ENVIRONMENTAL PROTECTION DIVISION

ENVIRONMENTAL SUSTAINABILITY DIVISION

MINISTRY OF ENVIRONMENT

Water Quality Assessment and Objectives for the Mercantile Creek Community Watershed

TECHNICAL REPORT

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EXECUTIVE SUMMARY

This document presents a summary of the ambient water quality of Mercantile Creek, British Columbia, and proposes water quality objectives designed to protect existing and future water uses. The water quality assessment for the creek and an evaluation of the watershed form the basis of the objectives.

Mercantile Creek, with a length of 8.9 km, drains into Ucluelet Inlet near Ucluelet, BC. The District of Ucluelet withdraws drinking water from Mercantile Creek. The water uses to be protected in Mercantile Creek include drinking water, wildlife and aquatic life. Extensive forest harvesting has occurred in the watershed and logging roads provide recreational access for hunters, ATV users and hikers. These activities, as well as forestry and wildlife, all potentially affect water quality in the creek.

Water quality monitoring was conducted between 2002 and 2005. The results of this monitoring indicated that the overall state of the water quality is very good. All chemical, physical and biological parameters met provincial water quality guidelines with the exception of temperature, turbidity, aluminum, fecal coliforms and *Escherichia coli* (both of which exceeded the drinking water guidelines on occasion), and dissolved aluminum (which exceeded the aquatic life guideline on occasion). In order to maintain and protect the water quality in Mercantile Creek, ambient water quality objectives were set for temperature, turbidity, non-filterable residue (total suspended solids), true colour, total organic carbon, dissolved aluminum and *E. coli*.

Future monitoring recommendations include attainment monitoring every 3-4 years, depending on available resources and whether activities, such as forestry or development, are underway within the watershed. This monitoring should be conducted during the summer low flow and fall flush period (five weekly samples in 30 days) at the District of Ucluelet intake.

Water Quality Objectives for Mercantile Creek

Variable	Objective Value
Temperature	15°C (max)
Turbidity	5 NTU (max) 2 NTU (mean)
Non-filterable Residue (TSS)	26 mg/L (max) 6 mg/L (mean)
True Colour	15 TCU (max)
Total Organic Carbon	4.0 mg/L (max)
Dissolved Aluminum	0.10 mg/L (max) 0.05 mg/L (mean)
Escherichia coli	≤60 CFU/100 mL (90th percentile)

Note: all calculations are based on a minimum of 5 samples in 30 days

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1.0 INTRODUCTION

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

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

Figure 1. Map of Vancouver Island Ecoregions.

Partnerships formed between the MOE, local municipalities and stewardship groups are a key component of the water quality network. Water quality sampling conducted by the public works departments of local municipalities and stewardship groups has enabled the Ministry to significantly increase the number of watersheds studied 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, have resulted in strong relationships with local government and interest groups, provided valuable input and local support and, ultimately, resulted in a more effective monitoring program.

The Mercantile Creek community watershed provides a significant source of drinking water to the local community and has important fisheries values, with chum and coho both present at some point during the year (FISS, 2006). Anthropogenic land uses within the watershed include timber harvesting and recreation. These activities, as well as natural erosion and the presence of wildlife, all potentially affect water quality in Mercantile Creek.

This report examines the existing water quality of Mercantile Creek and recommends water quality objectives for this watershed based on potential impacts and water quality parameters of concern. Mercantile Creek was designated as a community watershed in 1995, as defined under the *Forest Practices Code of British Columbia Act* ("the drainage area above the downstream point of diversion and which are licensed under the *Water Act* for waterworks purposes"). This designation was grandparented and continued under the *Forest and Range Practices Act* (FRPA) in 2004 and infers a level of protection. In the 2011 ratification of the Maa-nulth Treaty, ownership of the watershed was transferred to the Ucluelet First Nation, and the standards and objectives under the community watershed designation still apply (BC MARR, 2008). In addition, the MOE uses other tools, such as water quality objectives, and legislation, such as the *Private Managed Forest Land Act* and the *Drinking Water Protection Act* (BC Gov, 2011), to ensure that water quality within watersheds is protected and managed in a consistent manner.

2.0 WATERSHED PROFILE AND HYDROLOGY

2.1 BASIN PROFILE

Mercantile Creek is a second-order stream 8.89 km in length, entering Ucluelet Inlet near the community of Ucluelet, BC. The community watershed portion includes approximately 7.5 km of Mercantile Creek upstream from the District of Ucluelet water intake (Figure 2), is 1,142 ha in area, and ranges from 40 m at the intake to 774 m elevation at Mount Frederick in the upper watershed. There are no lakes within the watershed boundaries.

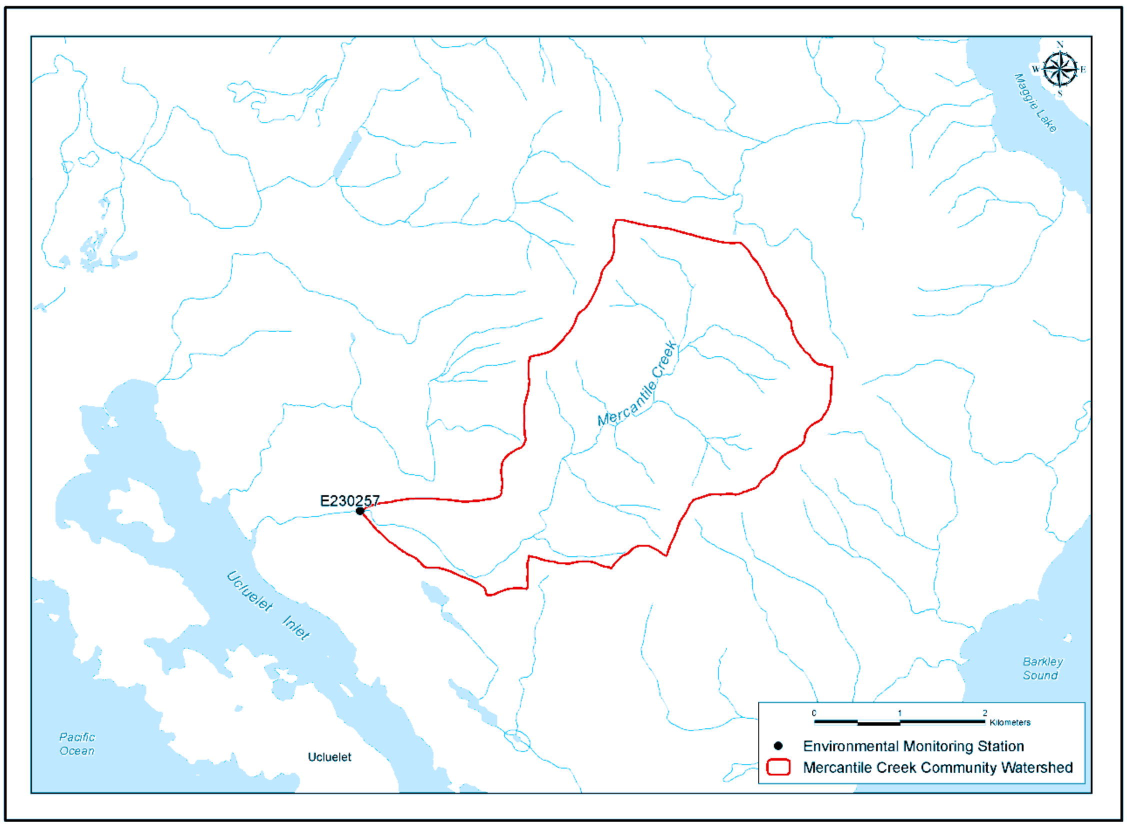

Figure 2. Map of Mercantile Creek watershed.

The entire watershed falls within the Coastal Western Hemlock (submontane very wet maritime, CWHvm1) biogeoclimatic zone. Mercantile Creek lies within the Windward

Island Mountain (WIM) ecoregion (see Figure 1) established for Vancouver Island by MOE staff. The bedrock of the area consists of granodioritic intrusive rock, calc-alkaline volcanic rock and undivided intrusive rock (GeoBC, 2010).

2.2 HYDROLOGY AND PRECIPITATION

The nearest climate station to the watershed for which climate normal data were available was the Tofino A station (elevation 24 m) (Environment Canada Climate Station 1038205), located approximately 20 km north-west of the Mercantile Creek watershed. Temperature and precipitation data (1971 – 2000) are summarized in Figure 3. Average daily temperatures ranged from 4.5 °C in January to 14.8 °C in August. Average total annual precipitation between 1971 and 2000 was 3,306 mm, with only 43 mm (water equivalent) (1%) of this falling as snow. Temperatures at higher elevations in the watershed would be cooler than recorded at sea level. A larger portion of the annual total precipitation occurred as snowfall in the higher-elevation terrain of the watershed. Most precipitation (2,450 mm, or 74%) fell between October and March.

Water Survey Canada (WSC) operated a hydrometric station on Mercantile Creek near the Forest Service road crossing between 1979 and 1984. Minimum, maximum and average daily flows for this period are shown in Figure 4. Flow measurements were restricted to the months of May through November, and so likely underestimate peak flows that typically occur with higher rainfall (see Figure 3) between November and February at lower elevations in the watershed. Peak flows measured between 1979 and 1984 were approximately 20.3 m^3/s, while minimum flows were approximately 0.106 m^3/s (Figure 4).

Triton Environmental Consultants Ltd. (1996) also conducted a hydrometric study of Mercantile Creek as part of their overview assessment report. They used hydrometric measurements from nearby watersheds to estimate peak flows, as well as 2, 20, 50 and 100 year maximum daily and instantaneous discharges (Table 1).

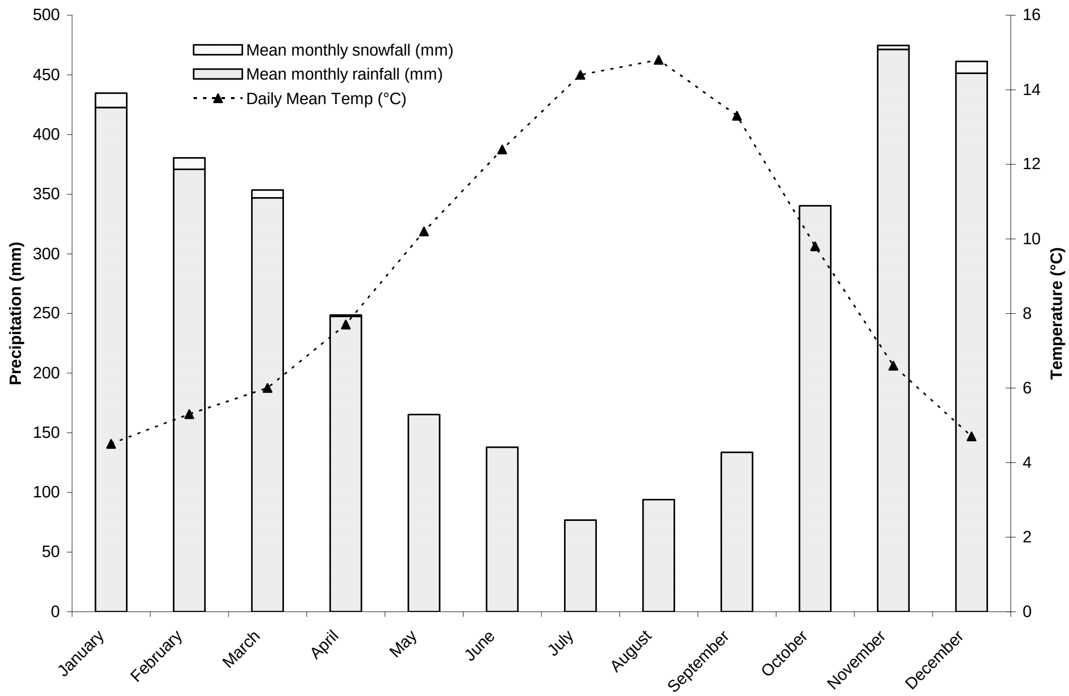

Figure 3. Climate data (1971 – 2000) for Tofino (Environment Canada Climate Station 1038205).

