Water Quality in the Georgia Basin 2003 to 2007

Ayisha Yeow, Stephanie Strachan,
Sheena Pappas and Andrea Ryan

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Executive Summary

Ecosystem Goal

The Georgia Basin Action Plan (GBAP) began in 2003 and is a multi-partnered initiative working to improve sustainability in the Georgia Basin. One of the goals of GBAP is to protect aquatic ecosystem health in the Georgia Basin. The GBAP is also interested in increasing our understanding of the sources, distribution and impacts of toxic substances. As one of the partners of GBAP, Environment Canada is committed to attaining the highest level of environmental quality to preserve the Georgia Basin ecosystem. In this report, physical-chemical and biological water quality indicators—as determined by the Canadian Council of Ministers of the Environment (CCME), Water Quality Index (WQI) and the Canadian Aquatic Biomonitoring Network (CABIN) program—are reported to indicate how close we are to achieving these goals. The results in this report are specific to watersheds in the Georgia Basin.

Water Quality Index

The WQI currently used as the Canadian Freshwater Quality Indicator, allows experts to translate large amounts of complex water quality data into a simple overall rating (**Excellent, Good, Fair, Marginal** or **Poor**) at a given location for a specific time period. Nationally, the indicator is intended to incorporate environmental values into decision making frameworks. It is currently endorsed by the CCME to report on water quality in Canada.

Canadian Aquatic Biomonitoring Network

CABIN provides standardized sampling methods and analytical procedures to produce a freshwater ecosystem health indicator based on the benthic macroinvertebrate community. This approach is used nationally by all CABIN participants. The indicator is intended to be used as a screening tool, thereby enhancing traditional water quality monitoring programs by verifying physical-chemical assessments or identifying aquatic ecosystem health problems that were not detected by physical-chemical measurements.

The CABIN approach compares the benthic macroinvertebrate community at a location of interest to a range of reference communities that are predicted to be similar based on empirical models. These empirical models relate habitat characteristics to biological communities. The assessment defines four categories of freshwater ecosystem health based on the divergence from the expected community (**Similar to Reference, Mildly Divergent, Divergent** and **Highly Divergent**). The more different the benthic community at a station is from what is expected, the more environmental stress is assumed to be exerted on that freshwater ecosystem. The CABIN data were analysed using an empirical model developed specifically for the Fraser River Basin and the Georgia Basin.

Data Sources

This report is based on data collected from 2003 to 2007. Water chemistry at all sites was sampled at two-week intervals under the Canada-British Columbia Water Quality Monitoring Agreement. The benthic macroinvertebrate community was sampled once per year at each site by Environment Canada. These water quality monitoring programs play an important role in determining long-term trends in freshwater quality and in identifying emerging ecosystem concerns. Data from these programs are available at www.ec.gc.ca/eaudouce-freshwater and www.ec.gc.ca/rcba-cabin.

Water Bodies Considered

Twelve rivers and streams in the Georgia Basin are included in this report: three from the Upper Cheakamus River, three from the Lower Fraser River and six from Vancouver Island. Most of these stations were chosen because of various human activities in the watersheds, such as agriculture, dams, industrial plants, hatcheries, logging, mining, recreation, and urban development. Two of these stations were chosen to represent relatively undeveloped watersheds.

Ranking Overall Water Quality

Together, water quality and biological assessments are used to indicate general water quality condition. Of the 12 stations monitored from 2003 to 2007, six streams were similar and generally ranked water quality and biological assessments as **Excellent/Good**, and **Similar to Reference/Mildly Divergent**, respectively.

In four streams, water quality assessments indicated **Fair/Marginal** conditions, while the biological assessment indicated that these stations were **Similar to Reference/Mildly Divergent**. At these particular locations, the biological communities were more pollution-tolerant than the expected communities at other locations. Therefore the biological assessments were not sensitive to the stressors driving the water quality (i.e. elevated nutrients).

Conversely for two stations, water quality assessments indicated **Excellent/Good** conditions while biological assessments indicated **Highly Divergent/Divergent** conditions. At these locations, the biological indicator was detecting effects from habitat disturbance that were not detected by physical-chemical measurements.

Future Directions

Regular water quality monitoring will continue through the Federal Provincial Water Quality Monitoring Network to assess long term status and trends and to contribute to National WQI Canadian Environmental Sustainability Indicators reporting, as part of the initiative. Biological monitoring by Environment Canada will move to a three-year cycle at these stations beginning in 2008.

Sommaire exécutif

French

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Introduction

Figure 1. The Georgia Basin, located in southwestern British Columbia.

The Georgia Basin is located in southwest British Columbia and includes watersheds on the B.C. mainland and Southern Vancouver Island, draining into the Straits of Georgia and Juan de Fuca, as shown in Figure 1. The geographical basin was defined by the Georgia Basin Action Plan (GBAP), which was started in 2003 as a multi-partnered ecosystem initiative working to improve sustainability in the Georgia Basin. Key activities of this initiative included measuring and reporting progress in ecosystem health indicators, including water quality. Environment Canada, in partnership with British Columbia Ministry of Environment (BCMOE), enhanced its water quality monitoring network in the Georgia Basin. In addition to increased physical-chemical monitoring, an annual biological monitoring component was implemented to provide a more comprehensive picture of the status of freshwater quality in the basin.

In this report, we present the status and trends in water quality for several streams and rivers in the Georgia Basin, based on physical-chemical parameters and benthic macroinvertebrate communities measured between 2003 and 2007.

Background

Water Quality Monitoring Program Description

As part of Canada's national water quality monitoring program, water quality monitoring in B.C. is primarily achieved through a network jointly operated by Environment Canada and BCMOE, under the Canada-British Columbia Water Quality Monitoring Agreement. Water quality samples are collected on a routine basis throughout the year.

The network was initially established to assess long-term changes in physical-chemical water quality through trend assessment, but the data are also used for a range of other purposes including status and environmental assessments, formulating water quality guidelines and objectives for protecting water uses, assessing compliance with existing guidelines and objectives, calculating contaminant loadings, evaluating the effectiveness of government policies and programs, planning water resource initiatives and detecting emerging issues. The current (2010) federal-provincial network consists of 39 water quality monitoring stations in B.C.; an additional six stations are operated in partnership with Parks Canada.

Twelve of the above mentioned federal-provincial stations are located in the Georgia Basin. Most are sampled every two weeks for a range of water quality variables including trace metals, nutrients, major ions, fecal coliform bacteria, and other variables of site-specific importance (e.g. dissolved oxygen and microbiological indicators such as E.Coli).

CABIN provides nationally standardized protocols for the collection and identification of benthic macroinvertebrates as well as associated water quality and aquatic habitat information, a national training program, and shared online data management and reporting.

Canadian Aquatic Biomonitoring Network Description

Biological monitoring in the Georgia Basin is conducted as part of the Canadian Aquatic Biomonitoring Network (CABIN), a collaborative program for the collection, assessment, reporting and distribution of biological information in Canada (www.ec.gc.ca/rbca-cabin). This type of monitoring assesses the condition of the aquatic ecosystem, including water quality, by observing and measuring the benthic macroinvertebrate community response to its environment. Benthic macroinvertebrates are the insects and other animals that live at the bottom of streams and rivers (Figure 2).

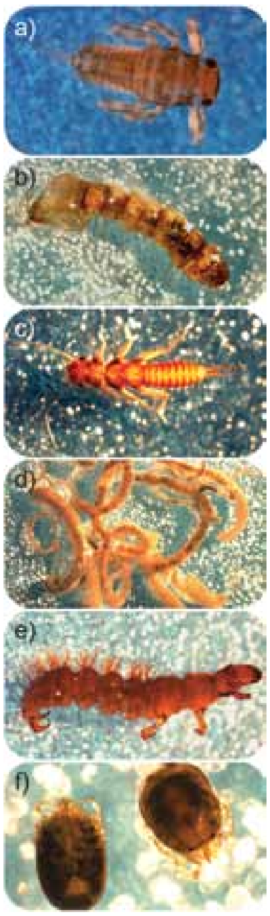


Figure 2. Examples of common benthic macroinvertebrates:
a) mayfly (Ephemeroptera larvae)
b) midge (Diptera larvae)
c) stonefly (Plecoptera larvae)
d) worms (Clitellata)
e) caddisfly (Trichoptera larvae) and
f) mites (Arachnida).

Using the Reference Condition Approach, CABIN assesses the condition of benthic macroinvertebrate communities. This is achieved by establishing a baseline of reference communities located at relatively undisturbed sites in a basin. Reference site data (such as biological and habitat data) are used to develop a model that predicts an expected biological community based on habitat characteristics. This model is then applied to data from a potentially impacted or "test site". The difference between the expected biological community, based on reference conditions (as predicted by the model), and the community actually observed at a test site is evaluated. This determines whether the test site is similar to reference sites, or divergent, thus assumed to be impacted. The degree of divergence represents the degree of impact (Rosenberg et al., 1999).

The CABIN program has focused on using benthic macroinvertebrates to conduct biological monitoring. Sampling is conducted annually in late summer or early fall. In many cases, these macroinvertebrates live in streams for up to three years, before they emerge and become adult insects. Different insects emerge at different times of the year, therefore it is important to sample at the same time every year to avoid confounding seasonal effects. Other macroinvertebrates live in the streams their entire life. In general, macroinvertebrates are relatively sedentary and are found everywhere, making them easy to collect. Benthic macroinvertebrates reflect cumulative effects of a variety of environmental stressors over their life cycle, and therefore are excellent indicators of ecosystem health.

Water Quality and Biological Assessments

There are several reasons for conducting both physical-chemical and biological monitoring of water quality. For example, physical-chemical monitoring only provides a snapshot of conditions at the time of sampling. Water quality is variable, changing with flow, land use activity and weather conditions over time. Pulses of contaminants that may acutely affect aquatic biota can pass quickly through a stream, and may not be captured by routine water sampling. In addition, mixtures of pollutants can have synergistic or antagonistic effects on aquatic biota that can't be predicted by comparison of single chemical concentrations to their respective toxicity criteria or guidelines.

Limitations also exist when relying on biological monitoring as the only indicator of water quality. No single group of organisms can be the most sensitive to all classes of contaminants, however most biological organisms are affected in some way. For example, algae may be more sensitive to nutrient contamination than benthic macroinvertebrates, while benthic macroinvertebrates can still detect nutrient impacts but at higher concentrations. In addition, impairment of benthic macroinvertebrate communities does not always reflect chemical water quality impairment; rather it can reflect impairment to aquatic ecosystem health from disturbances to the physical environment.

Biomonitoring can verify or complement water quality monitoring based on physical-chemical measures. It can be used to confirm water quality assessments, identify concerns not detected by water sampling (such as habitat degradation, extreme water quantity fluctuations or exotic species) and provide an integrated assessment of water quality condition over time. Together, these two types of monitoring provide a more comprehensive depiction of the aquatic ecosystem health.

Typical Physical – Chemical Water Quality and Biological Variables Assessed in this Report

Physical Variables:
flow, turbidity, specific conductance, pH and water temperature

Chemical Variables:
metals, nitrogen, phosphorus, chloride, dissolved oxygen and alkalinity

Biological Variables:
fecal coliform bacteria and benthic macroinvertebrates

Methods

Water Quality

Water Quality Sample Collection

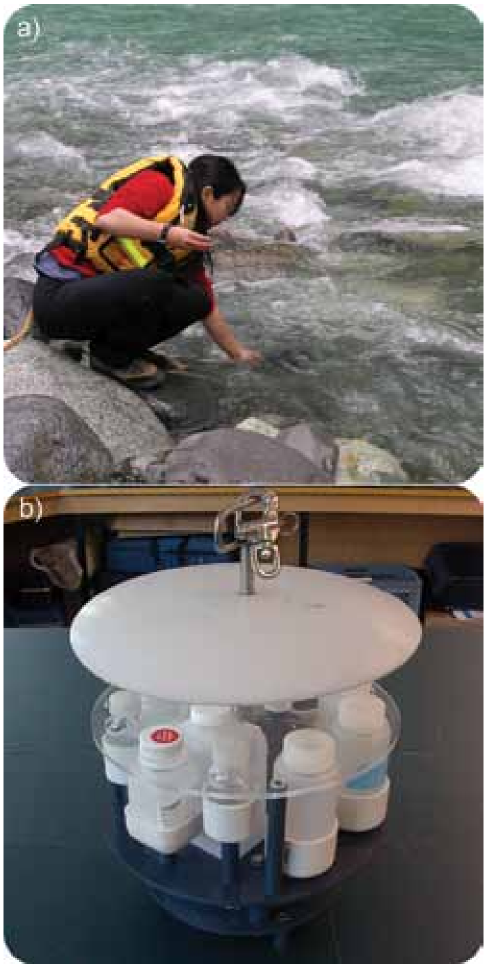


Figure 3. a) Shore water sample collection b) Multi-sampler used to collect water samples from bridges.

Grab samples from each station were collected every two weeks and analysed for trace metals, nutrients, major ions, fecal coliform bacteria and other variables of site-specific importance. In addition to these regular samples, field blanks and replicates were processed three times a year for quality assurance purposes.

Samples were usually collected at the same time on the same day of the week every two weeks. Collection was primarily carried out by trained contractors that are audited by either BCMOE or Environment Canada staff at least once per year to ensure quality control and safety. Field measurements such as air temperature, water temperature, dissolved oxygen, weather and other observations, as well as sample date and time were all recorded at the time of sampling.

Water samples were collected in accordance with the sampling protocols described in *Water Sampling Procedures, Safety and Quality Assurance* (Ryan et al., 2005). Two collection methods were used, depending on access; bridge sampling, or sampling from shore.

Samples obtained from bridge sites were collected using a multi-sampler (Figure 3). Wading and shore samples were collected by submerging and filling sample bottles while standing perpendicular to the flow, facing upstream. Bottles were packed immediately after sample collection. Samples were kept cool and shipped by courier to the laboratory within 48 hours. Dissolved oxygen samples were collected and tested in the field using the LaMotte Dissolved Oxygen sampler and kit.

Analysis of Water Quality Samples

Water samples were prepared and analysed at either Maxxam Analytics in Burnaby, B.C. or at the National Laboratory for Environmental Testing (NLET) in Burlington, Ontario. Both labs are accredited under the Canadian Association for Environmental Analytical Laboratories Incorporated Field and laboratory analytical methods, and method detection limits are outlined in Appendix 1.

Validation and Approval of Water Quality Data

Data were validated according to the procedures outlined in the Canada-British Columbia Water Quality Monitoring Agreement *Data Approval Protocol* (Pommen et al., 1991). The five most recent years of data for each station were graphed against time. Applicable water quality guidelines/objectives for the protection of aquatic life, as well as field blanks and replicates were included on each graph. Outliers were then identified, verified with the laboratory reports and evaluated relative to field comments. Verification with the laboratory report ensured that the data were correctly entered into the database. Field comments were reviewed to help explain anomalous values or identify potential sources of contamination or error. Field replicate and blank data were reviewed to ensure that program data quality objectives were met.

Water Quality Assessment

Water Quality Index

The Water Quality Index (WQI) is a communication tool that allows experts to translate large amounts of complex water quality data into a simple overall rating at a given location and for a specific time period. The outcome or score of the WQI is based on compliance with selected water quality guidelines and provides a description of overall water quality condition (Table 1).

The WQI is calculated based on variables that characterize and/or may be of concern at a particular station. It considers three factors: the number of water quality variables not meeting guidelines, the number of times the guidelines are not met and the extent to which the guidelines are not met.

In this report, the WQI was calculated on an annual basis for data collected between January and December.

Table 1. CCME WQI categories, scores and descriptions.

WQI	Description
Excellent (95-100)	Indicates that water quality measurements never or very rarely exceed water quality guidelines. Aquatic life is not threatened or impaired.
Good (80-94)	Indicates that measurements rarely exceed water quality guidelines and, if so, usually by a narrow margin. Aquatic life is protected with only a minor degree of threat or impairment.
Fair (65-79)	Indicates that measurements sometimes exceed water quality guidelines and, possibly, by a wide margin. Aquatic life is protected, but at times may be threatened or impaired.
Marginal (45-64)	Indicates that measurements often exceed water quality guidelines by a considerable margin. Aquatic life frequently may be threatened or impaired.
Poor (0-44)	Indicates that measurements usually exceed water quality guidelines by a considerable margin. Aquatic life is threatened, impaired or even lost.

(modified from CCME, 2001)

Guidelines

The application of the WQI uses a variety of water quality guidelines to protect aquatic life. In the freshwater environment aquatic life may include but is not limited to fish, invertebrates and aquatic plants. Guidelines are specific limits developed for water quality variables by the Canadian Council of Ministers of the Environment (CCME) or the BCMOE.

Site specific guidelines (SSGs) are science based limits developed by regional water quality specialists that have site specific knowledge of the river. They take into account the local water quality conditions and establish a reference against which the state of water quality at that site can be compared.

Elevated nutrient levels in aquatic ecosystems are considered non-toxic stressors but can lead to significant changes in the trophic status of rivers (Chambers et al, 2006). It is therefore important to include nutrients in the WQI. Figure 2 summarizes a tiered approach for evaluating phosphorus concentrations. Using the approach, trophic

Table 2. Canadian trigger ranges for total phosphorus.

Trophic Status	Canadian Trigger Ranges Total Phosphorus (mg/L)
Oligotrophic	< 0.025
Mesotrophic	0.025 – 0.075
Eutrophic	> 0.075

(modified from GC, 2008)

status is defined by ranges of total phosphorus concentrations. These values are used as phosphorus guidelines in the WQI calculations.

Guidelines used to calculate the WQI are selected on a station-specific basis from recommended CCME, BCMOE, or site-specific guidelines. Guidelines used to calculate the WQI for each station are presented in Appendix 2.

Seasonality and Trend Analysis

Trend analysis was conducted at monitoring stations with a minimum of eight years of data. Natural changes in water chemistry through the year correspond largely to changes in the hydrologic regime within a basin. Seasons were defined by examining hydrologic patterns and observed water quality concentration patterns.

Streamflow of pacific coastal streams is highly variable, depending on whether the precipitation in the basin falls as rain or snow. At higher elevations precipitation in the winter is stored in the snowpack and glaciers. Runoff from melting snowpack typically peaks in the spring and early summer whereas runoff from glaciers peak during July and August, the warmest periods of summer. At lower elevations most of the precipitation is rain occurring between October and March. Peak flows are generated by single strong storm events or successive moderate storm events that occur over several days (Naiman and Bilby, 2001).

Water quality data is seasonal by nature so the Seasonal Kendall test which performs the Mann-Kendall (MK) trend test for individual seasons of the year was performed on regular data as well as flow-adjusted data. Flow-adjusting data before trend analysis removes flow effects and helps to determine the magnitude and statistical significance of trends which are not explained by flow.

