ENVIRONMENTAL QUALITY SERIES

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

December 2021

The **Environmental Quality Series** are scientific technical reports relating to the understanding and management of B.C.'s air and water resources. The series communicates scientific knowledge gained through air and water environmental impact assessments conducted by BC government, as well as scientific partners working in collaboration with provincial staff. For additional information visit:

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## EXECUTIVE SUMMARY

This report summarizes and assesses water quality data collected in 2012 and 2013 for lower Shawnigan Creek and numerous other freshwater tributaries to Mill Bay, as well as bacteriological analysis of several marine sites within Mill Bay. The assessment was done to determine if local activities, development, and land use changes are impacting land uses within the watershed. Water uses to be protected in the Mill Bay marine waters include aquatic life - shellfish harvesting and recreation. Water uses to be protected in the freshwater tributaries include drinking water, aquatic life and wildlife, recreation, and irrigation. Non-point sources are likely the only major input of pollutants to the freshwater tributaries and marine waters of Mill Bay. 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 Mill Bay study area.

Overall, the water quality presented in this report indicates that the state of water quality is generally good. Water temperatures are occasionally higher than BC Water Quality Guidelines at the outlet of Shawnigan Lake, and some of the freshwater tributaries to Mill Bay have occasional elevated turbidity, total suspended solids, and metals. Bacteriological contamination is a concern both in the freshwater tributaries and in the marine water sites. Further investigation should occur to better identify specific sources of water quality contaminants.

*Recommended Water Quality Objectives for Mill 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 |

All statistics are to be calculated based on five 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 recommend 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 km2). 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 developed for each of the representative lake and stream watersheds 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 BC ENV, local municipalities, other stakeholders, Indigenous Nations and stewardship groups are a key component of the water quality network. Water quality sampling conducted by the public works departments of local municipalities, Indigenous Nations and stewardship groups has enabled the Ministry to significantly increase the number of watersheds studied and the sampling regime within these watersheds. These partnerships have: allowed the Ministry to study watersheds over a greater geographic range and in more ecoregions across Vancouver Island; 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

Shawnigan Creek and other small tributary streams drain into the Mill Bay study area, which is located approximately 20 km south of Duncan, BC, on Vancouver Island. This area is the traditional land of the Malahat First Nations. The Shawnigan Creek watershed, which includes Shawnigan Lake, is used as a drinking water source and has high recreational and fisheries values with steelhead, rainbow trout, cutthroat trout, kokanee, coho salmon, chum salmon and brown catfish present at some point during the year (Habitat Wizard, 2015). Marine waters of Mill Bay contain shellfish beds for harvest (closed due to fecal contamination) and recreational fishing and swimming/diving areas (BC ENV, 1996). Mill Bay is also used for boating, with a marina located within the Bay, and the Mill Bay Nature Park is a seven-acre waterfront park located on the northern end of the Bay (BC ENV, 1996). This study discusses water quality downstream of Shawnigan Lake only; for Shawnigan Lake and upper Shawnigan watershed studies above the lake, see Kopat and Sokal (2019a), Rieberger (2007), Kopat and Sokal (2019b), and Barlak and Javorski (2020).

The Shawnigan community watershed makes up a significant portion of the total drainage area in the study area and provides a significant source of drinking water to local communities, mainly from Shawnigan Lake. The Shawnigan community watershed was designated as a community watershed in 2000, as defined under the *Forest Practices Code of British Columbia Act* (i.e., "the drainage area above the downstream point of diversion and which are licensed under the *Water Act* for waterworks purposes") (DataBC, 2015b). This designation was grand-parented and continued under the *Forest and Range Practices Act* (FRPA) in 2004 and infers a level of protection.

Some of the Shawnigan Lake community watershed is on private land, and the FRPA does not apply to these privately-owned portions of the watershed. 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 BC *Drinking Water Protection Act* (BC Gov, 2001) (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, Island Health requires all surface water supply systems to provide two types of treatment processes (VIHA, 2010). There is a community water system, operated by the Mill Bay Waterworks District (MBWD), 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. Drinking water originates from wells, which is then disinfected and pumped to reservoirs for storage (MBWD, 2021). Island Health continues to allow the Cowichan Valley Regional District (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; MBWD, 2021). Residents also obtain drinking water from either private water systems or private groundwater wells (AECOM, 2010). There are several domestic water licences issued for Shawnigan Creek and tributaries to Mill Bay, therefore water quality protection is a primary concern for residents, purveyors, and resource managers.

Anthropogenic land uses within the study area include residential development, recreation, commercial/industrial, agriculture and fishing. 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 Mill 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. A sanitary closure to bivalve shellfish harvesting in Mill Bay is currently in place (Fisheries and Oceans Canada, 2021).

The BC ENV Environmental Protection Division worked in partnership with the CVRD, Island Health, Malahat First Nations, Shawnigan Watershed Roundtable, Shawnigan Research Group and Shawnigan Basin Society in 2012 and 2013 to collect marine and freshwater monitoring data in the Mill Bay study area (Mill Bay marine areas and tributaries to the Bay). This report examines the existing water quality

(2012 – 2013) of the Mill Bay study area 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, 90th 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 Mill Bay study area is approximately 54.5 $km^2$ in area, located on southern Vancouver Island It is comprised of the marine areas of Mill Bay, as well as two different sets of drainages: lower Shawnigan Creek, which flows out of Shawnigan Lake and enters the ocean at Mill Bay, and several small creeks that drain directly into Saanich Inlet (e.g., Malahat Creek). For the purposes of this report, the study area is defined as the watershed boundary shown in **Error! Reference source not found.**.

The lower Shawnigan Creek drainage area, which is included in the Mill Bay study area, is part of the Shawnigan watershed (DataBC, 2015a). The Shawnigan watershed lies within the Shawnigan Community Watershed, which is larger (105 $km^2$) and includes tributaries to Shawnigan Lake, Shawnigan Lake proper, as well as the land draining to Shawnigan Creek below the lake outlet to Mill Bay (DataBC, 2015b). The main portion of the Lower Shawnigan Creek watershed is separated from the coast by the Malahat Range, until it curves around the northern end of these mountains and enters the ocean at Mill Bay. The distance from the outflow of the lake to Mill Bay is about 5 km, but due to the winding course, the actual instream length of the creek is approximately 11 km. The basin slopes first to the north and then east into tidewater at Mill Bay. It is bordered by the Koksilah River watershed to the north and west, the Sooke River watershed to the west and south, the Goldstream watershed to the south, and numerous small creeks to the east that drain directly into Saanich Inlet (Best, 2001). Shawnigan Creek is the largest tributary directly entering Saanich Inlet. The communities of Shawnigan Lake (near the outlet of the lake) and Mill Bay (near the outlet of Shawnigan Creek into Mill Bay) are within the drainage area. Highway 1 crosses over Shawnigan Creek on a high double bridge, located just upstream of the creek's outfall into the ocean in Mill Bay.

Lower Shawnigan Creek is characterized by shallow, rocky/gravelly, pool/riffle habitat punctuated by a series of bedrock falls that are total or near-total barriers to fish passage and break the lower creek into distinct habitat sub-units (Best, 2001). The largest of these falls occur just above tidewater, where they form an impassible physical barrier to the migration of fish from the ocean. Thus, this watershed has never historically supported runs of salmon or any other anadromous fish, which is atypical as most other coastal streams of similar size on Vancouver Island support anadromous fish populations. Fish observations in Lower Shawnigan Creek (Habitat Wizard, 2015) are associated with the presence of fish in Shawnigan Lake and from human attempts to introduce salmon species into the Lower Shawnigan Creek watershed (Best, 2001).

There is a large wetland located on the mainstem of the creek near the Cameron-Taggart Road bridge. This wetland, locally known as "Cameron/Taggert swamp" has an area of approximately 0.25 $km^2$ and a perimeter of 2.8 km. This swamp is identified on Figure 3 by the 'Little Shawnigan Lake' sampling station. The swamp is predominated by willow species rooted in shallow standing water (Best, 2001). There are two areas of deep open water in this wetland; one is teardrop shaped with an approximate area of 3,700 $m^2$, and the second is slightly to the east with an area of 2,875 $m^2$. The habitat throughout this large swamp is distinctively different than the rest of Lower Shawnigan Creek, and is characterized by standing water, high temperatures and low dissolved oxygen (Best, 2001).

The underlying geology in the region is different in the coastal and inland areas. The inland area (west of Cameron-Taggart Road) is described as the Bonanza Group. It is composed of calc-alkaline volcanic rocks from the Lower Jurassic period. The geology is described as massive amygdaloidal and pillowed basalt to andesite flows, dacite to rhyolite massive or laminated lava, green and maroon tuff, feldspar crystal tuff, breccia, tuffaceous sandstone, argillite, pebble conglomerate and minor limestone (DataBC, 2015c). The coastal area adjacent to Mill Bay is described as Middle Jurassic – Vancouver Island. It is composed of granodioritic intrusive rocks from the Jurassic period, and is described as granodiorite, quartz diorite, quartz monzonite, diorite, agmatite, feldspar porphyry, minor gabbro and aplite (DataBC, 2015c).

Mill Bay study area falls within the Coastal Douglas Fir biogeoclimatic zone (wet, CDFb). The watershed falls within the Nanaimo Lowland (NAL) ecoregion established for Vancouver Island by BC ENV staff (**Error! Reference source not found.**).

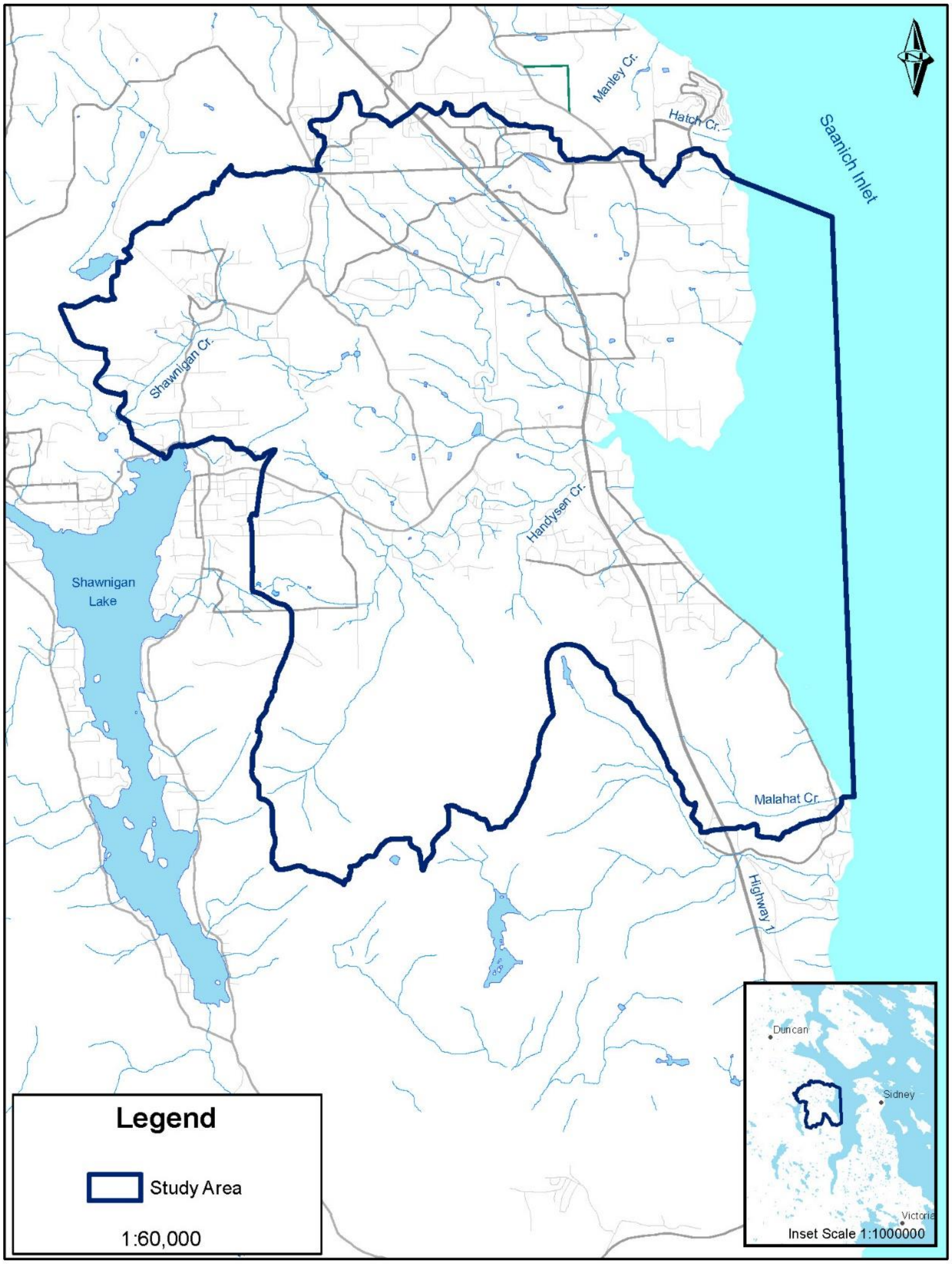


*Figure 2: Map of Mill Bay area, showing boundaries of the study area*

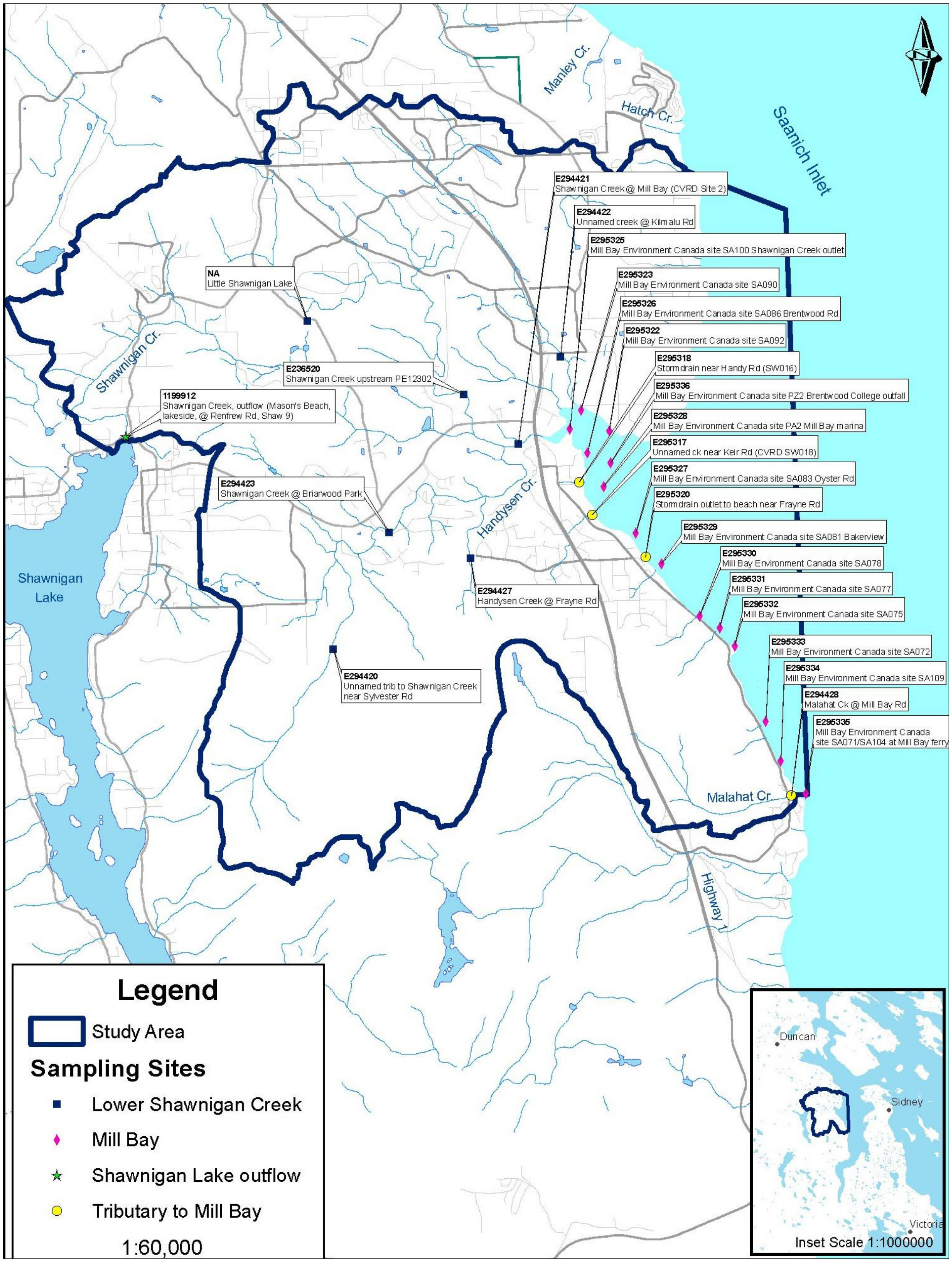


*Figure 3. Map of Mill Bay study area, showing water quality monitoring locations*

The Mill Bay Village was established in the 1860's along the Saanich Inlet in Electoral Area A (Mill Bay/Malahat) as a lumber and milling community. The Village is surrounded by parks, wineries, fields and straits and channels well-known for boating and salt-water fishing. The long, sandy stretch of Mill Bay Beach is a scenic and popular spot for swimming and picnicking, and the Mill Bay Nature Park features many oceanfront trails. Bamberton Provincial Park (located just south of the study area) is also a superb location for hiking and swimming, as well as camping. Of the 4,733 people residing in Electoral Area A (Mill Bay/Malahat) (2016 Census), about 2,700 live in Mill Bay Village (CVRD, 2011a). There are about 1,000 residences in the Village, almost all of which are single family dwellings. Only small pockets within the community currently have community sewer services (CVRD, 2011a). There are approximately 1,085 septic tanks in the Mill Bay area, most of which are old and aging (AECOM, 2010; CVRD, 1996). Mill Bay's business/commercial sector serves as the main commerce activity area for most of South Cowichan. Due to its location near the Capital Regional District, and limitations on local employment opportunities, there are a high percentage of residents who commute to Victoria each day to work (CVRD, 2011a).

## 2.2 Hydrology and Precipitation

The nearest climate station to the watershed for which climate normal data were available was the Shawnigan Lake station (elevation 159.00 m: Environment Canada Climate Station 1017230). Average daily temperatures between 1981 – 2010 ranged from 3.1°C in December to 17.9°C in August. Average total annual precipitation between 1981 and 2010 was 1,318 mm, with 10.3% of this falling as snow [i.e., based on calculating the snow water equivalent (SWE) as 136 mm, assuming 20% snow density]. Most precipitation (1,072 mm, or 81%) fell between October and March (Government of Canada, 2014; Figure 4).