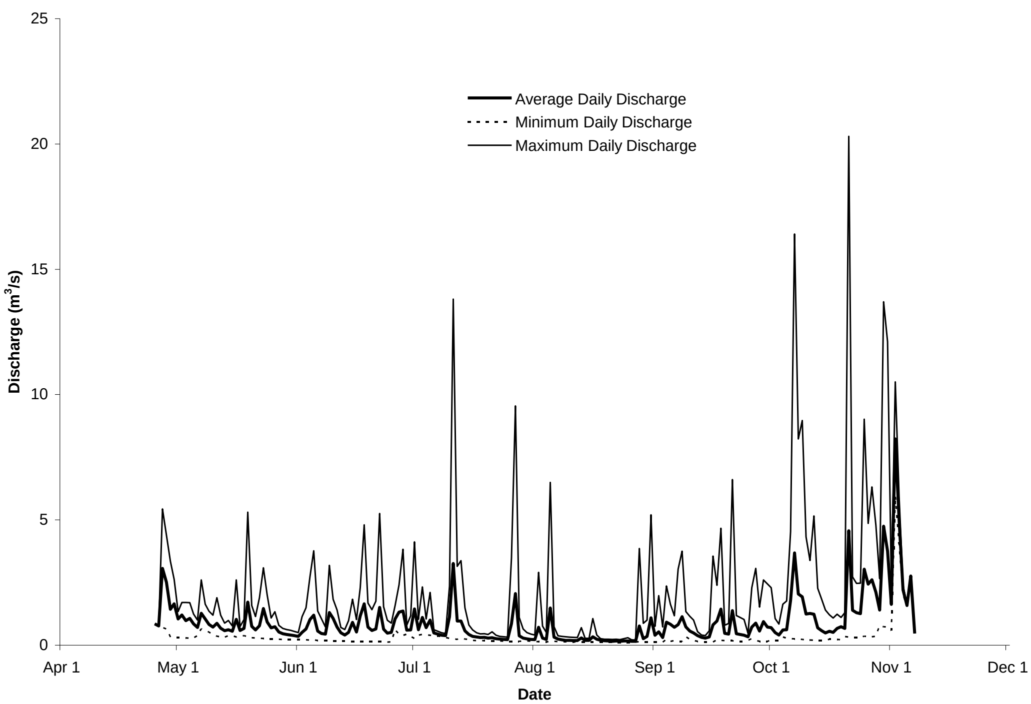

Figure 4. Minimum, maximum and average daily discharge data for Mercantile Creek near (Water Survey Canada Station 08HB002) between 1979 and 1984 (WSC, 2005).

Table 1. Summary of hydrometric analysis conducted by Triton Environmental Consultants Ltd. (1996).

Drainage area of the entire watershed	13.2 km²
Drainage area upstream of the former WSC station #08HB064	10.4 km²
Mean annual discharge	1.38 m^3/s
Mean annual runoff	3,300 mm
Mean summer 7 day low discharge	0.13 m^3/s
Mean winter 7 day low discharge	0.22 m^3/s
Return Period Discharges (maximum daily discharge):	
2 year return period	28.0 m^3/s
20 year return period	59.0 m^3/s
50 year return period	70.0 m^3/s
100 year return period	78.4 m^3/s
Return Period Discharges (maximum instantaneous discharge):	
2 year return period	56.0 m^3/s
20 year return period	118.0 m^3/s
50 year return period	140.0 m^3/s
100 year return period	156.0 m^3/s
Unit mean annual discharge	0.1045 $m^3/s/km^2$

3.0 WATER USES

3.1 WATER LICENSES

Seven water licenses have been issued for Mercantile Creek (Table 2), allowing for the withdrawal of 1,468dam^3/a of water annually and at the same point of diversion. The District of Ucluelet supplies water to approximately 2, 200 users. Ucluelet also utilizes groundwater from the Wellfield aquifer (located at the junction of Highway 4 and the Pacific Rim Highway) when turbidity is elevated in Mercantile Creek (such as after major landslides in January 2005). The District of Ucluelet relied solely on the groundwater source from January 2005 until the summer of 2006, when low water levels in the aquifer caused them to once again utilize Mercantile Creek as the primary water source. Mercantile Creek is the preferred source of drinking water, due to marginal pH levels in the Wellfield aquifer. This water is chlorinated prior to consumption.

Table 2. Summary of licensed water withdrawals from Mercantile Creek.

Use	No. Licensed Withdrawals	Total Volume (dam^3/a)	Principal Licensee
Waterworks – Local Authority	5	1,182	District of Ucluelet
Waterworks – Other	1	166	Ucluelet First Nation
Ice Making	1	119	465792 BC Ltd.

3.2 FISHERIES

Mercantile Creek has high fisheries values, and species present include chum (*Oncorhynchus keta*), and coho (*O. kisutch*) (DFO, 2011). It is likely that both chum and coho spawn in the lower 200 m portion of Mercantile Creek, below a set of falls, with chum the dominant species in the creek (FISS, 2006). As well, anecdotal evidence suggests that resident cutthroat trout (*O. clarki*) and Dolly Varden char (*Salvelinus malma*) inhabit Mercantile Creek above the falls at 200 m (Triton Environmental Consultants, 1996).

3.3 RECREATION

A logging road runs parallel with, and near, the mainstem of Mercantile Creek, and allows access to most of the watershed. Though there are no BC Forest Service recreation sites or other sanctioned camping areas in the watershed, the proximity of the watershed to the community of Ucluelet, coupled with the high number of tourists that visit the area during the summer and the unrestricted access to the watershed, results in recreational use of the watershed. These uses include hiking, mountain biking, ATV riding, and hunting.

3.4 FLORA AND FAUNA

The Mercantile Creek watershed provides habitat to a variety of species typical of west coast Vancouver Island, including blacktail deer (*Odocoileus hemionus columbianus*), black bear (*Ursus americanus*), cougar (*Puma concolor*), and numerous other small mammals and birds. However, the BC Conservation Data Centre does not show any sensitive occurrences of red- or blue-listed species within the watershed boundaries (BCCDC, 2006).

3.5 DESIGNATED WATER USES

Designated water uses are those identified for protection in a 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 should include drinking water, aquatic life, and wildlife.

4.0 INFLUENCES ON WATER QUALITY

4.1 LAND OWNERSHIP

In the 2011 ratification of the Maa-nulth Treaty, ownership of the watershed was transferred to the Ucluelet First Nation, which now has governance power over the land (BC MARR, 2008). The treaty agreement states that the Ucluelet First Nation will acknowledge that the First Nation Community Watershed Lands are designated as a community watershed by Provincial Law, and will manage, use and develop the lands in accordance with the standards and objectives under that law.

There are a number of surveyed parcels within the watershed, primarily in the lower portion below the community watershed boundary. There are no residences located within the watershed, and so potential sources of contamination associated with households (such as runoff, septic fields, fertilizers and pesticides) are not an issue.

4.2 LICENSED WATER WITHDRAWALS

There is a maximum licensed water withdrawal from the Mercantile Creek community watershed of 1,468dam^3/a. Assuming water was withdrawn from Mercantile Creek at a constant rate throughout the year (an unlikely scenario), the average withdrawal rate would be about 0.047 m^3/s. As average daily flows between 1979 and 1984 ranged from 0.106 m^3/s during the mid-summer to 20.3 m^3/s during spring rain on snow events (see Figure 4), water withdrawals are likely to impact downstream flows in Mercantile Creek only during summer low-flow periods when water consumption is highest.

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.

Extensive forest harvesting has occurred within the Mercantile Creek watershed, primarily between the mid-1950's and early 1960's, with a number of small blocks harvested in the 1980's and 1990's. As of 1996, when the most recent watershed assessment was conducted, 78% of the watershed had been harvested. Hazard indices calculated for the watershed as part of the 1996 Coastal Watershed Assessment show that the watershed has been highly impacted by logging activities and road construction, with all indices exceeding 0.93 (below 0.5 indicates a low potential impact, 0.5 to 0.7 indicates a moderate potential impact, and a value greater than 0.7 indicates a high potential impact) (Cuthbert *et al.*, 1996) (Table 3).

Table 3. Summary of Hazard Indices for the Mercantile Creek Watershed (Cuthbert *et al*., 1996).

Watershed Component	Hazard Index
Peak Flows	1.00
Surface Erosion	1.00
Riparian Buffers	1.00
Landslides	0.93
Headwaters	1.00

Contributing to these high hazard indices for Mercantile Creek are the large percentage (78%) of the watershed that has been harvested and several of the activities associated with timber harvesting. In 1996 the weighted equivalent clearcut area (ECA) remained at 61%. In addition, 36 km of roads have been constructed in this small watershed, resulting in a concentration of 3.2 km of road/km^2 of watershed. Of this, 0.3 km/km^2 are on erodible soils and 1.1 km/km^2 are located near streams (increasing the likelihood of suspended sediments associated with runoff from the roads entering the stream). Finally, there are 1.5 stream crossings/km^{2}of watershed, which is considered high. Of the total streambank (including tributaries), 77% was logged as of 1996, including 66% of the fish-bearing portion of the stream. In all, 51% of the mainstem was logged. There were also a large number of landslides noted within the watershed (17 as of 1996), resulting in a concentration of 1.3 slides/km^2, also considered high. Further contributing to potential landslides is the fact that 0.3 km/km^2 of roads are constructed on unstable terrain, and

12% of the watershed is logged on unstable or potentially unstable terrain (Cuthbert *et al*., 1996).