Summary Statistics and Status

Status summaries were generated for monitoring stations with less than eight years of data. Variables of concern at each station were selected based on potential site-specific impacts. Summary statistics were calcualted, including: sample size, mean, median, maximum, minimum, standard deviation and 90th and 10th percentile values. Additionally, box plots were generated and examined for the WQI reporting period. Detailed summary statistics are presented in Appendix 3.

Why analyse for water quality trends?

- To determine whether the water chemistry is changing through time or if there are any emerging issues.
- To determine if observed changes are attributable to natural patterns or anthropogenic influences
- Observed changes in water chemistry could affect the biological integrity of the aquatic ecosystem

Variables used to calculate the WQI and for trend analysis in this report are described below:

Alkalinity indicates the amount of acid (e.g., from acid rain or pollutants) that can be added to water before the pH changes. Large changes in water pH will harm aquatic life. In natural systems carbonates and bicarbonates enter the water through the erosion of rocks high in calcium carbonate. When high concentrations of carbonates occur, as in *hard water*, the stream is said to have a high buffering capacity and is less sensitive to acid inputs. *Soft water*, with lower carbonate concentrations, has a low buffering capacity and can be highly sensitive to acid inputs.

pH is the measure of the hydrogen ion activity in a solution. The lower the pH, the more acidic the solution. Most aquatic organisms have adapted to life at very specific pH ranges and may suffer from slight changes in pH. The optimum pH range for most aquatic life is between 6.5 and 9. pH also affects the solubility and bioavailability of other substances such as metals, which become more toxic when dissolved in water.

Chlorides are salts resulting from the combination of chlorine and a metal. They can enter surface water through road salt run-off, industrial effluent, sewage, irrigation, inorganic fertilizers, certain animal feeds and seawater intrusions in coastal areas. In addition, chlorine remains the most commonly used drinking water disinfectant in Canada. In aquatic organisms, exposure to elevated levels of chloride in water can disrupt osmoregulation, leading to impaired survival, growth or reproduction.

Dissolved oxygen is needed for respiration by all aquatic life. Flowing water contains higher dissolved oxygen concentrations than standing water because more water gets circulated to the surface where it absorbs more oxygen from the air. Microbes use dissolved oxygen to decompose organic matter, therefore high levels of organic matter can lead to low oxygen in streams. Low dissolved oxygen levels can lead to increased mortality of fish eggs or severely stress aquatic life. Oxygen levels are also affected by temperature, salinity and atmospheric pressure.

Phosphorus is one of the key elements necessary for growth of plants and animals. Phosphorus is naturally occurring in rocks, animal waste, plant material and in the atmosphere. High levels of phosphorus can increase vegetation growth causing an imbalance of production versus consumption of living plants and algae in an ecosystem. This process is called eutrophication and can eventually lead to decreased dissolved oxygen levels, suffocation of fish and other aquatic life. Human activities such as the discharge of sewage effluent and run-off from residential and agricultural lands can cause eutrophication.

Nitrogen is the most abundant element in the ecosystem. Approximately 80% of the air we breathe contains nitrogen. It is essential for many biological processes in plants and animals. Organic nitrogen in animals is found in all amino acids that make up proteins, DNA and RNA. Like phosphorus, large amounts of nitrogen in the aquatic ecosystem can lead to eutrophication.

Metals occur naturally in the environment, leaching into water from rocks and soil. Living organisms need varying amounts of metals such as iron, manganese, zinc, molybdenum, copper and cobalt to survive, however high levels of these metals will become toxic to the organism. Other metals such as lead, cadmium and vanadium are toxic to organisms. Metal pollution can arise from mining and smelting operations and urban runoff.

Water temperature is important as most aquatic organisms are cold blooded, meaning they are unable to regulate their core body temperature. Fish, insects, zooplankton, phytoplankton and other aquatic species all have optimal temperature ranges. Temperatures which are too far above or below this range can result in the death of species. As temperature increases, the rate of chemical reactions increases which in turn affects the biota. For example warmer water holds less dissolved oxygen than colder water, thereby reducing its ability to sustain aquatic life.

Specific conductance is a measure of the ability of water to conduct an electrical current. This directly depends on the amount of dissolved solids (such as salts) in the water. Monitoring dissolved ions is a good way to note changes in aquatic ecosystems quickly. Human activities such as discharging wastewater and producing agricultural and urban run-off cause increased specific conductance.

Turbidity is a measure of particulate matter in water. Clay, silt, organic and inorganic matter, plankton and microorganisms can all cause water to be turbid. In aquatic ecosystems high turbidity can affect light penetration thus reducing plant growth, and can smother benthic habitats. Turbidity associated with fine sediments can clog gill structures in aquatic organisms and affect particle feeders. High turbidity can be caused by soil erosion from agricultural and urban run-off, removal of riparian vegetation, channelization, dredging and eutrophication.

Fecal coliform bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm blooded animals, and enter water bodies from human or animal waste. Although fecal coliform bacteria do not directly affect aquatic life, they can affect human health and are an indicator of poor water quality. Agricultural run off and wastewater treatment plants are sources of fecal coliform bacteria.

Biological Water Quality

Benthic Macroinvertebrate Sample Collection

Figure 4. Kicknet sampling path in an upstream direction through the sampling reach.

Benthic macroinvertebrate samples and habitat variables were collected following the standardized protocols of the CABIN program (Reynoldson et al., 2001). Macroinvertebrates were collected using a 400 µm mesh triangular kicknet and kicking up the substrate while travelling in a zig-zag, upstream direction for a standardized period of three minutes (Figure 4).

In addition to macroinvertebrate samples, several habitat variables were measured at the stations. These included map-scale variables such as latitude and longitude, and reach-scale variables such as type of vegetation present and canopy coverage, as well as types of aquatic habitats and macrophyte coverage. Ecoregion and stream order were determined for each station. A channel survey was conducted at a single cross section and slope, depth, width and velocity were measured. Substrate size and embeddedness characteristics were also recorded.

Analysis of Benthic Macroinvertebrate Samples

Benthic macroinvertebrate samples were preserved using 10% buffered neutral formalin in the field and transferred to 70% ethanol upon arrival at the taxonomy laboratory. The samples were subsampled to 300 organisms using a Marchant subsampler (Marchant, 1989) consisting of a box of 100 cells in which the sample is evenly distributed. Cells were randomly picked for organisms until 300+ organisms were acquired. All organisms were identified to the lowest possible taxonomic level (usually genus level) and entered into the web accessible CABIN database (www.ec.gc.ca/rcba-cabin). Sample processing and enumeration procedures were conducted according to standardized CABIN protocols (Reynoldson et al., 2001).

Interpretation of Benthic Macroinvertebrate Data

Biological assessments were performed using the online CABIN analytical tools (www.ec.gc.ca/rcba-cabin). The Reference Condition Approach (RCA) (Bailey et al., 2004) is the basis for the CABIN assessments (Rosenberg et al., 1999). The initial development of the RCA model for the Fraser River was conducted by Rosenberg et al. (1999) and later expanded to include the Georgia Basin by Sylvestre et al. (2005).

The RCA incorporates benthic macroinvertebrate community information collected from a wide range of reference or minimally disturbed sites throughout a catchment or region, in this case

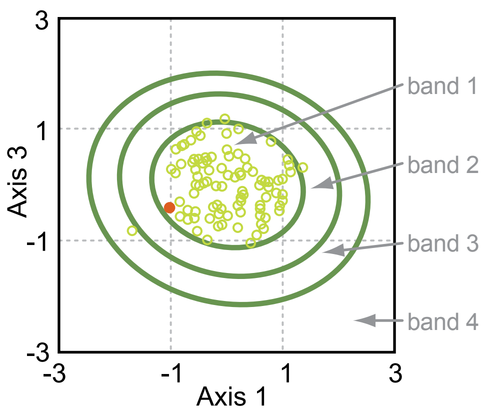


Figure 5. Example plot of benthic macroinvertebrate reference and test communities based on similarity.

the Fraser River and Georgia Basin. Using multivariate statistical techniques, a predictive assessment model is developed from the reference data which defines the relationship between the macroinvertebrate communities and the habitat variables. The macroinvertebrate communities are classified into groups of similar assemblages. Habitat characteristics which best discriminate between these groups are the predictor variables used in the model.

To assess a site, the model uses habitat information from the test site community to predict to which group of reference sites it should be most similar. The CABIN assessment compares the observed test site community to a group of reference sites (range of expected communities), based on the habitat features of the test site. The five reference groups for the Fraser River Georgia Basin model from Sylvestre et al. (2005) are described below.

The assessment is displayed as a multi-dimensional scaling (MDS) ordination plot of the macroinvertebrate communities and their similarity to each other based on the Bray-Curtis dissimilarity measure (Figure 5). The degree of impairment is based on the distance between test sites and the range of reference sites. The closer the test site community falls to the cloud of reference sites, the more similar the test site is to reference conditions. Conversely, the further the test site is from the cloud of reference sites, the more different it is. Confidence ellipses, similar to confidence intervals, are drawn around the reference sites to define bands of divergence. Definitions of these confidence ellipses or bands are described in Table 3. All points within a MDS ordination affect the final plot, therefore assessment bands are assigned by plotting only the test site from a given sampling year with the predicted reference group. Samples from the same site in different years are plotted individually for the determination of the assessment. A summary of the yearly assessments is provided for each site. Individual yearly ordination plots are not provided in this report.

Table 3. Confidence band descriptions used in CABIN assessments.

CABIN Assessment	Description
Band 1: **Similar to Reference** (< 90% probability)	The benthic community is assumed to be unstressed by the environment because it is similar to the reference communities
Band 2: **Mildly Divergent** (90-99% probability)	The benthic community is assumed to be only possibly stressed by the environment as some reference sites are also found in this band.
Band 3: **Divergent** (99-99.9% probability)	The benthic community is assumed to be stressed by the environment as it is different from the reference communities.
Band 4: **Highly Divergent** (> 99.9% probability)	The benthic macroinvertebrate community is assumed to be severely stressed by the environment as it is very different from the reference communities.

Reference Group 1: This group is composed of 91 sites. It is characterized by headwater streams with steep slopes, fast velocities, large cobble substrates and lower alkalinities. These sites are widely distributed within the Fraser and Georgia basin. A large proportion of sites are situated in the Pacific Ranges Ecoregion. Benthic communities in this reference group are generally dominated by EPT taxa–mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera)–with relatively even distribution among these taxa and low total abundances.

Reference Group 2: This group is composed of 16 sites from large streams with large cobble substrates and greater proportions of sand in the stream bottoms. Streams are primarily located in the upper mainstem of the Fraser River but are also found elsewhere in the basin. Benthic communities in this reference group are dominated by stonefly (Plecoptera) and mayfly (Ephemeroptera) taxa, with overall relatively low abundances and even distribution of other taxa.

Reference Group 3: This group is comprised of 80 sites of medium sized streams with fast velocities, large cobbles and water chemistry of moderate alkalinity and conductivity. These sites tend to be located in the Fraser Plateau ecoregion, but are also located throughout the basin. Benthic communities in this reference group are typically dominated by EPT taxa with larger abundances of midges (Chironomidae) and three mayfly families (Baetidae, Heptageniidae and Ephemerellidae).

Reference Group 4: This group is composed of 19 sites which tend to be located at lower altitudes in the Lower Mainland ecoregion, but also in the northern part of the Fraser Basin. Streams are characterized by deep channels and slow velocities, high proportion of sand and silt, with a small proportion of gravel substrate. Water chemistry was typically of low alkalinity, conductivity and pH. Benthic communities in this reference group are largely composed of midges (Diptera: non-Chironomidae families and Chironomidae) and worms (Annelida: Naididae and Tubificidae families).

Reference Group 5: This reference group is composed of 68 sites from small streams located in high altitudes, many from the Fraser River Plateau ecoregion. Water chemistry at these sites is characterized by high alkalinity, conductivity and pH. Benthic communities typically have very high abundances and are equally dominated by mayflies (Ephemeroptera) and midges (Chironomidae family). Larger proportions of beetles (Coleoptera) and higher abundances of stonefly families (Capniidae, Chloroperlidae, Nemouridae and Perlodidae) occur in this group of sites.

Study Location – Georgia Basin

Figure 6. The location of twelve water quality monitoring stations in the Georgia Basin, British Columbia.

Assessments from water quality monitoring stations discussed in this report are organized into one of three general geographic regions within the Georgia Basin. These regions are: Upper Cheakamus River, Lower Fraser River, and Vancouver Island.

A total of twelve stations were routinely monitored for biological and water quality (Figure 6). There are six stations on the mainland (three in the Upper Cheakamus River Watershed and three in the Lower Fraser River Watershed) and six stations on Vancouver Island. Specific information about each station is summarizes in Table 4. Routine water quality samples are collected and the data is managed as part of the federal-provincial water quality monitoring network. While some stations have been in operation for many years, others stations were initiated as part of GBAP and therefore have fewer years of data.

Table 4. Georgia Basin water quality and biological monitoring stations.

Area	Station	Monitoring rationale and potential influences on water quality	Period of Record Reported	
			Water Quality	Biological
Upper Cheakamus River	Callaghan Creek at Callaghan Lake	Control station upstream of Olympic development.	2004–2007	2004-2007
	Callaghan Creek at Highway	Olympic development.	2004-2007	2003-2007
	Cheakamus River at Daisy Lake Forest Road	Urban development and municipal effluent.	2004-2007	2003-2007
Lower Fraser River	Fraser River at Hope	Pulp mills, industrial and municipal effluents. Major fisheries and B.C. and Canadian Heritage River System.	2003–2007 (WQI) 1979–2007 (Trend)	2003-2007
	Sumas River at International Boundary	Agriculture and trans-boundary river.	2003–2007 (WQI) 1979–2007 (Trend)	2003-2005 2007
	North Alouette at 132nd Avenue and Edge Street	Urban development, B.C. Heritage River System.	2004-2007	2003-2007
Vancouver Island	Quinsam River near the Mouth	Coal mine, important fisheries river.	2005–2007	2003-2007
	Tsolum River below Murex Creek	Abandoned mine.	2005–2007	2003-2007
	Englishman River at Highway 19	Agriculture, forestry and urban development.	2005–2007	2004-2007
	Cowichan River 1 km downstream of Somenos Creek	Agriculture and municipal effluents, B.C. and Canadian Heritage River System.	2005–2007	2004-2007
	Koksilah River at Highway 1	Agriculture and forestry.	2005–2007	2004-2007
	San Juan River at Island Road	Forestry.	2005–2007	2003-2007

Presentation of Water Quality Results and Discussion

Table 5. General water quality condition integrating water quality (WQI) and biological (CABIN) assessment results.

Biological (CABIN)	Water Quality (WQI)
Similar to Reference (within 90% ellipse)	Excellent (95-100)
Mildly Divergent (between 90-99% ellipse)	Good (80-94)
Divergent (between 99-99.9% ellipse)	Fair (65-79)
Highly Divergent (outside 99.9% ellipse)	Marginal (45-64)
	Poor (0-44)

General geographical summaries and an area map are provided at the beginning of each section to provide information on major rivers in the area, prevailing climate and flow conditions, major human activities and wildlife.

For each station a description of the *River Characteristics*, *Site-specific Influences on Water Quality*, *Water Quality Assessment*, *Biological Assessment*, followed by a summary of *Overall Water Quality Condition*, is provided. Water quality and biological data for these stations is available at www.ec.gc.ca/eaudouce-freshwater and www.ec.gc.ca/rbca-cabin. Water quantity data is available through Water Survey Canada (NSC) at http://www.ec.gc.ca/rhc-wsc/ (WSC, 2009).

An overall summary of water quality and biological assessment results are presented at the top of each page. Individual categories between the water quality and biological assessments have been integrated using colour codes to show if assessments are indicating similar or different water quality conditions (Table 5). An example of specific water quality and biological assessment results is provided in Table 6. A summary of individual scores for all stations is provided at the end of the report.

Table 6. Example summary of water quality and biological assessment results.

Year	2003	2004	2005	2006	2007
Biological	Mildly Divergent	Divergent	Divergent	Mildly Divergent	Mildly Divergent
Water Quality	Good	Fair	Marginal	Good	Good

Figure 7. Icons used to indicate types of land use or activities that may influence water quality.

River Characteristics

This section describes the general hydrology of the river including drainage area, major tributaries, common fish species found in the river, the water quality monitoring station location and other environmental stations of interest to the location if present.

Site-specific Influences on Water Quality

This section describes both the natural and human influences on water quality including natural hydrological patterns and point and non-point sources of pollution.

Icons used to depict types of land use or activities that may influence water quality at each station are also displayed (Figure 7).

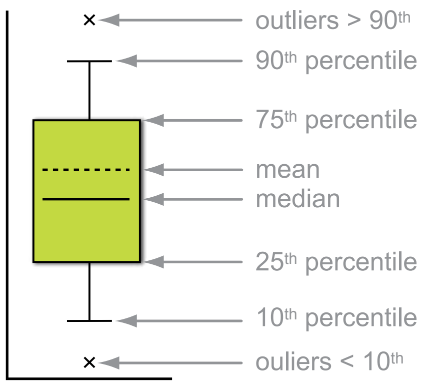


Figure 8. Example box and whisker plot used to compare and describe water quality data.

Water Quality Assessment

Water quality assessments were conducted using the WQI. The short-term datasets were then assessed for status, and longterm datasets were assessed for trends. Guidelines used in the WQI calculations for each station are provided in Appendix 1.

Box and whisker plots (Figure 8) are also used in this report to help analyse and explain water quality data. They are a graphical display used for summarizing the distribution of a data set. Data for selected variables collected from a station over a certain time period is plotted either annually or together. The solid line within the larger box marks the median, the dashed line is the mean, and the lower and upper ends of the larger box are the 25th and 75th quartiles. The whiskers displayed are the 10th and 90th percentiles. Outliers greater than the 10th or 90th percentiles are displayed as an "x".

Biological Water Quality Assessment Results

Figure 9. Example plot of benthic macroinvertebrate reference and annual test communities based on similarity. Green dots represent reference sites and the orange dots represent annual test site results plotted on a multivariate axes.

MDS ordination plots used for CABIN assessment (Figure 9) are presented in this report to illustrate how the test site community changes from year to year with respect to the predicted reference communities. As indicated in the previous analysis section, sites that are close together in a MDS plot are similar and sites that are far apart are dissimilar. The measure used for similarity between sites is the Bray-Curtis dissimilarity measure. These combined ordinations are not used for assigning an assessment score but for illustrating yearly changes at a test site relative to the predicted reference condition. The confidence ellipses in these plots are illustrated for reference only because assessment scores determined from these combined plots may differ slightly from the individual plots.

Overall Water Quality Condition

A summary of the two assessments is provided in this section to provide further description of the overall water quality condition at each site.