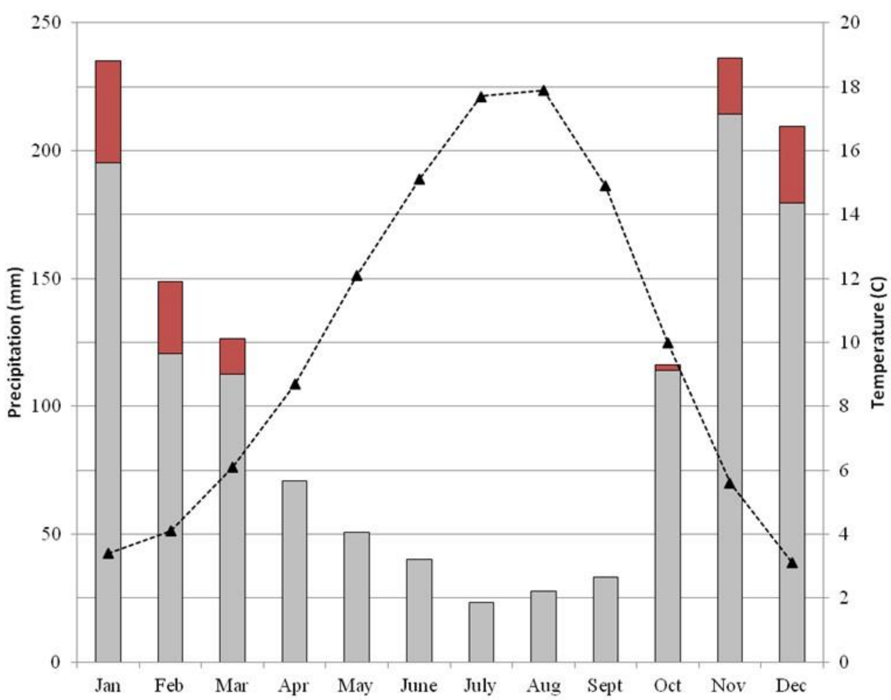


*Figure 4. Climate data (1981 – 2010) for Shawnigan Lake (ECCC Climate Station 1017230)*

Water Survey Canada (WSC) operated a hydrometric station between 1974 and 2009 on Shawnigan Creek near Mill Bay (Station 08HA039). Minimum, maximum, and average discharges for this period are shown in Figure 5. Peak flows measured between 1974 and 2009 were 44.7 $m^3/s$ (Figure 5). Peak flows occurring during the winter corresponded to high rainfall events, while spring peaks were a result of snowmelt in the upper watershed. The mean annual discharge of Shawnigan Creek near Mill Bay is 2.17 $m^3/s$ (WSC, 2015). The creek is essentially dry in August and September and has very low flow from May through July (BC ENV, 1996).

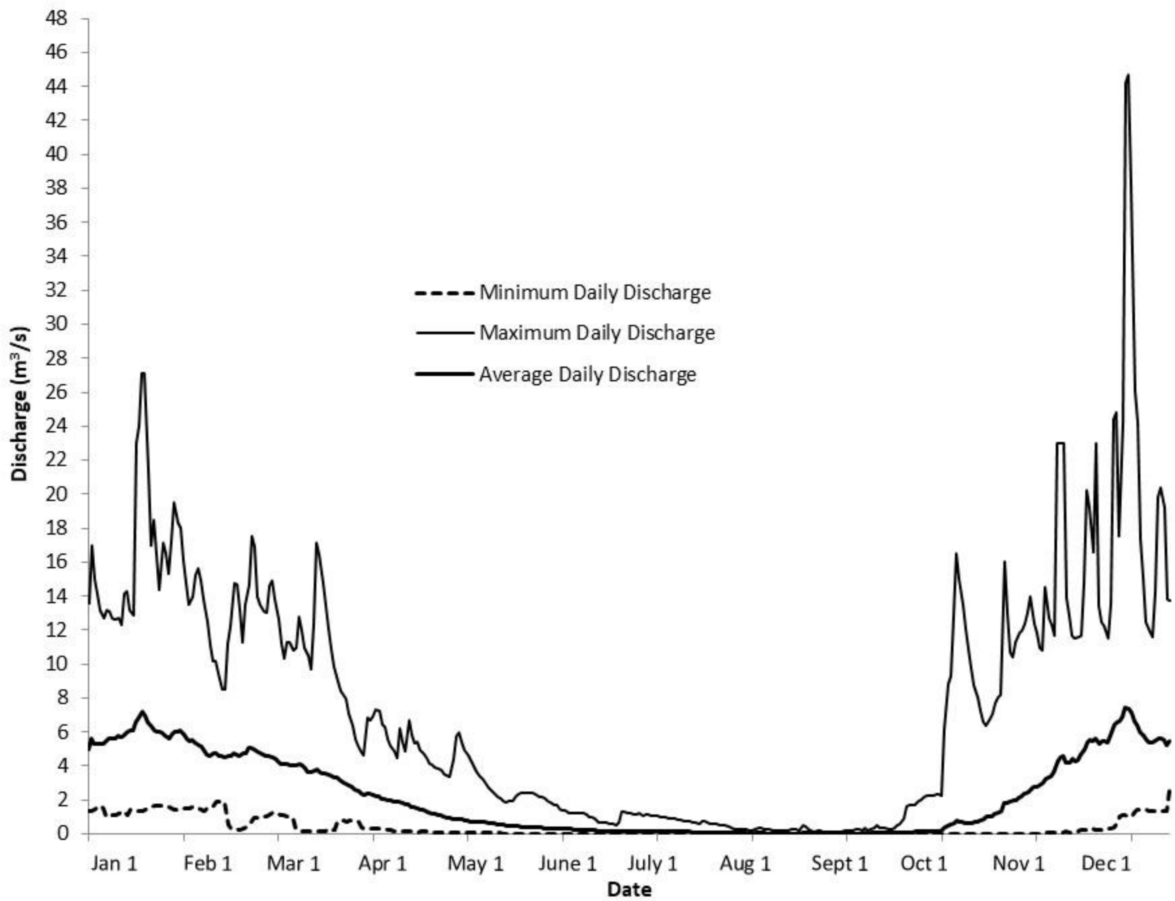


*Figure 5. Minimum, maximum and average daily discharge data for Shawnigan Creek near Mill Bay (WSC Station 08HA033) between 1974 and 2009 (WSC, 2015).*

Between 1997 and 1999, Water Survey Canada (WSC) operated hydrometric stations on two smaller nearby streams: Handysen Creek and Wilken Creek. Minimum, maximum, and average water levels for this period are shown in Figure 6 and Figure 7. Peak flows measured between 1997 and 1999 were 1.04 $m^3/s$ on Handysen Creek, and 0.11 $m^3/s$ on Wilken Creek. Minimum flows were close to 0 $m^3/s$ on both creeks (Figure 6, Figure 7). Timing of peak flows in these smaller tributaries were similar to those seen in Shawnigan Creek.

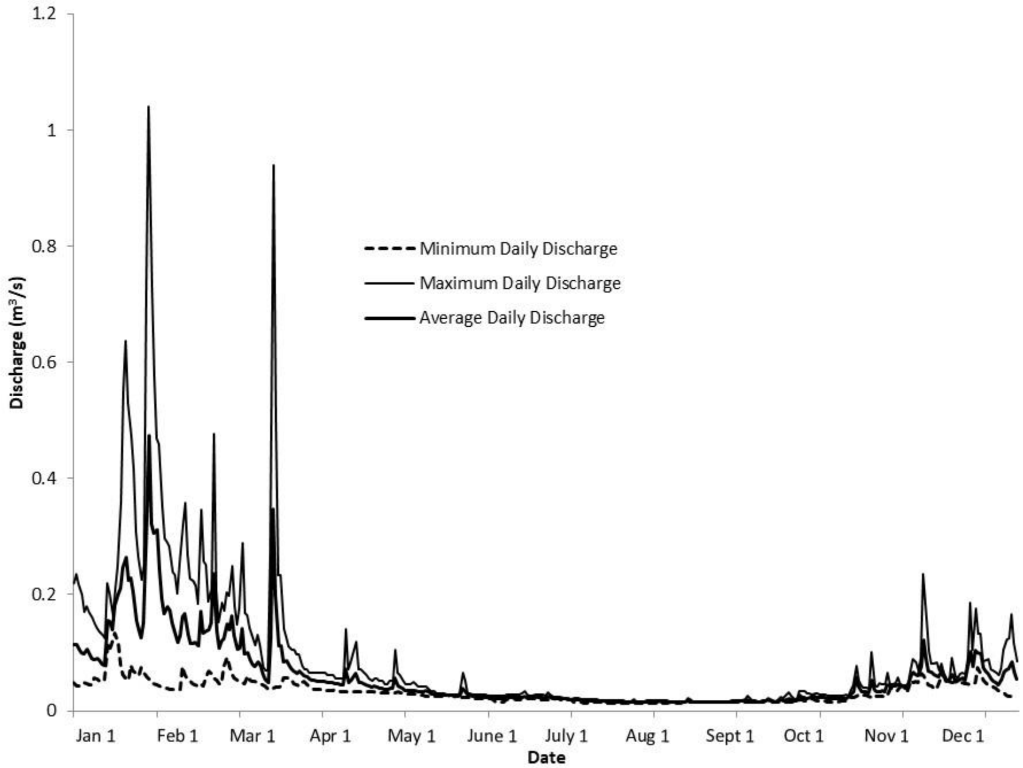


*Figure 6. Minimum, maximum and average daily discharge data for Handysen Creek near Mill Bay (WSC Station 08HA067) between 1997 and 1999 (WSC, 2015).*

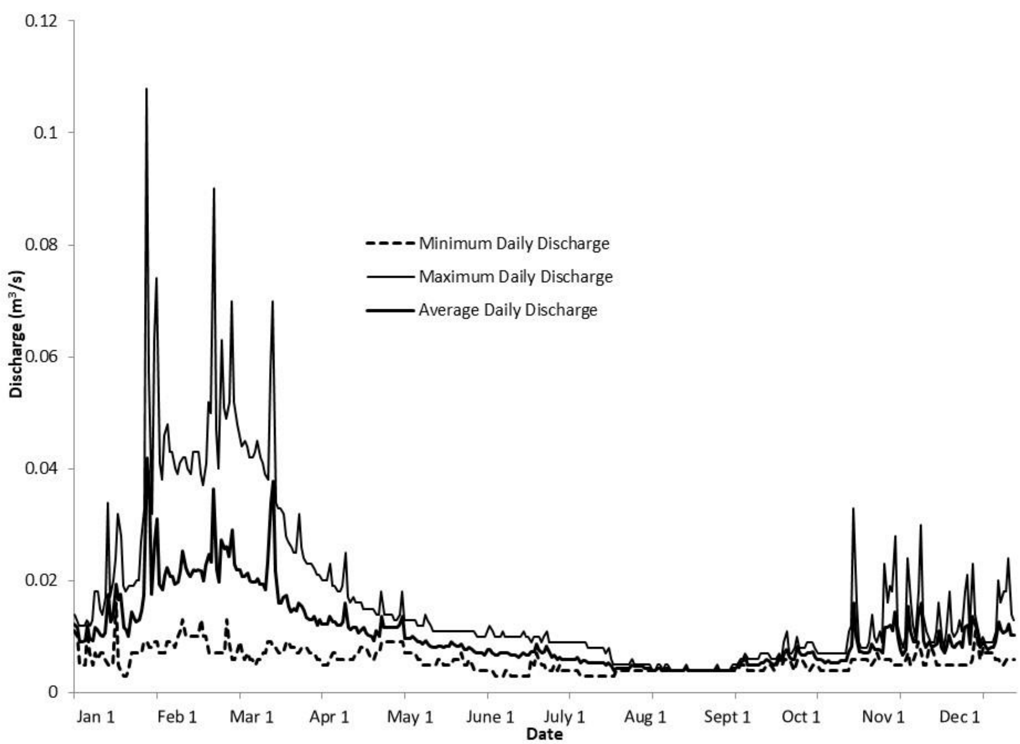


*Figure 7. Minimum, maximum and average daily discharge data for Wilken Creek near Mill Bay (WSC Station 08HA066) between 1997 and 1999 (WSC, 2015).*

## 2.3 Oceanography

Mill Bay is the only embayment on the western side of Saanich Inlet. Whiskey Point, on the northern end of the bay, is the boundary of the embayment. Waters in Saanich Inlet have limited exchange and mixing with the marine waters of the open ocean, which are flushed in and out of the Juan de Fuca Straight and the Salish Sea through tidal exchanges (Thompson, 1981). The longer residence time of water makes the waters and sediments of Saanich Inlet vulnerable to elevated levels of contaminants.

Predominant features of the shoreline in Mill Bay are rocky beaches and the estuary where Shawnigan Creek flows into the ocean. Water circulation in the Bay is moderate and sensitive environments in the Bay include eelgrass beds, a productive soft-bottom invertebrate community, and rocky shores with high biodiversity south of the Bay (BC ENV, 1996; Figure 8). There is a seal haul-out at the Mill Bay marina, as well as good bird-viewing areas (BC ENV, 1996). The Mill Bay Nature Park is located on the waterfront on the northern end of Mill Bay. This 3-hectare park provides beach access and access to the tidal flats of the estuary.

The Mill Bay ferry terminal is located on the coast south of Mill Bay, near the mouth of Malahat Creek.

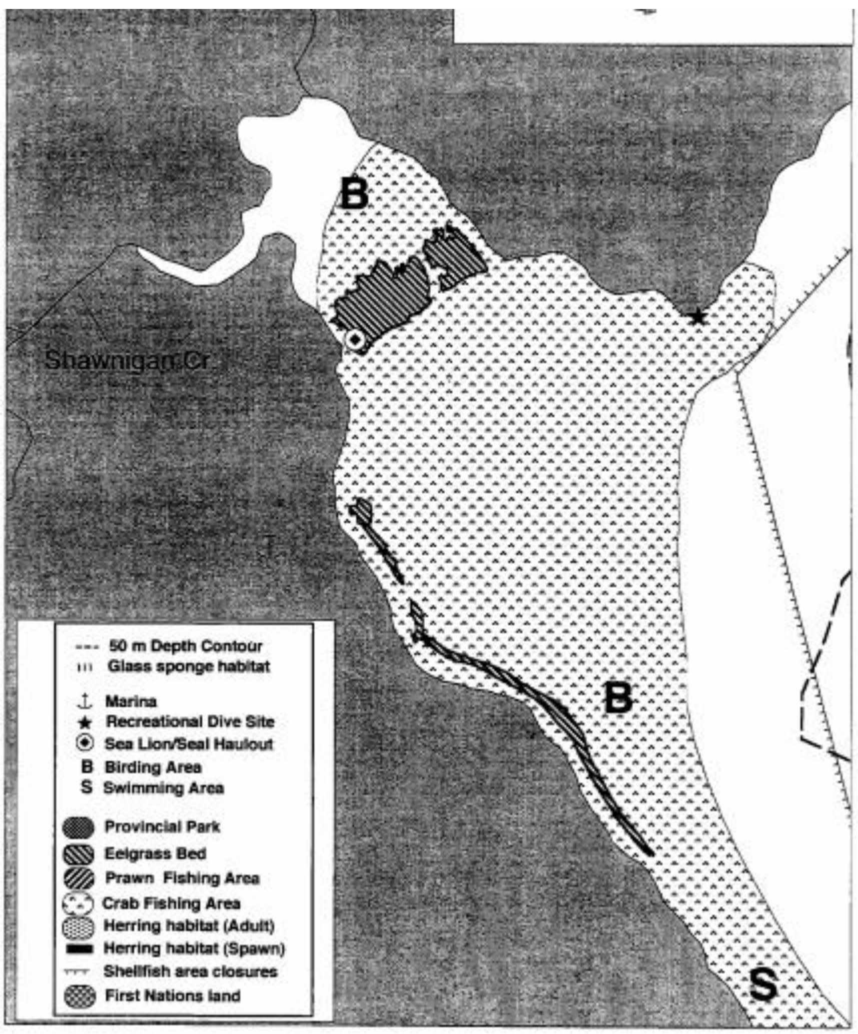


*Figure 8. Map of Mill Bay showing key uses and sensitive resources (BC ENV, 1996).*

# 3. WATER USES

## 3.1 Water Licenses

There are 16 surface water courses in the watershed that are licenced for water withdrawals (Table 1). There are also numerous springs that are licenced for water withdrawal (including Law Spring, Benko Spring, Wood Spring, Rodger Spring, Nisbet Springs, and Lind Spring) not included in this discussion, as they are considered groundwater (rather than surface water) sources. There are a total of 55 active water licenses and/or applications issued for these water bodies permitting the extraction of 3,253 $m^3$/day for consumptive uses (Table 1). In addition, 8,267 $m^3$/day of water is licensed for storage in the Mill Bay study area.

*Table 1. Licenced domestic water withdrawals and storage volumes ($m^3$/day) for Mill Bay study area (BC MFLNRO, 2015).*

| Creek Name | # of licenses | Water Use | | | |
|---|---|---|---|---|---|
| | | Domestic/ Waterworks | Irrigation | Other[1] | Storage |
| Shawnigan Creek | 27 | 1,180 | 60 | 1,256 | 7,913 |
| Malahat Creek | 1 | 91 | | | |
| Hollings Creek | 3 | 34 | 1.2 | | 34 |
| Wheelbarrow Creek | 1 | | 1.7 | | |
| Bird Creek | 1 | 2.3 | | | |
| Wilkin Creek | 7 | 18 | 5.1 | | |
| Goodhope Creek | 1 | | | 23.7 | |
| Bamford Brook | 1 | | | 1.4 | |
| Filleul Brook | 1 | | | 0.85 | |
| Burt Brook | 1 | 2.3 | | | |
| Taggart Creek | 5 | 4.5 | 213 | | 101 |
| North Taggart Creek | 2 | | 270 | | 135 |
| Avery Brook | 1 | | 67.5 | | 67.5 |
| Ericson Creek | 1 | | 16.9 | | 16.9 |
| Kilmalu Creek | 1 | | 1.5 | | |
| Burnham Creek | 1 | 2.3 | | | |
| **Total** | **55** | **1,334.4** | **636.9** | **1,281.95** | **8,267.4** |

*[1]Other = land improvement, conservation, or fire protection*

The majority of the licensed volume is for use by local water utilities (CVRD, Lidstech Holdings Ltd and Mill Bay Waterworks), which represents approximately 1,735 $m^3$/day for withdrawal and 7,900 $m^3$/d for storage (Table 2). The Department of Fisheries and Oceans is another significant licensee with 1,210 $m^3$/day storage to maintain minimum summer flows to support fish populations. The remaining licenses are for domestic use, irrigation and institutions/enterprises.

*Table 2. Major water purveyors licenced to withdraw water from surface waters in the Mill Bay study area (BC MFLNRO, 2015).*

| Water Body | Licencee | Purpose | Quantity ($m^3/d$) |
|---|---|---|---|
| Shawnigan Creek | Mill Bay Waterworks District | Waterworks Local Auth | 1137 |
| Shawnigan Creek | Fisheries & Oceans Canada | Conserv.-Use Of Water | 1210 |
| Shawnigan Creek | Cowichan Valley Regional District | Storage-Non Power | 3488 |
| Shawnigan Creek | Lidstech Holdings Ltd | Storage-Non Power | 2352 |
| Shawnigan Creek | Mill Bay Waterworks District | Storage-Non Power | 2001 |
| Shawnigan Creek | Shawnigan Lake Recreation Association | Storage-Non Power | 56 |
| Shawnigan Creek | British Columbia Conference Property Dev | Storage-Non Power | 17 |
| Malahat Creek | Malahat Indian Band | Waterworks (Other) | 91 |
| Goodhope Creek | Mill Bay Waterworks District | Land Improve | 24 |
| Taggart Creek | Willswikk Farms Ltd | Irrigation | 213 |
| North Taggart Creek | J William Wikkerink Farms Ltd. | Irrigation | 270 |

## 3.2 Fisheries

The following fish species are reported as being present at some point during the year in Shawnigan Creek, near the mouth of Mill Bay: steelhead (*Onchorhynchus. mykiss*), rainbow trout (*O. mykiss*), cutthroat trout (*O. clarki*), kokanee (*O. nerka*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), threespine stickleback (*Gasterosteus aculeatus*), prickly sculpin (*Cottus asper*) and the introduced pumpkinseed (*Lepomis gibbosus*) and brown catfish (*Ameiurus nebulosus*) (HabitatWizard 2015). In addition, rainbow trout (*O. mykiss*) and cutthroat trout (*O. clarki*) have been observed in Shawnigan Creek at a location near the Little Shawnigan Lake site (also known as Cameron/Taggart swamp). Pumpkinseed sunfish have also been observed in the Cameron/Taggart swamp (Best, 2001).

Since 2004, the Mill Bay Conservation Society has trucked coho salmon from Mill Bay, past impassable falls, to Shawnigan Creek at the north end of the lake (the main drop off points are where Cameron Taggart Road and Filgate Road cross the creek). Coho stocking has ranged from 78 fish in 2011 to 4,736 fish in 2012 (Gray, pers. comm. 2014). Fish stocking reports were searched (FFSBC, 2015), and there are no reported fish stocking events within the Mill Bay study area.