In January 2005, a large debris torrent swept down one of the lower tributaries to Mercantile Creek, carrying huge volumes of rock, soils, vegetation and other debris to the mainstem of Mercantile Creek. This debris torrent dammed the main stem of Mercantile Creek resulting in a large pool forming behind the dam. The dam eventually burst, releasing a flood of water and debris down the main channel of Mercantile Creek. This in turn resulted in the water intake being closed due to extremely high suspended sediment and turbidity levels, and the District of Ucluelet was forced to rely on groundwater from the Wellfield aquifer for their drinking water. A large volume of debris remains in the channel of the tributary, culminating in a vertical wall over 2 m high at the edge of Mercantile Creek.

Significant impacts have occurred to the watershed from historic road building and forest harvesting activities. Due to the relatively high concentration of roads within the watershed, especially adjacent to the creek, runoff from these roads has the potential to impact turbidity levels in the creek, particularly during periods of road grading or road construction. Potential impacts from these roads may continue for some time but will decrease as roads are deactivated and reclaimed.

4.4 RECREATION

Recreational activities can affect water quality in a number of ways. Erosion associated with 4-wheel drive and ATV vehicles, direct contamination of water from vehicle fuel, and fecal contamination from human and domestic animal wastes (*e.g.*, dogs or horses) are typical examples of potential effects. While no specific studies have been conducted on recreation within the Mercantile Creek watershed, limited seasonal impacts are likely (primarily during the summer months) but remain relatively insignificant compared with other impacts that have occurred.

4.5 WILDLIFE

Wildlife can influence water quality because warm-blooded animals can carry pathogens such as *Giardia lamblia*, which causes giardiasis or “beaver fever”, and *Cryptosporidium* oocysts which cause the gastrointestinal disease, cryptosporidiosis (Health Canada, 2004). In addition, warm-blooded animals excrete fecal coliforms and *Escherichia coli* in their feces, and can cause elevated levels of these microbiological indicators in water. 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.

Mercantile Creek watershed contains valuable wildlife habitat, and provides a home for a wide variety of warm-blooded species. Therefore, the risk of contamination from endemic wildlife exists.

4.6 MINING

Mining activities can potentially impact water quality by introducing high concentrations of metals and other contaminants (e.g. sulphate) to waterbodies. The leaching of waste rock or adit discharges can also contribute to acidification of the water. Mining activities generally include road construction and land-clearing, which can change water movement patterns and result in increased turbidity levels.

There is one mineral prospect in the Mercantile Creek community watershed (MINFILE, 2005). It is called the Wildcat, Ozzard showing and contains some magnetite, pyrrhotite and pyrite. This showing is located in the far upper reaches of the watershed, and has not been developed. Future developments of this or other mineral claims within the watershed would be subject to environmental impact assessments to ensure that they do not adversely affect water quality.

5.0 STUDY DETAILS

One water quality monitoring location was selected within the Mercantile Creek watershed. Environmental Monitoring System (EMS) Site E230257 is located near the District of Ucluelet water intake (see Figure 2). 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 establishment of water quality objectives.

Water quality data were collected from 2002 to 2005. Drinking water is one of the designated water uses in Mercantile Creek and so water quality variables relevant to the protection of raw drinking water supplies were included. Based on the current knowledge of potential anthropogenic impacts to the sub-watersheds (generally associated with forestry and recreation), natural features (wildlife), and the lack of authorized waste discharges within the watershed, the following water quality variables were included:

- Physical: pH, true color, specific conductivity, turbidity, non-filterable residue (total suspended solids);
- Carbon: dissolved organic carbon;
- Nutrients: total phosphorus, total dissolved phosphorus, ortho-phosphate, nitrate and nitrite;
- Microbiological indicators: fecal coliforms and *E. coli*; and
- Total and dissolved metal concentrations.

To represent the worst case scenario, water samples were collected at the site on a weekly basis for five consecutive weeks during the summer low flow and fall high flow periods from 2002 to 2005, and usually on a monthly basis for the remainder of the year between 2002 and early 2006.

Grab samples were collected at the water surface in strict accordance with Resource Inventory Standards Committee (RISC) standards (Cavanagh *et al.*, 1998) by trained personnel including District of Ucluelet public works staff. Water chemistry analyses were conducted by Maxxam Analytics Inc. in Burnaby, BC. Bacteriological analyses were conducted by Cantest Laboratories in Burnaby, BC. Summary statistics were calculated on all available data, and 90th percentiles were calculated using data from a minimum of five weekly samples in 30 consecutive days for each site.

An automated water quality/quantity monitoring station was also installed at the site from June 2004 to May 2005 to measure turbidity, conductivity, temperature and water level. Readings were collected every 15 minutes. Here, a McVan analyte SDI-12 turbidity sensor was installed within the stream flow and polled every 15 minutes by a FWS-12 datalogger.

6.0 WATER QUALITY ASSESSMENT AND OBJECTIVES

There are two sets of guidelines that are commonly used to determine the suitability of drinking water. The BC MOE water quality guidelines (available at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html) are used to assess water at the point of diversion of the natural stream into a waterworks system. These BC guidelines are also used to protect other designated water uses such as recreation and habitat for aquatic life. Water quality guidelines provide the basis for the development of water quality objectives for a specific waterbody, which can be integrated into an overall fundamental water protection program designed to protect all uses of the resource, including drinking water sources.

The *BC Drinking Water Protection Act* sets minimum disinfection requirements for all surface supplies as well as requiring drinking water to be potable. The Vancouver Island Health Authority (VIHA) determines the level of treatment and disinfection required based on both source and end of tap water quality. As such, VIHA requires all surface water supply systems to provide two types of treatment processes. Currently the District of Ucluelet only treats through chlorine disinfection prior to distribution (Crowther, pers. comm., 2011). To effectively treat the water for viruses and parasites, such as *Cryptosporidium* and *Giardia*, the District may be required to provide additional disinfection, such as UV or ozone, and/or treatment, such as filtration. The following sections describe the characteristics considered in assessing the water quality of Mercantile Creek.

6.1 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 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.

pH in Mercantile Creek ranged from 6.5 to 8.0 pH units with a mean of 7.4 pH units (Appendix I) for 42 samples collected. Only the minimum value (6.5 pH units) was near the guideline threshold, and the next-lowest measurement was 6.9 pH units. This suggests that pH is not presently a concern in Mercantile Creek. Therefore, no water quality objective is proposed for pH in this watershed.

6.2 TEMPERATURE

Temperature is considered in drinking water for aesthetic reasons. The aesthetic guideline is 15 °C; temperatures above this level are considered to be too warm to be aesthetically pleasing (Oliver and Fidler, 2001). 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 and other coldwater species are based on species-specific life history stages such as incubation, rearing, migration, and spawning, and each species has its own optimum temperature range. Of the species of fish present in Mercantile Creek (chum, coho, cutthroat and Dolly Varden) (DFO, 2011), chum are the most sensitive to warmer temperatures (12-14 °C for rearing). Chum juveniles, however, are not present in the river during the summer months. Coho, cutthroat trout and Dolly Varden, which are present throughout the year, all have a maximum optimum temperature for rearing of 16 °C (Oliver and Fidler, 2001).

Water temperatures in Mercantile Creek varied seasonally, with maximum temperatures occurring in the late July. Water temperatures measured by the automated station ranged from 2.0 °C in the winter months to a maximum of 16.0 °C in July 2004 (Figure 5).

Water temperatures exceeded the aesthetic guideline of 15 °C for a few days during July and August 2004. Temperatures were below the salmonid spawning guideline during the fall period when chum and coho spawn. Temperature data were only collected for one summer period, but it is likely that the aesthetic drinking water guideline is exceeded occasionally each year.

In comparison, McKelvie Creek, which is in the same ecoregion, had water temperatures of 1.5°C to 12.3°C during objectives development monitoring. The higher temperatures observed in Mercantile Creek may be related to forestry impacts such as removal of stream canopy cover. In McKelvie Creek, the provincial drinking water guideline was adopted as the temperature objective. As the provincial drinking water guideline is only occasionally exceeded in Mercantile Creek, this guideline is appropriate for this creek too. To protect the creek from future activities in the watershed ***a water quality objective is proposed for water temperature in Mercantile Creek. It is recommended that maximum instantaneous water temperatures at the District of Ucluelet water intake should not exceed 15 °C during the summer months.*** As the streambank along both Mercantile Creek and its tributaries recovers from logging activities, maximum summer temperatures should begin to decrease with the amount of sunlight reaching the water.

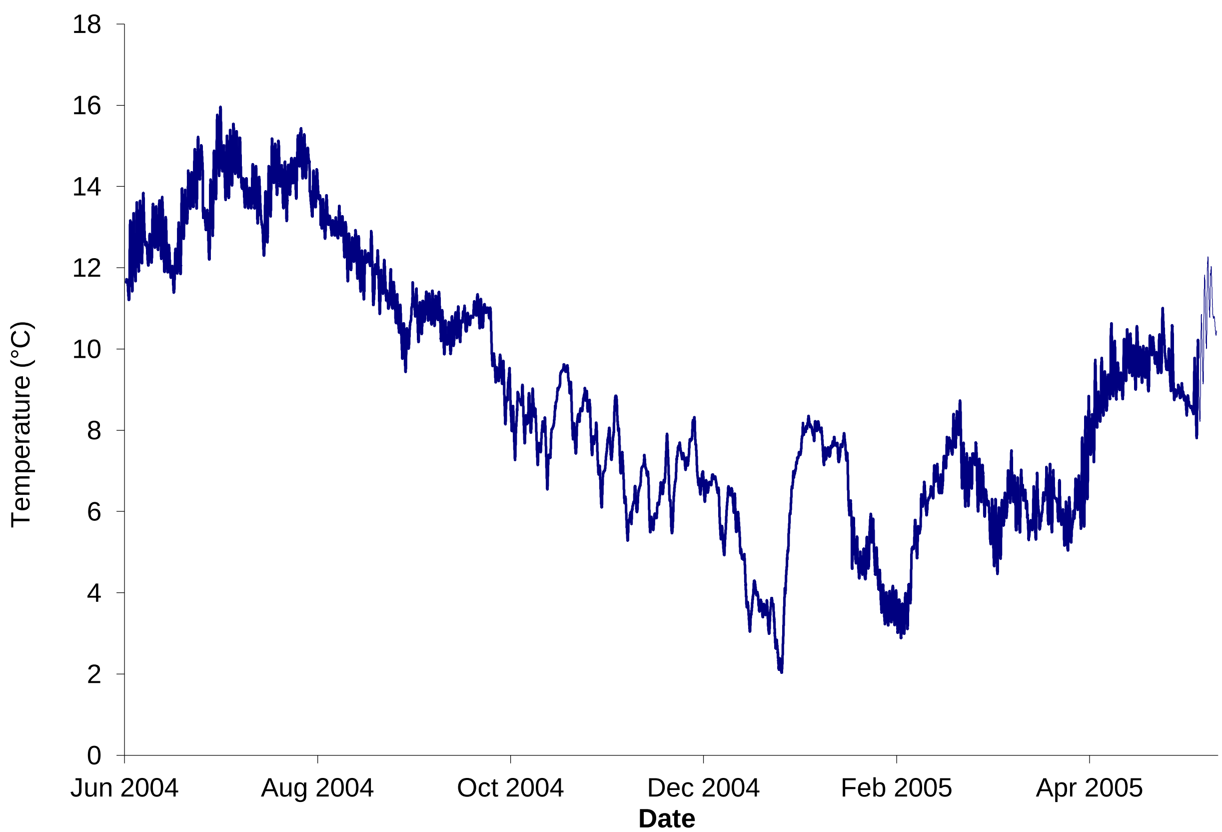

Figure 5. Automated water temperature data collected from Mercantile Creek at the District of Ucluelet intake between June 2004 and May 2005.