Figure 10. Location of Upper Cheakamus River Watersheds within the Georgia Basin.

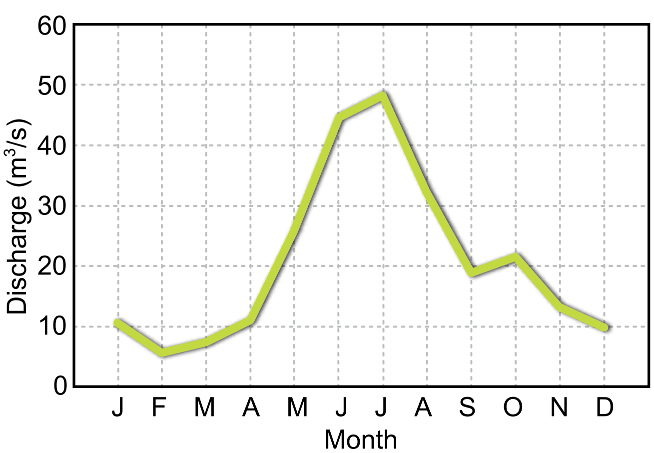


Figure 11. Mean monthly discharge for the Cheakamus River from 2003 to 2007.

The Cheakamus River basin is situated in the southern coastal mountains (Figure 10). It originates in the Fitzsimmons Range of the Coast Mountains in Garibaldi Provincial Park about 25 km southeast of Whistler. The total watershed area is 1070 km^2. From the headwaters, it flows through Cheakamus Lake and the Daisy Lake Reservoir to empty into the Squamish River about 13 km from Howe Sound. Major tributaries to the Cheakamus River include Callaghan Creek, Brandywine Creek and the Cheekeye River (Figure 12). The river is in the traditional territories of the Lil'wat and Squamish First Nations (B.C., 2008). The basin also supports numerous fish species, including rainbow trout, cutthroat trout, Dolly Varden, char, mountain whitefish, steelhead and five species of Pacific salmon. Water quality stations on Callaghan Creek and the Cheakamus River were assessed in this report.

The Daisy Lake dam and reservoir are located approximately 40 km north of Squamish, adjacent to the Sea to Sky Highway. It impounds water flowing south from the Cheakamus River headwaters and diverts it through a tunnel to the Cheakamus Generating Station, where it is then discharged into the Squamish River. A portion of the water is also released from Daisy Lake Dam into the lower Cheakamus River (BC Hydro, 2005).

The Cheakamus River basin is dominated by mountainous terrain, with headwaters located in glaciated alpine basins. The lower Cheakamus River floodplain was unstable and carrying large sediment loads until it was dyked between 1947 and 1950 (Clague et al., 2003). The climate in the basin is transitional between the mild Pacific Coast and the colder interior climatic regimes. Fall and winter storms commonly occur from late September to March. Peak flows in the basin occur in the summer months and are driven by summer snow and glacier melt. This is typical of high elevation rivers (Wade et al., 2001). Figure 11 shows mean monthly discharge for the Cheakamus River from 2003 to 2007. Approximately 75% of the total inflow to the Cheakamus River originates upstream of the dam (BC Hydro, 2005).

Non-point sources of pollution to the river include logging and urban runoff from Whistler. Logging in the basin has occurred since the 1950s and still supports a significant portion to the economy in the Sea to Sky Corridor (B.C., 2008). Point sources to the river include the Whistler Wastewater Treatment Plant (WWTP), the adjacent Whistler landfill that operated from the 1970s to 2007 (RMOW, 2009a) and the new Wastewater Treatment Plant located in the lower Callaghan Valley. Whistler hosted the 2010 Olympic and Paralympic Games at three venues: the Whistler Sliding Centre, Olympic Park and Whistler Mountain (RMOW, 2009b) from February 12-28 and March 12-21, 2010.

Possible impacts to water quality from non-point sources include possible increased flow, suspended solids and temperature in streams from logging (EC, 2001) and construction in the Callaghan Valley. Increased flow, sediment, nutrients, metals, chloride, pesticides, hydrocarbons and bacteria may occur due to urban runoff. Potential impacts to water quality from WWTPs include increased nutrients, chloride, cyanide, sulfides, phenols, surfactants and heavy metals. Emerging substances such as pharmaceuticals, endocrine disruptors and personal care products are also found in municipal effluents (EC, 2001). Significant upgrades were completed on the Whistler WWTP in 2009.

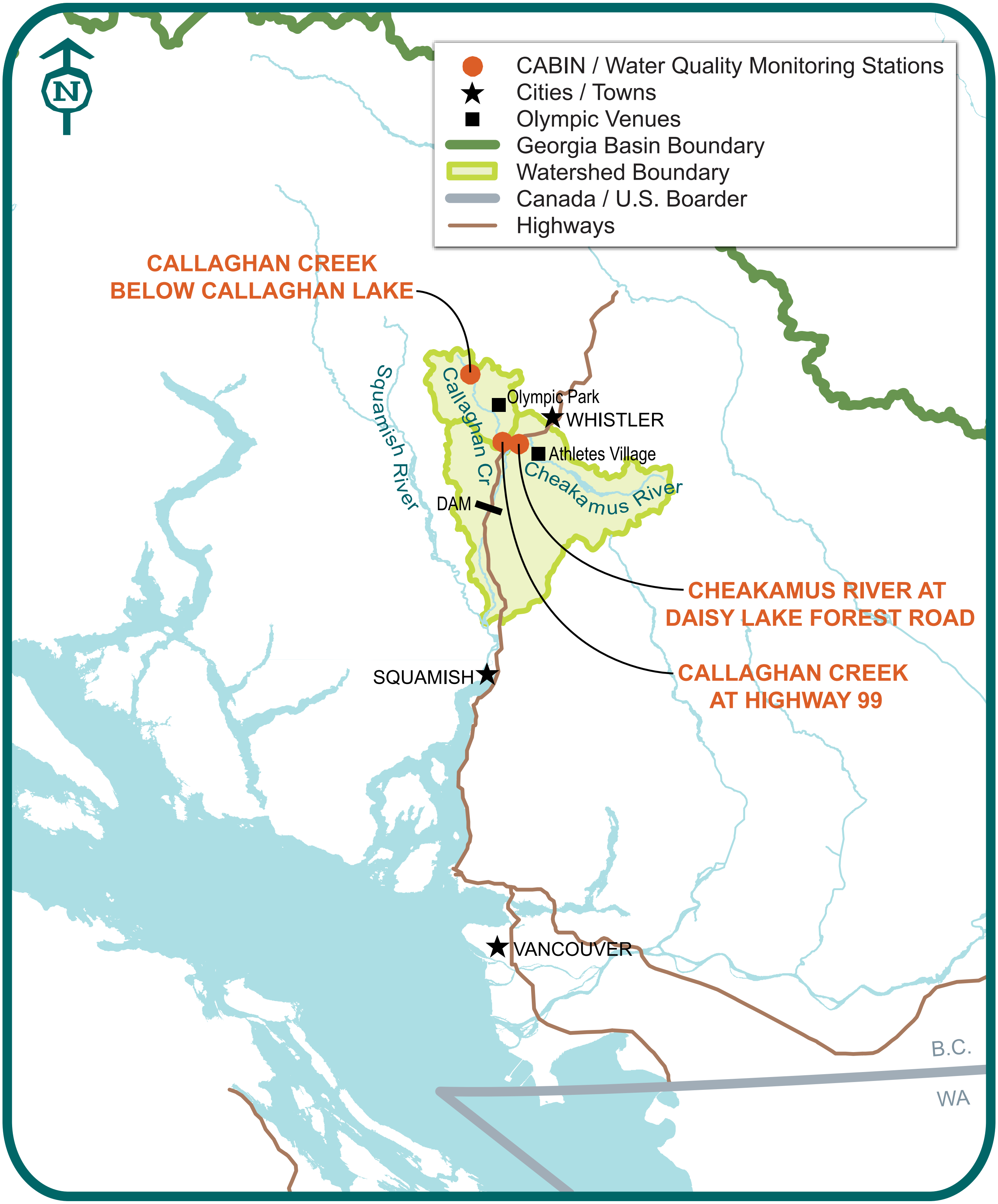
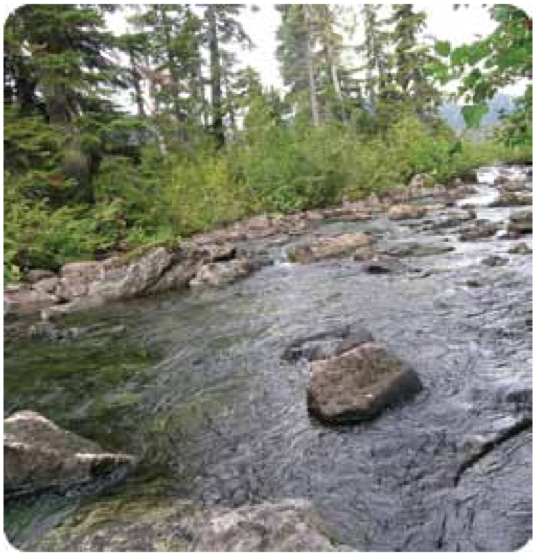


Figure 12. Upper Cheakamus River map showing water quality monitoring stations.

Callaghan Creek below Callaghan Lake

Year	2003	2004	2005	2006	2007
Biological	--	Similar to Reference	Mildly Divergent	Mildly Divergent	Similar to Reference
Water Quality	--	Good	Good	Good	Excellent



River Characteristics

Callaghan Creek drains approximately 200 km^2 of Callaghan Lake Provincial Park before flowing into the Cheakamus River. Madeley Creek is a major tributary to Callaghan Creek and enters below the monitoring station. Both Callaghan Creek and Callaghan Lake contain wild stocks of Dolly Varden, char and rainbow trout (VANOC, 2004) while Callaghan Creek contains kokanee salmon (BCMOE, 2008b)

The monitoring station is located downstream of the lake outlet in Callaghan Lake Provincial Park. Bi-weekly sampling was initiated in 2004 to provide background information upstream of upcoming Olympic devlopment. Another environmental station of interest to this location is the Environment Canada Callaghan Valley climate station (ID: 1101300).

Site-specific Influences on Water Quality

Callaghan Creek is typical of high elevation Pacific coastal streams. These usually have less acid neutralizing capacity, and lower hardness, total ions, nutrients and metals than lowland waters (Naiman and Bilby, 2001).

Predominant human influences on water quality at this station are recreational activities in Callaghan Lake Provincial Park and surrounding area. This station is considered an upstream reference location for the Callaghan Creek at Highway 99 station.

Water Quality Assessment

Water quality guidelines for the variables used to calculate the WQI at this site are shown in Table 7. Results indicate **Good** to **Excellent** water quality from 2004 to 2007. Minor guideline exceedances for total copper and phosphorus were observed from 2004 to 2006 during periods of elevated turbidity. During these periods, the total copper and phosphorus were associated with the suspended sediment, and therefore likely not of concern to aquatic life. Water temperature

Table 7. Callaghan Creek below Callaghan Lake: Water quality variables used to calculate the WQI.

Variable
water temperature, pH
total copper, total lead, total zinc, total cadmium
total dissolved nitrogen, total phosphorus
dissolved chloride

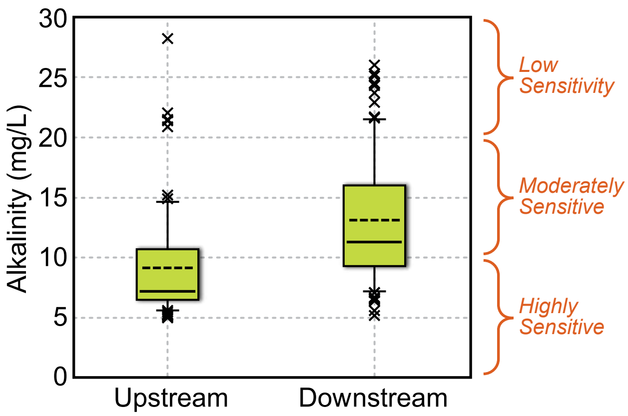


Figure 13. Box plots showing alkalinity concentrations at upstream and downstream locations for Callaghan Creek from 2004 to 2007.

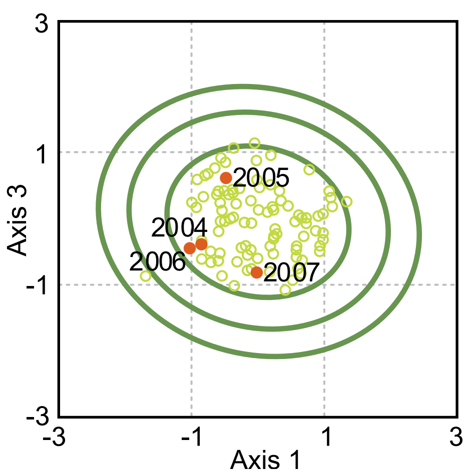


Figure 14. Comparison of annual benthic community samples at Callaghan Creek below Callaghan Lake in 2004 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

exceeded the B.C. Guideline for Dolly Varden once in the summer of 2004. No guidelines were exceeded in 2007.

The status assessment indicated that Callaghan Creek below Callaghan Lake had low alkalinity and was oligotrophic in nutrient status, making it highly sensitive to acid inputs and nutrient enrichment. Figure 13 compares alkalinity concentrations at the upstream and downstream Callaghan Creek stations.

Biological Assessment

The Callaghan Creek below Callaghan Lake station was most similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005), as the habitat characteristics of this station were similar.

Individual CABIN assessments indicated that the benthic macroinvertebrate community at upper Callaghan Creek was **Similar to Reference** or **Mildly Divergent** from the predicted reference communities. Figure 14 illustrates the combined plot of the annual samples compared with the predicted range of assemblages in Reference Group 1. There was some change from year to year at this station, but the communities were within the range of the reference communities. The degree of change from year to year suggests that the benthic community is not stable. This observation, in conjunction with the proximity to the 90% confidence ellipse, suggests that this station should be monitored for potential divergence from the reference condition in the future. No CABIN sampling took place at this station in 2003.

Overall Water Quality Condition

Overall, the water quality and biological assessments indicate similar water quality conditions, **Good** and **Mildly Divergent** or **Similar to Reference**. The benthic macroinvertebrate community indicated mild divergence in 2005 and 2006, but was still within our expectations of what is acceptable. It will be important to continue to observe these communities over time.

Callaghan Creek at Highway 99

Year	2003	2004	2005	2006	2007
Biological	Mildly Divergent	Divergent	Mildly Divergent	Mildly Divergent	Mildly Divergent
Water Quality	--	Good	Good	Good	Good

River Characteristics

Callaghan Creek drains an approximate area of 200 km² of Callaghan Lake Provincial Park before flowing into the Cheakamus River. Madeley Creek is a major tributary to Callaghan Creek. Both Callaghan Creek and Callaghan Lake contain wild stocks of Dolly Varden, char and rainbow trout. The river is in the traditional territory of the Squamish and Lil-wat nations (VANOC, 2004).

The monitoring station is located at the Sea to Sky footbridge in the Cal-Cheak campsite. Bi-weekly sampling began at this station in 2004 to establish baseline data prior to Whistler Olympic Park construction. Another environmental station of interest to this location is the Environment Canada Callaghan Valley climate station (ID: 1101300).

Site-specific Influences on Water Quality

Tributaries to Callaghan Creek are fed by glacial outwash making the creek naturally turbid during peak flow events. Elevated turbidity levels can have lethal and sublethal effects on stream biota (Naiman and Bilby, 2001). Turbidity and related variables may rise as a result of increased surface water run-off from both the venue and the road.

Logging began in the Callaghan Valley in the 1950s. Since then, more than 21 km² have been logged. Western Forest Products maintains active logging in the valley today. (VANOC, 2004).

In 1968, the British Columbia Ministry of Energy, Mines and Petroleum Resources designated a *no staking* reserve over the uppermost part of the Callaghan Valley. Northair Group operated an underground gold mine just outside of this reserve between 1977 and 1981. Currently, water drains from the old mine site into Callaghan Creek (VANOC, 2004).

Whistler Olympic Park, located in the lower Callaghan Valley, hosted the Nordic events for the 2010 Winter

Olympic and Paralympic Games. Venue capacity was 12,000 people per day in each of the stadiums. Construction of the venue and road began in 2005. Road construction was completed in 2007 (David Mitchell, 2009 pers. comm.) and the facilities were completed in 2008. Wastewater from the venue is treated on-site by tertiary membrane filtration and ultraviolet disinfection and discharged to Madeley Creek. A third party environmental monitoring group tests the water from the creek to ensure that VANOC is complying with their environmental assessment requirements (VANOC, 2009).

The monitoring station is located approximately 12 km downstream of Olympic Park.

Water Quality Assessment

Water quality guidelines for the variables used to calculate the WQI at this station are shown in Table 8. Results indicated **Good** water quality between 2004 and 2007. Cadmium exceeded guidelines three times from 2004 to 2005 and silver exceeded guidelines once in 2006. Phosphorus exceeded guidelines twice in 2007. These exceedances were typically associated with high turbidity events that may have been exacerbated by road and facilities construction. The metals and phosphorus were bound to the sediments and likely unavailable to aquatic life.

Construction of the Callaghan Valley Nordic Road during 2005 and 2006 appeared to have limited impact on water quality in terms of turbidity and related variables. However, prolonged turbidity increases during high water may have been exacerbated by bridge and facilities construction during the summer in 2007 (Figure 15).

Table 8. Callaghan Creek at Highway 99: Water quality variables used to calculate the WQI.

Variable
water temperature, pH
total copper, total lead, total zinc, total cadmium, total silver
total phosphorus
dissolved chloride

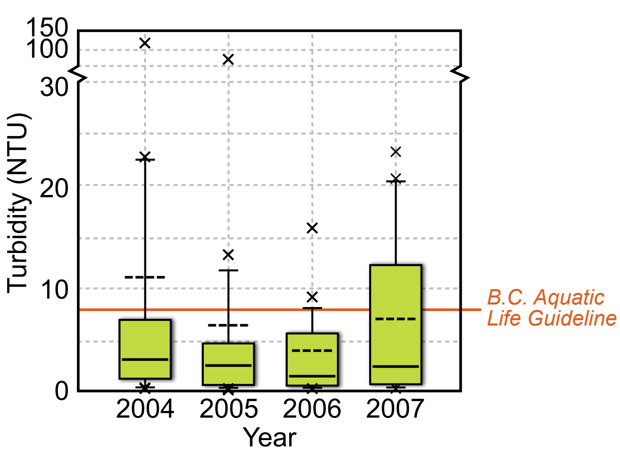


Figure 15. Annual median turbidity values at Callaghan Creek at Highway 99 from 2004 to 2007.