The marine waters surrounding Mill Bay are a popular destination for local recreational fishers seeking a variety of salmon and rock fish (BC Parks, 2015). Numerous shellfish species are found in the inlet/harbor and basin. The area is currently closed for direct harvesting of bivalves due to identified pollution sources such as septic seepage, urban and agricultural runoff and wildlife (Figure 9; Fisheries and Oceans Canada, 2021). The shellfish harvesting closure has likely had critical and long-lasting impacts for First Nations, as shellfish has food, social and ceremonial value for generations.

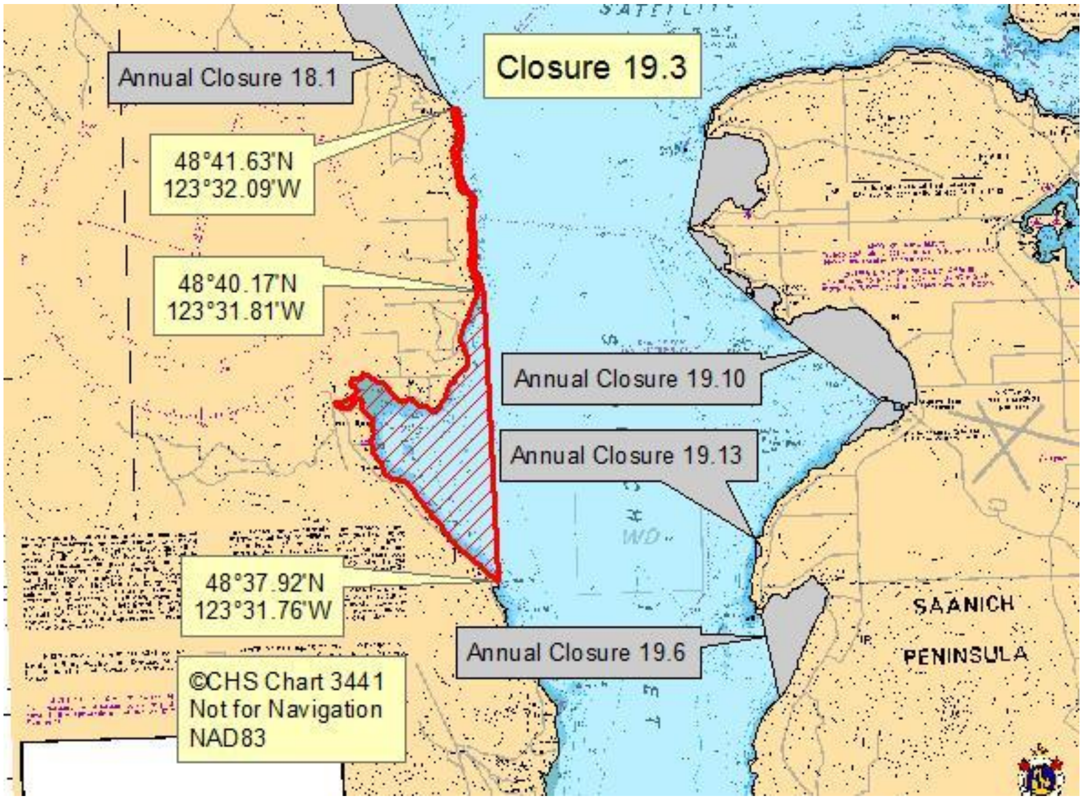


*Figure 9. Map of Area 19 sanitary closures (Fisheries and Oceans Canada, 2021).*

## 3.3 Recreation

Although tourism is a growth industry in the Cowichan Valley, the Mill Bay Official Community Plan (OCP) recognizes that only a limited degree of tourist recreational activity exists in the Electoral Area A (Mill Bay-Malahat; CVRD, 2011a). The Mill Bay area provides several outdoor recreational opportunities including boating, kayaking, diving, hiking, cycling, swimming, horseback riding and fishing. There are no provincial parks within the study area, but Bamberton Provincial Park is located just south of the study area, on the waterfront near the Mill Bay ferry terminal.

Boating and fishing are popular activities in this oceanfront area. There is a small government float in Mill Bay providing temporary moorage for visitors and providing access to shore for those who want to walk into the village (Wolferstan, 1989). The Mill Bay marina is located about 1 kilometer south of the Mill Bay estuary and offers full services, including a boat launch and a shuttle service for tourists to use to visit attractions in the area. The area offers world class prawning and crabbing opportunities (Mill Bay Marina, 2015).

The study area includes many parks and trails (Figure 10; CVRD, 2015), and it is anticipated that as the community continues to develop, more parks and trails will be added (CVRD, 2011a). The long, sandy stretch of Mill Bay Beach is a scenic and popular spot for swimming.

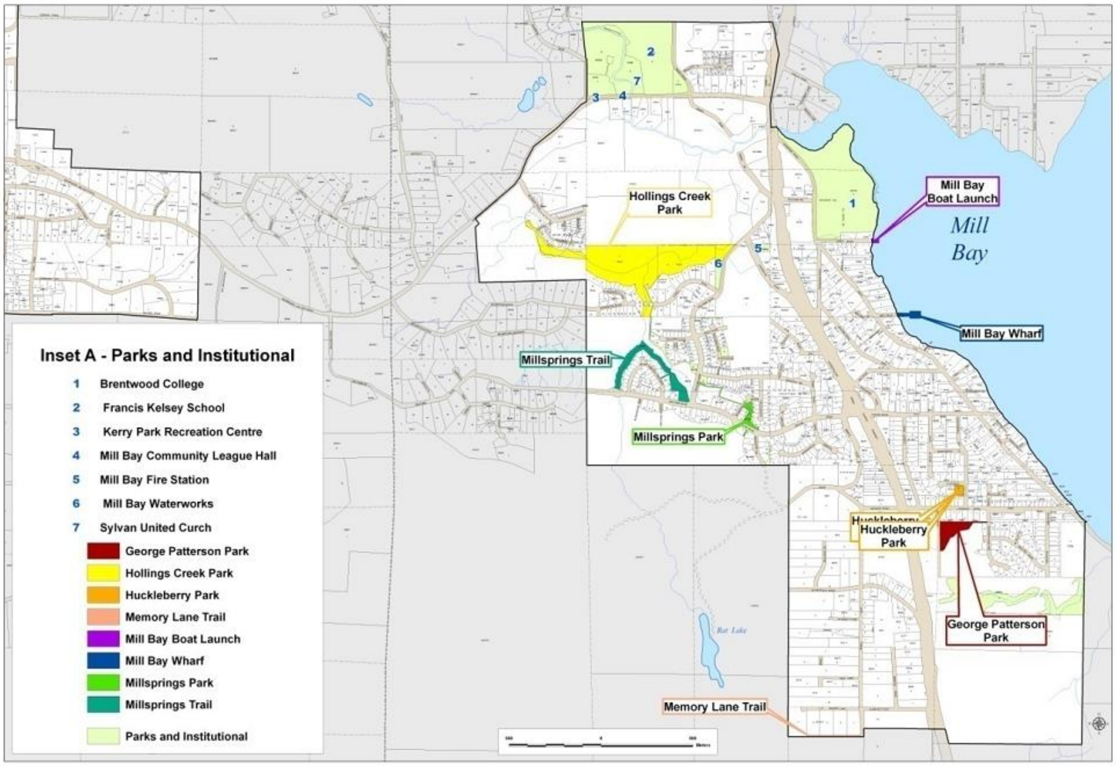


*Figure 10. Parks within the village of Mill Bay.*

Historical development patterns in Mill Bay have resulted in limited access to the waterfront, and the CVRD's most recent OCP provides policies that specify that "all applications for rezoning a parcel of land along the Mill Bay shoreline will be conditional on the provision of public access to the waterfront, to accommodate the construction of a public walkway along the shoreline" (CVRD, 2011a). The OCP also indicates that developments on the waterfront should follow the Mill Bay Village Development Permit Area guidelines to protect Saanich Inlet (CVRD, 2011a).

## 3.4 Flora and Fauna

The Shawnigan River Community watershed provides valuable habitat to a variety of animal species including blacktail deer (*Odocoileus hemionus columbianus*), black bear (*Ursus americanus*), cougar (*Puma concolor*), and numerous other small mammals and birds. The BC Conservation Data Centre reports the presence of six red- or blue-listed plant and animal species within the study area (Table 3; BC CDC, 2015).

*Table 3. Summary of red- and blue-listed plant and animal species in the Mill Bay study area (BC CDC, 2015).*

| Name Category/Class | Species Level | Scientific Name | English Name | BC List |
|---|---|---|---|---|
| Invertebrate Animal | Insect | *Euphyes vestris* | Dun Skipper | Red |
| Invertebrate Animal | Insect | *Coenonympha tullia insulana* | Common Ringlet, *insulana* subspecies | Red |
| Vascular Plant | Monocot | *Triteleia howellii* | Howell's *triteleia* | Red |
| Vascular Plant | Dicot | *Heterocodon rariflorum* | heterocodon | Blue |
| Vertebrate Animal | Amphibian | *Rana aurora* | Northern Red-legged Frog | Blue |
| Fungus | | *Leptogium polycarpum* | Peacock vinyl | Red |

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

- European Beachgrass and Japanese Knotweed 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 Hedgehog Dogtail in upland areas.

There were no studies found on the marine areas of Mill Bay, but similar to neighboring areas like Cowichan Bay, Mill Bay would provide valuable habitat for a variety of coast birds, mammals and estuarine/marine invertebrates (CENC, 2015).

## 3.5 Groundwater

Groundwater is a valuable drinking water resource in the Mill Bay study area and there are five aquifers that have boundaries that fall within the watershed (DataBC, 2015d; Table 4). 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.

*Table 4. Aquifers and their classifications within the Mill Bay study area (DataBC, 2015d).*

| Aquifer Number | Descriptive Location | Classification | Size ($km^2$) | Productivity | Vulnerability | Material | Use |
|---|---|---|---|---|---|---|---|
| 0204 | Cobble Hill / Mill Bay | IIB | 16.6 | Moderate | Moderate | Bedrock | Multiple |
| 0205 | Cobble Hill / Shawnigan Lake | IIC | 2.7 | Moderate | Low | Sand and Gravel | Multiple |
| 0206 | Mill Bay | IIA | 2.6 | Moderate | High | Sand and Gravel | Multiple |
| 0207 | Mill Bay / Shawnigan Lake | IIB | 25.1 | Moderate | Moderate | Bedrock | Multiple |

One of the aquifers within the Mill Bay study area, located near the village of Mill Bay (aquifer number 0206), has a classification of IIA, indicating low-moderate development and high vulnerability. Aquifers with this classification usually require particular care and attention regarding land use activities that could affect water quality (Bernardinucci and Ronneseth, 2002).

There are two aquifers that are classified IIB (low-moderate development, moderate aquifer vulnerability). These aquifers may be able to support additional withdrawals; however, until site specific studies are undertaken, aquifers with this classification require care and attention for development activities that could affect water quality of quantity (Bernardinucci and Ronneseth, 2002).

There are over 100 wells constructed in the Mill Bay study area (DataBC, 2015e). 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 hydrogeographical reporting requirements were developed to direct new development permits and zoning applications to protect this valuable resource.

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

Approximately 17% of the Electoral Area A (Mill Bay/Malahat) is located within the Agricultural Land Reserve (Figure 11; West Coast Law, 2015), and since 2007 there have been few exclusions (Doyle-Yamaguchi, pers. comm., 2014). In some cases, large areas within the ALR are not being farmed but, due primarily to soil capability ratings, they are suitable for future farm use. The maintenance of local food production is an important component of the CVRD Official Community Plan and is an important sector of the economy (CVRD, 2011b). It is recognized that small scale farm operations play an important role in society, providing country living for people, as well as greenhouse operations, market gardens, orchards and other labour-intensive farm activities (West Coast Law, 2015). To support agricultural activities, there are several water licences issued for freshwater streams for which the designated use is irrigation (see Section 3.1, Table 1).

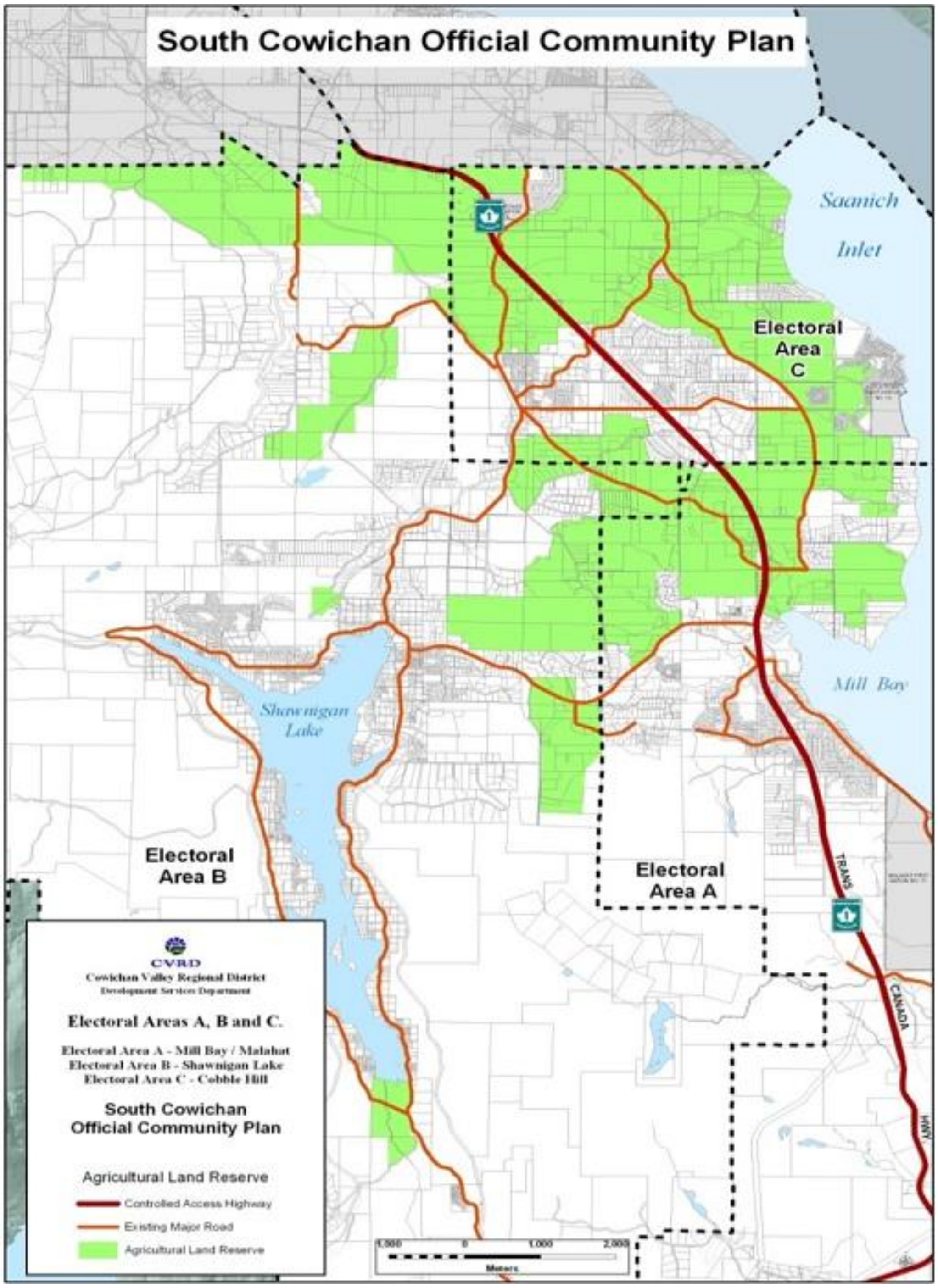


Figure 11. Areas within the Agricultural Land Reserve in Electoral areas A, B and C of the CVRD (West Coast Law, 2015)

## 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 Mill Bay marine areas are:

- aquatic life – shellfish harvesting
- 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 Shawnigan Creek and tributaries to Mill Bay (freshwater) are:

- drinking water
- recreation (secondary contact)
- aquatic life
- wildlife
- irrigation

The most sensitive uses of the freshwater streams are aquatic life or drinking water, 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 A (see **Error! Reference source not found.** and Figure 11) which supports a population of 4733 (based on the 2016 census), a 7.8% increase over the 2011 population, and an 81% increase relative to the 1986 population (CVRD, 2016). Lands within CVRD Electoral Area A are within the traditional territory of several Coast Salish Nations, including the Cowichan, Tsawout, Malahat, Pauquachin and Tsartlip Nations. The Malahat, Pauquachin and Cowichan First Nations have members residing within and adjoining the local plan area, and the Malahat Nation occupies a reserve south of Mill Bay (CVRD, 2021).

A summary of land use statistics for the Mill Bay study area is provided in Table 5. Private forestry is the dominant land use in the watershed with residential development and agriculture comprising most of the remaining land base. Figure 12 shows the locations of the major land use categories in Electoral Areas A and B (the Mill Bay study area boundary is within Electoral Area A but is not equivalent; see Figure 2). Over two thirds of the land within the Mill 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 Mill Bay study area. Notably, there is a proportionally minor amount of land in Electoral Area A that is protected as, or zoned for, park use.

*Table 5. Land use statistics for the Mill Bay study area (electoral area A) based on CVRD zoning (source: CVRD; statistics are approximate).*

| AREA A | |
|---|---|
| **Land Use** | **% of Total Area** |
| | |
| AGRICULTURAL | 14% |
| COMMERCIAL | 1% |
| CROWN FORESTRY | 0% |
| FIRST NATIONS | 5% |
| INDUSTRIAL | 3% |
| MIXED USE | 2% |
| PARKS AND INSTITUTIONAL | 4% |
| PRIVATE FORESTRY | 48% |
| RESIDENTIAL | 22% |
| Total | 100% |

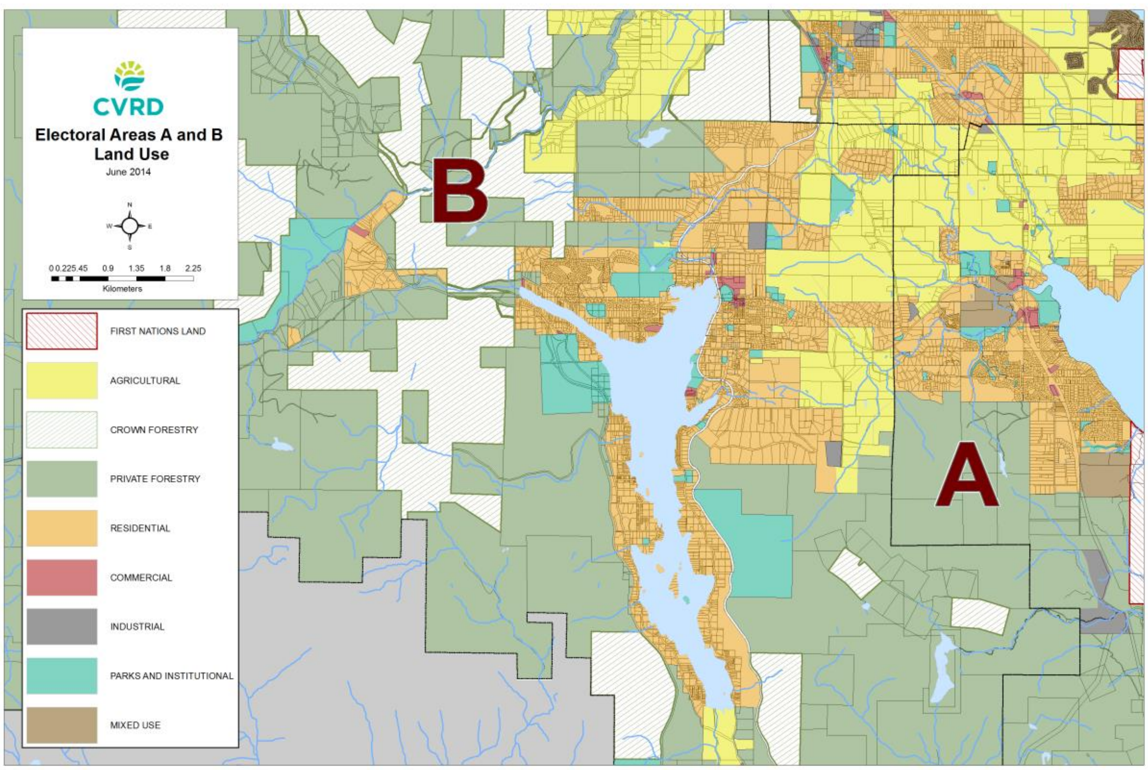


*Figure 12. CVRD land use for Electoral Areas A and B.*

## 4.1 *Environmental Management Act* Authorized Effluent Discharges

There are 20 active authorized discharges within the Mill Bay study area. The CVRD has four authorized discharge permits under the municipal wastewater regulation, and three other organization have permits under this regulation. There are 12 other authorized discharges with the authorization type identified as 'Permit' and one instance of 'Code of Practice for Concrete and Concrete Products'.