6.3 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 amount of dissolved ions in the water. The more ions dissolved in a solution, the greater the electrical conductivity. As temperature affects the conductivity of water (a 1 ºC increase in temperature results in approximately a 2% increase in conductivity), specific conductivity is used (rather than simply conductivity) to compensate for temperature. Coastal systems, with high annual rainfall values and typically short water retention times, generally have low specific conductivity (<80 µS/cm), while interior watersheds generally have higher values. Increased flows resulting from precipitation events or snowmelt tends 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 stream, specific conductivity levels tend to increase. As such, significant changes in specific conductivity can be used as an indicator of potential impacts.

In Mercantile Creek, specific conductivity values in the discrete samples ranged from 25 µS/cm to 64 µS/cm, with an average of 44 µS/cm for 42 samples collected (Appendix I). At the automated station, values ranged from 10 µS/cm to 70 µS/cm, with an average of 44 µS/cm. Values were correlated with flows, with the highest conductivity occurring during low summer flows (when dilution was lowest) and conductivity values dropping during the winter (when dilution from rainfall was highest) (Figure 6). As there is no BC Water Quality Guideline for specific conductivity, and the average specific conductivity observed was typical of coastal systems, no objective is proposed for specific conductivity in the Mercantile Creek watershed.

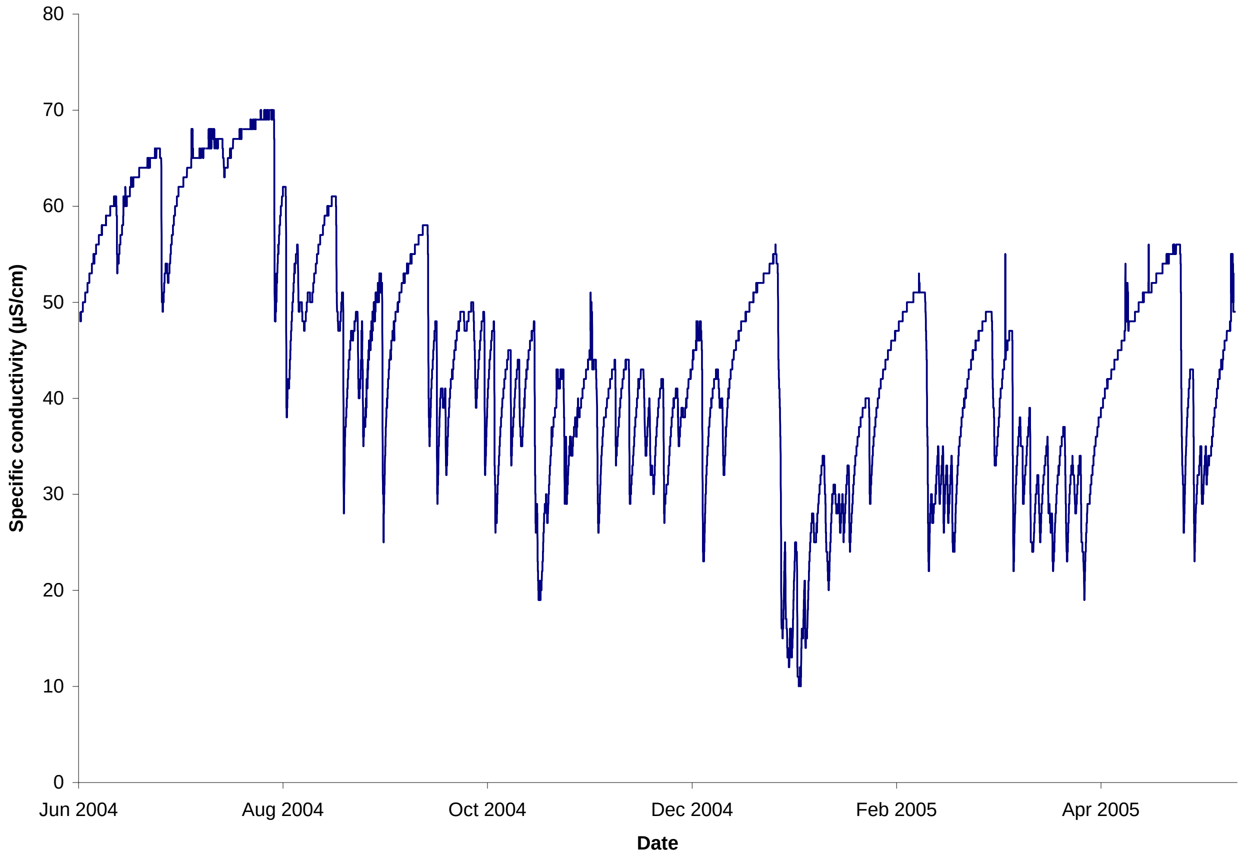

Figure 6. Specific conductivity measured in Mercantile Creek near the District of Ucluelet intake between June 2004 and May 2005.

6.4 TURBIDITY

Turbidity is a measure of the clarity or cloudiness of water, and is measured by the amount of light scattered by the particles in the water as nephelometric turbidity units (NTU). Elevated turbidity levels can decrease the efficiency of disinfection, allowing microbiological contaminants to enter the water system. As well, there are aesthetic concerns with cloudy water, and particulate matter can clog water filters and leave a film on plumbing fixtures. The 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 of 5 NTU (during turbid flow periods) (Caux *et al.*, 1997). VIHA's goal for surface source drinking water for systems that do not receive filtration, such as Mercantile Creek, is that it demonstrate 1 NTU turbidity or less (95%

of days) and not above 5 NTU on more than 2 days in a 12 month period when sampled at the intake (Enns, pers. comm., 2009).

At the intake site, turbidity values based on grab samples, ranged from 0.23 NTU to 3.30 NTU, with an average of 0.82 NTU for the 42 samples collected between 2002 and 2006 (Appendix I). The highest value (3.30 NTU) occurred on November 6, 2002. On 13 of the 14 dates when turbidity exceeded 1 NTU, there had been significant rainfall within the past 24 hours (Environment Canada, 2011). The exception to this was May 16, 2005, when a turbidity value of 1.40 NTU was measured. However, rainfall had occurred less than 48 hours prior to that sample being collected. Therefore it can be stated that elevated turbidity levels in Mercantile Creek are almost invariably associated with rain events, which flush material into the creek.

A summary of turbidity data collected using automated sampling equipment between June, 2004 and May, 2005 is given in Table 4. The distribution of data shows that about 81% of values were below 1 NTU, and 94% of values were below 5 NTU. Therefore, about 6% of the time, or about 500 of the 8,100 hours when turbidity was measured over the course of the study, turbidity values were higher than 5 NTU. Turbidity can be difficult to measure accurately with automated equipment due to the wide variety of factors that can affect measurements, including fish and other aquatic organisms, algae, air bubbles and sampling location. In this study, it was felt that values greater than 50 NTU (0.2% of values, or 59 samples) may have been affected by such factors.

Table 4. Summary of automated turbidity data measured at Mercantile Creek at District of Ucluelet intake station between June 2004 and May 2005.

	Number	Percentage	Cumulative %
Number Turbidity <=1 NTU	26,336	80.9%	80.9%
Number Turbidity >1, <=5 NTU	4,184	12.9%	93.8%
Number Turbidity >5, <=10	1,133	3.5%	97.3%
Number Turbidity >10, <=50	825	2.5%	99.8%
Number Turbidity >50	59	0.2%	100.0%
Totals:	**32,537**	**100**	

It is important to consider not only the total amount of time the criterion was exceeded, but also how long each exceedance lasted. For example, high turbidity levels for five consecutive hours are more likely to impact drinking water quality than five one-hour events separated by a few hours of low-turbidity water. Turbidity events in Mercantile Creek tended to be of moderate duration and occurred primarily between the months of November and February (Figure 7).

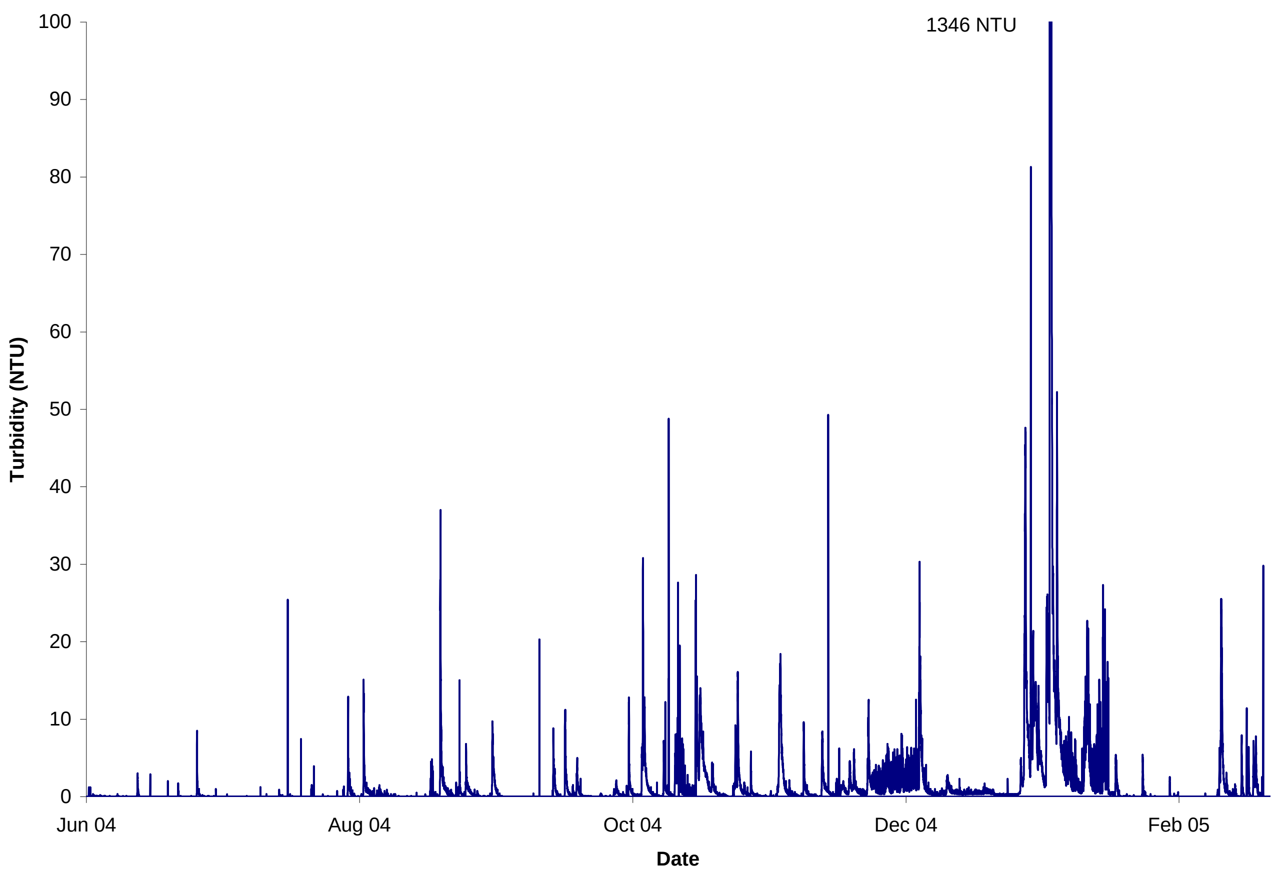

Figure 7. Turbidity levels in Mercantile Creek between June 2004 and May 2005 measured at 15-minute intervals by the automated water quality monitoring station near the District of Ucluelet intake.