Biological Assessment

Callaghan Creek at Highway 99 was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005) in 2003 to 2007. Group 1 reference sites are dominated by mayflies (Ephemeroptera), while these samples were dominated by caddisflies (Trichoptera). The relatively reduced presence of mayflies may attributed to the unique substrate at this station, which is dominated by bedrock

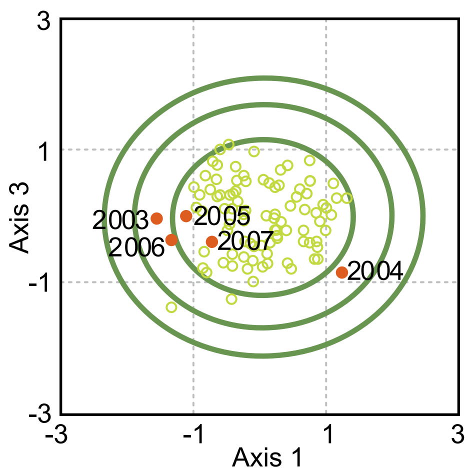


Figure 16. Comparison of annual benthic community samples at Callaghan Creek at Highway 99 in 2003 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

with little gravel or cobble to act as habitat or refuge for the mayflies, rather than a water quality issue. The station is also silty due to high suspended sediment concentrations, likely from glacial inputs from Mount Callaghan and surrounding peaks. Regardless of the silt content and the bedrock substrate, the community was composed of sensitive taxa and was within the expected range of macroinvertebrate community composition for Group 1.

An assessment of **Mildly Divergent** was observed in 4 of 5 years. In 2004, the assessment declined to **Divergent**, but increased to **Mildly Divergent** in subsequent years. The sample observed in 2004 was very different than the samples from other years, as seen in Figure 16. However, the samples from subsequent years were similar to those sampled prior to 2004. The benthic macroinvertebrate community was dominated by the sensitive EPT taxa–mayfly (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera)–throughout the sample years; though the benthic community had fewer Chironomidae (midges) than expected in 2004. The **Divergent** status in 2004 was a result of the reduced midge composition, which recovered to the expected abundances in subsequent years although it is unknown what environmental factor may have caused this assessment in 2004.

Overall Water Quality Condition

Overall the water quality and biological assessments indicated similar **Good** and **Mildly/Divergent** water quality conditions, with the exception of 2004. The biological assessment indicates environmental stress in 2004; however there were minimal impacts to water quality and macroinvertebrates from road and venue construction in 2005 to 2007.

Fecal coliform bacteria counts and nutrient concentrations will be monitored for changes due to the new upstream wastewater treatment plant in Whistler Olympic Park. Turbidity concentrations will also be monitored for increased surface run-off.

Cheakamus River at Daisy Lake Forest Road

Year	2003	2004	2005	2006	2007
Biological	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
Water Quality	--	Good	Good	Fair	Good




River Characteristics

The Cheakamus River has its headwaters in Garibaldi Provincial Park, upstream from Cheakamus Lake. It flows into the Squamish River near Squamish; eventually emptying into Howe Sound. The watershed area of the upper Cheakamus River is 285 km^2 and contains fish species including chinook, coho, chum, pink and sockeye salmon, cutthroat trout and Dolly Varden. It is within the traditional territory of the Squamish and Lil'wat Nations.

The monitoring station is located approximately 6 km downstream of the Whistler WWTP at the Daisy Lake Forest Road bridge. Bi-weekly sampling was initiated in 2004 to assess impacts from the upstream Wastewater Treatment Plant and Olympic construction.

Other environmental stations of interest to this location include: the upstream Cheakamus River at Cheakamus Lake Road and Millar Creek at Function Junction (operated by BCMOE) water quality monitoring stations, the WSC Cheakamus River above Millar Creek (ID: 08GA072) water quantity station and the Environment Canada Whistler climate station (ID: 1048898).

Site-specific Influences on Water Quality

Influences on the Cheakamus River include significant historical logging, a BC Hydro hydroelectric dam and urban development in Whistler. Other potential impacts include dyking (CEAA, 2004), leachate from the old landfill closed in 2007, and municipal effluent from the upstream WWTP (RMOW, 2009a).

The 2010 Whistler Olympic and Paralympic Athlete Village is located on the banks of the upper Cheakamus River at the old landfill and recycling site. Construction was completed in the fall 2009. The Village includes infiltration swales, rain gardens and wetlands to help manage storm water entering the Cheakamus River and Crater Creek. A separation wall was also constructed between the landfill and the central stormwater

Table 9. Cheakamus River at Daisy Lake Forest Road: Water quality variables used to calculate the WQI.

Variable
water temperature, pH
total copper, total lead, total zinc, total cadmium
total phosphorus
dissolved chloride

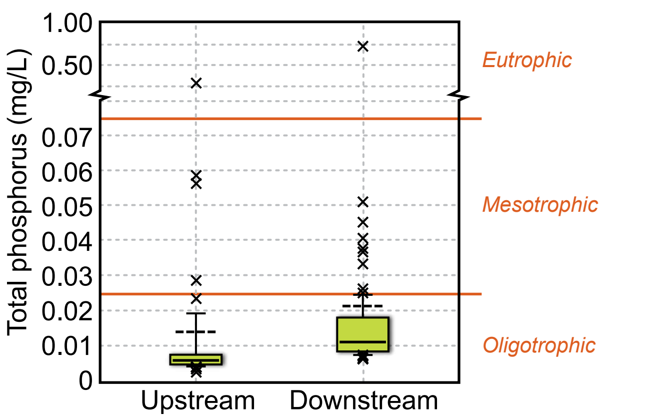


Figure 17. Box plots of total phosphorus concentrations for the Cheakamus River upstream and downstream of the Whistler Wastewater Treatment Plant from 2004 to 2007.

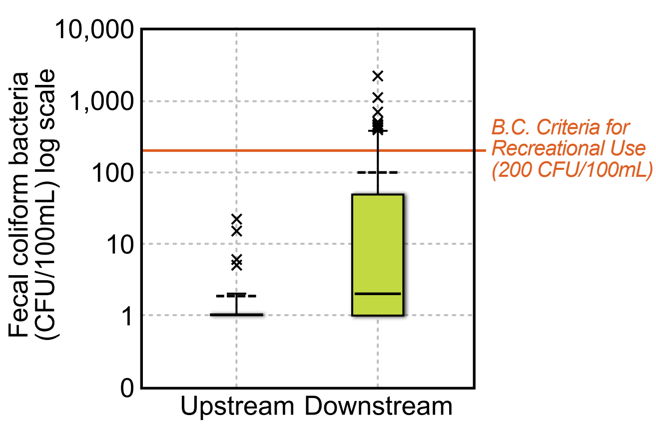


Figure 18. Fecal coliform bacteria counts for the Cheakamus River upstream and downstream of the Whistler Wastewater Treatment Plant from 2004 to 2007.

treatment wetland to prevent possible leachate from mixing with groundwater (Belfry and Zabil, 2008).

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 9. Annual WQI results were calculated for the 2004-2007 period based on the availability of data. Results show **Good** water quality from 2004 to 2007 with a **Fair** rating in 2006. Phosphorus exceeded trigger for oligotrophic systems nine times between 2004 and 2007. By comparing phosphorus levels between the monitoring stations upstream and downstream of the WWTP and Whistler, it appears that the upstream plant and urban run-off via Millar Creek may be contributing to the exceedances (Figure 17).

Copper, cadmium and phosphorus each exceeded guidelines during a single rain event in 2006 that significantly lowered the WQI calculation for that year. The exceedances were associated with a natural high turbidity event at both the upstream and downstream locations. The metals and phosphorus were generallybound to the sediment and likely unavailable to aquatic life.

Chloride concentrations and fecal coliform bacteria counts (in addition to phosphorus as noted above) are higher at the Cheakamus River station downstream of the Whistler WWTP compared with the upstream Cheakamus station, indicating impacts from the WWTP and/or urban development (Figure 18).

Fecal coliform bacteria counts were not used in WQI calculations; however they frequently exceeded the BCMOE Recreational Guideline during the 2006 and 2007 winter seasons presumably as a result of sewage input and urban run-off from the Municipality of Whistler. Construction for upgrades to the Whistler WWTP began in August 2008 and was completed in 2009 (RMOW, 2009c). The WWTP now uses microbes to reduce nitrogen and ammonia toxicity and ultra violet disinfection before discharging effluent to the Cheakamus River. More recent data has indicated that fecal coliform counts have since decreased.

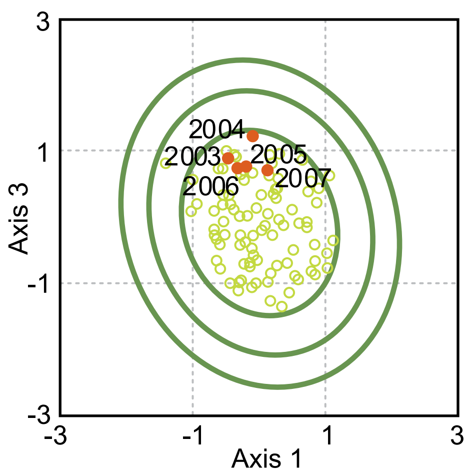


Figure 19. Comparison of annual benthic community samples at Cheakamus River at Daisy Lake Forest Road in 2003 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

Biological Assessment

This Cheakamus River station was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005).

As indicated in Figure 19, the CABIN water quality assessments of benthic macroinvertebrate communities in the River were **Similar to Reference** in each year sampled and very similar from year to year. The community at this station is dominated by the EPT taxa, as 50% or more of the macroinvertebrate families belong to these sensitive orders. Overall, the community at this station is diverse and species rich.

Overall Water Quality Condition

Overall, water quality and biological assessments indicated similar water quality conditions, **Similar to Reference** and **Good** in 2004, 2005 and 2007. In 2006, a single turbid event resulted in several parameters exceeding guidelines causing a **Fair** water quality rating. The benthic community was either unaffected by this event or experienced short term effects and was able to recover prior to CABIN sampling, as the CABIN assessment did not change between 2005 and 2007.

Nutrients (phosphorus), chloride and bacteria concentrations are all higher at the monitoring station downstream of Whistler and the WWTP than at the upstream station, indicating impacts from both urban run-off and the WWTP prior to upgrades in 2008. Monitoring at this station will continue in order to assess the potential benefits of the WWTP upgrades over time.

Lower Fraser River Watersheds

Figure 20. Location of Lower Fraser River Watershed within the Georgia Basin.

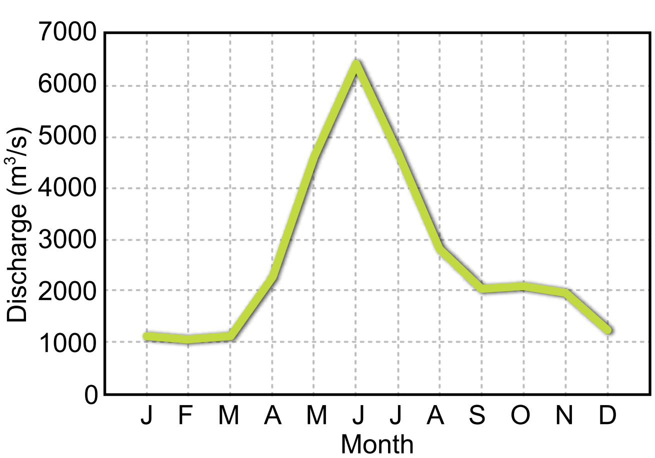


Figure 21. Mean monthly discharge for Fraser River at Hope from 2003 to 2007.

The Fraser River is the longest river in B.C. and is the fifth largest drainage basin in Canada. It has no mainstem dams and is one of the greatest salmon rivers in the world. It flows for 1400 km from the headwaters near Mount Robson, draining into the Pacific Ocean at Vancouver. The lower Fraser River turns west below the Fraser Canyon, flows through the Lower Fraser Valley and discharges to the Strait of Georgia at Vancouver (Reynoldson et al., 2005). Water quality stations on the lower Fraser, Sumas and North Alouette Rivers have been assessed in this report (Figure 20 and Figure 22).

The lower Fraser climate is dominated by moist pacific air and orographic rainfall (precipitation due to uplift of air masses over the mountains). In the winter, a steady succession of low pressure systems bringing wet conditions moves eastward from the Pacific Ocean. In the summer, a persistent high pressure area develops off the coast, decreasing the frequency of storms (Reynoldson et al., 2005).

Lower Fraser River tributaries are characterized by high autumn and winter flows, while summer flows are low (Figure 21). At lower elevations in the Coast Mountains, mid-winter melt events are common and decrease snowpack that can be released during the spring melt. However, the main stem Fraser River is generally dominated by snowmelt, with high flows occurring in spring and summer, and low flows in the winter when most of the precipitation upstream falls as snow. Runoff peaks in June. The tidal effect on water level reaches as far inland as Chilliwack during low flow and Mission during high flow. The salt wedge ranges from 22 km upstream during low flow and is at the river mouth during high flow. In 1894, the largest freshet on record caused major flooding in the Lower Fraser Valley, prompting the construction of dykes and drains that consolidated the river channel and the delta (Reynoldson et al., 2005).

Midges (Chironomidae) were the most widely distributed and abundant family in the river. Other common genera in the Fraser River are stoneflies, mayflies and worms. In addition to supporting six salmon species, the lower Fraser supports marine and estuarine species such as starry flounder, smelt, eulachon and lamprey, and freshwater species such as sturgeon, trout, whitefish, peamouth chub, redside shiner, sticklebacks, sculpins and suckers. The marshes in the Fraser River delta provide habitat for migrating birds on the Pacific Flyway (Reynoldson et al., 2005).

Land uses in the lower Fraser River basin include forestry, agriculture and urban development. Forestry operations occur in the mountains (Reynoldson et al., 2005). Agriculture is B.C.'s third largest industry and the lower Fraser Valley has the highest livestock density in Canada. Agricultural intensification is a result of the relatively small amount of fertile land available in the Lower Mainland and the high capability of the soil and climate for agricultural production (Smith, 2004). In terms of urban development, the Lower Mainland contains the largest population center in B.C. The J.A.M.E.S Water Pollution Control Centre (DKL, 2001), and Annacis Island, Lulu Island and Northwest Langley WWTPs all discharge to the lower Fraser River (MV, 2009).

Potential impacts on water quality in the Lower Fraser River from forestry, agriculture and urban run-off include increased nutrients (nitrogen and phosphorus) which can lead to eutrophication, chloride, pesticides, hydrocarbons and bacteria. Mixtures of nutrients, chloride, cyanide, sulfides, phenols, surfactants and heavy metals are all found in municipal wastewater effluents as well as emerging substances such as pharmaceuticals, endocrine disruptors and personal care products (EC, 2001).

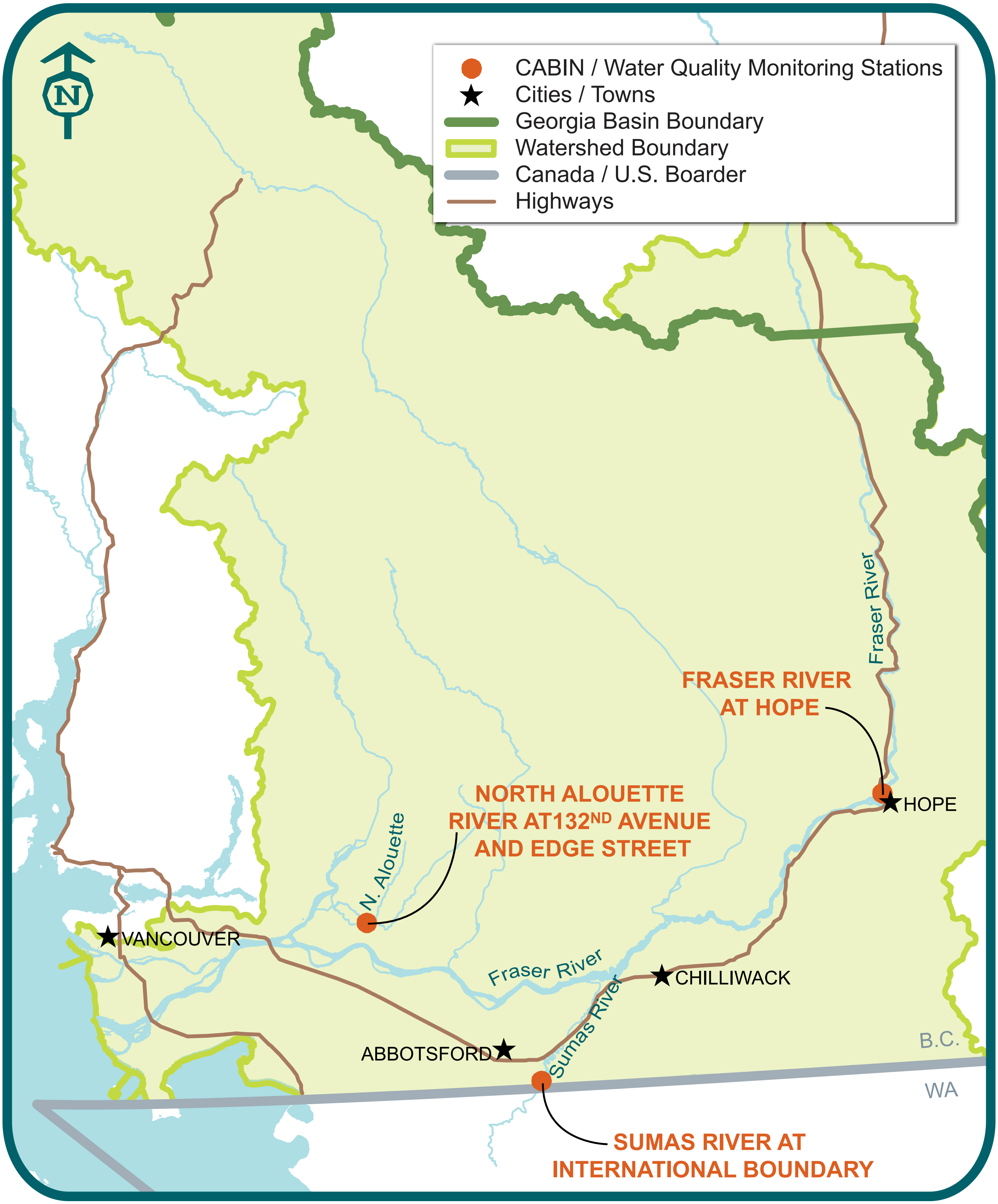


Figure 22. Lower Fraser River map showing water quality monitoring stations.