Only small pockets within Mill Bay currently have community sewer services (CVRD, 2011a). There are approximately 1,085 septic tanks in the Mill Bay area, most of which are old and aging (AECOM, 2010). Septic systems are a dominant means of disposing of domestic effluent in the Mill 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 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).

The policies in the CVRD Official Community Plan (CVRD, 2011a) support the future provision of community sewer services in Mill Bay Village, both to allow growth and to prevent the possibility of future impacts on the Saanich Inlet. The CVRD south sector Liquid Waste Management Plan (LWMP), which includes Electoral Area A (Mill Bay-Malahat), identified that environmental problems attributable to sewage effluent have been identified on the foreshore of Mill Bay (CVRD, 1998). The goal of the LWMP is to ensure that wastewater in the South Sector is collected, treated and disposed of in an environmentally acceptable manner (CVRD, 1998).

The many vessels that dock in the Mill Bay marine waters are another potential source of human bacterial contamination. Vessels 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 Mill Bay Marina has a sani-dump station for vessels.

## 4.2 Licensed Water Withdrawals

Water is withdrawn from surface water and groundwater sources in the Mill Bay study area to support many uses, including conservation, industrial, residential, commercial, and institutional use, crop irrigation, land improvement, stock watering, 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, watershed management and land use in the Mill Bay Study area (Urban Systems Ltd., 2014), as well as community land use plans. The present water governance structure in British Columbia results in limitations to local governments' (i.e., CVRD) abilities to implement and enforce water use policies within their jurisdictions (Infrastructure & Environment, 2009).

Infrastructure & Environment (2009) prepared a report for the CVRD on the preliminary assessment of water supply and needs with the South Cowichan Region. In addition, 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 South Cowichan Region is comprised of three watersheds: Shawnigan, Cowichan, and Saanich Inlet. The Mill Bay study area lies within the Saanich Inlet watershed, as defined by the Infrastructure & Environment (2009) study. The Infrastructure & Environment (2009) report presented data on quantity of groundwater wells and quantity of surface water licensed for withdrawal each year. The report concluded that: more detailed withdrawal data are necessary to determine water use demand, as existing data did not provide a clear picture of the total volume of water withdrawn and; that low flow issues in many creeks (including Lower Shawnigan Creek) may be associated with excessive surface water diversion, decreased groundwater base flow, and climate variability, and that the summer low flow situations are detrimental to aquatic system health (Infrastructure & Environment, 2009).

The low flows in Lower Shawnigan Creek are due in part to insufficient storage in Shawnigan Lake to support both domestic use and downstream needs in summer. The CVRD manages and co-owns (with Mill Bay Waterworks District and Shawnigan Village Waterworks) a weir at the outlet of Shawnigan Lake. The weir was originally constructed in 1964 and was replaced in 2007 by the CVRD to provide better fish passage between the lake and the creek. The weir is located approximately 450 metres downstream of Shawnigan Lake, on Shawnigan Creek, and was constructed to store 1.2 million cubic metres of spring runoff in the lake (Infrastructure & Environment, 2009). Water is withdrawn from Shawnigan Lake as drinking water; therefore, there is a need to ensure sufficient storage in Shawnigan Lake to maintain the water supply for the community of Shawnigan Lake. This results in low flow conditions in Lower Shawnigan Creek. For waterways modified by flow control structures, the BC ENV endorses a 20% Mean Annual Discharge (MAD) to protect healthy fish habitat. In Shawnigan Creek, the flow is 1% of the MAD (0.014 m3/s) between March and October, which is insufficient flow to sustain ecological function (Infrastructure & Environment, 2009).

As the population increases in the study area, the residential demand for water will subsequently increase. The Infrastructure and Environment (2009) and van der Gulik *et al.* (2013) studies reports suggest that uncontrolled water use for farming, cattle rearing, wineries, and new land development projects will place increasing pressure on existing water resources. Agricultural activities account for a substantial proportion of water uses in the South Cowichan area (15 million $m^3$ for agricultural use, compared to 7 million $m^3$ for residential and 3 million $m^3$ for “other” urban uses; Infrastructure & Environment, 2009). These circumstances highlight the need for water 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.

## 4.3 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.

Including lands managed by private forest companies, approximately 48% of the CVRD Electoral Area A (Mill Bay-Malahat) is currently zoned under forestry management (Table 5). However, only a small portion of these forestry lands (in the northwest portion of the study area just north of Shawnigan Lake, and in the upper reaches of Handysen Creek, in the southwest portion of the study area) are inside the study area for this report.

## 4.4 Recreation

The Mill Bay study area experiences high levels of recreational activity, primarily during the summer months. Activities include swimming, sun-bathing, boating, fishing, diving, and various other water-based activities, as well as hiking, cycling, and horseback riding. 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 Mill 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.

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

## 4.6 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 levels. There is one prospect in the eastern lower watershed (Hollings Creek watershed) that contains iron, magnetite, copper, gold and silver (Willoron) as well as one showing of magnetite and copper in the same watershed, one past producer of limestone (Bonner's Quarry), and one showing of limestone in the lower Shawnigan Creek Watershed (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.

## 4.7 Highways and Transportation

Highways and transportation corridors can influence water quality through run-off of pollutants such as oil and gasoline and alter flow patterns. The Mill 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 a waterway, 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 Mill 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, Malahat First Nation and community members 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.

Studies have been conducted in the freshwater and marine waters of the study area since 1995 that focused on coliform contamination (Drinnan *et al.,* 1995; AECOM, 2010). These data, along with ongoing data collection by the CVRD and Environment Canada, are not summarized in this report but information within them was considered in the recommendation of objectives for the Mill Bay study area.

## 5.1 Sampling Sites and Schedule

Existing CVRD and Environment and Climate Change Canada (ECCC) sample sites were used in this study to maximize comparability with historical data. Figure 3 shows the sampling locations and Table 6 lists location details of water quality monitoring sampling sites within the Mill Bay study area (2012-2013). The water quality monitoring sites include freshwater sites on Lower Shawnigan Creek (including at the Shawnigan Lake outflow), other tributaries to Mill Bay, and marine sites in Mill Bay.

Based on current knowledge of potential anthropogenic impacts to the watershed (generally associated with agriculture and human land-use), water quality parameters were measured in water samples collected from the freshwater tributaries to Mill Bay and marine sites in Mill Bay, during 2012 (CVRD sampling) and 2013 (BC ENV sampling) sampling. Sampling was conducted during the summer low flow (July-August) and fall flush (October-November) periods. Five weekly samples were collected over 30 days (5-in-30 sampling), during one or both periods (where possible during low flow periods). Parameters measured and frequency of sampling were as follows:

- Fall and summer period sampling was conducted for some freshwater sites in Shawnigan Creek and the tributaries to Mill Bay in 2012 and 2013 and analyzed for:
    - Total metals and hardness
        - seven sites in 2013 - three in Shawnigan Creek (summer sampling at only two of these sites) and four in Mill Bay tributaries (summer sampling at only one site)
    - Temperature and dissolved oxygen (DO)
        - eight sites in Shawnigan Creek in 2012 and six sites in 2013
        - one of the Mill Bay tributaries (‘Malahat Creek at Mill Bay Rd’) in 2012 and 2013
    - Total suspended solids (TSS)
        - four sites in Shawnigan Creek and at the ‘Malahat Creek at Mill Bay Rd’ Mill Bay tributary site in 2012
    - Turbidity
        - five sites in the fall of 2012 - four sites in Shawnigan Creek and one Mill Bay tributary (‘Malahat Creek at Mill Bay Rd’)
        - summer and fall of 2013 at seven sites in Shawnigan Creek (all sites except the ‘Unnamed Creek at Kilmalu Rd’) and four sites in Mill Bay tributaries (summer only at ‘Malahat Creek at Mill Bay Rd’)

- pH
  - four sites in the summer of 2012
- Specific Conductance
  - six sites in Shawnigan Creek in 2012 (one sample only) and 2013 (four samples summer 2013; three samples fall 2013)
- Nutrients (total phosphorus (P), ammonia ($NH_3$), dissolved nitrate ($NO_3$), dissolved nitrite ($NO_2$), dissolved sulphate ($SO_4$))
  - four sites in Shawnigan Creek in 2012 (only three sites sampled in summer), six sites in 2013 (only one sites sampled in fall)
  - one Mill Bay tributary site ('Malahat Creek at Mill Bay Rd') in both 2012 (summer and fall sampling) and 2013 (summer sampling only).

- *Escherichia coli* was measured in the freshwater sites during summer and fall of 2012 and 2013.
  - four sites in 2012 and seven sites in 2013 in Shawnigan Creek, one site in 2012 and four sites in 2013 in Mill Bay tributaries.
- Enterococci and fecal coliforms were measured at the 14 Mill Bay marine sites in the fall of 2013.

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 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 and microbiological analyses were conducted by Maxxam Analytics Inc. in Burnaby, BC. 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.

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. 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.

*Table 6. List of water quality monitoring sites, including station descriptions, EMS ID Number, and Latitude/Longitude.*

| Site Description | EMS ID | Latitude | Longitude |
|---|---|---|---|
| ***Lower Shawnigan Creek*** | | | |
| Shawnigan Creek upstream PE12302 | E236520 | 48.660712 | -123.572234 |
| Unnamed Trib to Shawnigan Creek near Sylvester Rd | E294420 | 48.633369 | -123.595102 |
| Shawnigan Creek at Mill Bay (CVRD Site 2) | E294421 | 48.655136 | -123.563591 |
| Unnamed creek at Kilmalu Rd | E294422 | 48.664503 | -123.556137 |
| Shawnigan Creek at Briarwood Park | E294423 | 48.645899 | -123.585297 |
| Handysen Creek at Frayne Rd | E294427 | 48.64281 | -123.572072 |
| Little Shawnigan Lake | N/A | 48.669355 | -123.597534 |
| ***Mill Bay*** | | | |
| Mill Bay Environment Canada site SA092 | E295322 | 48.656218 | -123.548589 |
| Mill Bay Environment Canada site SA090 | E295323 | 48.658611 | -123.55303 |
| Mill Bay Environment Canada site SA100 Shawnigan Creek outlet | E295325 | 48.656578 | -123.554954 |
| Mill Bay Environment Canada site SA086 Brentwood Rd | E295326 | 48.653924 | -123.552251 |
| Mill Bay Environment Canada site SA083 Oyster Rd | E295327 | 48.644888 | -123.544797 |
| Mill Bay Environment Canada site PA2 Mill Bay marina | E295328 | 48.650109 | -123.549818 |
| Mill Bay Environment Canada site SA081 Bakerview | E295329 | 48.641477 | -123.540785 |
| Mill Bay Environment Canada site SA078 | E295330 | 48.635613 | -123.53479 |
| Mill Bay Environment Canada site SA077 | E295331 | 48.634253 | -123.531558 |
| Mill Bay Environment Canada site SA075 | E295332 | 48.632232 | -123.529184 |
| Mill Bay Environment Canada site SA072 | E295333 | 48.623869 | -123.524468 |
| Mill Bay Environment Canada site SA109 | E295334 | 48.619503 | -123.522218 |
| Mill Bay Environment Canada site SA071/SA104 at Mill Bay ferry | E295335 | 48.615859 | -123.51837 |
| Mill Bay Environment Canada site PZ2 Brentwood College outfall | E295336 | 48.652681 | -123.548515 |
| ***Shawnigan Lake outflow*** | | | |
| Shawnigan Creek outflow (Mason's Beach, lakeside, at Renfrew Rd) | 1199912 | 48.657384 | -123.628017 |
| ***Tributary to Mill Bay*** | | | |
| Malahat Ck at Mill Bay Rd | E294428 | 48.615599 | -123.52068 |
| Unnamed Ck near Keir Rd (CVRD SW018) | E295317 | 48.647033 | -123.551819 |
| Stormdrain near Handy Rd (SW016) | E295318 | 48.650676 | -123.553787 |
| Stormdrain outlet to beach near Frayne Rd | E295320 | 48.642222 | -123.543333 |

## 5.2 Data Interpretation

Data from different sources (BC ENV, CVRD) was compiled in a Microsoft Access database. Each station and sample in the database was associated with an area (i.e., Shawnigan Creek, tributary to Mill Bay, or Mill Bay marine) and the sampling season (i.e., fall or summer), to expedite summarizing and analyzing the results. Statistical analysis was conducted using Microsoft Excel (version Office 2007).

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. Conventional parameters measured in duplicate in freshwater samples (pH, TSS, total hardness and turbidity) were generally within the 25% acceptability limit, except for turbidity (five of the eight samples with duplicate analyses exceeded the limit). The same pattern was observed for nutrients measured in duplicate at freshwater sites (only one exceedance of the acceptability limit was observed, for ammonia at the Little Shawnigan Lake site). Biological parameters (*E. coli*, enterococci and fecal coliforms) were measured in duplicate for 24 samples, with 11 exceedances of the acceptability limit of 25% observed for *E. coli*. However, this is not a concern as this parameter is not naturally homogeneously distributed throughout the water column. Variability noted in all duplicate and triplicate samples is 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 in the Mill Bay study area (Shawnigan Creek and other freshwater tributaries into Mill Bay, and the marine waters of Mill Bay). 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 Mill Bay (Table 7) and should continue to be in the future. For this reason, no objectives are recommended for the Mill 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 Mill 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<br>(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

Temperature is important to the quality of drinking water supplies for both health and aesthetic reasons. As water temperature increases, so does the potential for biological growth. Increased biological growth will increase the amount of chlorine required to effectively disinfect the water. In addition, decaying organics in the water can cause taste and odor problems for the consumer. Water temperature is also a critical factor for aquatic life. Fish and invertebrate's body temperatures are, to a large extent, controlled by their environment. Water temperature directly affects activity and physiological processes of fish and aquatic invertebrates at all life stages. The capacity for water to carry dissolved oxygen, which is critical to most aquatic life, is inversely related to temperature. Temperature can also affect the toxicity of other parameters (such as ammonia) and increase the solubility of chemical compounds.

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 is based on species and specific life history stages such as incubation, rearing, migration and spawning.

Steelhead, rainbow trout, cutthroat trout, coho and chum salmon are present in Shawnigan Creek (HabitatWizard, 2015). Of the species present in the Mill 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. For steelhead, the optimum temperature ranges are: 10 – 12°C for incubation; 16 – 18°C for rearing; and 10 – 15.5°C for spawning (Oliver and Fidler, 2001). Steelhead and coho have similar temperature thresholds and maturation of the embryos is temperature-dependent, but coho typically emerge by mid-May and steelhead typically emerge by late June. 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 of trout and juvenile salmonids, particularly coho (Obee and Epps, 2011).

In the tributaries to Mill 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. Minimal existing data in Shawnigan Creek varied seasonally, with maximum temperatures occurring in July and August (Table 8). In July through September of 2012 and 2013, field-measured water temperatures in Shawnigan Creek ranged from 9.3°C to 21.3°C, and from 11.0°C to 14.2°C at the site on Malahat Creek (a tributary to Mill Bay). As expected, water temperatures were lower in the cooler winter months, ranging from 4°C to 11.1°C. Water temperatures were highest at the outlet of Shawnigan Lake, and were lower downstream (likely due to cooler groundwater infiltration and canopy cover).

*Table 8. Summary of summer water temperature (°C) in Shawnigan Creek and Malahat Creek in summer 2012 and 2013.*

| Station | Summer 2012 | | | | Summer 2013 | | | |
|---|---|---|---|---|---|---|---|---|
| | # samples | Min | Max | Avg | # samples | Min | Max | Avg |
| ***Shawnigan Creek*** | | | | | | | | |
| Shawnigan Creek, outflow | 1 | 20.9 | 20.9 | 20.9 | 4 | 18.8 | 21.3 | 20.1 |
| Little Shawnigan Lake (CVRD site) | 5 | 13.4 | 16.5 | 15.4 | -- | -- | -- | -- |
| Shawnigan Creek upstream PE12302 | 1 | 16.2 | 16.2 | 16.2 | 4 | 14.8 | 16.4 | 15.5 |
| Shawnigan Creek at Mill Bay (CVRD Site 2) | 6 | 10.9 | 15.4 | 13.5 | 4 | 14.7 | 16 | 15.2 |
| Shawnigan Creek at Briarwood Park | 6 | 9.3 | 15.2 | 12.5 | 4 | 13.9 | 15.3 | 14.4 |
| Handysen Creek at Frayne Rd | 1 | 11 | 11 | 11.0 | 4 | 10.5 | 11 | 10.8 |
| Unnamed Trib to Shawnigan Creek near Sylvester Rd | 1 | 14.6 | 14.6 | 14.6 | 4 | 13.9 | 14.7 | 14.2 |
| ***Tributary to Mill Bay*** | | | | | | | | |
| Malahat Creek at Mill Bay Rd | 6 | 10.95 | 14.2 | 12.3 | 4 | 13 | 14 | 13.5 |

In Shawnigan Creek, limited existing water temperature results remained consistently below the aquatic life guidelines for the incubation and spawning period for salmonids. However, maximum summer water temperatures exceed the guideline for both coho (16°C) and steelhead (18°C) rearing at the Shawnigan Creek outflow site (EMS ID 1199912) during 2012 and 2013 sampling. The maximum summer water temperatures exceeded the guideline for coho rearing (16°C) at the Little Shawnigan Lake site, the 'Shawnigan Creek upstream PE12302' site (EMS ID E236520) and the 'Shawnigan Creek at Mill Bay' site (E294421).

Many watersheds on the west coast of Vancouver Island have elevated summer water temperatures. The removal of riparian vegetation for forestry or development decreases canopy cover and increases exposure of the creek to sunlight, resulting in warmer temperatures. Therefore, efforts should be made to protect riparian areas to retain vegetative cover over streams and keep stream temperatures from increasing where land clearing from development occurs.

While maximum temperatures may exceed the guideline in some portions of Shawnigan creek, if refuges remain with average temperatures below the guideline, juvenile fish should be protected during periods of elevated temperatures. To protect trout and juvenile salmonids in Shawnigan Creek and any other fish-bearing tributary to Mill Bay, future data from the Mill Bay tributaries should continue to be assessed relative to the objectives developed for the Cowichan and Koksilah Rivers. 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 forestry, stormwater and agricultural runoff, aging septic systems and land development, which are prevalent in the Mill Bay watershed, may also play a role by increasing the nutrient load, and thus productivity, in the lake and the streams, therefore increasing the risk of low DO concentrations. 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 measured at eight sites on Shawnigan Creek in 2012 and six sites in 2013, as well as in both years at one of the tributaries to Mill Bay (Malahat Creek; E294428). The average BC water quality guideline was not met at the Shawnigan Creek outflow site (1199912) in 2013, and both the minimum and average guideline were not met in Little Shawnigan Lake (Table 9). In Shawnigan Creek sites, dissolved oxygen concentrations ranged from 4.28 mg/L to 10.89 mg/L during the summer months, and from 5.09 mg/L to 13.25 mg/L during the fall months. In the one site sampled in the tributaries to Mill Bay (Malahat Creek), dissolved oxygen concentrations were generally higher, ranging from 9.97 mg/L to 10.73 mg/L during the summer months, and from 10.76 mg/L to 11.72 mg/L during the fall months. The water quality objective for the Cowichan and Koksilah rivers was not met at two Shawnigan Creek sites in summer, and was not met at five Shawnigan Creek sites and one Mill Bay tributary site in fall.