Table 5 shows a summary of the intensity and duration of turbidity events occurring at the automated station between 2003 and 2005. A turbidity event, for the sake of this summary, is defined as a number of consecutive turbidity values measured at 15-minute intervals exceeding the 5 NTU threshold. The recovery time is the length of time that has passed since the previous turbidity event (i.e., since the turbidity last exceeded 5 NTU). For the sake of brevity and ease of reading, Table 5includes only the longest-duration events (i.e., events over 5 hours in length) – the remainder of the summary is included as Appendix II, arranged in chronological order. The longest turbidity event was 82 hours in length, with a maximum value of over 1,300.00 NTU. Most turbidity events (over 78% of all events) occurred between the months of November and February.

Table 5. Summary of turbidity events for Mercantile Creek exceeding 5 hours in duration reported by automated turbidity meter at Ministry of Environment station between 2004 and 2005.

Start Date	Start Time	Recovery Time (hrs)	Duration of event (h)	Max turb (NTU)	Min turb (NTU)	Avg. turb (NTU)	St.Dev.
25/10/2004	12:45	1	5.25	12.8	4.2	8.7	2.7
15/11/2004	00:15	8.5	6.25	16.1	4.5	10.5	3.8
02/04/2005	22:15	35	6.75	13.6	4	8.2	2.1
18/01/2005	09:00	6	7	81.3	4.3	12.3	15.0
05/04/2005	19:00	5.75	7	12	4.5	7.6	1.7
15/04/2005	23:15	16.5	7	20.7	4.5	11.4	5.0
25/10/2004	04:15	2.5	7.25	30.8	3.4	14.1	8.5
10/04/2005	16:15	84.5	8	13	4.8	7.4	2.1
20/01/2005	02:15	4.25	8.25	14.3	4.4	8.0	2.8
10/09/2004	16:30	399.75	8.5	37	2.4	14.5	8.6
05/11/2004	21:15	0.25	9.5	28.6	0	9.6	4.8
06/04/2005	16:15	10.25	10.5	19.1	4.9	10.7	4.3
01/03/2005	02:45	5	13	25.5	4.6	13.2	6.6
26/03/2005	01:00	71.75	13	38	4.6	16.6	9.5
24/12/2004	21:30	0.5	14	30.3	2.1	11.7	5.1
24/11/2004	03:00	147.25	15.75	18.4	4.7	11.1	3.6
06/11/2004	15:15	8.25	18.75	14	4.4	8.8	2.5
30/01/2005	10:15	0.25	20.25	22.7	4.7	11.3	4.0
18/01/2005	20:00	0.75	26.25	21.4	4.8	11.3	3.6
16/01/2005	22:45	536.75	28	47.6	3.3	17.0	12.4
31/03/2005	05:00	51	28.75	25.3	4.1	11.9	5.5
21/01/2005	19:30	25.75	82	1346	4	52.4	140.2

Table 6 shows a comparison of grab sample laboratory results compared with the automated data collected at the same time. In those instances where laboratory samples were not collected on the 15-minute interval, automated data from immediately before and immediately after the lab sample was collected is shown. This table shows that in all 11 instances, turbidity values reported by the laboratory and by the automated equipment were within 2 NTU, which is an acceptable level (MELP, 1998). However, most of the samples were collected when turbidity was very low (< 1 NTU), and are therefore not indicative of the occasional turbidity events that occur in this watershed. Future monitoring should focus on collecting water samples following significant rain events, in order to try and capture these occasional elevated turbidity levels. In the event of a significant turbidity event (*i.e.*, turbidity values exceeding 5 NTU for a period of at least 24 hours), grab-samples should be collected at other monitoring sites within the system to determine the origin of the problem.

Table 6. Comparison of turbidity values reported by laboratory analyses and automated turbidity probe.

Sample date / time	Laboratory Result (NTU)	Automated Sensor Result (NTU)	Difference (Laboratory - Automated) (NTU)
07/07/2004 11:30	0.34	0.00	0.34
04/08/2004 10:15	0.31	0.00	0.31
01/09/2004 7:30	0.40	0.00	0.40
06/10/2004 7:30	1.15	0.40	0.75
03/11/2004 11:30	0.76	0.10	0.66
08/12/2004 10:45	1.51	1.00	0.51
10/01/2005 11:30	0.43	0.20	0.23
08/02/2005 11:45	0.66	0.00	0.66
07/03/2005 9:40	1.30	1.00/1.20	0.30/0.10
13/04/2005 12:20	1.80	2.70/1.90	-1.10/-0.10
16/05/2005 11:55	1.40	0.00/0.00	1.40

Turbidity values measured over the course of this study (between 2002 and 2006) reflect past logging practices, as well as the recovery of Mercantile Creek water quality from the 2005 landslide event. Therefore, it is anticipated that as the ECA decreases and slides stabilize, turbidity events will decrease in both frequency and severity.

Water quality objectives can be developed using a background concentration approach. However, in Mercantile Creek water quality data collected during the sampling period do not reflect natural or background conditions due to past timber harvesting practices. Therefore, using the ecoregion approach described in the introduction, objectives developed from another watershed within the same ecoregion can be applied to other watersheds without objectives on an interim basis. As turbidity for the Mercantile Creek site it not considered background, the water quality data for the nearby McKelvie Creek (Epps, 2007) were incorporated into this review.

Turbidity in McKelvie Creek was lower than in Mercantile Creek (Tables 7 & 8), but similarly was driven by storm events. As there was little or no activity in the McKelvie Creek watershed during the monitoring, the data are reflective of background conditions in the Windward Island Mountains ecoregion. Therefore, it is recommended that the turbidity objectives be based on those from McKelvie Creek. Thus, ***it is recommended that total turbidity measured at the intake should not exceed a maximum of 5.0 NTU at any time and the mean of five weekly samples in a 30-day period should not exceed 2.0 NTU (1 NTU above ambient levels, as measured in the McKelvie Creek watershed).*** It should be noted that turbidity values above 2.0 NTU are considered likely to affect disinfection in a chlorine-only system (Anderson, pers. comm., 2006).

Table 7. Comparison of grab sample data for turbidity (NTU) for Mercantile Creek (2002-2006) and McKelvie Creek (1998-2005).

	Mercantile Ck	McKelvie Ck
Min	0.23	0.05
Max	3.30	4.31
Mean	0.82	0.30
No.	42	39

Table 8. Comparison of continuous monitoring data for Mercantile Creek (2004-2005) and McKelvie Creek (2003-2004).

	Mercantile Ck	McKelvie Ck
Percentage of results ≤ 1 NTU	81%	91%
Percentage of results ≤ 5 NTU	94%	99%
Length of longest turbidity event	82 hrs	18 hrs
Max turbidity measured during an event	1346.0 NTU	423.4 NTU

6.5 TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS), or non-filterable residue (NFR), include all of the undissolved particulate matter in a sample. This value should be closely correlated with the turbidity value, 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 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).

Concentrations of TSS ranged from below detectable limits (< 1 mg/L) (42 of 67 measurements) to 9 mg/L (on November 20, 2002 after a winter rain event). Total suspended solids values were consistently low with elevated fluctuations only occurring during rain storm events. Data were collected on three occasions to determine average levels: fall 2002 (n = 5), summer 2003 (n = 4) and fall 2004 (n = 4). The averages for each of those periods were 4 mg/L, 1 mg/L, and 1 mg/L, respectively. The average summer TSS level was 1 mg/L, and the average fall TSS level was 2 mg/L (Table 9).

Table 9. Seasonal summary of total suspended solids (mg/L) data from Mercantile Creek at Intake, 2002-2005.

	Summer	Fall
Min	<1	<1
Max	1	9
Mean	1	2
No.	5	10

As with turbidity, TSS in Mercantile Creek is likely affected by past logging practices and does not represent background conditions. Data from the nearby McKelvie Creek were incorporated into this review to represent background conditions for the Windward Island Mountains ecoregion (Table 10).

Table 10. Comparison of grab sample data for total suspended solids (mg/L) for Mercantile Creek (2002-2006) and McKelvie Creek (1998-2005)

	Mercantile Ck	McKelvie Ck
Min	<1	<1
Max	9	12
Mean	2	2
No.	67	55

Results from the two creeks are very similar. However, because the provincial water quality guideline is based on a change from background, and it is believed that Mercantile Creek TSS does not represent background conditions, the McKelvie Creek water quality objective for TSS should be adopted for Mercantile Creek. For McKelvie Creek, the provincial water quality guideline of 25 mg/L over background (maximum) and 5 mg/L over background (mean) was adopted as the objective, using a background value of 1 mg/L. Therefore, ***it is recommended that total suspended solids measured at the Mercantile Creek intake should not exceed 26.0 mg/L at any time and the mean of five samples in 30-days should not exceed 6.0 mg/L***. Means of five weekly samples in 30 days were chosen (rather than maximum values of 30 samples in a 30 day period, as recommended in the guideline) considering the practicality of, and resources available for, monitoring, as well as the local hydrology and the fact that Vancouver Island streams have clear flows for most of the year.

6.6 COLOUR AND TOTAL ORGANIC CARBON

Colour in water is caused by dissolved and particulate organic and inorganic matter. True colour is a measure of the dissolved colour in water after the particulate matter has been removed, while apparent colour is a measure of the dissolved and particulate matter in water. Colour can affect the aesthetic acceptability of drinking water, and the aesthetic water quality guideline is a maximum of 15 true colour units (TCU) (Moore and Caux, 1997). Colour is also an indicator of the amount of organic matter in water. When organic matter is chlorinated it can produce disinfection by-products such as trihalomethanes, which may pose a risk to human health.