Fraser River at Hope

Year	2003	2004	2005	2006	2007
Biological	Similar to Reference	Similar to Reference	Mildly Divergent	Similar to Reference	Similar to Reference
Water Quality	Good	Good	Good	Good	Good

River Characteristics

Below the confluence with the Thompson River the Fraser River turns west at Hope eventually draining into the Pacific Ocean at Vancouver. The drainage area at Hope is 217,000 km^2. Tributaries to the lower Fraser include the Harrison, Sumas, Chilliwack, Pitt, Stave and Coquitlam Rivers. The Fraser River system supports more salmon than any other river system in the world. The Fraser River Estuary is also recognized as an important staging and nesting area for migratory birds and other water fowl. The Fraser River is designated as a Canadian Heritage River (CHRS, 2009).

The monitoring station is located on the Highway 1 Bridge north of Hope. Bi-weekly sampling has been conducted at this station since 1979. The WSC Fraser River at Hope (ID: 08MF005) water quantity station is also located at this station and there are two Environment Canada climate stations in Hope (ID: 1113539 and 1113541).

Site-specific Influences on Water Quality

Historical records indicate that flow typically rises in May and peaks in June and falls from July to September. Minimum flows are observed in winter between December and March. Fraser River water chemistry is characterized mainly by its high sediment load; a result of natural erosion as the river flows through the glacial deposits and drift material in the central plateau (Reynoldson et al., 2005).

Main influences on water quality in the Fraser River at Hope are treated effluent from pulp mills at Prince George, Quesnel and Kamloops, treated municipal wastewater effluent from several communities including Prince George, Quesnel, Kamloops and Williams Lake, and non-point sources of pollution from agriculture, forestry and urban areas along the entire length of the river (Reynoldson et al., 2005).

Table 10. Fraser River at Hope: Water quality variables used to calculate the WQI.

Variable
water temperature, pH, dissolved oxygen
total arsenic, total copper, total silver, total thallium, total zinc
total dissolved nitrogen, total dissolved phosphorus

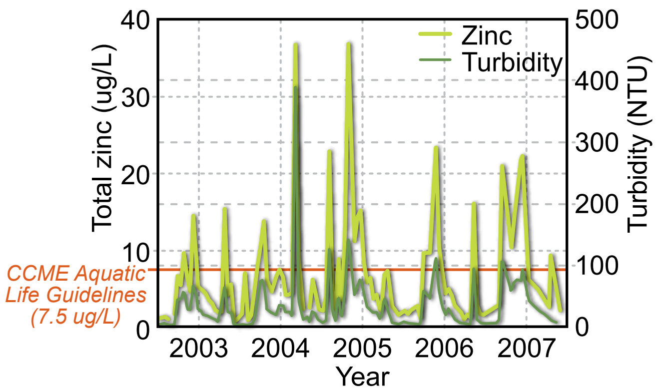


Figure 23. Zinc concentrations and turbidity at Fraser River at Hope from 2003 to 2007.

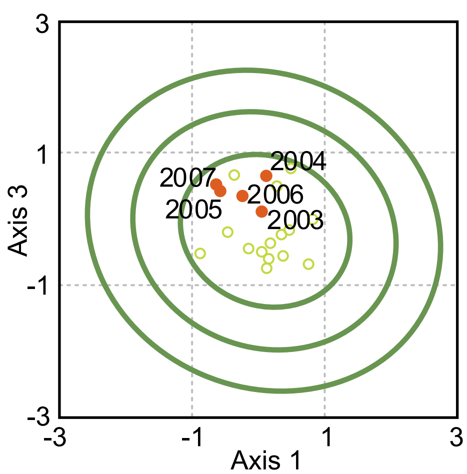


Figure 24. Comparison of annual benthic community samples at Fraser River at Hope in 2003 to 2007 with Group 2 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

Water Quality Assessment

Water quality variables used to calculate the WQI and assess for trends at this station are shown in Table 10.

WQI results indicated **Good** water quality at this station from 2003 to 2007. Zinc exceeded the site-specific guideline during high flow and turbidity events. The zinc was bound to the sediment and likely unavailable to aquatic life (Figure 23). Silver also exceeded the guideline to a limited extent in 2005 and 2006. Water temperature exceeded guidelines occasionally during the summer months in 2003, 2004 and 2007.

Significant increasing trends in turbidity and total dissolved nitrogen have been identified in assessments from 1979 to 2007. However, there was also a significant decreasing trend in chloride, likely due to abatement measures at upstream pulp mills in the early 1990s.

Biological Assessment

The Fraser River at Hope was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 2 (Sylvestre et al., 2005). These tend to be large river sites where benthic communities are dominated by stonefly (Plecoptera) and mayfly (Ephemeroptera) taxa, with an overall relatively low abundance and even distribution of other taxa.

The benthic macroinvertebrate community in the Fraser River at Hope was within the acceptable range of community composition in all years (Figure 24). The benthic macroinvertebrate community at this station was assessed as **Similar to Reference** as it was dominated by the EPT taxa, with 50% or more of the macroinvertebrate families belonging to the sensitive EPT orders.

Overall Water Quality Condition

Biological and water quality assessments indicate similar water quality condition at this station. The CABIN assessment verifies the physical-chemical assessment of **Good** water quality at this site by providing a similar assessment of the biological community. The station was also assessed as **Good** in the 2004 B.C. and YT Water Quality Report (EC, BCMOE, EY, 2007).

Sumas River at International Boundary

Year	2003	2004	2005	2006	2007
Biological	Similar to Reference	Similar to Reference	Similar to Reference	--	Mildly Divergent
Water Quality	Fair	Fair	Fair	Fair	Fair

River Characteristics

The Sumas River has a drainage area of 197 km^2. It flows from its headwaters on Sumas Mountain, Washington, United States, north into Canada, joining the Vedder Canal which enters the Fraser River west of Chilliwack. The Johnson River and Swift Creek in the United States are major tributaries to the Sumas River. In B.C., Marshall Creek, which receives the majority of its water from the Abbotsford Aquifer, is the main tributary (MacDonald, 2007). The Sumas River is important to local Pacific salmon as a migratory route for brief periods each year (IRC, 1994).

The monitoring station is located upstream of the bridge on Boundary Road about 3 km east of the Huntingdon border crossing. Sampling was initiated at this location in July 1979 and since 2002 has occurred on a bi-weekly basis. Other environmental stations of interest to this location include a continuous automated water quality probe deployed at this location in 2008, the WSC Sumas River near Huntingdon (ID: 08MH029) water quantity station and Environment Canada's Abbotsford A climate station (ID: 1100030).

Site-specific Influences on Water Quality

Sumas River hydrology is predominantly precipitation-driven with peak flows occurring during the winter between November and March. Figure 25 shows mean monthly discharge from 2003 to 2007.

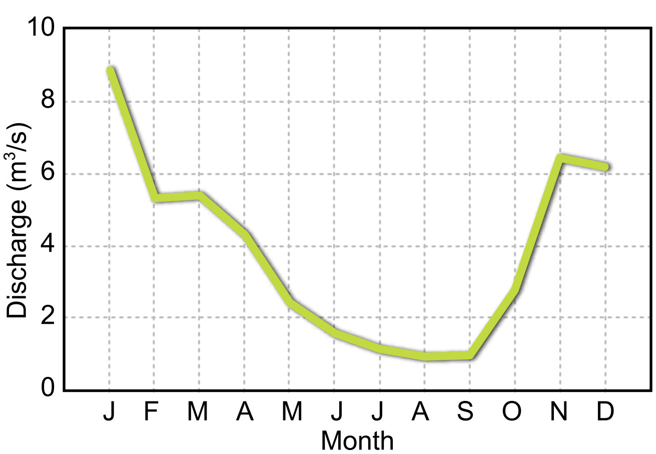


Figure 25. Mean monthly discharge for Sumas River at International Boundary from 2003 to 2007.

Agriculture is the main human influence on water quality in the Sumas River. Agricultural activities in this watershed include dairy farms, vegetable and berry farms and livestock production on both sides of the border. The Lower Fraser Valley has the highest livestock density in Canada (Smith et al., 2007). Impacts from intense agriculture in the watershed include excess nutrients leading to high concentrations of nitrogen and phosphorus, trace metals from agricultural sources related to supplements in animal feed and pathogens from manure applications and animal access to streams.

This station was downstream of the City of Sumas Sewage Treatment Plant until 1999. Since then, sewage has been diverted to the J.A.M.E.S Water Pollution Control Centre in Abbotsford (Curtis, 2000), which discharges to the lower Fraser River.

A large landslide on Sumas Mountain, Washington, occurred in the 1930s, and continues to be a source of large annual sediment loads to Swift Creek, a tributary in the Sumas watershed, during the winter. The slide material contains large quantities of natural asbestos, nickel, cobalt, chromium and magnesium. Nickel, chromium and magnesium sediment concentrations have increased significantly in the United States portion and along the Canada/U.S. border regions of the watershed since 1994, suggesting an increased contribution and deposition of asbestos rich sediments downstream over time (Schreier and Lavkulich, 2009).

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 11.

Table 11. Sumas River at International Boundary: Water quality variables used to calculate the WQI.

Variable
water temperature, pH, dissolved oxygen
total cadmium, total chromium, total copper, total lead, total molybdenum, total nickel, total zinc
dissolved nitrate, total phosphorus
dissolved sulphate

Results for the WQI indicated **Fair** water quality from 2003 to 2007 at this station. Total phosphorus concentrations at this station frequently exceeded the trigger range for oligotrophic systems and nitrate concentrations frequently exceeded the guideline. The median phosphorus value from 2003 to 2007 indicated the river is eutrophic (GC, 2008). However, trend analysis shows an overall decreasing phosphorus trend from 1979 to 2007. On the other hand, nitrate/nitrite was increasing. Figure 26 illustrates median values of nitrate concentrations above the guideline in 2004, 2005 and 2007. In a recent national report, this station was only one of three stations exceeding guidelines as frequently.

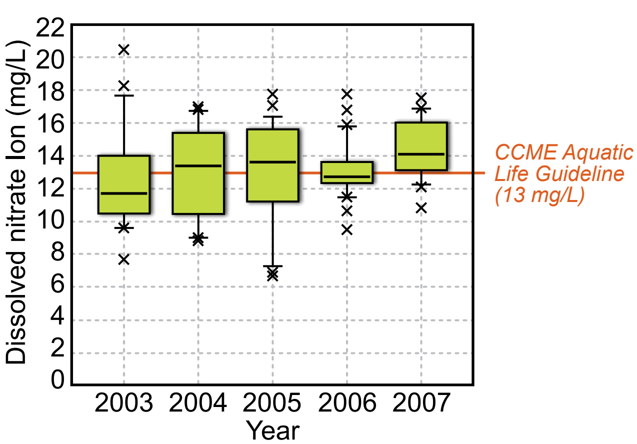


Figure 26. Annual box plots of dissolved nitrate concentrations at the Sumas River station from 2003 to 2007.

Total copper values frequently exceeded the guideline during the rainy season and were typically associated with elevated turbidity. Copper and zinc are routinely added to livestock feed in North America, and they are commonly associated with agricultural waste. Studies indicate that sediment concentrations of copper and zinc have increased since 1994 (Smith et al., 2007).

Total chromium values also exceeded guidelines

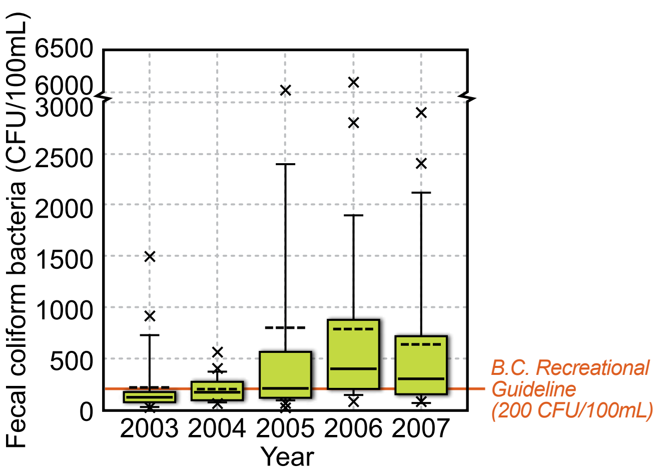


Figure 27. Annual box plots of fecal coliform bacteria counts at the Sumas River station from 2003 to 2007.

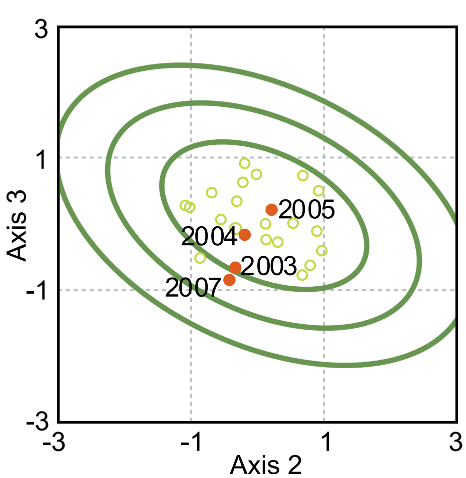


Figure 28. Comparison of annual benthic community samples at Sumas River at International Boundary in 2003 to 2007 (excluding 2006) with Group 4 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

during the rainy season in 2005 and 2006. These were typically associated with elevated turbidity levels and are associated with downstream deposition of asbestos rich sediments from the Sumas slide (Schreier and Lavkulich, 2009).

Significant increasing trends in turbidity, specific conductivity, sulphate, hardness and alkalinity have been identified in assessments from 1979 to 2007. Fecal coliform bacteria also appear to be increasing, although the data record is too short to statistically analyse this variable for trends. Figure 27 shows that fecal coliform bacteria counts frequently exceeded the B.C. Recreational Guideline in 2006 and 2007

Biological Assessment

The Sumas River at the International Boundary was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 4 (Sylvestre et al., 2005) in 2003 to 2007. This is a small group of reference sites with low gradients, small substrates and deeper channels. These communities are dominated by true flies (Dipterans) and non-insects which are considered pollution tolerant.

Results from the benthic macroinvertebrate community analysis indicated **Similar to Reference** condition in 2003 to 2005. Most of these samples were dominated by true flies (Diptera) and non-insects as seen in the reference sites. However, some pollution sensitive mayflies (Ephemeroptera) and caddisflies (Trichoptera) were also present.

CABIN sampling was not conducted at this location in 2006 due to dredging at this location. In 2007, the CABIN station was moved further downstream and showed some mild divergence from the reference communities (Figure 28).

Overall Water Quality Condition

Similar to results in the 2004 B.C. and YT Water Quality Report (EC, BCMOE, EY, 2007), the water quality condition at this site was assessed as **Fair**; however the biological assessment indicated a **Similar to Reference** condition.

Although the water chemistry indicates various guideline exceedances for the protection of aquatic life, the benthic macroinvertebrate community did not appear to respond to the elevated metal and nutrient concentrations detected by the water quality sampling, as the expected community is characterized by pollution-tolerant organisms. The community appeared to be within the expected range of community composition for the habitat characteristics at the site (i.e. deep channels, low gradient, gravel substrate). Further investigation is required to determine if the benthic macroinvertebrates are not able to take up the elevated metals and nutrients at this location directly or indirectly through the food chain, and if a more sensitive biological indicator is needed to understand the potential for effects to other aspects of aquatic health of this system.

The re-activated Sumas slide has been moving downhill for about 60 years and continues to deposit between 25,000 and 150,000 cubic yards of material into Swift Creek annually. A large flood event in January 2009 deposited asbestos-containing sediments along the banks and in the upland regions surrounding the Sumas River. In a study conducted by the United States Environmental Protection Agency in May 2009, asbestos concentrations were higher in samples collected from downstream locations relative to upstream samples, with the highest concentrations found in bank and upland sediment samples close to the Canada/U.S. border (EPA, 2009).

North Alouette River at 132nd Avenue and Edge Street

Year	2003	2004	2005	2006	2007
Biological	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent	Similar to Reference
Water Quality	--	Fair	Good	Good	Good

River Characteristics

The North Alouette River headwaters are located in Malcolm Knapp Research Forest from where it flows through some agricultural and suburban areas into the Pitt River, which enters the Fraser River at New Westminster. The river provides important fish habitat and supports many species including Pacific salmon (BCMOE, 2008b). The Alouette watershed is an important part of the Katzie First Nation culture (Katzie First Nation, 2002).

The monitoring station is located upstream of the 132nd Avenue bridge at Edge Street in Maple Ridge. Bi-weekly sampling was initiated at this location in March 2004 to establish baseline data prior to anticipated upstream urban development of Silver Valley. Other environmental stations of interest to this location include WSC North Alouette at 232nd Street (ID: 08MH006) water quantity monitoring station and Environment Canada's climate station Maple Ridge at Kanaka Creek (ID: 1004R02).

Site-specific Influences on Water Quality

As illustrated in Figure 29, the river hydrology is typical of a rain-driven system, influenced by high precipitation events. Flooding events generally occur between October and February, as a result of heavy rains combined with snowmelt (Nichols, 1990). pH and alkalinity are naturally very low at this station, making the North Alouette River highly sensitive to acid inputs.

Main influences along the North Alouette River are agriculture, with horse farming being the primary use, residential and urban development (BCMOAFF, 2004). Designated water uses include domestic, livestock watering, irrigation, wildlife and aquatic life usage (Swain, 1989).

Development in Silver Valley, located in the hills upstream of the monitoring station, started in 2005. The development will accommodate up to 11,000 residences (CDMR, 2006).

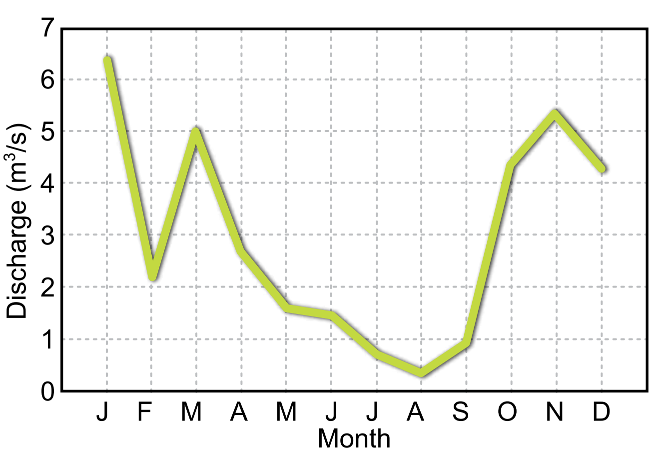


Figure 29. Mean monthly discharge for the North Alouette River from 2003 to 2007.

Table 12. North Alouette River at 132nd Avenue and Edge Street: Water quality variables used to calculate the WQI.

