Creek at Wilmot Road 12:25; E291159 | 1,900 | - | + | +f | - | - | - | + | **ruminant animal**, pig, general *Bacteroides* |
| 257600 | Spiers Creek at Cowichan Bay Rd A 11:45; E291160 | 1,600 | + | + | + | - | - | - | + | **human, ruminant animal, pig**, general *Bacteroides* |
| 257601 | Spiers Creek at Hillbank Rd 12:36; E291161 | 4,100 | *+ | + | + | - | - | - | + | human, **ruminant animal, pig**, general *Bacteroides* |
| 257602 | Treffery Creek at Cowichan Bay Rd 11:58; E291163 | 1,400 | - | + | + | - | - | - | + | **ruminant animal, pig**, general *Bacteroides* |
| 257604 | Treffery Creek at HWY; E291162 | 2,000 | - | + | + | - | - | - | + | **ruminant animal, pig**, general *Bacteroides* |

**Note:** The system of scoring is as follows: '+' denotes a definitively positive result (all markers possible for a particular species are present, clear and sufficiently bright). '*+' denotes a sample for which 1 out of 2 markers was detected (for those species with more than one marker), which is not as definitive as if both markers were present, but is still a positive result with one well-defined band. The occurence of 1 out of 2 markers, or a faint or unsure result, may be due to a few reasons: 1. the method is at the edge of detection for this sample with respect to the amount of fecal matter present for a particular species. 2. not every single organism may carry both markers but in a herd (or larger number) of animals, you would expect to find both markers represented. In cases like this then, it is probable that an individual organism, possibly two organisms, caused this fecal pollution and that this particular individual did not have both markers. 3. the fecal material inoculation is old,or other sample conditions (*eg* protozoa, temperature) are allowing the bacteria and DNA to degrade (bands can become smeared; *i.e.* there appears to be 'something' in the area of interest but it is blurry).

**Note:** A positive result for general *Bacteroides* only indicates fecal contamination without implicating a specific source. If a sample also tests positive for markers from one or more specific animal group tested, then this is likely the, or definitely one of the contributors of the general Bacteroides. We do not have specific primers for other potential contributors (eg birds, seals, bears) at this time. If a sample tests positive for only general Bacteroides, it could be interpreted as "other species of animal" and the fecal contamination in the sample could not be attributed to human, ruminant animal, pig, horse, dog or elk sources.

**QA/QC passed:** All three negative controls (equipment blank, extraction blank and PCR blank) tested clear, and the PCR positive control reference test worked well.

## APPENDIX IVB. BACTERIAL SOURCE TRACKING (BST) RESULTS FROM PESC LABORATORY – 2013 SAMPLING

*Table 31. Cowichan Bay and tributaries bacterial source tracking (BST) results from PESC laboratory, 2013 sampling.*

**Bacterial Source Tracking (BST) Analysis Sheet**

Environment Canada, Environmental Toxicology Section, Pacific and Yukon Laboratory for Environmental Testing (PYLET)

Environment Canada Environnement Canada

**Client and Sample Information:**

Name Deb Epps
Affiliation BCMOE
Project Cowichan Bay
Sampling Date 03-Dec-13

| | |
|---|---|
| Arrival at PESC: | 04-Dec-13 |
| Folder number: | 201300780, 201300781 |
| Analyst(s): | LB, MLS |
| Results checked by: | LB, MLS |
| Report date: | 28-Jan-14 |

Legend:
- = absent
+ = all possible markers present (1 of 1 for pig, horse, dog, elk; 2 of 2 for human, ruminant animal; result is **bolded**)
*+ = 1 of 2 possible markers present
+f or *+f = faint
? = unsure (potentially present)

| PYLET Sample # | Client's Sample Description | Fecal Count | Human | Ruminant Animal | Pig | Horse | Dog | Elk | Gull | General *Bacteroides* | Summary of fecal pollution source identification |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 276210 | E291151 - Garnett Creek at Telegraph Road | 91 | *+f | *+f | - | - | ? | - | - | + | human, ruminant animal, dog?, general *Bacteroides* |
| 276219 | E291161 - Spiers Creek at Hillbank Road | 64 | - | - | - | - | - | - | - | + | general *Bacteroides* |
| 276224 | E206976 - Koksilah River at Koksilah Road | 44 | - | - | - | - | - | - | - | + | general *Bacteroides* |
| | | | | | | | | | | | |

**QA/QC passed:** All three negative controls (equipment blank, extraction blank and PCR blank) tested clear, and the PCR positive control reference test worked well.

**Note:** The system of scoring is as follows: '+' denotes a definitively positive result (all markers possible for a particular species are present, clear and sufficiently bright). '*+' denotes a sample for which 1 out of 2 markers was detected (for those species with more than one marker), which is not as definitive as if both markers were present, but is still a positive result with one well-defined band. The occurence of 1 out of 2 markers, or a faint or unsure result, may be due to a few reasons: 1. the method is at the edge of detection for this sample with respect to the amount of fecal matter present for a particular species. 2. not every single organism may carry both markers but in a herd (or larger number) of animals, you would expect to find both markers represented. In cases like this then, it is probable that an individual organism, possibly two organisms, caused this fecal pollution and that this particular individual did not have both markers. 3. the fecal material inoculation is old,or other sample conditions (*eg* protozoa, temperature) are allowing the bacteria and DNA to degrade (bands can become smeared; *i.e.* there appears to be 'something' in the area of interest but it is blurry).