Colour was only measured at the intake site on September 21, 2006 and was 10 TCU (Appendix I). This measurement was below the provincial guideline; however, occasional high colour levels are observed in this ecoregion. Colour in McKelvie Creek ranged from 3 TCU to 14 TCU, with an average of 7.75 TCU for 12 samples collected. While the source of this colour is likely natural processes within the watershed, it can be exacerbated by anthropogenic activities; therefore, we recommend an objective to ensure that this parameter continues to be monitored. ***It is recommended that maximum colour values should not exceed 15 TCU at the District of Ucluelet intake.*** If colour levels are consistently high during some periods of the year, trihalomethanes should also be measured in the finished water (after chlorination) to determine if disinfection by-products are a concern.

Elevated total organic carbon (TOC) levels (above 4.0 mg/L) can result in higher levels of trihalomethanes in finished drinking water if chlorination is used to disinfect the water (Moore, 1998). As Ucluelet uses chlorine to disinfect their drinking water, TOC concentrations should be monitored. During the study period, TOC concentrations were measured only twice in Mercantile Creek, with values of 2.7 mg/L and 3.3 mg/L. Instead, dissolved organic carbon (DOC) values were measured. TOC consists of two fractions: DOC and particulate organic carbon, with the majority generally as DOC. Concentrations of dissolved organic carbon (DOC) ranged from below detection limits (< 0.5 mg/L) to a maximum of 10.0 mg/L for 32 samples collected between July 2002 and October 2005. The next highest value was 5.7 mg/L. ***For this reason, and the reasons listed above, a water quality objective for total organic carbon is proposed. It is recommended that maximum TOC values should not exceed 4.0 mg/L at the intake.***

6.7 NUTRIENTS (NITRATE, NITRITE AND PHOSPHORUS)

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

The guideline for the maximum concentration for nitrate in drinking water is 10 mg/L as nitrogen and the guideline for nitrite is a maximum of 1 mg/L as nitrogen. When both nitrate and nitrite are present, their combined concentration must not exceed 10 mg /L as N. For the protection of freshwater aquatic life, the nitrate guidelines are a maximum concentration of 31.3 mg/L and an 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). There are no BC guidelines for phosphorus in streams.

Nitrogen concentrations were measured in terms of dissolved nitrite (NO_2) and dissolved nitrate (NO_3). Dissolved nitrate concentrations ranged from below detectable limits (< 0.002 mg/L) to a maximum of 0.67 mg/L as N for 42 samples, with an average of 0.16 mg/L. Concentrations of total nitrite were consistently low, with almost half of the 42 measured values below detectable limits (< 0.002 mg/L) and a maximum of only 0.006 mg/L. All values of both nitrate and nitrite species were well below the existing aquatic life guidelines (Appendix I). As concentrations of nitrogen are generally low in Mercantile Creek, no objective is proposed for this parameter.

The BC MOE is working towards a phosphorus objective for Vancouver Island. This proposed objective 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 proposed total phosphorus objective applies from May to September and is an average of 5 µg/L and a maximum of 7 µg/L (BCMOE, *in press*). As this objective is under development, the numbers and the way in which they are applied are subject to change.

Total phosphorus concentrations ranged from below detectable limits (< 2 µg/L) to a maximum of 14 µg/L for 42 values. All of the values above 5 µg/L except one (June 13, 2005) occurred between the months of October and February, when solar inputs are at their lowest, and are therefore less of a concern. It is possible that the higher values were related to past forestry activity and flushing by rain events. As values were generally low, and are likely to be further reduced as recovery from logging continues, no objective is proposed for phosphorus at this time. The need for an objective should be re-evaluated after the next attainment monitoring period.

6.8 METALS

Total metal concentrations were measured on 39 occasions and dissolved metal concentrations were measured on 38 occasions in Mercantile Creek. The concentrations of most metals were below detection limits, and well below guidelines for drinking water and aquatic life. The exceptions were copper and aluminum.

Copper concentrations on one sampling date (August 18, 2004) were much higher than all other results (total Cu = 5.61 µg/L, dissolved Cu = 4.71 µg/L) and exceeded the provincial guideline. There had not been any significant rainfall in the two weeks prior to this sampling date, and none of the other metals showed unusually high results. This high copper result therefore likely represents an anomaly and is not representative of the conditions in Mercantile Creek. All other copper results were well below the provincial guideline.

For the protection of aquatic life. the provincial guideline for dissolved aluminum is a maximum concentration of 100 µg/L and an average concentration of 50 µg/L. To protect drinking water, the maximum concentration is 200 µg/L. Dissolved aluminum was measured 38 times in Mercantile Creek, with values ranging from 10.3 µg/L to a maximum of 291.0 µg/L. Three results exceeded the maximum aquatic life guideline, including one which also exceeded the drinking water guideline (291.0 µg/L on November 6, 2002, 128.0 µg/L on November 20, 2002, 160.0 µg/L on August 25, 2004). Samples were collected with sufficient frequency (a minimum of five weekly samples within 30 days) to compare to average guidelines on four occasions (Table 11). Two of these sampling periods exceeded the average aluminum guideline for the protection of aquatic life. The summer and fall 2003, and the summer 2004 sample periods only had 4 samples collected within a 30 day period, but these data are included in the table to aid in the assessment.

Table 11. Summary of dissolved aluminum data collected at Mercantile Creek at intake, showing means calculated when a minimum of five weekly samples were collected within a 30-day period (µg/L). Boldfaced values exceed the BC Water Quality Guidelines for dissolved aluminum of 50 µg/L.

	2002		**2003**		**2004**		**2005**		
	Sum	**Fall**	**Sum***	**Fall***	**Sum***	**Fall**	**Sum**	**Sum Mean**	**Fall Mean**
Dissolved Aluminum (µg/L)	37.0	**111.3**	19.5	**67.7**	**76.6**	**74.7**	18.4	37.9	**84.6**

*based on 4 weekly samples in 30 days

The elevated concentrations of dissolved aluminum in Mercantile Creek are almost certainly a result of the natural geography of the area rather than any anthropogenic activities. However, all elevated concentrations occurred immediately after rainfall events and were likely related to elevated turbidity. As turbidity levels in Mercantile Creek are higher than background, elevated dissolved aluminum values may occur more frequently than they would in an unimpacted Winward Island Mountains watershed.

McKelvie Creek, by comparison, had only one dissolved aluminum result that exceeded the provincial guideline during water quality objectives development monitoring. This supports the suggestion that the higher aluminum concentrations in Mercantile Creek are related to increased sediment transport. For this reason, a dissolved aluminum objective is proposed for Mercantile Creek. Attainment monitoring should show a decrease in results as the watershed recovers from forestry impacts. ***It is recommended that, at any location in the river, dissolved aluminum should not exceed a maximum of 100 µg/L at any one time and the mean of five weekly samples in 30 days should not exceed 50 µg/L.***

Metal speciation determines the biologically available portion of the total metal concentration. Only a portion of the total metals level is in a form which can be toxic to aquatic life. Naturally occurring organics in the watershed can bind substantial proportions of the metals which are present, forming metal complexes that are not biologically available. The relationship will vary seasonally, depending upon the metal (e.g. copper has the highest affinity for binding sites in humic materials). Levels of organics as measured by DOC vary from ecoregion to ecoregion. To aid in future development of metals objectives, DOC has been included in the Mercantile Creek monitoring program. As water hardness can affect the toxicity of copper and some other metals, hardness has also been included in the Mercantile Creek monitoring program.

6.9 MICROBIOLOGICAL INDICATORS

Fecal contamination of surface waters used for drinking and recreating can result in high risks to human health from pathogenic microbiological organisms as well as significant economic losses due to closure of beaches (Scott *et al*., 2002). 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). 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), and *E. coli* (a thermotolerant coliform considered to be specifically of fecal origin) (Yates, 2007).

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).

Total and fecal coliforms have traditionally been used in the assessment of water for domestic and recreational uses. However, research in recent years has shown that there are many differences between the coliforms and the pathogenic microorganisms 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 do 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; thus it is not always clear where to direct management efforts.

The BC-approved water quality guidelines for microbiological indicators were developed in 1988 (Warrington, 1988) and include *E. coli*, enterococci, *Psudomonas aeruginosa*, and fecal coliforms. The monitoring programs of the BC MOE have traditionally measured total coliforms, fecal coliforms, *E. coli* and enterococci, either alone or in combination, depending on the specific program. As small pieces of fecal matter in a sample can skew the overall results for a particular site the 90th percentiles (for drinking water) and geometric means (for recreation) are generally used to determine if the water quality guideline is exceeded, as extreme values would have less effect on the data. The

BC MOE drinking water guideline for raw waters receiving disinfection only is that the 90th percentile of at least five weekly samples collected in a 30-day period should not exceed 10 CFU/100 mL for either fecal coliforms or *E. coli* (Warrington, 2001).

To represent the worst case scenario, bacteriological samples were only collected during summer low flow (August/September) and fall flush (October/November) periods. Fecal coliform concentrations were measured 33 times in Mercantile Creek, with values ranging from below detection limits (<1 CFU/100 mL) to a maximum of 310 CFU/100 mL. In the four instances when the requisite sampling frequency was met (a minimum of five weekly samples within 30 days), the 90th percentiles ranged from 7 CFU/100 mL to 196 CFU/100 mL (Table 12). Fecal coliform concentrations tended to be highest during the August and September sampling period. The summer 2002 and 2004 sample periods had only four weekly samples in 30 days. Though these could not be directly compared to BC water quality guidelines, they were useful in understanding sample period trends and are included in Table 12.

Table 12. Summary of 90th percentile values for fecal coliforms (CFU/100ml) and *E. coli* (CFU/100ml) at Mercantile Creek Intake, calculated with a minimum of five samples were collected within a 30-day period.

	2002		**2003**		**2004**		**2005**	
	Summer*	**Fall**	**Summer**	**Fall**	**Summer***	**Fall**	**Summer**	**Fall**
Fecal coliform	16	44	196	7	231	—	48	—
E. coli	12	25	150	5	215	5	46	—

*n=4

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). 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 Mercantile Creek.

E. coli concentrations ranged from below detection limits (< 1 CFU/100 mL) to 290 CFU/100 mL, for 38 samples. In the five instances when the requisite sampling frequency was met (at least five weekly samples in 30 days), the 90th percentiles ranged from 5 CFU/100 mL to 150 CFU/100 mL (Table 12). The summer 2002 and 2004 sample periods had only 4 weekly samples in 30 days. These were also not directly comparable to BC water quality guidelines, but captured low flow and flushing events, thus were also included in Table 12 and in the determination of an objective. As with fecal coliforms, the highest values were seen in August and September.