Variable
water temperature, pH, dissolved oxygen
total cadmium, total copper, total lead, total zinc
total phosphorus, total dissolved nitrogen

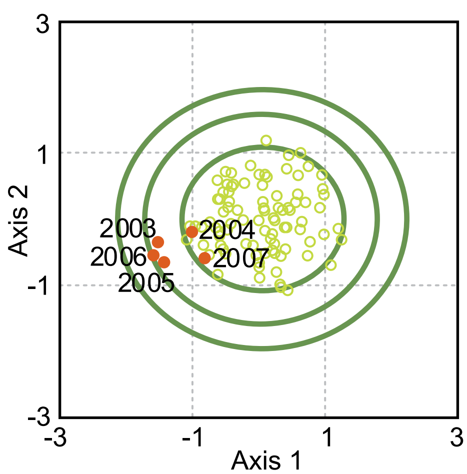


Figure 30. Comparison of annual benthic community samples at North Alouette River at 132nd and Edge Street in 2003 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 12. Results indicated **Fair** to **Good** water quality from 2004 to 2007 at this station. pH levels were often outside of the site-specific guideline range, but these levels are likely natural. Total cadmium exceeded the guideline occasionally between 2004 and 2006; however most exceedances were associated with high flow and turbidity events.

It should also be noted that a relatively small dataset was available for establishing site-specific guidelines. The pH guidelines, in particular, may change over time as additional background information is collected at this station.

Biological Assessment

The North Alouette River at 132nd Avenue and Edge Street was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005) in 2003 to 2006.

CABIN water quality assessment results for this station indicated **Mildly Divergent** assessments in three out of five years sampled. Biological condition was most similar to reference in 2004 and 2007. Regardless of the assessment, the community was very similar from year to year relative to the reference group, as seen by the proximity of the points in Figure 30. The benthic community is relatively consistent from year to year and hovers around the assessment boundaries. Therefore, the change from one category to the next is an artifact of delineating an assessment boundary rather than an indication of significant change in the community.

Overall Water Quality Condition

Water quality and biological assessment results indicated similar water quality condition, **Good** and **Similar to Reference**. The **Fair** WQI rating in 2004 was likely due to small exceedances of several water quality guidelines that generated a score two points below the **Good** category. Further refinement of site-specific guidelines will help to better assess water quality at this station.

Figure 31. Location of Vancouver Island Watersheds within the Georgia River Basin.

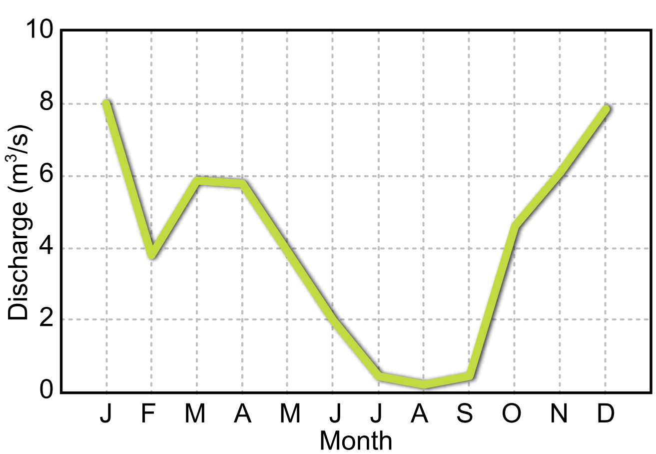


Figure 32. Mean monthly discharge for the Tsolum River below Murex Creek from 2003 to 2007.

Vancouver Island is characterized by coastal plains to the east, long fjords on the western coast and a chain of glaciated mountains along the north-south axis. The majority of its residents live along the eastern coast with over half the population concentrated in the urban centres of Victoria, Nanaimo and Campbell River (B.C., 2000). Water quality stations on the Quinsam, Tsolum, Englishman, Cowichan, Koksilah and San Juan rivers have been assessed in this report (Figure 31 and Figure 33).

The climate of Vancouver Island is warm, with dry summers and wet, mild winters. Average annual temperatures range from 3 to 14 degrees Celsius. Average annual precipitation ranges from 3500 mm on the west coast to less than 750 mm near Victoria. The majority of precipitation occurs in the fall and winter (B.C., 2000).

Streams and rivers generally flow out from interior lakes and snow packs, to the Pacific Ocean or the Strait of Georgia. River hydrology on Vancouver Island is predominantly rain-driven, as illustrated in Figure 32. This is characterized by low stream discharge and low rainfall in the summer, with heavy rainfalls and high flows in the winter (Wade et al., 2001). Critical low summer flows are experienced on the southeast portion of the Island. Water needs by agricultural, rural residential and some commercial activities are supplied by groundwater sources (B.C., 2000).

Vancouver Island rivers support a variety of fish including the five species of Pacific salmon, steelhead and cutthroat trout. Resident and anadromous fish populations of Island streams and lakes support valuable commercial and sport fisheries, as well as aboriginal sustenance fisheries. Past human activities have resulted in destruction of spawning and rearing habitats, while changing biophysical conditions and increased fishing in marine waters have all had impacts on the number of anadromous fish returning to spawn in Vancouver Island streams (B.C., 2000).

Land use on Vancouver Island is dominated by forestry as forests cover about 91% of the Island. Just under half of this is original old growth forest and the remainder is managed second growth. Agriculture, urban settlements, parks and protected areas and mining make up the remaining 9%. Urban growth has been primarily concentrated around the Capital (Victoria), Nanaimo and Cowichan Regional Districts.

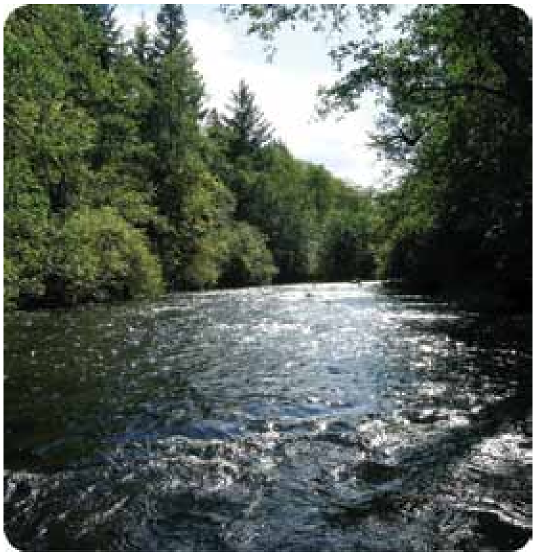
Historical and current mines on Vancouver Island include the Mount Washington, Myra Falls, Quinsam Coal, Island Copper and the Boliden-Westmin mines. The Quinsam River at the Mouth and Tsolum River below Murex Creek water quality stations are downstream of the Quinsam Coal and abandoned Mount Washington, mines respectively. Arsenic, manganese, iron and sulphate are contaminants of concern in the Quinsam River as a result of mining operations and naturally high background levels in surrounding sandstone and mudstone. The waste rock from the Mount Washington mine is generating copper bearing acid rock drainage that is impacting the Tsolum River.

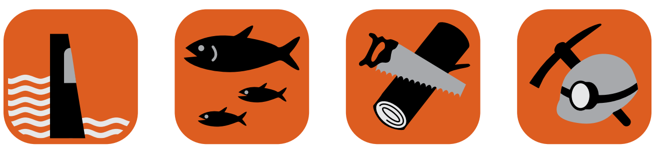
Impacts to water quality from forestry include possible increased flow, suspended solids and temperature in streams from logging. Agriculture and urban run-off can lead to increased nutrients (nitrogen and phosphorus), chloride, pesticides, hydrocarbons and bacteria. Mixtures of nutrients, chloride, sulfides, phenols, surfactants and heavy metals are all found in municipal wastewater effluents as well as emerging substances such as pharmaceuticals, endocrine disruptors and personal care products (EC, 2001).

Figure 33. Vancouver Island map showing water quality monitoring stations.

Quinsam River near the mouth

Year	2003	2004	2005	2006	2007
Biological	Highly Divergent	Highly Divergent	Divergent	Mildly Divergent	Mildly Divergent
Water Quality	Good	Good	Good	Good	Good





River Characteristics

The Quinsam River is located on eastern Vancouver Island, southeast of the town of Campbell River, B.C. The Quinsam River originates south of Upper Quinsam Lake. It flows north into Upper Quinsam Lake, then into Wokas Lake and then east into Middle Quinsam Lake. From there, it continues to flow east into Quinsam Lake and finally into the Campbell River. The Iron River is a major tributary to the Quinsam River. The total drainage area of the Quinsam River is 280 km^2. The river supports five species of Pacific salmon, both wild and hatchery-raised, as well as steelhead and cutthroat trout (DFO, 2006).

The monitoring station is located upstream of the Highway 20 bridge just west of Campbell River. Bi-weekly sampling was initiated at this station in February 1986. Other environmental stations of interest to this location include WSC Quinsam River near Campbell River (ID: 08HD005) water quantity monitoring station and Environment Canada's Quinsam River Hatchery climate station (ID: 1026639).

Site-Specific Influences on Water Quality

The river responds to winter rain events with peak flows generally occurring from November to January. Low flow conditions prevail throughout the summer months and into early fall (Figure 34).

There are two dams on the Quinsam River; a storage dam at the outlet of Wokas Lake and a diversion dam, diverting water to Lower Campbell Lake for hydroelectric power generation at Ladore and John Hart power stations, between Wokas Lake and Middle Quinsam Lake (Swain, 2007).

Other land uses include mining, forestry and a fish hatchery. Quinsam Coal, currently an underground thermal coal mine located upstream of Middle Quinsam Lake, began mining in the watershed in 1987. Most of the watershed has also been logged or burned since the 1930s, resulting in nearly 70% of

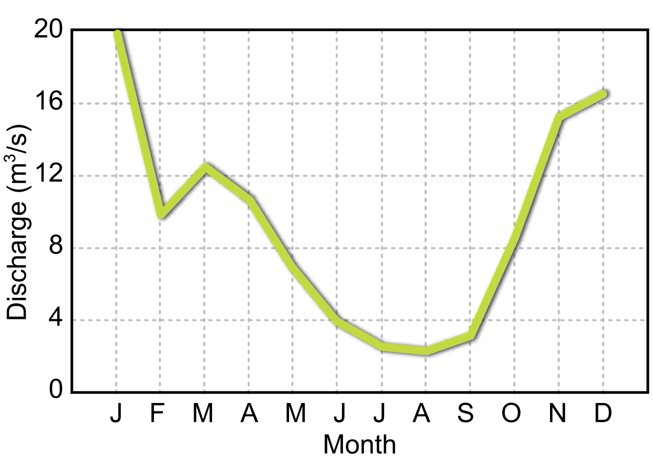


Figure 34. Mean monthly discharge for Quinsam River near the mouth from 2003 to 2007.

the watershed being young or recently logged forest (Navus, 2006).

Fishing is also popular on the river. Beginning in 1974, the Quinsam River fish Hatchery, located 3 km from the mouth of the river, has boosted returns of coho, chinook and pink salmon runs in the river (DFO, 2006)

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 13.

Table 13. Quinsam River near the mouth: Water quality variables used to calculate the WQI.

Variable
water temperature, total alkalinity, pH
total arsenic, total copper, total iron, total lead, total zinc
total dissolved nitrogen, total dissolved phosphorus

Results using the WQI indicated **Good** water quality from 2003 to 2007. Alkalinity dropped below the guideline occasionally; however the river has naturally low alkalinity. Total dissolved phosphorus exceeded guidelines twice in 2003. Copper exceeded the guideline during turbidity events from 2003 to 2007. Iron also exceeded the guideline in 2005 and 2007 during high flow events.

Significant increasing trends in turbidity, specific conductivity, alkalinity, hardness and sulphate were identified in assessments from 1986 to 2007. With the exception of turbidity, the increasing trends are likely indications of neutralized acid drainage from the upstream Quinsam coal mine (BWP, 2002). However, these trends appear to have leveled off since 2000 (Figure 35). Open pit mining stopped at Quinsam Coal in 1994 (HRL, 2009).

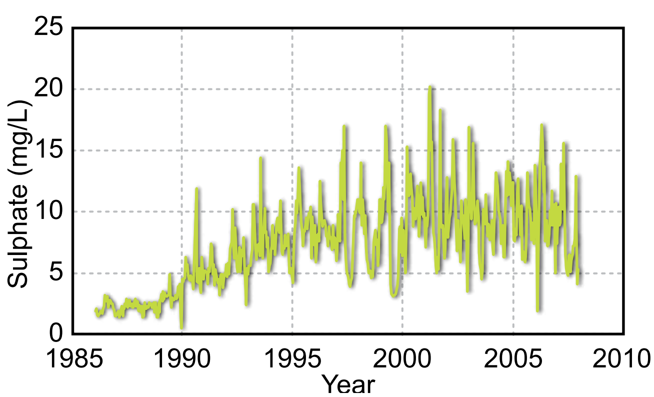


Figure 35. Sulphate concentrations at the Quinsam River station from 1986 to 2007.

A recent study conducted by UBC in 2010 found arsenic sediment concentrations in Long Lake that have been attributed to acid rock drainage and other chemical processes associated with mine waste. High arsenic levels were also associated with high sulphate levels in water from Long Lake. However, nearby lakes including Middle Quinsam Lake were unaffected. Higher arsenic loadings were also detected in mussels from the Quinsam River in relation to the same species collected in another watershed (UBC, 2010).

Figure 36. Comparison of annual benthic community samples at the Quinsam River near the mouth in 2003 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

Biological Assessment

The Quinsam River station was predicted to be similar to the Fraser/Georgia Basin macroinvertebrate communities in Reference Group 1 (Sylvestre et al., 2005).

CABIN water quality assessment results indicated biological condition improving from **Highly Divergent** to **Mildly Divergent** classification from 2003 to 2007 (Figure 36). In 2003 and 2004, the community was dominated by worms and midges, with few sensitive taxa present compared to predicted reference communities. In 2005 to 2007, the abundance and richness of sensitive insects increased while the dominance of worms and midges decreased (Strachan et al., 2009), becoming more similar to reference communities.

Overall Water Quality Condition

The prominence of worms and midges, and the lack of sensitive insect taxa found in early CABIN assessments, suggests nutrient enrichment or low dissolved oxygen conditions. Although neither of these variables were divergent from expected water quality conditions, other water quality variables (alkalinity and some other dissolved constituents) continued to increase over time, but rarely exceeded guidelines and were not expected to affect aquatic life. Thus, a combination of other habitat disturbances, such as bank sloughing, extreme hydrologic events and a nutrient pulse related to a salmon die-off event, may have contributed to the changes noted in the biological assessment and were not otherwise detected by physical-chemical measurements (Strachan et al., 2009).

Early water quality and biological assessment results report different aquatic health conditions at this station. Strachan et al. (2009) reported a detailed study of the biological and water quality assessments of this watershed, and the differences were attributed multiple sources, such as habitat degradation and extreme hydrologic fluctuations that were not detected by the physical-chemical measurements but still affected the biological communities. However, in 2006 and 2007, water quality and biological assessments indicated similar conditions (**Good** and **Mildly Divergent**). The biological assessments illustrate a gradual overall improvement in the benthic macroinvertebrate community condition from 2003 to 2007.

Hillsborough Resources Limited submitted a request for a mine permit amendment to further develop the mine in 2009. Monitoring by Environment Canada, the BCMOE and Quinsam Coal Corporation is continuing to track any changes in water quality.

Tsolum River below Murex Creek

Year	2003	2004	2005	2006	2007
Biological	Similar to Reference	Similar to Reference	Similar to Reference	Mildly Divergent	Similar to Reference
Water Quality	--	--	Fair	Marginal	Fair

River Characteristics

The Tsolum River originates on Mount Washington and flows southeast about 30 km before joining the Puntledge River, just before the Puntledge enters the Strait of Georgia. The total drainage of the Tsolum River is 258 km^2. Historically, the Tsolum River has supported large populations of steelhead and resident rainbow trout, anadromous cutthroat trout, coho, pink and chum salmon (Deniseger and Pommen, 1995).

The monitoring station is located along the Duncan Bay Main logging road and is co-located with the WSC water quantity station (ID: 08HB089) of the same name. Bi-weekly water quality sampling was initiated at this location in May 2005. Another environmental station of interest to this location is Environment Canada's Black Creek climate station (ID: 1020880).

Site-specific Influences on Water Quality

Murex Creek is a tributary that drains 41 km^2 on the eastern flank of Mount Washington, including acid drainage from an abandoned open pit copper mine. The drainage area of the Tsolum just downstream from Murex Creek is 78 km^2.

The most significant impact on water quality in the Tsolum River is the abandoned copper mine on Mount Washington that operated between 1964 and 1967. By the 1980s, copper leaching from the mine had virtually eliminated the fisheries resource in the watershed. The province of B.C. funded a remediation project at the mine site from 1988 to 1991 that had some partial success, but was not sufficient to reinstate the fishery (BCMOE, 2008a).

In 2003 the completion of the Passive Wetland Treatment project resulted in reduced copper levels in the river to the point that fish have begun to return (Figure 37). The wetland has an effective lifespan of five to ten years (BCMOE, 2008a). The Tsolum River Restoration Society has reported increases in cutthroat trout, pink and coho stocks, but declines in chum

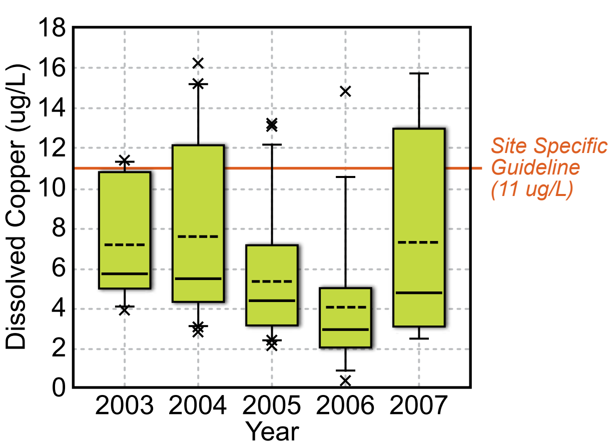


Figure 37. Box plots showing annual dissolved copper concentrations at the Tsolum River below Murex Creek from 2003 to 2007.

Table 14. Tsolum River below Murex Creek: Water quality variables used to calculate the WQI.

Variable
pH
dissolved aluminum, total copper, total cadmium, total lead, total selenium, total zinc
dissolved sulphate

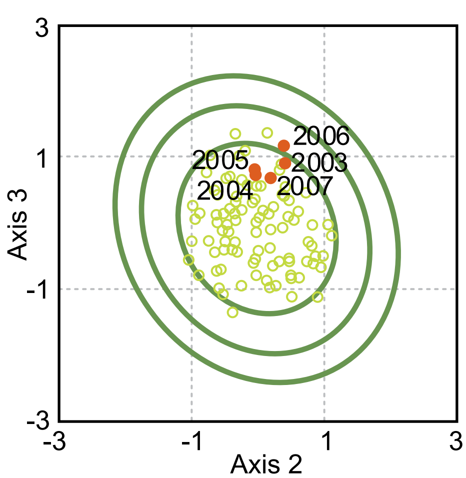


Figure 38. Comparison of annual benthic community samples at the Tsolum River below Murex Creek in 2003 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

salmon in 2009 (TRRS, 2009).