*Table 9. Summary statistics for DO results collected by the CVRD in Shawnigan Creek and Malahat Creek.*

| Station | Sample Year | Summer | | | | | Fall | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Count | Min | Max | Avg | StDev | Count | Min | Max | Avg | StDev |
| ***Shawnigan Ck*** | | | | | | | | | | | |
| Shawnigan Ck, outflow | 2012 | 1 | 6.8 | 6.8 | 6.8 | -- | -- | -- | -- | -- | -- |
| Little Shawnigan Lake (CVRD site) | 2012 | 4 | 4.3 | 4.9 | 4.6 | 0.3 | 5 | 5.1 | 8.4 | 6.8 | 1.6 |
| Shawnigan Ck upstream PE12302 | 2012 | 1 | 9.5 | 9.5 | 9.5 | -- | -- | -- | -- | -- | -- |
| Unnamed Ck at Kilmalu Rd | 2012 | -- | -- | -- | -- | -- | 5 | 10.3 | 11.2 | 10.6 | 0.4 |
| Shawnigan Ck at Mill Bay (CVRD Site 2) | 2012 | 5 | 9.2 | 9.9 | 9.5 | 0.4 | 5 | 10.2 | 11.3 | 10.7 | 0.5 |
| Shawnigan Ck at Briarwood Park | 2012 | 5 | 9.5 | 10.4 | 9.8 | 0.4 | 5 | 10.3 | 11.2 | 10.7 | 0.4 |
| Handysen Ck at Frayne Rd | 2012 | 1 | 10.6 | 10.6 | 10.6 | -- | -- | -- | -- | -- | -- |
| Unnamed trib to Shawnigan Ck near Sylvester Rd | 2012 | 1 | 8.5 | 8.5 | 8.5 | -- | -- | -- | -- | -- | -- |
| Shawnigan Ck, outflow | 2013 | 4 | 5.0 | 6.6 | 5.9 | 0.7 | 5 | 8.7 | 10.1 | 9.6 | 0.6 |
| Shawnigan Ck upstream PE12302 | 2013 | 4 | 8.7 | 10.1 | 9.7 | 0.7 | 5 | 11.3 | 13.1 | 12.5 | 0.7 |
| Shawnigan Ck at Mill Bay (CVRD Site 2) | 2013 | 4 | 9.2 | 9.7 | 9.4 | 0.2 | 5 | 11.4 | 13.1 | 12.4 | 0.7 |
| Shawnigan Ck at Briarwood Park | 2013 | 4 | 8.8 | 10.4 | 9.7 | 0.7 | 5 | 11.4 | 13.3 | 12.4 | 0.8 |
| Handysen Ck at Frayne Rd | 2013 | 4 | 10.1 | 10.9 | 10.4 | 0.4 | 5 | 11.4 | 12.7 | 12.1 | 0.6 |
| Unnamed trib to Shawnigan Ck near Sylvester Rd | 2013 | 4 | 8.5 | 9.1 | 8.8 | 0.3 | 5 | 11.3 | 12.7 | 12.1 | 0.6 |
| ***Tributary to Mill Bay*** | | | | | | | | | | | |
| Malahat Ck at Mill Bay Rd | 2012 | 5 | 10.1 | 10.7 | 10.4 | 0.3 | 5 | 10.8 | 11.7 | 11.2 | 0.4 |
| Malahat Ck at Mill Bay Rd | 2013 | 4 | 10.0 | 10.4 | 10.3 | 0.2 | -- | -- | -- | -- | -- |

As there is potential for freshwater streams in the Mill Bay study area to experience very low flows, and since there are limited data for DO levels in the freshwater tributaries to Mil Bay, it is recommended to measure DO in future monitoring programs. Given the smaller size of Shawnigan Creek and Mill Bay 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 pH

pH measures the concentration of hydrogen ions ($H^+$) in water. The concentration of hydrogen ions in water can range over 14 orders of magnitude, so pH is defined on a logarithmic scale between 0 and 14. A pH between 0 and less than 7 is acidic (the lower the number, the more acidic the water) and a pH between 7 and 14 is alkaline (the higher the number, the more basic the water). The aesthetic objective for drinking water is a pH between 6.5 and 8.5 (McKean and Nagpal, 1991). Corrosion of metal plumbing may occur at both low and high pH outside of this range, while scaling or encrustation of metal pipes may occur at high pH. The effectiveness of chlorine as a disinfectant is also reduced outside of this range. The aquatic life guideline allows a pH range between 6.5 and 9.0 pH units. Outside of this range, toxicity to aquatic organisms begins to occur (McKean and Nagpal, 1991).

In the summer of 2012, pH was measured at two sites on Shawnigan Creek (‘Shawnigan Creek at Mill Bay’ and ‘Shawnigan Creek at Briarwood Park’), in Little Shawnigan Lake and one site in the tributaries to Mill Bay (Malahat Creek). At these sites, pH ranged from 7.2 to 8.0 for the 20 samples collected. This suggests that pH is not presently a concern in the study area.

## 6.4 Conductivity

Conductivity refers to the ability of a substance to conduct an electric current. The conductivity of a water sample gives an indication of the concentration of dissolved ions in the water. The more ions dissolved in a solution, the greater the electrical conductivity. Thus, sea water has very high conductivity. Temperature affects the conductivity of water (a 1$^{o}$C increase in temperature results in approximately a 2% increase in conductivity), so conductivity is normalized to 25$^{o}$C (i.e., specific conductivity) to allow comparisons to be made. Coastal BC systems, with high annual rainfall values and typically short water retention times, generally have low specific conductivity (<80 microsiemens/centimeter (μS/cm)), while interior watersheds generally have higher values. Increased flows resulting from precipitation events or snowmelt tend to dilute the ions, resulting in decreased specific conductivity levels with increased flow levels. Therefore, water level and specific conductivity tend to be inversely related. However, in situations such as landslides, where high levels of dissolved and suspended solids are introduced to the water body, specific conductivity levels tend to increase. As such, significant changes in specific conductivity can be used as an indicator of potential impacts.

Field measurements of conductivity were obtained by the CVRD from six locations on Shawnigan Creek on eight different dates in 2012 and 2013. During the summer months, which included five sampling dates, specific conductivity ranged from 30.2 μS/cm to 151.9 μS/cm (Figure 13). During the fall months, which included three sampling dates, specific conductivity ranged from 39.3 μS/cm to 119.9 μS/cm. Conductivity was correlated with streamflow, with higher conductivity occurring during the summer months when ions were less diluted. Conductivity was somewhat higher than average for coastal streams (typically about 80 μS/cm), likely due to groundwater influences at times of low flow. However, conductivity was well within natural ranges and there is no indication that anthropogenic activities within the watershed are resulting in elevated conductivity. Continued collection of conductivity is recommended to help interpret results and to rule out tidal influence at any freshwater sites.

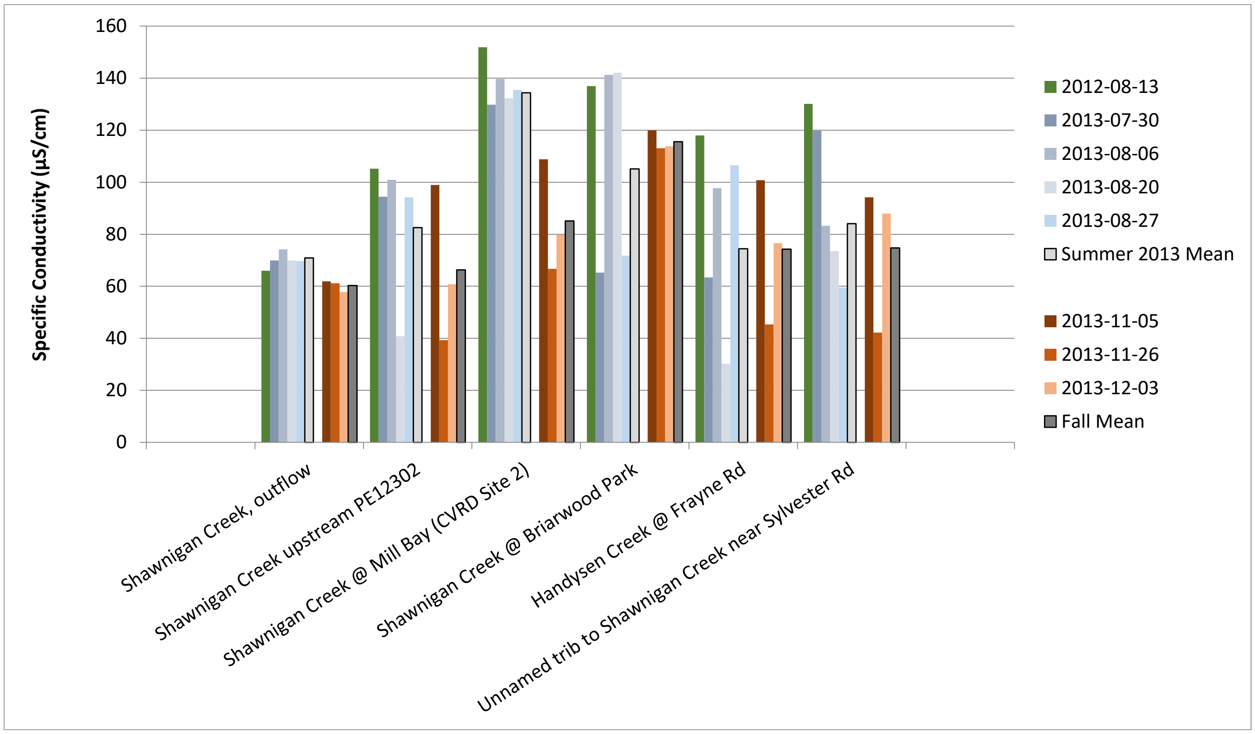


*Figure 13. Field measurements of specific conductivity (µS/cm) at locations in Shawnigan Creek (CVRD 2012-2013 sampling).*

## 6.5 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 water systems. 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).

There are many licenses for domestic water use (which includes drinking water) on Shawnigan Creek and the tributaries to Mill Bay (see Table 1). VIHA's goal for surface source drinking water quality for systems that do not receive filtration, such as domestic use licenses, is that they 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 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). As there are no unimpacted creeks within the study area to determine background or ambient conditions, the ecoregion approach is recommended (see Section 1.1). Under this approach, water quality objectives for the nearby Cowichan and Koksilah rivers were used to assess water quality in Shawnigan Creek and the Mill Bay tributaries. The water quality objective for the Cowichan and Koksilah Rivers are that from October to April (when turbid flows can occur) turbidity measured should not exceed a maximum of 5 NTU; during the remainder of the year (clear flow periods) turbidity should not exceed a maximum of 2 NTU (1 NTU above ambient levels, as measured in the Cowichan River from 1985 to 2008; Obee and Epps, 2011).

Turbidity was measured during the clear-flow period (defined as May through September, with all samples collected in July and August for this study) on five occasions at six sites in Shawnigan Creek and its tributaries, as well as in one tributary to Mill Bay (Malahat Creek) (Table 10). Turbidity was also measured during the turbid-flow period (defined as October through April, with all samples collected between October and December for this study) at eight sites on Shawnigan Creek and its tributaries, and four sites on tributaries to Mill Bay (Table 11). Turbidity was measured five times in a 30-day period in 2012 and/or 2013.

Turbidity in Shawnigan Creek exceeded the 2 NTU objective on one occasion at both the Shawnigan Creek outflow site and in Handysen Creek at Frayne Road (Table 10). The fall objective of 5 NTU was exceed at four sites on October 29$^{th}$, 2012 (Table 11). Rainfall over the preceding three days ranged from 10.8 mm to 21.6 mm (measured at the nearby Mill Bay study area site, Environment Canada Station 1017230), likely contributing to the elevated turbidity levels by washing sediment into the creeks. Four of the five samples collected in 2012 at the Unnamed Creek at Kilmalu Road site (E294422) exceeded the 5 NTU objective. In the fall of 2013, turbidity at this site was considerably lower, with turbidity exceeding the objective on only one of the five sampling dates.

*Table 10. Summary of turbidity (NTU) measured in Shawnigan Creek and its tributaries, and tributaries to Mill Bay during 2012 clear-flow period. Highlighted values exceed Cowichan and Koksilah Rivers clear flow objective of 2 NTU.*

| Station | Min | Max | Avg. | Std Dev. | No. of samples |
|---|---|---|---|---|---|
| Shawnigan Creek, outflow | 0.64 | 2.78 | 1.28 | 0.87 | 5 |
| Shawnigan Creek upstream PE12302 | 0.39 | 0.53 | 0.44 | 0.05 | 5 |
| Shawnigan Creek @ Mill Bay (CVRD Site 2) | 0.76 | 1.19 | 0.89 | 0.18 | 5 |
| Shawnigan Creek @ Briarwood Park | 0.23 | 0.35 | 0.27 | 0.05 | 5 |
| Handysen Creek @ Frayne Rd | 0.42 | 4.37 | 1.66 | 1.59 | 5 |
| Unnamed Trib to Shawnigan Creek near Sylvester Rd | 0.1 | 0.34 | 0.17 | 0.10 | 5 |
| Malahat Creek @ Mill Bay Rd | 0.52 | 1.63 | 1.03 | 0.48 | 5 |

Although not all the tributaries serve as sources of drinking water, turbidity is also an indicator of other potential issues as it is often correlated with elevated levels of microbiological contaminants, nutrients, and metals. To protect water quality entering Mill Bay, future data from the Mill 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.

*Table 11. Summary of turbidity (NTU) measured in Shawnigan Creek and its tributaries, and tributaries to Mill Bay during 2012 and 2013 turbid-flow period. Highlighted values exceed Cowichan and Koksilah Rivers turbid flow objective of 5 NTU.*

| Station | Min | Max | Avg. | Std Dev. | No. of samples |
|---|---|---|---|---|---|
| Shawnigan Creek, outflow | 0.39 | 0.52 | 0.44 | 0.05 | 5 |
| Little Shawnigan Lake (CVRD site) | 0.7 | 1.5 | 1.10 | 0.34 | 5 |
| Shawnigan Creek upstream PE12302 | 0.43 | 1.41 | 0.90 | 0.45 | 5 |
| Unnamed Creek @ Kilmalu Rd | 1.2 | 32 | 7.17 | 9.19 | 10 |
| Shawnigan Creek @ Mill Bay (CVRD Site 2) | 0.48 | 20 | 3.45 | 6.26 | 9 |
| Shawnigan Creek @ Briarwood Park | 0.25 | 6.2 | 1.22 | 1.80 | 10 |
| Handysen Creek @ Frayne Rd | 0.2 | 0.38 | 0.31 | 0.07 | 5 |
| Unnamed Trib to Shawnigan Creek near Sylvester Rd | 0.11 | 0.59 | 0.25 | 0.20 | 5 |
| Stormdrain near Handy Rd (SW016) | 0.52 | 3.73 | 1.74 | 1.31 | 5 |
| Unnamed Creek near Keir Rd (CVRD SW018) | 0.36 | 4.47 | 1.46 | 1.71 | 5 |
| Stormdrain outlet to beach near Frayne Rd | 0.11 | 0.25 | 0.17 | 0.06 | 5 |
| Malahat Creek @ Mill Bay Rd | 0.32 | 10 | 2.09 | 2.89 | 10 |

## 6.6 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).

As with turbidity, the BC guidelines for TSS evaluate results relative to background conditions. Since none of the sites sampled in the Mill Bay study area can be considered representative of background conditions, the ecoregion approach (see Section 1.1) was followed for the tributaries to Mill Bay, whereby WQOs for TSS for the Cowichan and Koksilah rivers were applied to monitoring data collected from the tributaries in the Mill Bay study area. 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).

Concentrations of TSS were measured by the CVRD in the summer and fall of 2012 at four sites on Shawnigan Creek and one site in the tributaries to Mill Bay (Malahat Creek). At all sites, five samples were collected in both the summer and fall periods, within a 30-day period. Concentrations of TSS at all sites ranged from below detection limits (<3 mg/L or <5 mg/L) to a maximum of 54 mg/L at the 'Unnamed creek at Kilmalu Rd' site (Table 12). The mean water quality objective established for the

Cowichan and Koksilah Rivers ($\leq$ 7 mg/L) was exceeded at three of the monitored locations in the fall. Elevated TSS concentrations were measured on the October 29th, 2012 sampling date at all five of the sampling sites, and rainfall over the preceding three days ranged from 10.8 mm to 21.6 mm (as measured at the nearby Mill Bay study area site, Environment Canada Site 1017230), likely contributing to the elevated TSS levels by washing sediment into the creeks.

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 Mill Bay tributaries.

*Table 12. Summary of TSS concentrations (mg/L) for water samples collected by the CVRD in Shawnigan Creek and tributaries to Mill Bay in 2012. All statistics based on five samples collected in a 30-day period.*

| | Summer | | | | Fall | | | |
|---|---|---|---|---|---|---|---|---|
| **Station** | **Min** | **Max** | **Avg** | **StDev** | **Min** | **Max** | **Avg** | **StDev** |
| ***Shawnigan Creek*** | | | | | | | | |
| Little Shawnigan Lake | <3 | <5 | <5 | | <5 | 8.0 | 6.0 | 1.4 |
| Unnamed Creek @ Kilmalu Rd | | | | | <5 | 54.0 | 19.2 | 20.4 |
| Shawnigan Creek @ Mill Bay | <3 | <5 | <5 | | <5 | 24.0 | 9.2 | 8.3 |
| Shawnigan Creek @ Briarwood Park | <3 | <5 | <5 | | <5 | 9.0 | 6.2 | 1.8 |
| ***Tributary to Mill Bay*** | | | | | | | | |
| Malahat Creek @ Mill Bay Rd | <3 | <5 | <5 | | <5 | 19.0 | 8.2 | 6.1 |

[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.

## 6.7 Nutrients (Nitrogen and Phosphorous)

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. Lakes are typically sampled during the spring and fall because this is when turnover, or vertical mixing of the water column, occurs. Generally, spring turnover is when the highest concentrations of phosphorous are found. Later in the season, phosphorous is bound in micro-organisms such as phytoplankton, and is therefore found in lower quantities in the water column. However, if lakes are undergoing internal nutrient loading (as can occur in eutrophic lakes) then the highest concentrations of phosphorous may be found in the fall. In watersheds where drinking water is a priority, it is desirable that nutrient levels 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 organisms die and begin 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). Conversely, a certain amount of nutrients in a lake system are needed to maintain productivity (i.e. 5 – 15 µg/L total phosphorous for aquatic life; Nordin, 2001).

### *6.7.1 Total Nitrogen*

The BC guideline for nitrate as nitrogen in drinking water is a maximum concentration of 10 mg/L and the guideline for nitrite is a maximum of 1 mg/L as nitrogen (Meays, 2009). When both nitrate and nitrite are present, their combined concentration must not exceed 10 mg/L as nitrogen. For the protection of freshwater aquatic life, the nitrate guidelines are a maximum concentration of 32.8 mg/L and a 30-day average concentration of 3 mg/L. Nitrite concentrations are dependent on chloride; in low chloride waters (i.e., less than 2 mg/L) the maximum concentration of nitrite is 0.06 mg/L and the average concentration is 0.02 mg/L. Allowable concentrations of nitrite increase with ambient concentrations of chloride (Meays, 2009).

Total nitrogen concentrations were not measured in any samples. Dissolved nitrate and dissolved nitrite concentrations were measured at four sites during the summer of 2012 by the CVRD (5-in-30 sampling). The sites sampled were: 'Shawnigan Creek at Mill Bay', 'Shawnigan Creek at Briarwood Park', 'Malahat Creek at Mill Bay Rd' and 'Little Shawnigan Lake'. Dissolved nitrate concentrations ranged from 0.013 mg/L to 0.279 mg/L and dissolved nitrite concentrations were consistently below detection limits (<0.01 mg/L) in all samples. As concentrations of nitrate and nitrite are consistently well below guideline levels, these parameters are not of concern in Shawnigan Creek or in the Mill Bay tributaries. However, because land uses occur that contribute to nutrient loading, there are high total phosphorus values observed (see next section), and to better understand nutrient dynamics in the Mill Bay study area, it would be prudent to assess nitrate levels in future monitoring of this area.