E. coli results from nearby McKelvie Creek had an average 90th percentile value of 57 CFU/100 mL. The average 90th percentile value in Mercantile Creek was similar, at 66 CFU/100mL, but two of the seasonal datasets exceeded this value by a wide margin. While there are no anthropogenic sources of fecal coliforms in either watershed, Mercantile Creek has higher sediment transport rates due to forestry impacts, which may be causing higher microbiological results. It is recommended that the McKelvie Creek *E. coli* objective be adopted for Mercantile Creek. This will serve as a goal for improvement, and it is expected that as the watershed recovers from forestry disturbance, the microbiological numbers will decrease to levels consistent with background conditions. ***The objective is that the 90th percentile of a minimum of five weekly samples collected within a 30-day period must not exceed 60 CFU/100 ml at the intake for*** **E. coli.** No seasonal objective is recommended, due to the sporadic nature of precipitation events in this area and thus the difficulty in assessing when summer low flow and first fall flush periods occur. While this proposed objective is higher than the provincial guideline it does represent the natural variability within the Windward Island Mountains ecoregion with respect to bacteriological values. This highlights the need for water purveyors to provide adequate treatment prior to consumption. Meeting these objectives will provide protection from most pathogens but not from parasites such as *Cryptosporidium* or *Giardia.* Sampling for these pathogens falls under the auspices of the water purveyors, in this case the District of Ucluelet.

7.0 MONITORING RECOMMENDATIONS

In order to capture the periods where water quality concerns are most likely to occur (i.e., summer low-flow and fall flush) we recommend that a minimum of five weekly samples be collected within 30 days during each of these periods. Samples collected during the summer months should capture periods of little to no precipitation, and samples collected in the winter months should coincide with rain events whenever possible. In this way, the two critical periods (minimum dilution and maximum turbidity) will be monitored.

Precipitation data from the Environment Canada weather station in Tofino were used to assess the timing of rain events during the 2002-2005 monitoring (Environment Canada, 2011). In the years of the study, the timing of the first persistent rain events (i.e. >10 mm of precipitation on every day or every other day for at least a week) ranged from late August to early November. In all years except 2004, there were fewer than five days with measureable precipitation in August. However, on the days with measureable precipitation, it was often 40 mm to 80 mm in one day. These short-term rain storms could flush substantial amounts of sediment and thus other contaminants into the creek, especially if they occur after an extended dry period. As such, it is recommended that the summer low-flow sampling be completed by mid-August, and that the start of the fall sampling be determined by analyzing the long-range weather forecast and choosing the first period where significant and persistent rain is predicted for that year.

Samples should be analyzed for general water chemistry (including pH, specific conductivity, TSS, turbidity, true colour, DOC, TOC, total phosphorous), dissolved metals, hardness and *E. coli*, in addition to field measurements of temperature.

7.1 BIOLOGICAL MONITORING

Objectives development has traditionally focused on physical, chemical and bacteriological parameters. Biological data has been underutilized due to the highly specialized interpretation required and the difficulty in applying the data quantitatively. Notwithstanding this problem, with few exceptions, the most sensitive use of our water bodies is aquatic life. Therefore biological objectives need to be incorporated into the overall objectives development program.

In streams, benthic invertebrates have been accepted as a very important assessment tool. Considerable progress has been made in the development of benthic invertebrate indices, which can be incorporated into impact assessments and water quality objectives. On Vancouver Island, benthic sampling has been conducted at a limited number of sites, including Mercantile Creek, over the past three years. The dataset at present is too limited to be able to make a sound judgment as to the state of the ecosystem health. To be able to apply and test the benthic invertebrate approach, Vancouver Island regional staff will be collecting more data at a broad range of both reference and test sites. Once all the data has been compiled and analyzed, biological objectives and/or indices will be developed for those watersheds with water quality objectives, where possible.

8.0 SUMMARY OF PROPOSED WATER QUALITY OBJECTIVES AND MONITORING SCHEDULE

In BC, water quality objectives are based mainly on approved or working water quality guidelines. These guidelines are established to prevent specified detrimental effects from occurring with respect to a designated water use. Designated water uses for Mercantile Creek that are sensitive and should be protected are drinking water, aquatic life and wildlife. The water quality objectives recommended here (Table 13) take into account background conditions, impacts from current land use and any known potential future impacts that may arise within the watershed. These objectives should be periodically reviewed and revised to reflect any future improvements or technological advancements in water quality assessment and analysis

Table 13. Summary of water quality objectives for the Mercantile Creek Community Watershed.

Variable	Objective Value
Temperature	15°C (max)
Turbidity	5 NTU (max) 2 NTU (mean)
Non-filterable Residue (TSS)	26 mg/L (max) 6 mg/L (mean)
True Colour	15 TCU (max)
Total Organic Carbon	4.0 mg/L (max)
Dissolved Aluminum	0.10 mg/L (max) 0.05 mg/L (mean)
Escherichia coli	≤60 CFU/100 mL (90th percentile)

Note: all calculations are based on a minimum of 5 samples in 30 days

The recommended water quality monitoring program for Mercantile Creek is summarized in Table 14. It is recommended that future attainment monitoring occur once every 3-5 years based on staff and funding availability, and whether activities, such as forestry or land development, are underway within the watershed.

Table 14. Recommended water quality monitoring for the Mercantile Creek Watershed

Frequency and timing	Parameters to be measured
Mid-July to mid-August (low-flow season): five weekly samples in a 30-day period	pH, specific conductivity, TSS, turbidity, true colour, DOC, TOC, total phosphorus, dissolved metals, hardness, *E. coli*, and temperature
Approximately October to November (fall flush): five weekly samples in a 30-day period	pH, specific conductivity, TSS, turbidity, true colour, DOC, TOC, total phosphorus, dissolved metals, hardness, *E. coli*, and temperature
Once every five years	Benthic invertebrate sampling

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APPENDIX I. SUMMARY OF WATER QUALITY DATA

Table 15. Summary of general water chemistry at Site E230257, Mercantile Creek at District of Ucluelet intake.

	Min	Max	Average	Std. Deviation	No. of Samples
Fecal coliforms (CFU/100mL)	1	310	37	68	33
Total coliforms (CFU/100mL)	10	53	32	30	2
E. coli (CFU/100mL)	1	290	26	56	38
Streptococci (CFU/100mL)	1	55	21	28	5
Ammonia Dissolved (mg/L)	0.005	0.005	0.005		1
Carbon Dissolved Organic (mg/L)	0.5	10.0	2.5	1.9	32
Carbon Total Organic (mg/L)	2.7	3.3	3.0	0.4	2
Color True (Col.unit)	10	10	10		1
Nitrate (NO3) Dissolved (mg/L)	<0.002	0.670	0.156	0.102	42
Nitrate + Nitrite Diss. (mg/L)	0.013	0.669	0.158	0.102	42
Nitrogen - Nitrite Diss. (mg/L)	0.002	0.006	0.003	0.001	42
Nitrogen (Kjel.) Tot Diss (mg/L)	0.05	0.05	0.05		1
Nitrogen Organic-Total (mg/L)	0.05	0.05	0.05		1
Nitrogen Total (mg/L)	0.47	0.47	0.47		1
Nitrogen Total Dissolved (mg/L)	0.474	0.474	0.474		1
Ortho-Phosphate Dissolved (mg/L)	0.001	0.009	0.003	0.002	41
pH (pH units)	6.5	8.0	7.4	0.3	42
Phosphorus Tot. Dissolved (mg/L)	0.002	0.007	0.003	0.002	41
P--T (mg/L)	0.002	0.014	0.004	0.003	42
Residue Non-filterable (mg/L)	1	9	2	1	67
Specific Conductance (uS/cm)	25	64	44	11	42
Turbidity (NTU)	0.23	3.30	0.82	0.66	42
UV Absorbance 250nm (AU/cm)	0.03	0.27	0.11	0.07	13
UV Absorbance 254nm (AU/cm)	0.03	0.26	0.10	0.06	13
UV Absorbance 310nm (AU/cm)	0.01	0.13	0.05	0.03	13
UV Absorbance 340nm (AU/cm)	< 0.01	0.08	0.03	0.02	13
UV Absorbance 360nm (AU/cm)	< 0.01	0.06	0.02	0.01	13
UV Absorbance 365nm (AU/cm)	< 0.01	0.05	0.02	0.01	13
Ag-D (mg/L)	0.00002	0.00002	0.00002	0.00000	38
Ag-T (mg/L)	0.00002	0.00002	0.00002	0.00000	39
Al-D (mg/L)	0.0103	0.2910	0.0555	0.0522	38
Al-T (mg/L)	0.0163	0.4270	0.0796	0.0817	39
As-D (mg/L)	0.0002	0.0008	0.0005	0.0002	38
As-T (mg/L)	0.0002	0.0009	0.0006	0.0002	39
Ba-D (mg/L)	0.00104	0.00258	0.00184	0.00044	38

	Min	Max	Average	Std. Deviation	No. of Samples
Ba-T (mg/L)	0.0013	0.0028	0.0020	0.0004	39
Be-D (mg/L)	0.00002	0.00004	0.00002	0.00001	38
Be-T (mg/L)	0.00002	0.00003	0.00002	0.00000	39
Bi-D (mg/L)	0.00002	0.00002	0.00002	0.00000	38
Bi-T (mg/L)	0.00002	0.00013	0.00002	0.00002	39
Cd-D (mg/L)	0.00001	0.00013	0.00002	0.00002	38
Cd-T (mg/L)	0.00001	0.00016	0.00003	0.00004	39
Co-D (mg/L)	0.000005	0.000060	0.000021	0.000014	38
Co-T (mg/L)	0.000005	0.000114	0.000030	0.000024	39
Cr-D (mg/L)	0.0002	0.0004	0.0002	0.0000	38
Cr-T (mg/L)	0.0002	0.0005	0.0002	0.0000	39
Cu-D (mg/L)	0.00005	0.00471	0.00055	0.00076	38
Cu-T (mg/L)	0.00005	0.00561	0.00065	0.00088	39
Li-D (mg/L)	0.00005	0.00128	0.00012	0.00021	38
Li-T (mg/L)	0.00005	0.00165	0.00012	0.00026	39
Mn-D (mg/L)	0.00172	0.01050	0.00547	0.00264	38
Mn-T (mg/L)	0.0016	0.0163	0.0067	0.0034	39
Mo-D (mg/L)	0.00005	0.00030	0.00012	0.00007	38
Mo-T (mg/L)	0.00005	0.00026	0.00012	0.00007	39
Ni-D (mg/L)	0.00005	0.00039	0.00012	0.00010	38
Ni-T (mg/L)	0.00005	0.00206	0.00019	0.00033	39
Pb-D (mg/L)	0.00001	0.00024	0.00003	0.00004	37
Pb-T (mg/L)	0.00001	0.00026	0.00006	0.00005	38
Sb-D (mg/L)	0.000005	0.000047	0.000021	0.000010	38
Sb-T (mg/L)	0.000005	0.000097	0.000023	0.000016	39
Se-D (mg/L)	0.0002	0.0003	0.0002	0.0000	38
Se-T (mg/L)	0.0002	0.0005	0.0002	0.0001	39
Sn-D (mg/L)	0.00001	0.00013	0.00002	0.00002	38
Sn-T (mg/L)	0.00001	0.00013	0.00002	0.00002	39
Sr-D (mg/L)	0.011	0.034	0.022	0.007	38
Sr-T (mg/L)	0.0114	0.0361	0.0233	0.0076	39
Tl-D (mg/L)	0.000002	0.000016	0.000004	0.000003	38
Tl-T (mg/L)	0.000002	0.000021	0.000005	0.000005	39
U--D (mg/L)	0.000002	0.000014	0.000007	0.000003	38
U--T (mg/L)	0.000002	0.000033	0.000009	0.000007	39
V--D (mg/L)	0.00011	0.00042	0.00025	0.00007	38
V--T (mg/L)	0.00015	0.00051	0.00030	0.00009	39
Zn-D (mg/L)	0.0001	0.0066	0.0009	0.0012	38
Zn-T (mg/L)	0.0001	0.0042	0.0009	0.0009	39