In 1964, the Department of Fisheries and Oceans installed a concrete dam at the outlet of Wolf Lake below the Tsolum River water quality monitoring station to facilitate water storage and augment stream flow during low flow periods for fish passage (Gooding, 2007).

Other influences on the river include agriculture and residential development in the lower watershed and logging in the upper watershed (Campbell, 2001).

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 14.

Results indicated **Marginal** water quality in 2005 and 2006 with a **Fair** rating in 2007. Guideline exceedances were noted for aluminum, cadmium, copper and zinc. Aluminum exceeded the guideline seven times between 2005 and 2007, while zinc only exceeded the guideline once in 2007. Elevated cadmium exceedances were observed in 2005 and 2006 and are responsible for the low WQI results. Copper exceeded guidelines four times between 2005 and 2007.

Other concerns are low flows in summer, high water temperature and elevated turbidity during high flows. In April 2008, the province announced a $4.5 million fund for a three phase mine remediation project that includes the installation of a geomembrane to cover the entire site. This will be covered with glacial till and then covered with vegetation to protect the area from weathering and erosion and further reduce harmful runoff from the site (BCMOE, 2008a).

Biological Assessment

The Tsolum River below Murex Creek was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005).

CABIN water quality assessment results for this station on the Tsolum River indicate **Similar to Reference** to **Mildly Divergent** benthic macroinvertebrate community composition, from 2003 to 2007. Benthic macroinvertebrate communities were similar to the predicted assemblages and were similar from year to year (Figure 38).

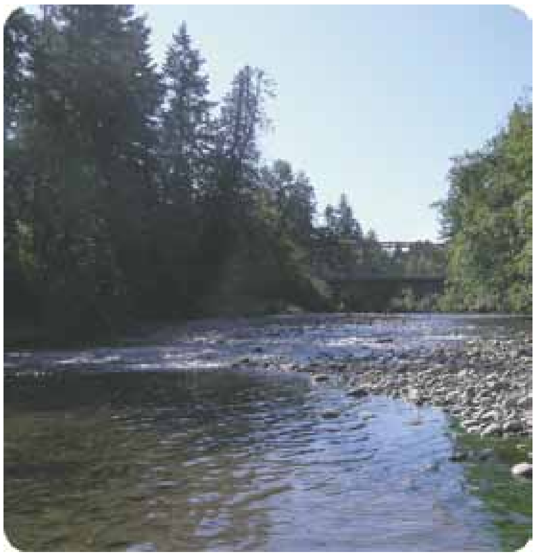
Overall Water Quality Condition

Water quality and biological assessment results indicated different conditions at this station. While the biological assessment indicates the benthic macroinvertebrate community is as expected in minimally disturbed watersheds, the water chemistry assessment suggests that there must be some potential impact to aquatic life. The WQI is largely driven by elevated cadmium concentrations, which are either not biologically available to the benthic macroinvertebrate communities or at concentrations below which community level effects can be detected.

The mine remediation project was mostly completed during the 2010 summer season (Ingram, 2010). Environment Canada, the BCMOE and local partners will continue monitoring at this station to assess the anticipated benefits of the mine remediation.

Englishman River at Highway 19

Year	2003	2004	2005	2006	2007
Biological	–	Mildly Divergent	Mildly Divergent	Mildly Divergent	Similar to Reference
Water Quality	--	--	Good	Good	Good



River Characteristics

The Englishman River is located on eastern Vancouver Island, and flows from its headwaters on Mount Arrowsmith east to Parksville, where it drains into the Strait of Georgia. Its total drainage area is 325 km^2. Major tributaries include the South Englishman River, Morison Creek and Marshall Creek. The river supports all species of salmon as well as steelhead and cutthroat trout (Nelitz et al., 2007).

The monitoring station is located on the downstream side of the old Highway 19 Bridge and is co-located with a BCMOE continuous automated water quality probe. Bi-weekly sampling was initiated at this station in November 2004. Other environmental stations of interest to this location include the WSC Englishman River near Parksville water quantity station (ID: 08HB002) and Environment Canada's climate station at Qualicum Airport (ID: 1026562).

Site-specific Influences on Water Quality

Peak flows occur between November and February, while minimum flows occur in late August or September. Figure 39 shows mean monthly discharge from 2003 to 2007. The Arrowsmith Dam was built to provide storage for a bulk water supply system to service Qualicum Beach, Parksville and the Regional District of Nanaimo. The dam controls the release of water from Arrowsmith Lake Reservoir to the Englishman River. The largest water licenses are allocated for domestic water use to Nanaimo Regional District and the City of Parksville (Nelitz et al., 2007).

The watershed is recovering from past logging beginning in the early 1900s, and again during the 1950s and 1960s. In the last 30 years logging has been reduced and is now focused primarily in the headwater areas (Bocking and Gaboury, 2001). In addition to logging, agriculture and urbanization are the other primary land uses in the watershed.

Low precipitation during the summer months,

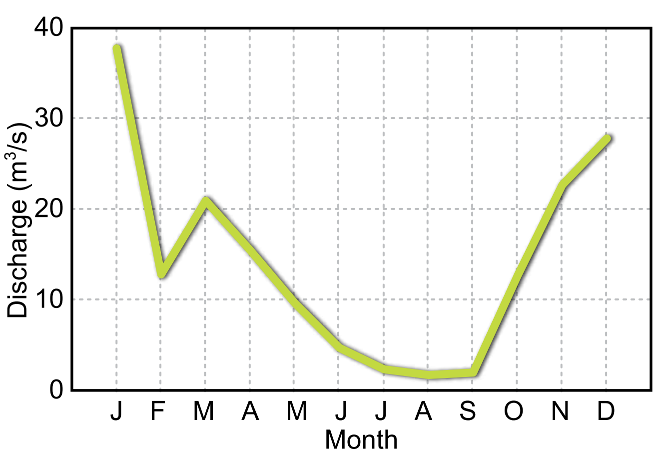


Figure 39. Mean monthly discharge for the Englishman River from 2003 to 2007.

insufficient storage at Arrowsmith Lake and increased summer demand for water are all contributing factors to low summer flows in the Englishman River. Habitat declines for salmon and steelhead in the river have been attributed to channel widening and sedimentation, induced by past logging practices. During the summer months this can lead to decreased wetted habitat for spawning fish (Lill, 2002 as cited in Nelitz et al., 2007).

Water Quality Index Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 15. Annual WQI results were calculated for the 2005 to 2007 period based on the availability of data. Results indicated **Good** water quality from 2005 to 2007.

Table 15. Englishman River at Highway 19: Water quality variables used to calculate the WQI.

Variable
water temperature, pH, turbidity
total cadmium, total copper, total lead, total zinc
total dissolved nitrogen, total phosphorus

Turbidity exceeded site specific guidelines most frequently during high flow periods in the winter. Water temperature exceeded site specific seasonal guidelines twice during the spring and once in the summer of 2005. Total phosphorus exceeded the guideline once in 2005.

Biological Assessment

The Englishman River at Highway 19 was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005) in 2004 to 2007.

CABIN water quality assessment results for this station indicated **Mildly Divergent** condition from 2004 to 2006, and **Similar to Reference** in 2007. No CABIN sampling took place at this location in 2003. There were only slight differences in the proportion of EPT taxa and non-insects measured at this station compared to those at Group 1 reference communities in 2004 to 2006. The community appeared to become more similar to the reference communities from 2004 to 2007 (Figure 40).

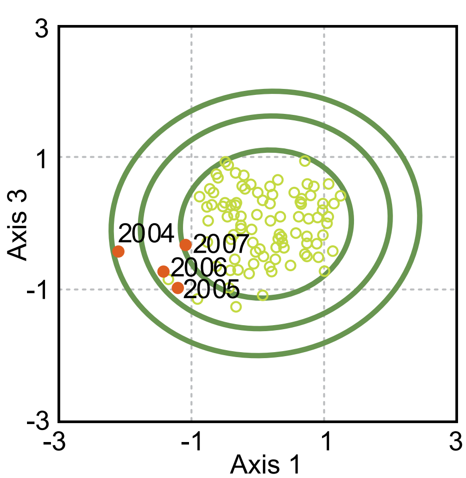


Figure 40. Comparison of annual benthic community samples at the Englishman River at Highway 19 in 2004 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

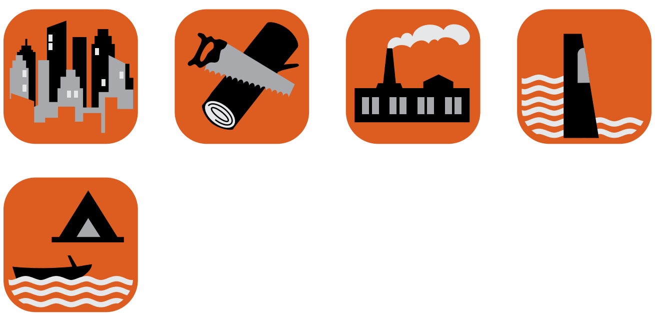
Overall Water Quality Condition

Generally, the chemical and biological assessments indicated similar **Good/Mildly Divergent** water quality conditions of the Englishman River from 2005 to 2007.

The BCMOE and the Nature Trust Lands established a Wildlife Management Area along the Englishman River in 2005 that spans 14 km from the estuary to Englishman River Falls Park (Nature Trust of British Columbia, 2005).

Cowichan River downstream of Somenos Creek

Year	2003	2004	2005	2006	2007
Biological	–	Similar to Reference	Mildly Divergent	Mildly Divergent	Mildly Divergent
Water Quality	--	--	Good	Fair	Fair



River Characteristics

The Cowichan River watershed is 939 km^2 with a mean annual discharge of 53 m^3/s (Rideout et al., 2000). The headwaters of the Cowichan River originate in the Insular Mountains on Vancouver Island. The upper half of the basin drains into Cowichan Lake; the river then flows 45 km east to the Cowichan Bay estuary.

The Cowichan River, with its low gradient waterways, has one of the largest remaining naturally spawning populations of Chinook salmon in the Georgia Basin (Nelitz et al., 2007). The River was designated a B.C. and Canadian Heritage River due to its habitat, recreation, First Nation and cultural significance. The Cowichan River Valley is the homeland of the Cowichan First Nation (CHRS, 2009).

The monitoring station is located 1 km downstream of Somenos Creek southeast of Duncan. Bi-weekly sampling was initiated at this location in July 1999. Other environmental stations of interest include the WSC Cowichan River near Duncan (ID: 08HA011) water quantity station and the Environment Canada North Cowichan climate station (ID: 1015628)

Site-specific Influences on Water Quality

Maximum runoff usually occurs between December and February, with minimum flows from August to October (Rideout et al., 2000). Cowichan Lake regulates the river's hydrology by stabilizing flows, settling sediment from tributaries, moderating water temperatures, and controlling inorganic and organic nutrients (Westland, 2007). Figure 41 shows mean monthly discharge from 2003 to 2007.

Most of the basin is designated for forestry. Many old growth trees in the basin have been logged and cutting of second growth is currently underway. Next to forestry, urbanization around Duncan, North Cowichan and Cowichan Lake is the primary land use in the basin. Agricultural land use is focused mainly around the Somenos Creek and Quamichan sub-basins

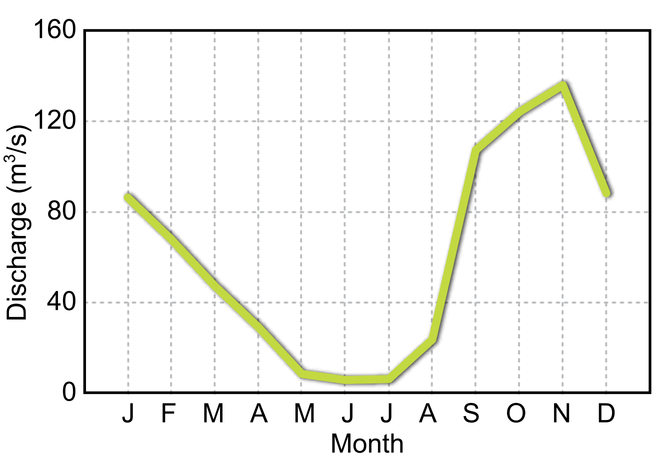


Figure 41. Mean monthly discharge for the Cowichan River from 2003 to 2007.

(Westland, 2007). Based on water licensing, current water uses in the basin include domestic, industrial, water storage, irrigation and conservation uses (Dessouki, 2010).

There is approximately 58 million m^3 of surface water withdrawn from the basin per year. Catalyst Paper Corporation withdraws approximately 89% of the total. Local utilities and individual surface water licensees withdraw the remainder. Water supply in the basin is limited in the summer, especially in September when water is removed from Cowichan Lake and Cowichan River at twice the rate of inflow. A low weir operated by Catalyst Paper was constructed at the outlet of Cowichan Lake in 1957. This helps prevent extreme low summer flows in the river and maintain ecological health (Westland, 2005).

There are currently three discharges of wastewater to the Cowichan River, the Duncan-North Cowichan Joint Utilities Board (JUB) Sewage Lagoons Waste Water Treatment Plant, the Town of Lake Cowichan Waste Water Treatment Plant and the provincial hatchery located in Duncan (Rideout et al., 2000). The monitoring station is located downstream of both the Duncan-North Cowichan JUB and the Town of Lake Cowichan WWTP discharges to the Cowichan River.

Table 16. Cowichan River downstream of Somenos Creek: Water quality variables used to calculate the WQI.

Variable
water temperature, pH, dissolved oxygen
total copper, total lead, total zinc
total phosphorus

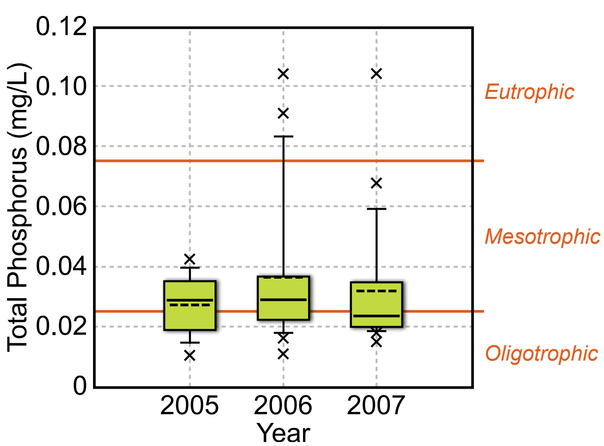


Figure 42. Box plots showing annual phosphorous concentrations at Cowichan River downstream of Somenos Creek station from 2005 to 2007.

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 16.

Results indicated **Good** water quality in 2005, with **Fair** water quality in 2006 and 2007. Total phosphorus concentrations frequently exceeded the trigger range for oligotrophic systems between 2005 and 2007 (Figure 39). Water temperatures frequently exceeded water quality guidelines during the summer months contributing to the Fair rating in 2006 and 2007. Dissolved oxygen levels dropped below the guideline in the fall from 2005 to 2007 and also in the spring of 2007.

Elevated phosphorus levels indicate the potential for eutrophication (increased algal growth) in the river. Eutrophication from elevated phosphorus levels and decreased flow during the summer months can

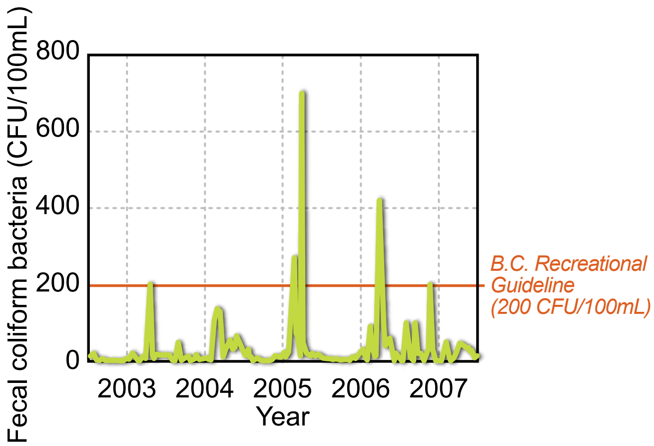


Figure 43. Fecal coliform bacteria counts at Cowichan River downstream of Somenos Creek station from 2003 to 2007.

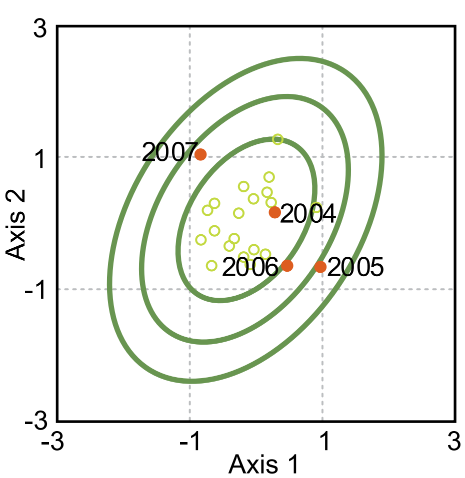


Figure 44. Comparison of annual benthic community samples at Cowichan River downstream of Somenos Creek in 2004 to 2007 with Group 4 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

lead to an increase in turbidity, an increase in algal biomass and anoxic sediment conditions, potentially impacting ecologically sensitive species (CCME, 2004). Due to concerns regarding impacts from excessive phosphorus levels, the Duncan-North Cowichan JUB WWTP added phosphorus removal in 2002, reducing phosphorus loadings to the river by more than 80% (pers. comm., John Deniseger, BCMOE).

Fecal coliform bacteria do not directly affect aquatic life and were not included in the WQI calculations. However, they are a potential concern in terms of human health at this station, as it is located one kilometer downstream of the Duncan-North Cowichan JUB WWTP. Bacteria counts exceeded the B.C. Recreational Guideline on occasion during the summer months between 2003 and 2007 (Figure 43). Prior to discharge wastewater effluent is disinfected. The primary source of fecal coliforms has been shown to be non-point sources upstream of the wastewater plant. As a result, fecal coliform levels are often slightly higher upstream of the wastewater plant (pers comm., John Deniseger, BCMOE). A water quality assessment conducted by BCMOE in 2010 reported fecal coliform bacteria levels were significantly increasing from 1999 to 2008 (Dessouki, 2010).

Biological Assessment

The Cowichan River downstream of Somenos Creek was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 4 (Sylvestre et al., 2005). This is a small group of reference sites from low gradients with small substrates and deeper channels. These communities are dominated by pollution tolerant organisms such as true flies (Diptera) and non-insects.