### *6.7.2 Total Phosphorus*

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 (5 µg/L) and a maximum of 0.010 mg/L (10 µg/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 phosphorus guidance, differing in that the maximum was 0.007 mg/L not 0.010 mg/L) (Obee and Epps, 2011).

Total phosphorous was measured in samples collected from eight sites on Shawnigan Creek and one site in the tributaries to Mill Bay (Malahat Creek) by the CVRD in 2012 and by BC ENV in 2013 (Table 13). Samples collected between May and September can be assessed using the guidance values, while those collected in later fall are not applicable because they are outside the growing season. The maximum guidance was exceeded at almost all the sampling locations during the summer monitoring, with maximum total phosphorus concentrations of 35 µg/L occurring in Shawnigan Creek at Mill Bay in both 2012 and 2013. Average concentrations were calculated from a dataset wtih a 5-in-30 frequency, not the required May-September monthly monitoring frequency, thus cannot be directly compared to the guidance values. However, if values from July and August (nine of the eleven instances in which averages were calculated were higher than the guidance of 5 µg/L) stayed at similar levels in the May-September months not sampled, it is likely the average May-September value would be also above the guidance of 5 µg/L. Concentrations of total phosphorus were higher in the fall, and were associated with elevated turbidity and TSS values that have likely anthropogenic sources.

*Table 13. Summary of total phosphorous concentrations (µg/L) for water samples collected in Shawnigan Creek and tributaries to Mill Bay (2012 and 2013). Highlighted values exceed the Vancouver Island Phosphorus Guidance value of a maximum of 10 µg/L (note average values were not collected at sufficient frequency to compare to guidance).*

| Site | Year | Summer (July - Sept) | | | | Fall (Oct – Dec) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Avg | StDev | Min | Max | Avg | StDev |
| ***Shawnigan Creek*** | | | | | | | | | |
| Little Shawnigan Lake | 2012 | 6.6 | 19.5 | 14.2 | 4.7 | 8 | 16 | 11.6 | 3.6 |
| Unnamed Creek @ Kilmalu Rd | 2012 | -- | -- | -- | -- | 4.2 | 152 | 57.9 | 55.7 |
| Shawnigan Creek @ Mill Bay | 2012 | 3.5 | 35 | 23.4 | 11.8 | 18.9 | 141 | 55.7 | 49.6 |
| Shawnigan Creek @ Briarwood Park | 2012 | 11 | 13.8 | 12.4 | 1.2 | 15.2 | 112 | 36.9 | 42.0 |
| Shawnigan Creek, outflow | 2013 | 6.5 | 14.3 | 9.2 | 3.6 | -- | -- | -- | -- |
| Shawnigan Creek upstream PE12302 | 2013 | 5.8 | 8.8 | 7.4 | 1.3 | 4.5 | 13.4 | 8.7 | 3.8 |
| Shawnigan Creek @ Mill Bay | 2013 | 3.8 | 35 | 24.8 | 12.7 | -- | -- | -- | -- |
| Shawnigan Creek @ Briarwood Park | 2013 | 1.0 | 11.8 | 5.0 | 5.2 | -- | -- | -- | -- |
| Handysen Creek @ Frayne Rd | 2013 | 11 | 19.6 | 14.2 | 3.2 | -- | -- | -- | -- |
| Unnamed Trib to Shawnigan Creek near Sylvester Rd | 2013 | 3.6 | 6.3 | 4.8 | 1.1 | -- | -- | -- | -- |
| ***Tributaries to Mill Bay*** | | | | | | | | | |
| Malahat Creek @ Mill Bay Rd | 2012 | 2.0 | 19.7 | 14.7 | 7.2 | 1.9 | 43.8 | 19.9 | 15.2 |
| Malahat Creek @ Mill Bay Rd | 2013 | 2.9 | 22.6 | 17.1 | 8.1 | -- | -- | -- | -- |

As maximum total phosphorus guidance values had the potential for exceedance (if levels observed during 5 in 30s were representative of the rest of the growing season) at almost all of the study sites, monitoring of total phosphorus should continue, including monthly May-September total phosphorus monitoring, with results compared to Vancouver Island Phosphorus Guidance values (BC ENV, 2014).

A research project has been conducted as part of a University of Victoria Master of Science degree thesis to compare nitrogen and phosphorous levels in the Sooke and Shawnigan Lake study areas (Rodgers, 2015). Although this project did not collect data from the Mill Bay study area, Shawnigan Lake is near the study area and therefore conclusions reached in the study may be relevant to the Mill Bay study area. The study analyzed data collected between 2004 and 2013 and one of the objectives of the study was to identify potential sources of excess nutrient loading. The study concluded that nitrogen exports from the second growth forests surrounding Shawnigan Lake may contribute to elevated nitrogen levels. In addition, anthropogenic factors (forest harvesting, residential clearing, fertilizer runoff, and failing septic systems) contribute to elevated nutrient levels in Shawnigan Lake, as compared to Sooke Lake (Rodgers, 2015).

### *6.7.3 Chlorophyll a*

In streams (as opposed to lakes), concentrations of chlorophyll *a* (rather than total phosphorous) are used as an approved provincial guideline, since several factors (including suitable water velocity, substrate, light, temperature, and grazing pressures) are necessary before phosphorous becomes a limiting factor in streams (Nordin, 2001). Chlorophyll *a* is the green pigment in algae and is indicative of algal productivity. The recreational guideline for chlorophyll *a* in streams is 50 $mg/m^2$, and the guideline for aquatic life is 100 $mg/m^2$ (Nordin, 2001).

Chlorophyll *a* was not measured in any of the sites sampled in Shawnigan Creek or the tributaries to Mill Bay. However, given the observed total phosphorus levels and known land use activities in the study area, it is recommended that chlorophyll *a* monitoring be conducted in future sampling of freshwater tributaries. The potential impact of algal biomass should be assessed relative to the BC Water Quality Guideline of a maximum concentration (biomass of periphtic algae) of 50 mg/m$^2$ for the protection of recreational values and aesthetics in streams (Nordin, 2001), which would also be protective of aquatic life.

## 6.8 Metals

In the freshwater tributaries to Mill Bay, total metals were measured in 2013 in both the summer and fall with 5-in-30 sampling at two sites on Shawnigan Creek ('Shawnigan Creek at Mill Bay' and 'Shawnigan Creek, outflow') and one site in a tributary to Mill Bay (Malahat Creek). An additional four sites were sampled during the fall only (5-in-30 sampling) and analyzed for total metals: 'Unnamed creek at Kilmalu Rd' on Shawnigan Creek and three sites in the tributaries to Mill Bay ('Stormdrain near Handy Rd', 'Stormdrain outlet to beach near Frayne Rd' and 'Unnamed creek near Keir Rd').

Water quality objectives for the Cowichan and Koksilah Rivers include objectives 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.

For other metals, total and dissolved metals concentrations from the various tributaries in the study area were compared with the maximum and 30-day average BC Water Quality Guidelines to identify exceedances. As the guideline for many metals depends on water hardness, the analysis utilized the lowest observed water hardness in historical sampling activities (23 mg/L, measured at the Shawnigan Creek outflow site on November 5, 2013). This lowest observed value represents the worst-case scenario and thus results in the most protective guideline values.

In many instances, concentrations of metals were below the laboratory detection limits. For those parameters where concentrations of metals were above the corresponding detection level, the values were generally below BC ENV's approved or working guidelines, or no guidelines were applicable. However, there were three sites at which the concentration of two or more metals exceeded the applicable guideline:

- At the 'Shawnigan Creek at Mill Bay' site (EMS ID E294421), maximum concentrations of total iron, manganese and arsenic exceeded guidelines in samples collected on November 26$^{th}$, 2013 (Appendix I). Hardness concentrations were also extremely high at this site on that day (547 mg/L, compared with the summer average of 61 mg/L at this site). The total iron concentration was 6780 µg/L (BC guideline is 1000 µg/L), the total manganese concentration was 1100 µg/L (BC guideline is 800 µg/L), and the total arsenic concentration was 7.32 µg/L (BC guideline is 5 µg/L). In each of these instances, the next-highest concentration of the metal was well below guideline levels (the next-highest iron concentration was 274 µg/L, the next highest manganese concentration was 3.71 µg/L and the next highest arsenic concentration was 0.18 µg/L). This sample site is above the first set of falls on Shawnigan Creek, thus is unlikely to be tidally influenced; however, the drainage area above the site is downslope of Shawnigan Lake road, which may contribute contaminants downstream. Turbidity was not elevated at this site on this sampling date, nor was their significant rainfall in the days prior, suggesting that the elevated metals concentrations were not associated with runoff from a storm event (a common cause of short-term increases in total metals concentrations).

- At the 'Unnamed creek at Kilmalu Rd' (EMS ID E294422), there were five different total metals that exceeded either the maximum or 30-day average guidelines or applicable Cowichan and Koksilah River Objectives: arsenic, copper, iron, manganese, and zinc (Appendix I). The exceedances of the maximums occurred in samples collected on a single sampling date (December 3rd, 2013); the same date that an unusually high measurement for total hardness (751 mg/L) occurred. As with the Shawnigan Creek at Mill Bay site (discussed above), the next-highest concentration of these metals measured on other dates during the monitoring program was five to 100 times lower than the maximum that occurred on this date, and well below guideline levels. Also similar to the Shawnigan at Mill Bay site, turbidity and precipitation data suggest that the elevated metals concentrations were not associated with runoff from a storm event. This sampling site is located downslope of a major highway intersection and an agricultural area which may present site-specific conditions that would result in elevated metals concentrations in runoff.
- At the 'Stormdrain near Handy Rd' site (EMS ID E295318), the maximum total copper guideline was slightly exceeded in one sample (4.48 µg/L measured on November 12, 2013, compared with the Cowichan and Koksilah Rivers maximum objective of 4 µg/L.

The reason for the elevated hardness and metals concentrations in isolated samples at two different sites in 2013 is unclear. However, to ensure that these were isolated incidents and do not reflect potential contamination, we recommended continued monitoring of metals and hardness in the tributaries to Mill Bay, with an emphasis on assessing arsenic, iron, manganese, copper and zinc levels, particularly on sites downstream of major roadways. It would be prudent to include chloride and or specific conductance analysis with every sample to confidently rule out marine influences at any sample locations.

## 6.9 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 Mill Bay study area.

The BC ENV water quality guidelines were used to assess water quality in Mill Bay and the tributaries to Mill Bay based on the designated water uses, i.e., Mill Bay: aquatic life and wildlife; shellfish harvesting; and recreation and aesthetics (primary and secondary contact); Shawnigan Creek and other freshwater tributaries to Mill Bay: aquatic life and wildlife; drinking water; irrigation; and recreation (secondary contact) (Table 14). 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. 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 90th 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.

*Table 14. 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 |

### *6.9.1 Freshwater – E. coli*

Samples collected from 12 sites in 2012 (CVRD sampling) and 2013 (BC ENV sampling) were analyzed for *E. coli,* including eight sites on Shawnigan Creek and four sites in the tributaries to Mill (Table 15). CVRD collected fall and summer 5-in-30 samples at five sites, except at the 'Unnamed creek at Kilmalu Rd' site (summer samples were not collected because the creek was dry). BC ENV collected fall and summer 5-in-30 samples at 11 sites, although four of these sites did not include summer sampling. The requisite sampling frequency (a minimum of five samples within a 30-day period) was met in all cases.

*E. coli* ranged from below detection limits (< 1 CFU/100 mL) to a maximum of 2,400 CFU/100 mL (in Shawnigan Creek at Mill Bay in the fall of 2012) (Table 15). The drinking water guideline (90$^{th}$ percentile of 10 CFU/100 mL) was exceeded in 25 of the 27 sets of five samples collected within a 30-day period. The recreational guideline (a geometric mean ≤200 CFU/100 mL) was exceeded in two of the 27 sets of samples (576 CFU/100 mL in Unnamed Creek at Kilmalu Road and 286 CFU/100 mL in Shawnigan Creek at Mill Bay). Exceedance of shellfish guidelines (90$^{th}$ percentile of 43 CFU/100 mL) occurred at 16 of 27 sets of samples; this information helps to assess potential impacts from freshwater contributions to marine shellfish areas.

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 Mill Bay. Exceedances of shellfish guidelines outlined above illustrate the potential for upland sources to contribute to fecal contamination in the marine environment.

The data indicate issues with microbiological contamination in the freshwater tributaries to Mill 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 occasional 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 domestic water licenses on the tributaries to Mill 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 Mill Bay tributaries, and that results should be compared to the *E. coli* objective existing for Cowichan and Koksilah Rivers of ≤ 10 CFU/100 mL.

### *6.9.2 Mill Bay marine areas - Fecal coliforms and Enterococci*

Samples collected from Mill Bay marine sites in the fall of 2013 were analyzed for enterococcus and fecal coliform concentrations. The requisite sampling frequency (a minimum of five samples within a 30-day period) was met in all cases, except the 'Environment Canada site PZ2 - Brentwood College outfall' (E295336), which had only four samples collected over a 30-day period.

Fecal coliform concentrations at the marine sites ranged from below detection limits (<1 CFU/100 mL) to a maximum of 140 CFU/100 mL (Table 16). Median concentrations ranged from 1 CFU/100 mL to 21 CFU/100 mL and the 90$^{th}$ percentile values ranged from 2 CFU/100 mL to 132 CFU/100 mL. Both shellfish harvesting guidelines (median≤14 CFU/100 ml) and 90$^{th}$ percentile ≤43 CFU/100 ml) were exceeded at the ECSA90 site, and the 90$^{th}$ percentile guideline was exceeded at the SA083 Oyster site (Table 16).

Enterococci concentrations ranged from below detection limits (< 1 CFU/100 mL) to a maximum of 170 CFU/100 mL (Table 17). Median concentrations ranged from 1 CFU/100 mL to 12 CFU/100 mL, and the shellfish harvesting guideline (median≤ 4 CFU/100 mL) was exceeded at four sites ((SA090, PZ2, SA083 and SA078). The 90$^{th}$ percentile concentrations of enterococci ranged from 2.8 CFU/100 mL to 116.8 CFU/100 mL, and the shellfish harvesting guideline (90$^{th}$ percentile ≤ 11 CFU/100 mL) was exceeded at six sites (SA090, SA092, SA083 SA077, SA075 and SA072). The recreation guideline (single sample ≤ 70 CFU/100 mL) was exceeded at two sites (SA090 and SA083). The geometric mean for enterococci ranged from 1.3 CFU/100mL to 20.77 CFU/100 mL (Table 17) and did not exceed recreational guidelines at any site.

*Table 15. Summary statistics for E. coli (CFU/100ml) in Shawnigan Creek and tributaries to Mill Bay in 2012 and 2013. Statistics are calculated based on five samples collected within a 30-day period. Grey highlighting indicates BC water quality guideline exceedances for drinking water and recreation.*

| EMS ID | Station description | Sample Year | Summer | | | | Fall | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Max | Geomean | 90th %ile | Min | Max | Geomean | 90th %ile |
| ***Shawnigan Creek*** | | | | | | | | | | |
| | Little Shawnigan Lake | 2012 | 12.5 | 31 | 20 | 28 | 68 | 330 | 153 | 282 |
| 1199912 | Shawnigan Creek, outflow | 2013 | 13 | 130 | 40 | 118 | <1 | 5 | 2 | 4 |
| E236520 | Shawnigan Creek upstream PE12302 | 2013 | 12 | 450 | 44 | 293 | 13 | 40 | 21 | 34 |
| E294422 | Unnamed creek @ Kilmalu Rd | 2012 | -- | -- | -- | -- | 170 | 1900 | 576 | 1580 |
| E294422 | Unnamed creek @ Kilmalu Rd | 2013 | -- | -- | -- | -- | 7 | 130 | 32 | 92 |
| E294421 | Shawnigan Creek @ Mill Bay | 2012 | 31 | 400 | 105 | 360 | 60 | 2400 | 286 | 1672 |
| E294421 | Shawnigan Creek @ Mill Bay | 2013 | 34 | 190 | 76 | 178 | 9 | 33 | 16 | 29 |
| E294423 | Shawnigan Creek @ Briarwood Park | 2012 | 12 | 52 | 29 | 49 | 85 | 1400 | 196 | 920 |
| E294423 | Shawnigan Creek @ Briarwood Park | 2013 | 6 | 180 | 42 | 164 | 1 | 82 | 9 | 57 |
| E294420 | Unnamed trib to Shawnigan Creek near Sylvester Rd | 2013 | 2 | 76 | 10 | 52 | <1 | 2 | 1 | 2 |
| E294427 | Handysen Creek @ Frayne Rd | 2013 | 4 | 25 | 11 | 22 | 1.5 | 17 | 3 | 11 |
| ***Tributary to Mill Bay*** | | | | | | | | | | |
| E295318 | Stormdrain near Handy Rd | 2013 | -- | -- | -- | -- | 1 | 200 | 13 | 158 |
| E295317 | Unnamed creek near Keir Rd | 2013 | -- | -- | -- | -- | 1 | 51 | 4 | 34 |
| E295320 | Stormdrain outlet to beach near Frayne Rd | 2013 | -- | -- | -- | -- | 9 | 33 | 19 | 29 |
| E294428 | Malahat Creek @ Mill Bay Rd | 2012 | 15 | 310 | 64 | 250 | 12 | 230 | 41 | 171 |
| E294428 | Malahat Creek @ Mill Bay Rd | 2013 | 3 | 30 | 12 | 28 | <1 | 21 | 2 | 14 |

*Table 16. Summary of fecal coliforms concentrations (CFU/100ml) in Mill Bay in 2013. Statistics are based on five samples collected within a 30-day period, except for Site E295336. Grey highlighting indicates BC water quality guideline exceedances for shellfish harvesting.*

| Station | Station description | No. of Samples | Min | Max | Median | 90th %ile | Geomean |
|---|---|---|---|---|---|---|---|
| E295322 | EC site SA092 | 5 | 1 | 52 | 4 | 38 | 6 |
| E295336 | EC site PZ2 Brentwood College outfall | 4 | <1 | 9 | 1 | 7 | 2 |
| E295323 | EC site SA090 | 5 | 9 | 140 | 21 | 132 | 32 |
| E295325 | EC site SA100 Shawnigan Creek outlet | 5 | 4 | 11 | 5 | 9 | 6 |
| E295326 | EC site SA086 Brentwood | 5 | <1 | 3.5 | 2 | 3 | 2 |
| E295327 | EC site SA083 Oyster | 5 | 1 | 120 | 5 | 76 | 7 |
| E295328 | EC site PA2 marina | 5 | 1 | 6 | 2 | 5 | 2 |
| E295329 | EC site SA081 Bakerview | 5 | <1 | 5 | 1 | 4 | 2 |
| E295330 | EC site SA078 | 5 | 3 | 6 | 4 | 6 | 4 |
| E295331 | EC site SA077 | 5 | 1 | 11 | 1 | 7 | 2 |
| E295332 | EC site SA075 | 5 | <1 | 47 | 1 | 30 | 3 |
| E295333 | EC site SA072 | 5 | <1 | 9 | 2 | 8 | 3 |
| E295334 | EC site SA109 | 5 | 1 | 2 | 2 | 2 | 2 |
| E295335 | EC site SA071/SA104 at ferry | 5 | <1 | 2 | 1 | 2 | 1 |

*Table 17. Summary statistics for enterococci (CFU/100ml) in Mill Bay in 2013. Statistics are calculated based on five samples collected within a 30-day period, except Site E295336 (where four samples were collected). Grey highlighting indicates BC water quality guideline exceedances for shellfish harvesting and recreation.*

| Station | Station description | No. of samples | Minimum | Maximum | Median | 90th %ile | Geomean |
|---|---|---|---|---|---|---|---|
| E295325 | EC site SA100 Shawnigan Creek outlet | 5 | <1 | 5 | 3 | 4.6 | 2.6 |
| E295323 | EC site SA090 | 5 | 5 | 150 | 11 | 110.8 | 20.8 |
| E295322 | EC site SA092 | 5 | 1 | 36 | 3 | 26.0 | 4.7 |
| E295326 | EC site SA086 Brentwood | 5 | <1 | 7 | 1 | 5.2 | 1.8 |
| E295336 | EC site PZ2 Brentwood College outfall | 4 | <1 | 8 | 4.5 | 8.0 | 2.8 |
| E295328 | EC site PA2 marina | 5 | <1 | 13 | 1 | 9.4 | 2.2 |
| E295327 | EC site SA083 Oyster | 5 | 1 | 170 | 12 | 116.8 | 11.8 |
| E295329 | EC site SA081 Bakerview | 5 | <1 | 8 | 1 | 7.2 | 2.2 |
| E295330 | EC site SA078 | 5 | 4 | 8 | 5 | 6.8 | 5.0 |
| E295331 | EC site SA077 | 5 | <1 | 36 | 1 | 22.4 | 2.4 |
| E295332 | EC site SA075 | 5 | <1 | 20 | 1 | 15.6 | 2.8 |
| E295333 | EC site SA072 | 5 | <1 | 18 | 2 | 12.0 | 2.6 |
| E295334 | EC site SA109 | 5 | <1 | 13 | 1 | 8.6 | 1.9 |
| E295335 | EC site SA071/SA104 at ferry | 5 | <1 | 4 | 1 | 2.8 | 1.3 |

While shellfish harvesting is closed in the inlet and surrounding area, it is a designated water use and traditional food source for local Indigenous people 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 6.9), 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 Mill Bay (shellfish harvesting guideline).***

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

In BC, water quality objectives are based on approved or working water quality guidelines (BC ENV, 2015). 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 Mill Bay study area include drinking water, recreation, aquatic life, wildlife and irrigation. Designated water uses for the marine areas of the Mill Bay study area include aquatic life (shellfish harvesting) and recreation. The water quality objectives recommended in this document (summarized in Table 18) apply only to the marine waters of Mill Bay. It is recommended that the Mill Bay freshwater tributaries and Shawnigan Creek 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), total phosphorus (compare to Vancouver Island Phosphorus Guidance) and some additional metals needing further investigation in the Mill Bay tributaries (summarized in Table 19).