APPENDIX II. SUMMARY OF TURBIDITY EVENTS > 0.5 HOURS IN DURATION MEASURED BY AUTOMATED STATION

Start Date	Start Time	Recovery Time (hrs)	Duration of event (h)	Max turb (NTU)	Min turb (NTU)	Avg. turb (NTU)	St.Dev.
19/07/2004	07:15	571	1	8.5	4.5	6.5	1.6
21/08/2004	11:15	247.5	2	12.9	5	8.6	2.4
24/08/2004	21:30	80.5	3.5	15.1	3	8.8	3.6
10/09/2004	16:30	399.75	8.5	37	2.4	14.5	8.6
16/09/2004	09:15	34	1.75	6.8	3.1	5.5	1.2
22/09/2004	03:30	136.75	4.25	9.7	4.2	7.3	1.6
05/10/2004	13:15	72.5	2	8.8	3.1	6.4	1.9
08/10/2004	02:30	59.5	4.25	11.2	3.5	8.6	2.3
22/10/2004	03:15	332.25	2.75	12.8	5	9.0	2.4
24/10/2004	23:45	66	0.75	5.5	2.5	4.4	1.6
25/10/2004	00:30	0.25	1.5	6.4	5	5.5	0.5
25/10/2004	12:45	1	5.25	12.8	4.2	8.7	2.7
25/10/2004	04:15	2.5	7.25	30.8	3.4	14.1	8.5
29/10/2004	19:15	97.5	2	7.2	4.8	6.0	0.8
01/11/2004	15:45	2	0.75	8.1	3.8	5.7	2.2
01/11/2004	23:00	0.75	0.75	27.6	2.2	12.0	13.7
01/11/2004	08:00	33.5	1	5.6	3.4	4.9	1.0
02/11/2004	00:30	0.5	0.75	5.9	3.7	4.9	1.1
02/11/2004	04:00	1.75	0.75	7.2	2.3	4.9	2.5
02/11/2004	08:15	0.75	0.75	19.5	1.2	8.7	9.6
02/11/2004	20:30	0.25	0.75	7.5	0.6	5.1	3.9
05/11/2004	18:15	62	3	25.3	0.2	10.8	7.0
05/11/2004	21:15	0.25	9.5	28.6	0	9.6	4.8
06/11/2004	15:15	8.25	18.75	14	4.4	8.8	2.5
07/11/2004	10:00	0.25	3.75	8.4	4.8	6.8	1.2
14/11/2004	12:45	166.75	3.25	9.2	3.9	6.9	1.6
15/11/2004	00:15	8.5	6.25	16.1	4.5	10.5	3.8
17/11/2004	23:00	64.75	1	5.8	3.9	5.2	0.9
24/11/2004	21:15	0.5	0.75	5.1	4.7	5.0	0.2
24/11/2004	19:00	0.5	2	6.4	4.8	5.5	0.5
24/11/2004	03:00	147.25	15.75	18.4	4.7	11.1	3.6
29/11/2004	13:00	111.25	3.25	9.6	3.2	7.5	1.9
03/12/2004	13:45	93.75	4.5	8.4	5	7.0	1.1
04/12/2004	23:15	29.25	0.75	49.3	0.6	18.7	26.7
10/12/2004	15:00	0.5	0.75	6.1	4.3	5.2	0.9
13/12/2004	17:30	74	5	12.5	5	8.3	2.6
18/12/2004	00:15	0.5	0.75	6.2	2.3	4.8	2.1
18/12/2004	01:00	0.25	0.75	6.4	1.5	4.4	2.6
18/12/2004	05:15	0.75	0.75	5.9	2.3	4.5	1.9
19/12/2004	12:15	0.75	0.75	6.1	2.8	4.7	1.7
21/12/2004	05:00	0.25	1	6.2	4.5	5.5	0.7
24/12/2004	17:00	0.25	0.75	5.7	4.7	5.3	0.6
24/12/2004	21:30	0.5	14	30.3	2.1	11.7	5.1
25/12/2004	11:30	0.25	0.75	6.2	5	5.5	0.6

Start Date	Start Time	Recovery Time (hrs)	Duration of event (h)	Max turb (NTU)	Min turb (NTU)	Avg. turb (NTU)	St.Dev.
16/01/2005	22:45	536.75	28	47.6	3.3	17.0	12.4
18/01/2005	16:45	1	2.75	7.2	4.9	6.1	0.8
18/01/2005	09:00	6	7	81.3	4.3	12.3	15.0
18/01/2005	20:00	0.75	26.25	21.4	4.8	11.3	3.6
20/01/2005	14:45	1.25	1	5.6	4.8	5.2	0.3
20/01/2005	15:45	0.25	2.25	5.9	5	5.4	0.3
20/01/2005	02:15	4.25	8.25	14.3	4.4	8.0	2.8
21/01/2005	19:30	25.75	82	1346	4	52.4	140.2
25/01/2005	12:45	0.25	0.75	5.9	5	5.3	0.5
25/01/2005	19:00	0.25	0.75	7.2	4.8	5.7	1.3
25/01/2005	05:30	0.25	1.5	5.9	4.8	5.5	0.4
25/01/2005	10:45	0.5	2	6.3	3.9	5.3	0.7
25/01/2005	16:00	0.5	2.25	6.4	4.8	5.5	0.5
25/01/2005	07:15	0.5	3.25	6	4.9	5.5	0.4
26/01/2005	06:00	2.25	0.75	6.4	3.2	5.3	1.8
26/01/2005	16:00	1.5	0.75	8.4	4.7	6.3	1.9
26/01/2005	21:15	0.25	0.75	6.9	3.7	5.3	1.6
26/01/2005	23:45	0.75	0.75	6.8	3.9	5.4	1.5
26/01/2005	17:00	0.5	1	6.4	4.1	5.6	1.0
26/01/2005	19:15	0.25	1	7.3	2.4	6.0	2.4
26/01/2005	20:15	0.25	1	10.3	4.7	6.8	2.5
30/01/2005	05:15	0.5	0.75	9.8	4.9	6.6	2.8
30/01/2005	03:30	0.75	1.5	9	4.9	6.7	1.5
30/01/2005	06:00	0.25	4.25	12.3	3.7	8.7	2.0
30/01/2005	10:15	0.25	20.25	22.7	4.7	11.3	4.0
31/01/2005	11:00	0.25	0.75	7.2	3.2	5.2	2.0
31/01/2005	09:00	1.25	1	8.4	4.2	6.8	1.9
31/01/2005	10:00	0.25	1	11.9	3.9	7.2	3.4
31/01/2005	06:30	0.25	1.5	11	4.5	8.0	2.3
02/02/2005	02:30	0.5	0.75	11.9	4	7.0	4.3
02/02/2005	04:00	1	0.75	10.1	1.4	6.5	4.5
02/02/2005	05:45	1.25	0.75	8.8	1	6.2	4.5
02/02/2005	07:30	0.25	0.75	10.4	4.1	6.6	3.4
02/02/2005	17:30	1.5	0.75	12.2	0.8	6.7	5.7
02/02/2005	06:30	0.25	1	6.4	2	5.0	2.1
02/02/2005	08:45	0.75	1	11.6	2.2	7.6	4.2
02/02/2005	10:30	1	1	11.1	0.8	6.5	4.3
02/02/2005	15:15	0.5	1	10.2	3.3	7.0	2.8
02/02/2005	11:30	0.25	1.25	15.1	2	7.6	4.7
03/02/2005	15:00	0.25	0.75	8.9	5	6.6	2.1
03/02/2005	17:00	0.25	0.75	24.2	4.5	13.0	10.1
03/02/2005	16:00	0.5	1	16.1	4.6	11.2	5.7
03/02/2005	12:00	0.25	2	17.3	3.7	11.7	4.9
03/02/2005	06:45	0.5	4.75	27.3	3.7	12.7	6.0
04/02/2005	00:30	1.75	0.75	10.5	1.3	5.7	4.6
04/02/2005	06:30	0.75	0.75	8.5	4.5	6.5	2.0
04/02/2005	09:00	0.5	1.5	15	2.4	7.9	4.6

Start Date	Start Time	Recovery Time (hrs)	Duration of event (h)	Max turb (NTU)	Min turb (NTU)	Avg. turb (NTU)	St.Dev.
28/02/2005	21:00	404.25	1	6.3	4.6	5.4	0.7
01/03/2005	02:45	5	13	25.5	4.6	13.2	6.6
05/03/2005	17:30	98	2.25	7.9	4.9	6.2	0.9
08/03/2005	08:15	24.5	2.25	7.2	4.3	6.1	0.8
08/03/2005	20:45	10.5	2.25	7.8	5	6.3	1.0
26/03/2005	14:15	0.5	0.75	5.1	5	5.1	0.1
26/03/2005	01:00	71.75	13	38	4.6	16.6	9.5
29/03/2005	00:15	57	2	8.3	4.7	6.8	1.2
31/03/2005	05:00	51	28.75	25.3	4.1	11.9	5.5
02/04/2005	22:15	35	6.75	13.6	4	8.2	2.1
05/04/2005	19:00	5.75	7	12	4.5	7.6	1.7
06/04/2005	02:00	0.25	1	5.3	4.8	5.1	0.2
06/04/2005	16:15	10.25	10.5	19.1	4.9	10.7	4.3
10/04/2005	16:15	84.5	8	13	4.8	7.4	2.1
15/04/2005	06:15	0.25	0.75	11.9	5	8.0	3.5
15/04/2005	03:30	0.25	2.75	11.5	4.3	7.8	1.8
15/04/2005	23:15	16.5	7	20.7	4.5	11.4	5.0
15/05/2005	03:15	356.75	3	11.1	4.4	7.5	2.0
18/05/2005	07:15	0.25	0.75	6.5	4.5	5.4	1.0
18/05/2005	08:00	0.25	2.25	6.6	4.7	6.0	0.6