**Note:** A positive result for general *Bacteroides* only indicates fecal contamination without implicating a specific source. If a sample also tests positive for markers from one or more specific animal group tested, then this is likely the, or definitely one of the contributors of the general Bacteroides. We do not have specific primers for other potential contributors (eg birds, seals, bears) at this time. If a sample tests positive for only general Bacteroides, it could be interpreted as "other species of animal" and the fecal contamination in the sample could not be attributed to human, ruminant animal, pig, horse, dog or elk sources.

**Note:** The level of confidence in a positively pig result it not as high as any of the other organisms because the pig primers for one of the markers have been noted to cross-prime with ruminant animal. If it is considered impossible that the sample contains pig fecal material, we would appreciate being told.

**Note:** When analyzed in the standard manner there is no evidence of *Bacteroides* presence. Given the pure genomic DNA gel following the extraction and knowing the FC result (forwarded by you), the lack of evidence of *Bacteroides* is surprising and it is suspected PCR inhibition is at play. It is likely a property or condition of the sample interfering with being able to isolate or amplify the target DNA. Compounds with high ionic content, chelating metals or some particular organic makeup might be to blame, and there are some strategies that I will try that I hope might take care of these to allow me to determine the source of the high FC seen for this (200700045, Jul07) and a previous sample of yours (200601278, Nov06) that resulted in a similar pattern. I'll let you know as soon as I have anything illuminating, but in the meantime "no Bacteroides detected" is the answer.

## APPENDIX IVC. MICROBIAL SOURCE TRACKING RESULTS FROM UVIC LABORATORY – 2013 SAMPLING.

*Table 32.. Cowichan Bay and tributaries microbial source tracking results from UVIC laboratory - 2013 sampling.*

| Sampling Date | Receiving Date | Analysis Date | Sampling Site | Sample Type (i.e., Raw Water, Pond Water, Storm | Internal Lab ID | *E.coli (CFU/100ml)* | | | Numbers of True E.Coli | Non- *E.coli* Coliforms (CFU/100ml) | | | Dilution Factor | Probable Sources | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plate 1 | Plate 2 | Mean | | Plate 1 | Plate 2 | Mean | | | | | | | | | | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Cowichan Bay -Marina #1 | Marine water | 23 | 40 | 30 | **35** | 9/10 | 60 | 73 | **67** | | Mule deer | Black bear | Black bear | Mule deer | Black bear | Black bear | Mule deer | NI | Marmot |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Cowichan Bay -Marina #2 | Marine water | 24 | 33 | 50 | **42** | 8/10 | 27 | 47 | **37** | | Coyote | NI | Horse | Human | Mule deer | Cow | NI | NI | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Cowichan Bay at Garnett Creek | Marine water | 25 | 1 | 1 | **1** | 1/1 | 20 | 30 | **25** | | Cow | | | | | | | | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Cowichan Bay- S of Wescan | Marine water | 26 | 25 | 26 | **26** | 9/10 | 100 | 82 | **91** | | NI | Human | Wolf | NI | NI | Human | Mule deer | Human | Horse |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Cowichan Bay out from Botwwod Stormdr | Marine water | 27 | 36 | 36 | **36** | 8/10 | 75 | 88 | **82** | | Mule deer | Horse | Raccoon | Human | Raccoon | Horse | Raccoon | Raccoon | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Garnett Creek at Telegraph Road | Marine water | 28 | TNTC | TNTC | **TNTC** | | TNTC | TNTC | **TNTC** | | | | | | | | | | |
| | | | | | | 48 | 58 | **53** | 8/10 | 40 | 70 | **55** | **2X** | Raccoon | Raccoon | NI | Human | Horse | NI | Human | Black bear | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Spiers Creek at Cowichan Bay Road | Marine water | 29 | 4 | 2 | **3** | 4/4 | 35 | 44 | **40** | | Black bear | Cow | Mule deer | NI | | | | | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Wessex Creek at Wessex Inn | Marine water | 30 | TNTC | TNTC | **TNTC** | | TNTC | TNTC | **TNTC** | | | | | | | | | | |
| | | | | | | 4 | 1 | **3** | 3/4 | 47 | 63 | **55** | **2X** | NI | Black bear | Cow | | | | | | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Treffery Creek at Hwy | Marine water | 31 | TNTC | TNTC | **TNTC** | | TNTC | TNTC | **TNTC** | | | | | | | | | | |
| | | | | | | 28 | 20 | **24** | 1/10 | 98 | 120 | **109** | **2X** | Mule deer | | | | | | | | |
| 4-Dec-17 | 5-Dec-17 | 5-Dec-17 | Stormdrain at Botwwd Lane | Marine water | 32 | 3 | 8 | **6** | 8/8 | 50 | 30 | **40** | | NI | NI | Mule deer | Mule deer | NI | Coyote | Mule deer | Cow | |