Recommended objectives for Mill Bay consider background conditions, impacts from current land use, contributions from 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 18. Summary of recommended water quality objectives for the Mill Bay study area.*

| **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 |

All statistics are to be calculated based on five samples in 30 days.

The recommended water quality monitoring program for Mill Bay study area is summarized in Table 20. It is recommended that future attainment monitoring occur once every three to five 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.

Monitoring consisting of at least five 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 and maximum turbidity), 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. These samples should be analyzed for total and dissolved metals and hardness, nutrients, conventional parameters, and *E. coli*. 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 BC Water Quality Guidelines. The samples collected in the marine areas should be analyzed for microbiological parameters (enterococci and fecal coliforms).

*Table 19. Summary of parameters and associated BC water quality guidelines or Cowichan and Koksilah Rivers Water Quality Objectives for consideration in Mill 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 Arsenic | ≤5 µg/L max | Freshwater | BC WQG |
| Total Copper | ≤ 2 µg/L (mean) | Freshwater | Cowichan/Koksilah River Water Quality Objectives |
| | ≤ 4 µg/L (max) | | |
| Total Iron | ≤1000 µg/L max | Freshwater | BC WQG |
| Total Manganese | ≤800 µg/L max | Freshwater | BC WQG |
| | ≤700 µg/L average | | |
| Total Zinc | ≤ 7.5 µg/L (mean) | Freshwater | Cowichan/Koksilah River Water Quality Objectives |
| | ≤ 33 µg/L (max) | | |
| *Escherichia coli* | ≤ 10 CFU/100 mL (90th 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.

*Table 20. Proposed schedule for future water quality monitoring for the Mill Bay study area.*

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

It is recommended that some limited sediment sampling be included during future attainment monitoring sampling at key sites such as the ‘Unnamed creek at Kilmalu Rd’ site, Shawnigan Creek inflow and outflow sites, and key marine sites (e.g., ‘EC site SA090’ near the Mill Bay Nature Park, and ‘EC site PA2’ at the Mill Bay marina). Many toxic 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).

It is recommended that microbial source tracking (MST) sampling occur during future attainment monitoring, to identify sources of microbiological contaminants.

## REFERENCES

AECOM. 2010. State of environment report, surface water quality in the Mill Bay Area. Project Number: 2592-010-00 (AIMS #60113969). Victoria, BC.

Anderson, G. 2006. Vancouver Island Health Authority. Landuse – Water Consultant, North Vancouver Island Health Service Delivery Area.

Barlak, R. and Javorski, A. 2020. Shawnigan Lake: Water Quality Objectives Attainment (2015-2019). Environmental Protection Division. Ministry of Environment and Climate Change Strategy. Nanaimo, B.C. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/shawnigan_lake_wqo_attain.pdf

BC CDC (British Columbia Conservation Data Centre), CDC iMap theme [web application]. April 2015. Victoria, British Columbia, Canada. Available online at: https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/conservation-data-centre

BC Gov (British Columbia Government). 2001. Drinking Water Protection Act – Drinking Water Protection Regulation. 2005. Available online at: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/legislation

BC MFLNRO (BC Ministry of Forests, Lands and Natural Resource Operations). Water Licenses Query [web application]. April 2015. Victoria, British Columbia, Canada. Available online at: http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 1996. Sannich Inlet study synthesis report: Technical version. Ministry of Environment, Environmental Protection Branch. Victoria, BC. Summary report is available online at: https://www.for.gov.bc.ca/hfd/library/documents/bib79546.pdf

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 1997. Ambient water quality criteria for dissolved oxygen. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/dissolvedoxygen-tech.pdf

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2012. Drinking water treatment objectives (microbiological) for surface water supplies in British Columbia. Version 1.1. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/how-drinking-water-is-protected-in-bc/part_b_-_5_surface_water_treatment_objectives.pdf

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2013. Decision tree for responding to a turbidity event in unfiltered drinking water. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/how-drinking-water-is-protected-in-bc/1078529_dwog_part_b_-_9_turbidity_decision_tree.pdf

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2014. Phosphorous management in Vancouver Island streams. Environmental Protection Division. Ministry of Environment. Nanaimo, BC.

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2015. Working water quality guidelines for British Columbia. 2015. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/bc_env_working_water_quality_guidelines.pdf

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2019. B.C. Recreational Water Quality Guidelines: Guideline Summary. Water Quality Guideline Series, WQG-02. Prov. B.C., Victoria B.C

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2020. B.C. Source Drinking Water Quality Guidelines: Guideline Summary. Water Quality Guideline Series, WQG-01. Prov. B.C., Victoria B.C.

BC MOE (British Columbia Ministry of Environment). 2013. British Columbia field sampling manual for continuous monitoring and the collection of air, air-emission, water, wastewater, soil, sediment, and biological samples.

Available online at: https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/laboratory-standards-quality-assurance/bc-field-sampling-manual

BC Parks. 2015. Bamberton Provincial Park. Available online at: http://www.env.gov.bc.ca/bcparks/explore/parkpgs/bamberton/

Bernardinucci, J. and K. Ronneseth. 2002. Guide to using the BC aquifer classification maps for the protection and management of groundwater. Ministry of Water, Land and Air Protection.

Best, R. 2001. Shawnigan watershed – a fisheries perspective. Available online at: https://a100.gov.bc.ca/pub/acat/documents/r36840/Shawnigan_creek_USHP_report_1371597494948_e1228f3ddc1b3dae1760dc90b8849c6403c386cb1ecb6f328c095aa64e94115c.pdf

Cabelli, V.J. 1983. Health effects for marine recreation waters. USEPA 600/1-80-031. Health Effects Research Laboratory, Research Triangle Park, N.C.

Caux, P.-Y., D.R.J. Moore, and D. MacDonald. 1997. Ambient Water Quality Guidelines (Criteria) for Turbidity, Suspended and Benthic Sediments. Water Management Branch, Ministry of Environment, Lands and Parks. Victoria, BC.

Cavanagh, N., Nordin, R.N. and Warrington, P.D. 1997. Freshwater Biological Sampling Manual. B.C. Ministry of Environment and Resource Information Standards Committee, Victoria, BC.

CENC (Cowichan Estuary Nature Centre). 2015. Available online at: http://www.cowichanestuary.ca/

CVRD (Cowichan Valley Regional District). 1996. Official community plan background document.

CVRD (Cowichan Valley Regional District). 1998. South Sector Liquid Waste Management Plan. Prepared for the CVRD by Stanley Consulting Group. Available online at: http://www.cvrd.bc.ca/lwmp

CVRD (Cowichan Valley Regional District). 2011a. Mill Bay Village Plan - Schedule A, Appendix A. Official Community Plan. No. 3510. Available online at: http://www.cvrd.bc.ca/DocumentCenter/Home/View/7506

CVRD (Cowichan Valley Regional District). 2011b. Main Document, Schedule A, South Cowichan Official Community Plan Bylaw No. 3510. Available online at: https://www.cvrd.ca/DocumentCenter/View/7334/MB_VillageOCP?bidId=

CVRD (Cowichan Valley Regional District). 2013. Cowichan Valley Regional District Electoral Area D – Cowichan Bay. Official Community Plan Bylaw No. 3605. Available online at: http://www.cvrd.bc.ca/DocumentCenter/Home/View/9799

CVRD (Cowichan Valley Regional District). 2011. Census population statistics. Available online at: https://www.cvrd.ca/285/Area-A

CVRD (Cowichan Valley Regional District). 2016. Census population statistics. Available online at: https://www.cvrd.ca/285/Area-A

CVRD (Cowichan Valley Regional District). 2021. Electoral Area A – Mill Bay/Malahat Local Area Plan. Available online at: https://www.cvrd.ca/DocumentCenter/View/102802/Area-A-Mill-BayMalahat-Local-Area-Plan

CVRD (Cowichan Valley Regional District). 2015. Community parks in Area A – Mill Bay/Malahat. Available online at: http://www.cvrd.bc.ca/index.aspx?nid=158

DataBC: Map Layer "Watershed Atlas (1:50000)" [web application]. April 2015a. Geographic Services, Government of British Columbia. Victoria, British Columbia, Canada. Available online at: https://maps.gov.bc.ca/ess/hm/imap4m/

DataBC: Map Layer "Community watersheds" [web application]. April 2015b. Geographic Services, Government of British Columbia. Victoria, British Columbia, Canada. Available online at: https://maps.gov.bc.ca/ess/hm/imap4m/

DataBC: Map Layer "Geological bedrock" [web application]. April 2015c. Geographic Services, Government of British Columbia. Victoria, British Columbia, Canada. Available online at: https://maps.gov.bc.ca/ess/hm/imap4m/

DataBC: Map Layer "Aquifer Boundary – outlined" [web application]. April 2015d. Geographic Services, Government of British Columbia. Victoria, British Columbia, Canada. Available online at: https://maps.gov.bc.ca/ess/hm/imap4m/

DataBC: Map Layer "Water wells" [web application]. April 2015e. Geographic Services, Government of British Columbia. Victoria, British Columbia, Canada. Available online at: https://maps.gov.bc.ca/ess/hm/imap4m/

Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. J. Fish. Res. Bd. Can. 32:2295-2331.

Davis, K., M.A. Anderson, and M.V. Yates. 2005. Distribution of indicator bacteria in Canyon Lake, California. Water Res., 39:1277-1288.

Demarchi, D.A. 1996. An introduction to the ecoregions of British Columbia. Victoria, BC. : B.C. Ministry of Environment, 1996.

Doyle-Yamaguchi, E. 2014. Personal communication. Environmental Analyst. Water Management Division, Engineering Services, CVRD. Duncan, BC.

Drinnan, R.W., Emmett, B., Humphrey, B., Austin, B. and Hull D.J. 1995. Saanich Inlet study water use inventory and water quality assessment. Prepared for Water Quality Branch, Environmental Protection Department, BC Ministry of Environment, Lands and Parks. Victoria, BC.

Edberg, S.C., E.W. Rice, R.J. Karlin, and M.J. Allen. 2000. Escherichia coli: the best biological drinking water indicator for public health protection. J. Appl. Microbiol., 88:106S-116S.

FFSBC (Freshwater Fisheries Society of BC) : Fish Stocking Reports [web application]. April 2015. Victoria, British Columbia, Canada. Available online at: http://www.gofishbc.com/fish-stocking-reports/reports-species.aspx

Field, K.G. and M. Samadpour. 2007. Fecal source tracking, the indicator paradigm, and managing water quality. Water Res., 41:3517-3538.

Fisheries and Oceans Canada (DFO). 2021. http://www.pac.dfo-mpo.gc.ca/fm-gp/contamination/sani/area-secteur-19/19.3-eng.html

Government of Canada. 2014. Historical Climate Data web application. Available online at: http://climate.weather.gc.ca/index_e.html#access (August 2014).

Gray, Ken. 2014. Personal communication. Mill Bay Conservation Society.

Griffin, D.W., E.K. Lipp, M.R. McLaughlin, and J.B. Rose. 2001. Marine recreation and public health microbiology: quest for the ideal indicator. BioScience 51: 817-825.

Haack, S.K., J.W. Duris, L.R., Fogarty, D.W. Kolpin, M.J. Focazio, E.T. Furlong, and M.T. Meyer. 2009. Comparing wastewater chemicals, indicator bacteria concentrations, and bacterial pathogen genes as fecal pollution indicators. J. Environ. Qual., 38:248-258.

HabitatWizard database. Accessed April 2015. Ministry of Environment. Available online at: https://maps.gov.bc.ca/ess/hm/habwiz/

Health Canada. 2004. Guidelines for Canadian drinking water quality: Supporting documentation — Protozoa: Giardia and Cryptosporidium. Water Quality and Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Infrastructure & Environment. 2009. South Cowichan Water Plan Study; A preliminary assessment of water supply & needs within the South Cowichan Region. Prepared for the Cowichan Valley Regional District. Victoria, BC.

Ishii, S. and M.J. Sadowsky. 2008. Escherichia coli in the environment: Implications for water quality and human health. Microbes Environ., 23(2): 101-108.

Kloot, R.W., B. Radakovich, X. Huang, and D. Brantley. 2006. A comparison of bacterial indicators and methods in rural surface water. Environ. Monior. Assess. 121: 275-287.

Kopat, M. and Sokal, M. 2019a. Water Quality Assessment of the Upper Shawnigan Lake Watershed (2013). Environmental Protection Division. Ministry of Environment and Climate Change Strategy. Nanaimo, B.C. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/monitoring-water-quality/west-coast-wq-docs/2019-05-09_shawnigan_creek_assessment.pdf

Kopat, M. and Sokal, M. 2019b. Water Quality Objectives Attainment for Shawnigan Lake (2006-2014). Environmental Protection Division. Ministry of Environment and Climate Change Strategy. Nanaimo, B.C. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/shawnigan_lake_attainment_2006-2014.pdf

Krewski, D., J. Balbus, D. Butler-Jones, C.N. Haas, J. Isaac-Renton, K.J. Roberts, and M. Sinclair. 2004. Managing microbiological risks of drinking water. J. Toxicol. Environ. Health Part A, 67:1591-1617.

Liggett, J., P. Lapcevic, and K. Miller. 2011. A guide to the use of intrinsic aquifer vulnerability mapping. Ministry of Environment, Nanaimo, BC and Cowichan Valley Regional District, Duncan, BC.

MacDonald, D.D. and Ingersoll, C.G. 2003. A guidance manual to support the assessment of contaminated sediments in freshwater, estuarine, and marine ecosystems in British Columbia. Industrial Wastes and Hazardous Contaminants Branch, Ministry of Environment, Lands, and Parks. Victoria, British Columbia.

McKean, C. J.P. 1989. Cowichan-Koksilah Rivers Water Quality Assessment and Objectives Technical Appendix. Water Management Branch, Ministry of Environment. Victoria, B.C.

McKean, C.J.P., and N.K. Nagpal. 1991. Ambient water quality criteria for pH. Technical appendix. Ministry of Environment, Water Management Division, Water Quality Branch, Victoria. BC

Meays, C. 2009. Water Quality Guidelines for Nitrogen (Nitrate, Nitrite and Ammonia) – Overview Report Update. Province of British Columbia. Ministry of Environment. Victoria. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_nitrate_waterqualityguideline_overview.pdf

Mill Bay Marina. 2015. Available online at: http://www.millbaymarina.ca

MBWD (Mill Bay Waterworks District). 2021. FAQ. Available online at: http://millbaywaterworks.ca/faq

MINFILE 2015. Ministry of Energy and Mines Mineral Inventory. Available online at: https://www2.gov.bc.ca/gov/content/industry/mineral-exploration-mining/british-columbia-geological-survey/mineralinventory

Nordin, R.N. 2001 update. Water Quality Criteria for Nutrients and Algae: B.C. Ministry of Environment, 2001. Victoria, BC. Available online: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/nutrients-or.pdf

Obee, N. and Epps, D. 2011. Water Quality Assessment and Objectives for the Cowichan and Koksilah Rivers. First Update. Environmental Protection Division and Environmental Sustainability & Strategic Policy Division, British Columbia Ministry of Environment, Victoria, BC.

Oliver, G.G. and L.E. Fidler. 2001. Towards a water quality guideline for temperature in BC. Prepared for Water Quality Section, Ministry of Environment, Lands and Parks. Victoria BC. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/temperature-tech.pdf

Rieberger, K. 2007. Water quality assessment and objectives for Shawnigan Lake: technical appendix. Science and Information Branch. Ministry of Environment. Victoria, BC.

RISC (Resource Inventory Standards Committee). 1997. Guidelines for Interpreting Water Quality Data. Available online at: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/guidlines_for_interpreting_water_quality_data.pdf

Rodgers, L. 2015. Chapter 1 A comparison of in-lake nitrogen and phosphorus in Sooke and Mill Bay study areas 2004-2013 and potential sources of excess nutrient loading in *Synthesis of Water Quality Data and Modeling Non-Point Loading in Four Coastal B.C. Watersheds: Implications for Lake and Watershed Health and Management.* Water and Aquatic Sciences Research Program, Department of Biology, University of Victoria. Victoria, BC. Available online at: https://colquitzcoalition.com/wp-content/uploads/2015/06/Rodgers_Lisa_MSc_2015.pdf

Scott, T.M., Rose, J.B., Jenkins, T.M., Farrah, S.R., and Lukasik, J. 2002. Microbial source tracking: Current methodology and future directions. Appl. Environ. Microbiol., 68(12): 5796-5803.

Tallon, P., B. Magajna, C. Lofranco, and K.T. Leung. 2005. Microbial indicators of faecal contamination in water: A current perspective. Water Air Soil Pollut., 166:139-166.

Thompson, R.E.1981. Oceanography of the British Columbia Coast. Can. Spec. Publ. Fish. Aquat. Sci. 56: 291 p.

Urban Systems Ltd. 2014. Regional surface and ground water management and governance study. Prepared for Cowichan Valley Regional District. Vancouver, B.C.

van der Gulik, T., D. Neilsen, R. Fretwell and S. Tam. 2013. Agricultural water demand model. Report for Cowichan Valley Regional District. Abbotsford, B.C.

VIHA (Vancouver Island Health Authority). 2010. Drinking water treatment for surface water supplies. Victoria, British Columbia.

WSC (Water Survey of Canada): Archived hydrometric data [web application]. April 2015. Environment Canada. Gatineau, Quebec, Canada. Available online at: http://wateroffice.ec.gc.ca/search/search_e.html?sType=h2oArc

Warrington, P.D. 2001 Update. Water quality criteria for microbiological indicators: Overview Report. BC Ministry of Environment. Victoria, BC. Available online at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_microbiological_indicators_waterqualityguidelines_overview.pdf

West Coast Law. 2015. Mill Bay – Malahat Official Community Plan Bylaw 1890.

Wolferstan, B. 1989. Cruising guide to British Columbia Vol. 1, Gulf Islands and Vancouver Island from Sooke to Courtenay. Vancouver, BC.

Yates, M.V. 2007. Classical indicators in the 21st century – far and beyond the coliform. Water Environ. Res., 79 (3):279-286.

## APPENDIX I. SUMMARY OF METALS DATA

*Table 21. Summary statistics for total metals (µg/L) for water samples collected in 2013 at sites in Shawnigan Creek and the tributaries to Mill Bay during the fall (Oct-Apr) summer (May-Sept) seasons, showing exceedances of the BC ENV approved or working Water Quality Guidelines (BC ENV, 2015). Statistics were calculated based on a minimum of five samples collected within a 30-day period. [1]Non-detected values were included in the calculation of summary statistics as the detection limit. [2]Total mercury results were not assessed for exceedances of the approved WQG for the protection of freshwater aquatic life (0.00125 µg/L), as all measurements were non-detected with a detection limit greater than the guideline (<0.01 to <0.05 µg/L).*

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum Guideline | Average Guideline | Approved or Working | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | | | | |
| ***Shawnigan Creek*** | | | | | | | | | | | | | | | | |
| 1199912 | Shawnigan Creek, outflow | Total Antimony | 5 | 0.5 | 0.5 | 0.5 | 0 | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Arsenic | 5 | 0.25 | 0.29 | 0.274 | 0.0152 | 5 | 0.13 | 0.22 | 0.178 | 0.0383 | 5 | | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Barium | 5 | 5.2 | 6.9 | 5.74 | 0.7021 | 5 | 4.9 | 5.9 | 5.28 | 0.3899 | | 1000 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Beryllium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Boron | 5 | 50 | 50 | 50 | 0 | 5 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Chromium | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | | 8.9 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Cobalt | 5 | 0.5 | 0.5 | 0.5 | 0 | 5 | 0.5 | 0.5 | 0.5 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Copper | 5 | 0.72 | 2.54 | 1.264 | 0.7824 | 5 | 0.69 | 0.96 | 0.752 | 0.1165 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| 1199912 | Shawnigan Creek, outflow | Total Iron | 5 | 92.5 | 422 | 179.06 | 138.07 | 5 | 56.3 | 131 | 82.54 | 30.861 | 1000 | | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Lead | 5 | 0.2 | 0.39 | 0.238 | 0.085 | 5 | 0.2 | 0.2 | 0.2 | 0 | 3 | | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Manganese | 5 | 13.8 | 31.5 | 20.96 | 7.4029 | 5 | 8.3 | 16.4 | 11.84 | 3.2593 | 800 | 700 | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Mercury (Hg)[2] | 5 | 0.05 | 0.05 | 0.05 | 0 | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| 1199912 | Shawnigan Creek, outflow | Total Molybdenum | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| 1199912 | Shawnigan Creek, outflow | Total Nickel | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 2.7 | 1.34 | 0.7603 | | 25 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Selenium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| 1199912 | Shawnigan Creek, outflow | Total Silver | 5 | 0.02 | 0.02 | 0.02 | 0 | 5 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| 1199912 | Shawnigan Creek, outflow | Total Thallium | 5 | 0.05 | 0.05 | 0.05 | 0 | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Uranium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | | 8.5 | Working | |
| 1199912 | Shawnigan Creek, outflow | Total Zinc | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 | 5 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum Guideline | Average Guideline | Approved or Working | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | | | | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Antimony | 5 | 0.5 | 0.5 | 0.5 | 0 | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Arsenic | 5 | 0.29 | 0.37 | 0.332 | 0.0327 | 5 | 0.18 | 7.32 | 1.626 | 3.1831 | 5 | | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Barium | 5 | 5.5 | 7.3 | 6.48 | 0.7155 | 5 | 5.4 | 99.8 | 24.56 | 42.062 | | 1000 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Beryllium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Boron | 5 | 50 | 50 | 50 | 0 | 5 | 50 | 613 | 162.6 | 251.78 | 1200 | | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Chromium | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | | 8.9 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Cobalt | 5 | 0.5 | 0.5 | 0.5 | 0 | 5 | 0.5 | 1.62 | 0.724 | 0.5009 | 110 | 4 | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Copper | 5 | 0.69 | 1.08 | 0.912 | 0.1509 | 5 | 0.7 | 1.94 | 1.124 | 0.4914 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| E294421 | Shawnigan Creek @ Mill Bay | Total Iron | 5 | 245 | 274 | 257.2 | 11.904 | 5 | 136 | 6780 | 1491.4 | 2956.6 | 1000 | | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Lead | 5 | 0.2 | 0.2 | 0.2 | 0 | 5 | 0.2 | 0.2 | 0.2 | 0 | 3 | | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Manganese | 5 | 29 | 37.1 | 31.78 | 3.3101 | 5 | 7.8 | 1100 | 230.04 | 486.34 | 800 | 700 | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Mercury (Hg)[2] | 5 | 0.05 | 0.05 | 0.05 | 0 | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| E294421 | Shawnigan Creek @ Mill Bay | Total Molybdenum | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1.1 | 1.02 | 0.0447 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E294421 | Shawnigan Creek @ Mill Bay | Total Nickel | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | | 25 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Selenium | 5 | 0.1 | 0.12 | 0.104 | 0.0089 | 5 | 0.1 | 0.1 | 0.1 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E294421 | Shawnigan Creek @ Mill Bay | Total Silver | 5 | 0.02 | 0.02 | 0.02 | 0 | 5 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E294421 | Shawnigan Creek @ Mill Bay | Total Thallium | 5 | 0.05 | 0.05 | 0.05 | 0 | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Uranium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.16 | 0.112 | 0.0268 | | 8.5 | Working | |
| E294421 | Shawnigan Creek @ Mill Bay | Total Zinc | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 | 5 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum Guideline | Average Guideline | Approved or Working | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | | | | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Antimony | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Arsenic | -- | -- | -- | -- | -- | 5 | 0.24 | 42.3 | 8.716 | 18.774 | 5 | | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Barium | -- | -- | -- | -- | -- | 5 | 8.1 | 615 | 130.4 | 270.9 | | 1000 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Beryllium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Boron | -- | -- | -- | -- | -- | 5 | 50 | 186 | 77.2 | 60.821 | 1200 | | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Chromium | -- | -- | -- | -- | -- | 5 | 1 | 7.9 | 2.38 | 3.0858 | | 8.9 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Cobalt | -- | -- | -- | -- | -- | 5 | 0.5 | 1.41 | 0.682 | 0.407 | 110 | 4 | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Copper | -- | -- | -- | -- | -- | 5 | 1.67 | 32.7 | 8.674 | 13.457 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Iron | -- | -- | -- | -- | -- | 5 | 282 | 86200 | 17606 | 38345 | 1000 | | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Lead | -- | -- | -- | -- | -- | 5 | 0.2 | 2.31 | 0.692 | 0.9162 | 3 | | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Manganese | -- | -- | -- | -- | -- | 5 | 16.1 | 4260 | 869.32 | 1895.5 | 800 | 700 | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Mercury (Hg)[2] | -- | -- | -- | -- | -- | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Molybdenum | -- | -- | -- | -- | -- | 5 | 1 | 2.2 | 1.24 | 0.5367 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Nickel | -- | -- | -- | -- | -- | 5 | 1 | 12.6 | 3.94 | 4.9948 | | 25 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Selenium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.55 | 0.19 | 0.2013 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Silver | -- | -- | -- | -- | -- | 5 | 0.02 | 0.054 | 0.0268 | 0.0152 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Thallium | -- | -- | -- | -- | -- | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Uranium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.2 | 0.12 | 0.0447 | | 8.5 | Working | |
| E294422 | Unnamed creek @ Kilmalu Rd | Total Zinc | -- | -- | -- | -- | -- | 5 | 5 | 28.7 | 9.86 | 10.535 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum Guideline | Average Guideline | Approved or Working | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | | | | |
| ***Tributary to Mill Bay*** | | | | | | | | | | | | | | | | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Antimony | 5 | 0.5 | 0.5 | 0.5 | 0 | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Arsenic | 5 | 0.27 | 0.31 | 0.296 | 0.0152 | 5 | 0.17 | 0.22 | 0.19 | 0.0212 | 5 | | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Barium | 5 | 3.7 | 4.4 | 4.04 | 0.3286 | 5 | 3.6 | 4.6 | 3.98 | 0.4494 | | 1000 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Beryllium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Boron | 5 | 50 | 50 | 50 | 0 | 5 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Chromium | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | | 8.9 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Cobalt | 5 | 0.5 | 0.5 | 0.5 | 0 | 5 | 0.5 | 0.5 | 0.5 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Copper | 5 | 0.53 | 0.77 | 0.65 | 0.1158 | 5 | 0.62 | 1.14 | 0.906 | 0.2597 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Iron | 5 | 210 | 273 | 228.8 | 25.371 | 5 | 116 | 196 | 149.6 | 31.342 | 1000 | | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Lead | 5 | 0.2 | 0.2 | 0.2 | 0 | 5 | 0.2 | 0.2 | 0.2 | 0 | 3 | | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Manganese | 5 | 11.7 | 23.4 | 14.74 | 4.8972 | 5 | 4.3 | 5.3 | 4.9 | 0.4183 | 800 | 700 | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Mercury (Hg)[2] | 5 | 0.05 | 0.05 | 0.05 | 0 | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Molybdenum | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Nickel | 5 | 1 | 1 | 1 | 0 | 5 | 1 | 1 | 1 | 0 | | 25 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Selenium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Silver | 5 | 0.02 | 0.02 | 0.02 | 0 | 5 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Thallium | 5 | 0.05 | 0.05 | 0.05 | 0 | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Uranium | 5 | 0.1 | 0.1 | 0.1 | 0 | 5 | 0.1 | 0.1 | 0.1 | 0 | | 8.5 | Working | |
| E294428 | Malahat Creek @ Mill Bay Rd | Total Zinc | 5 | 5 | 5 | 5 | 0 | 5 | 5 | 5 | 5 | 0 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum | Average | Approved | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | Guideline | Guideline | or Working | |
| E295317 | Unnamed creek near Keir Rd | Total Antimony | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Arsenic | -- | -- | -- | -- | -- | 5 | 0.14 | 0.3 | 0.204 | 0.0727 | 5 | | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Barium | -- | -- | -- | -- | -- | 5 | 2.6 | 4.2 | 3.3 | 0.6557 | | 1000 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Beryllium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Boron | -- | -- | -- | -- | -- | 5 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Chromium | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | | 8.9 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Cobalt | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Copper | -- | -- | -- | -- | -- | 5 | 0.51 | 1.59 | 0.856 | 0.4425 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| E295317 | Unnamed creek near Keir Rd | Total Iron | -- | -- | -- | -- | -- | 5 | 81.3 | 452 | 179.88 | 154.68 | 1000 | | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Lead | -- | -- | -- | -- | -- | 5 | 0.2 | 0.2 | 0.2 | 0 | 3 | | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Manganese | -- | -- | -- | -- | -- | 5 | 3.8 | 21.7 | 8.14 | 7.632 | 800 | 700 | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Mercury (Hg)[2] | -- | -- | -- | -- | -- | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| E295317 | Unnamed creek near Keir Rd | Total Molybdenum | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E295317 | Unnamed creek near Keir Rd | Total Nickel | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | | 25 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Selenium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E295317 | Unnamed creek near Keir Rd | Total Silver | -- | -- | -- | -- | -- | 5 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E295317 | Unnamed creek near Keir Rd | Total Thallium | -- | -- | -- | -- | -- | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Uranium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 8.5 | Working | |
| E295317 | Unnamed creek near Keir Rd | Total Zinc | -- | -- | -- | -- | -- | 5 | 5 | 12.1 | 7 | 2.9589 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum | Average | Approved | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | Guideline | Guideline | or Working | |
| E295318 | Stormdrain near Handy Rd | Total Antimony | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Arsenic | -- | -- | -- | -- | -- | 5 | 0.23 | 0.44 | 0.318 | 0.1031 | 5 | | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Barium | -- | -- | -- | -- | -- | 5 | 8.4 | 10.2 | 9.54 | 0.7057 | | 1000 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Beryllium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Boron | -- | -- | -- | -- | -- | 5 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Chromium | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | | 8.9 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Cobalt | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Copper | -- | -- | -- | -- | -- | 5 | 2.16 | 4.48 | 3.33 | 0.9176 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| E295318 | Stormdrain near Handy Rd | Total Iron | -- | -- | -- | -- | -- | 5 | 208 | 327 | 259.4 | 50.846 | 1000 | | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Lead | -- | -- | -- | -- | -- | 5 | 0.2 | 0.5 | 0.272 | 0.1301 | 3 | | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Manganese | -- | -- | -- | -- | -- | 5 | 27.4 | 33.5 | 31.46 | 2.3723 | 800 | 700 | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Mercury (Hg)[2] | -- | -- | -- | -- | -- | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| E295318 | Stormdrain near Handy Rd | Total Molybdenum | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E295318 | Stormdrain near Handy Rd | Total Nickel | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | | 25 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Selenium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.14 | 0.11 | 0.0173 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E295318 | Stormdrain near Handy Rd | Total Silver | -- | -- | -- | -- | -- | 5 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E295318 | Stormdrain near Handy Rd | Total Thallium | -- | -- | -- | -- | -- | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Uranium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 8.5 | Working | |
| E295318 | Stormdrain near Handy Rd | Total Zinc | -- | -- | -- | -- | -- | 5 | 8.7 | 14.5 | 10.58 | 2.4934 | 33 | 7.5 | Approved | Protection of FW aquatic life |

| EMS ID | Station description | Chemical | Summer | | | | | Fall | | | | | Maximum Guideline | Average Guideline | Approved or Working | Guideline description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Count | Min | Max | Mean | StDev | Count | Min | Max | Mean | StDev | | | | |
| E295320 | Stormdrain outlet to beach nea | Total Antimony | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | | 9 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Arsenic | -- | -- | -- | -- | -- | 5 | 0.1 | 0.11 | 0.102 | 0.0045 | 5 | | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Barium | -- | -- | -- | -- | -- | 5 | 3.6 | 4.3 | 3.96 | 0.2702 | | 1000 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Beryllium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 0.13 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Boron | -- | -- | -- | -- | -- | 5 | 50 | 50 | 50 | 0 | 1200 | | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Chromium | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | | 8.9 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Cobalt | -- | -- | -- | -- | -- | 5 | 0.5 | 0.5 | 0.5 | 0 | 110 | 4 | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Copper | -- | -- | -- | -- | -- | 5 | 0.54 | 0.88 | 0.684 | 0.1335 | 4.162 | 2 | Approved | Protection of FW aquatic life, based on hardness of 23 mg/L |
| E295320 | Stormdrain outlet to beach nea | Total Iron | -- | -- | -- | -- | -- | 5 | 11.2 | 51.5 | 24.92 | 15.831 | 1000 | | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Lead | -- | -- | -- | -- | -- | 5 | 0.2 | 0.23 | 0.206 | 0.0134 | 3 | | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Manganese | -- | -- | -- | -- | -- | 5 | 1 | 2.3 | 1.44 | 0.5413 | 800 | 700 | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Mercury (Hg)[2] | -- | -- | -- | -- | -- | 5 | 0.01 | 0.05 | 0.026 | 0.0219 | 1 | 0.00125 | Approved | Protection of DW (max); protection of FW aquatic life (avg) |
| E295320 | Stormdrain outlet to beach nea | Total Molybdenum | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | 50 | 1000 | Approved | Protection of wildlife (max); protection of FW aquatic life (avg) |
| E295320 | Stormdrain outlet to beach nea | Total Nickel | -- | -- | -- | -- | -- | 5 | 1 | 1 | 1 | 0 | | 25 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Selenium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.11 | 0.104 | 0.0055 | 1 | | Approved | This is the ALERT concentration for protection of aquatic life. |
| E295320 | Stormdrain outlet to beach nea | Total Silver | -- | -- | -- | -- | -- | 5 | 0.02 | 0.02 | 0.02 | 0 | 0.1 | 0.05 | Approved | Protection of FW aquatic life |
| E295320 | Stormdrain outlet to beach nea | Total Thallium | -- | -- | -- | -- | -- | 5 | 0.05 | 0.05 | 0.05 | 0 | | 0.8 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Uranium | -- | -- | -- | -- | -- | 5 | 0.1 | 0.1 | 0.1 | 0 | | 8.5 | Working | |
| E295320 | Stormdrain outlet to beach nea | Total Zinc | -- | -- | -- | -- | -- | 5 | 6.2 | 21.1 | 14.42 | 7.4476 | 33 | 7.5 | Approved | Protection of FW aquatic life |

## APPENDIX II. SUMMARY OF QA/QC DATA

*Table 22. Mill Bay and tributaries results of QAQC duplicate analysis.*

| Station | Sample Collection Date (YYYYMMDD) | Chemical | Sample Type | Result | Units | Qualifier | Relative Percent Difference |
|---|---|---|---|---|---|---|---|
| 1199912 | 20131203 | E. coli | Regular | 1 | CFU/100m | | 0 |
| 1199912 | 20131203 | E. coli | Replicate | 1 | CFU/100m | | |
| 1199912 | 20131203 | Turbidity | Regular | 0.44 | NTU | | 2.2 |
| 1199912 | 20131203 | Turbidity | Replicate | 0.45 | NTU | | |
| E236520 | 20130730 | E. coli | Regular | 32 | CFU/100m | | 0 |
| E236520 | 20130730 | E. coli | Replicate | 32 | CFU/100m | | |
| E236520 | 20130730 | Turbidity | Regular | 0.47 | NTU | | 22.6 |
| E236520 | 20130730 | Turbidity | Replicate | 0.59 | NTU | | |
| E236520 | 20130730 | Total Phos | Regular | 0.0084 | mg/L | | 4.7 |
| E236520 | 20130730 | Total Phos | Replicate | 0.0088 | mg/L | | |
| E294421 | 20120912 | Ammonia | Regular | 0.037 | mg/L | | 21.7 |
| E294421 | 20120912 | Ammonia | Replicate | 0.046 | mg/L | | |
| E294421 | 20120912 | Dissolved | Regular | 0.18 | mg/L | | 1.7 |
| E294421 | 20120912 | Dissolved | Replicate | 0.177 | mg/L | | |
| E294421 | 20120912 | Dissolved | Regular | 0.01 | mg/L | < | 0 |
| E294421 | 20120912 | Dissolved | Replicate | 0.01 | mg/L | < | |
| E294421 | 20120912 | Total Phos | Regular | 0.0277 | mg/L | | 3.3 |
| E294421 | 20120912 | Total Phos | Replicate | 0.0268 | mg/L | | |
| E294428 | 20120919 | Ammonia | Regular | 0.019 | mg/L | | 10 |
| E294428 | 20120919 | Ammonia | Replicate | 0.021 | mg/L | | |
| E294428 | 20120919 | Dissolved | Regular | 0.144 | mg/L | | 1.4 |
| E294428 | 20120919 | Dissolved | Replicate | 0.146 | mg/L | | |
| E294428 | 20120919 | Dissolved | Regular | 0.01 | mg/L | < | 0 |
| E294428 | 20120919 | Dissolved | Replicate | 0.01 | mg/L | < | |
| E294428 | 20120919 | Total Phos | Regular | 0.0194 | mg/L | | 6.4 |
| E294428 | 20120919 | Total Phos | Replicate | 0.0182 | mg/L | | |
| XXXXX | 20120830 | Ammonia | Regular | 0.012 | mg/L | | 45.2 |
| XXXXX | 20120830 | Ammonia | Replicate | 0.019 | mg/L | | |
| XXXXX | 20120830 | Dissolved | Regular | 0.036 | mg/L | | 21.5 |
| XXXXX | 20120830 | Dissolved | Replicate | 0.029 | mg/L | | |
| XXXXX | 20120830 | Dissolved | Regular | 0.01 | mg/L | < | 0 |
| XXXXX | 20120830 | Dissolved | Replicate | 0.01 | mg/L | < | |
| XXXXX | 20120830 | Dissolved | Regular | 1.41 | mg/L | | 8.2 |
| XXXXX | 20120830 | Dissolved | Replicate | 1.53 | mg/L | | |
| XXXXX | 20120830 | Total Phos | Regular | 0.0155 | mg/L | | 1.9 |
| XXXXX | 20120830 | Total Phos | Replicate | 0.0158 | mg/L | | |