CABIN water quality assessment results for this station indicate **Similar to Reference** to **Mildly Divergent** condition in 2004 to 2007. The benthic communities were relatively similar in 2004 to 2006, with very large abundances of organisms, dominated by Dipterans (i.e. Chironomidae) and non-insects. The community shifted in 2007 (Figure 44), and became dominated primarily by mayflies rather than midges (Chironomidae), as in previous years. Despite the shift in the community structure, the degree of similarity to the reference communities did not change. No CABIN sampling took place at this location in 2003. Significant storm events in November 2006 caused substantial deposition and bed movement in the lower reaches of the river, and may have affected the assessment results for 2007.

Overall Water Quality Condition

Water quality and biological assessment results generally indicate **Fair** and **Mildly Divergent** water quality conditions. The expected biological communities in deeper streams with smaller substrates are dominated by organisms which tend to be pollution tolerant organisms. These organisms can tolerate low dissolved oxygen and increased nutrient concentrations. As such, the macroinvertebrate community at this station appears not to be responding to the elevated phosphorus levels. Therefore, periphyton may be a more sensitive biological indicator of aquatic health for sites where elevated nutrients are a concern, at least in this case.

In response to growing concerns over water availability and water quality, local, provincial and federal governments, the Cowichan Tribes and Catalyst Paper began working on a Water Management Plan for the Cowichan Basin in December 2004. The Cowichan Basin Water Management Plan was released in 2007 (Westland, 2007).

Koksilah River at Highway 1

Year	2003	2004	2005	2006	2007
Biological	–	Mildly Divergent	Mildly Divergent	Mildly Divergent	Similar to Reference
Water Quality	--	--	Good	Fair	Fair

River Characteristics

The Koksilah River originates on Waterloo Mountain, flowing east and entering the Cowichan River 1 km upstream of the Cowichan Bay Estuary (Pommen, L.W., 2004). Mean monthly discharge is approximately 9.81 m^3/s. The main tributaries of the Koksilah are Fellows, Kelvin and Glenora creeks. The Koksilah River supports steelhead, coho, chum and chinook salmon, and trout (Pommen, L.W., 2004).

The monitoring station is located upstream of the Highway 1 Bridge. Bi-weekly sampling was initiated at this station in June 1999. Other environmental stations of interest to this location include the WSC Koksilah River at Cowichan Station (ID: 08HA003) and the Environment Canada Duncan Kelvin Creek climate station (ID: 1012573).

Site-specific Influences on Water Quality

The Koksilah River is subject to the same climatic conditions as the Cowichan River, with wet winters and dry summers. Peak flows are typically between December and February, with minimum flows between August and October. River flows are approximately 95% lower than in the Cowichan River so it responds more directly to storm events and dry periods due to lack of large lakes and upstream control structures. It is subject to low summer flows, sedimentation and flash floods (Rideout et al., 2000).

Forestry, agriculture and urban development are the main influences on the Koksilah River (Pommen, L.W., 2004). There are significant numbers of relatively large dairy farms along the Koksilah River mainstem and its tributaries. On-site sewage disposal systems and the dairy industry are potential sources of bacteriological and nutrient contamination (Rideout et al., 2000).

Based on licensing current water uses in the basin include domestic and industrial water supplies and irrigation (Dessouki, 2010). There is currently a gravel pit and washing facility located adjacent to the river

Table 17. Koksilah River at Highway 1: Water quality variables used to calculate the WQI.

Variable
water temperature, pH, dissolved oxygen
total copper, total lead, total zinc
total phosphorus

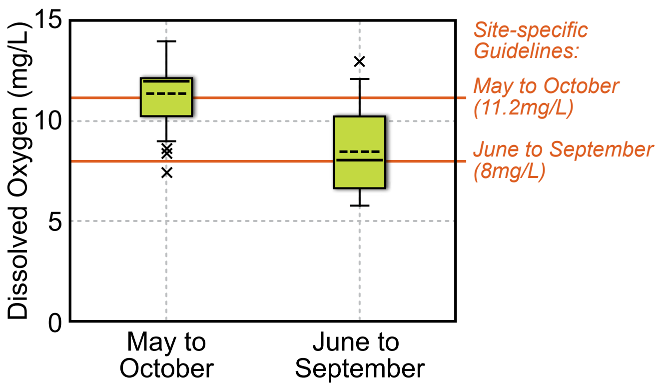


Figure 45. Dissolved oxygen concentrations grouped according to season at Koksilah River at Highway 1 from 2005 to 2007.

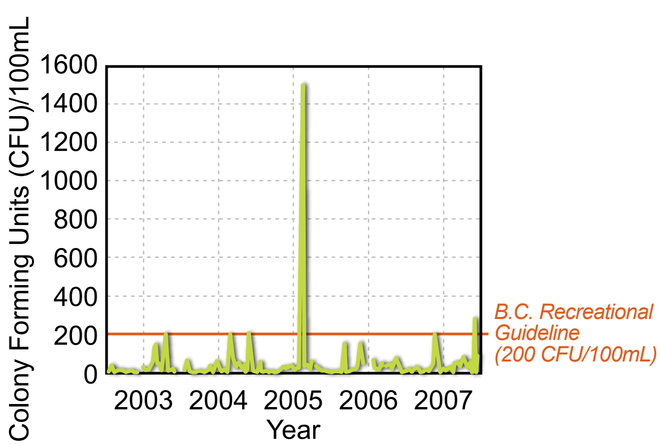


Figure 46. Fecal coliform bacteria counts at Koksilah River at Highway 1 from 2003 to 2007.

in Duncan. From 1970 to 1998, the Cowichan Valley Regional District operated a landfill and incinerator adjacent to the Koksilah River (CVRD, 2006).

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 17.

Results indicated **Good** to **Fair** water quality from 2005 to 2007. Dissolved oxygen frequently dropped below site specific seasonal guidelines between 2005 and 2007. Figure 45 shows median dissolved oxygen levels slightly below the seasonal guideline from June to September. Reduced oxygen levels have been shown to cause lethal and sublethal effects in various organisms, particularly fish (CCME, 1999).

Temperature often exceeded the guideline during the summer in 2006 due to extended warm, dry weather and occasionally in 2007, contributing to the Fair rating for those years. Total phosphorus exceeded the trigger range for oligotrophic systems once in 2005 and occasionally in 2006 and 2007.

There are non-point sources of nutrient and bacteria contamination at this station. Fecal coliform bacteria do not directly affect aquatic life and were not included in the WQI calculations, however they are a potential concern with respect to human health. Fecal coliform bacteria counts were at or exceeded the B.C. Recreational Guideline on occasion during rain events from 2003 to 2007 (Figure 46). A recent water quality assessment conducted by BCMOE reported generally higher fecal coliform bacteria measurements in the Koksilah River than in the Cowichan River however, there were no significant trends from 1999 to 2008 (Dessouki, 2010).

Biological Assessment

The Koksilah River at Highway 1 was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 4 (Sylvestre et al., 2005). This is a small group of reference sites from low gradients with small substrates and deeper channels. These communities are dominated by pollution tolerant organisms such as true flies (Diptera) and non-insects.

Mildly Divergent conditions were detected in 2004

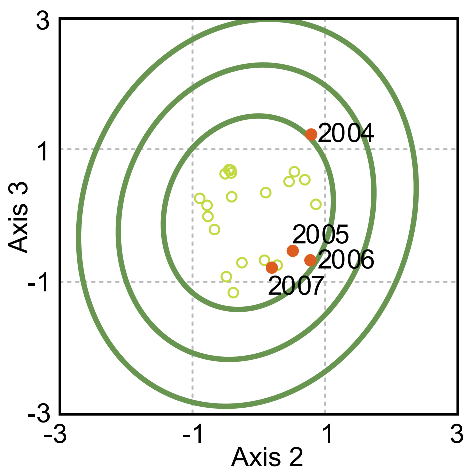


Figure 47. Comparison of annual benthic community samples at Koksilah River at Highway 1 in 2004 to 2007 with Group 4 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

to 2006, and the station was **Similar to Reference** in 2007. Communities were very similar in 2005 to 2007 despite the difference in assessment scores. In 2004, although the community was similar to the reference sites, there was a very large abundance of organisms relative to what was found in following years (Figure 44). As expected for sites similar to Group 4 reference communities, Diptera and non-insect taxa tended to dominate the community at this station. These organisms also tend to be pollution tolerant organisms and are not sensitive to small increases in nutrient concentrations or oxygen depletion.

Overall Water Quality Condition

Water quality and biological assessment results generally indicate **Fair** and **Mildly Divergent** water quality conditions.

As expected based on the predicted assemblages, the benthic communities did not respond to the elevated temperature, occasional phosphorus exceedances, or depressed dissolved oxygen. Given the nature of this macroinvertebrate reference group and their generalized pollution tolerance, periphyton may be a more sensitive biological indicator of aquatic health for sites where elevated nutrients and temperature are a concern.

San Juan River at Island Road

Year	2003	2004	2005	2006	2007
Biological	Mildly Divergent	Mildly Divergent	Highly Divergent	Highly Divergent	Mildly Divergent
Water Quality	--	--	Excellent	Fair	Good

River Characteristics

The San Juan River has a total drainage area of 670 km^2. Harris Creek and Lens Creek are major tributaries to the river, which empties into Port San Juan near Port Renfrew on the west coast of Vancouver Island. The River supports anadromous steelhead and cutthroat trout, chinook, coho, chum and pink salmon along with resident cutthroat and rainbow trout (Smith, 2004). It is a culturally significant river to the Pacheedaht First Nations (Rideout, 2004).

In the winter sampling occurs from shore at Island Road and the summer sampling station is co-located with the WSC San Juan River near Port Renfrew (ID: 08HA010) water quantity station. Bi-weekly sampling was initiated at this location in October 2003. Another environmental station of interest to this location is the Environment Canada Port Renfrew climate station (ID: 1016335).

Site-specific Influences on Water Quality

The San Juan valley faces west and is open to Pacific storms that reach the coast. Maximum daily rainfalls typically occur in winter between November and February. Discharge closely follows precipitation, with maximum flows occurring in December and January, and minimum flows in August. Since the 1960s, maximum instantaneous flows have exceeded 1000 m^3/s at least once each decade (NHC, 1994). The last major flood event was during the 1998/1999 winter season (Muller and Muller, 1999). Figure 48 shows mean monthly discharge from 2003 to 2007.

The San Juan River watershed has been extensively logged since the 1930s, causing channel simplification, hill slope erosion and bank instability within the watershed. Second growth forest is currently being harvested (NHC, 1994). Recreational fishing and camping are popular along the river.

Fish escapements have declined over the past 20 years, due to the habitat degradation mentioned above and

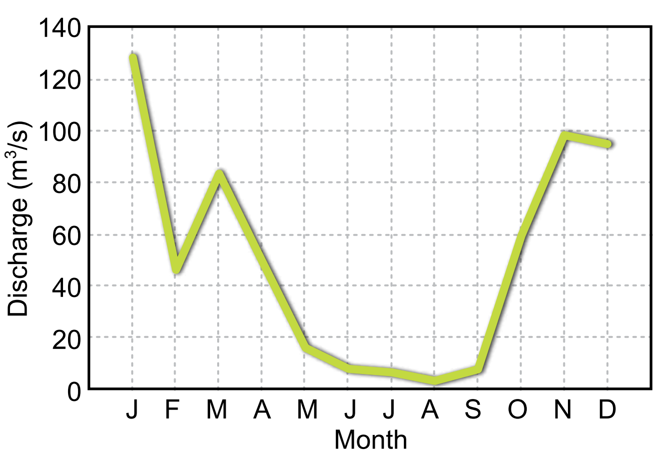


Figure 48. Mean monthly discharge for the San Juan River from 2003 to 2007.

variable ocean survival rates (Griffith, 1996 as cited in Smith, 2004). Since the mid 1990s, the watershed has been the focus of many restoration activities such as the creation of side channels on tributaries to enhance fish habitat (Smith, 2004). A salmon hatchery is also located in the watershed on Four Mile Creek above Fairy Lake.

Water Quality Assessment

Water quality variables used to calculate the WQI at this station are shown in Table 18.

Table 18. San Juan River at Island Road: Water quality variables used to calculate the WQI.

Variable
water temperature, pH
total cadmium, total chromium, total copper, total lead
total dissolved phosphorus

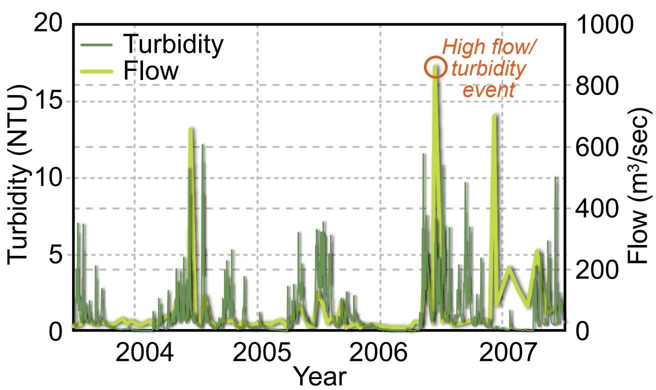


Figure 49. Turbidity concentrations and flow at San Juan River at Island Road from 2004 to 2007.

Results using the WQI indicated **Excellent**, **Fair** and **Good** water quality condition at this station in 2005, 2006 and 2007 respectively. Total cadmium, chromium and copper concentrations exceeded the guidelines once during a high flow and turbidity event in 2006. The 2006 WQI rating was significantly lower due to this event (Figure 46). At this time the metals were bound to the sediment, and therefore likely unavailable to aquatic life. Also, there were fewer samples collected in 2005 and water quality may not have been fully characterized for that year.

A study conducted in 1994 of the San Juan watershed showed that the volume of sediment contributed to the river has increased greatly from 1952 to 1980. Most of the extra sediment generated by landslides was from logged terrain. As a result, the lower San Juan River has widened greatly and straightened, primarily as a result of sediment contributed by Harris, Lens and Hemmingsen creeks. Substrate quality can affect spawning success, incubation success, rearing habitat quality and macroinvertebrate production. Fine sediments are particularly detrimental to successful salmon reproduction (NHC, 1994).

Two major log jams on the San Juan River occurred in June 2007, blocking the north arm and diverting water to the south arm of the river. Some of the logs were cleared out in August 2007 (Lavoie, 2007).

Biological Assessment

The San Juan River at Island Road was predicted to be similar to the Fraser/Georgia Basin communities in Reference Group 1 (Sylvestre et al., 2005).

CABIN water quality assessment results for this station

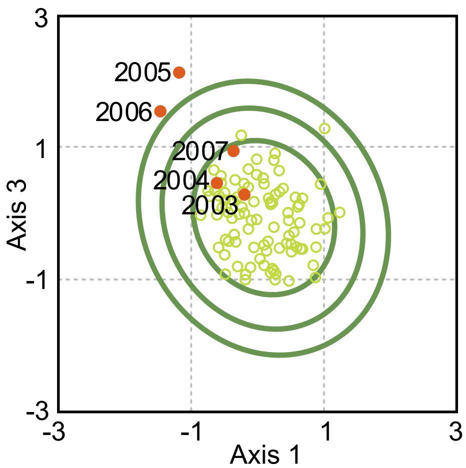


Figure 50. Comparison of annual benthic community samples at San Juan River in 2003 to 2007 with Group 1 reference communities in a multi-dimensional scaling plot using Bray-Curtis dissimilarities.

on the San Juan River indicated **Mildly Divergent** to **Highly Divergent** conditions from 2003 to 2006, and returned to **Mildly Divergent** conditions in 2007. The community changed substantially from one year to the next, as dominance of Chironomidae increased from 10% in 2003 to 15% in 2004. The population then increased to nearly 90% in 2005, followed by a slight decrease to 70% in 2006 and a substantial decrease to 23% in 2007. It appears that the community was continuously diverging from the reference communities from 2003 to 2005, but may be moving back toward the reference communities beginning in 2006 (Figure 48). Continued monitoring will be required to confirm this.

Overall Water Quality Condition

Overall water quality and biological assessment results indicate different impacts at this station. In 2005 and 2006, CABIN results indicate **Highly Divergent** conditions based on the biological community while the WQI indicated **Excellent** and **Fair** water quality based on physical-chemical composition.

The CABIN assessment may be detecting habitat degradation from sedimentation by landslides, as burrowing organisms heavily dominated the community in 2005 and 2006. These landslides were due to later spring and summer rain events, as indicated by data from the downstream Water Survey of Canada station (WSC, 2009). Such events would not necessarily be detected by physical-chemical measurements, including those used to calculate the WQI.

Table 19. Summary of WQI and CABIN assessments.

Station	Indicator	2003	2004	2005	2006	2007
UPPER CHEAKAMUS RIVER WATERSHEDS						
Callaghan Creek below Callaghan Lake	Biological	--	Similar to Reference	Mildly Divergent	Mildly Divergent	Similar to Reference
	Water Quality	--	93.5 Good	93.5 Good	87.1 Good	100 Excellent
Callaghan Creek at Highway 99	CABIN (Gp 1)	Mildly Divergent	Divergent	Mildly Divergent	Mildly Divergent	Mildly Divergent
	Water Quality	--	93.6 Good	93.5 Good	93.6 Good	93.6 Good
Cheakamus River at Daisy Lake Forest Road	CABIN (Gp 1)	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference	Similar to Reference
	Water Quality	--	85.2 Good	85.6 Good	78.3 Fair	85.5 Good
LOWER FRASER RIVER WATERSHEDS						
Fraser River at Hope	CABIN (Gp 2)	Similar to Reference	Similar to Reference	Mildly Divergent	Similar to Reference	Similar to Reference
	Water Quality	89.4 Good	89.2 Good	89.0 Good	89.3 Good	88.7 Good
Sumas River at International Boundary	CABIN (Gp 4)	Similar to Reference	Similar to Reference	Similar to Reference	--	Mildly Divergent
	Water Quality	75.2 Fair	69.7 Fair	67.3 Fair	70.3 Fair	68.2 Fair
North Alouette River at 132nd Avenue and Edge Street	CABIN (Gp 1)	Mildly Divergent	Similar to Reference	Mildly Divergent	Mildly Divergent	Similar to Reference
	Water Quality	--	78.2 Fair	86.4 Good	87.0 Good	93.5 Good
VANCOUVER ISLAND WATERSHEDS						
Quinsam River near the mouth	CABIN (Gp 1)	Highly Divergent	Highly Divergent	Divergent	Mildly Divergent	Mildly Divergent
	Water Quality	82.6 Good	88.4 Good	94.1 Good	82.7 Good	82.6 Good
Tsolum River below Murex Creek	CABIN (Gp 1)	Similar to Reference	Similar to Reference	Similar to Reference	Mildly Divergent	Similar to Reference
	Water Quality	--	--	69.0 Fair	56.1 Marginal	68.0 Fair
Englishman River at Highway 19	CABIN (Gp 1)	--	Mildly Divergent	Mildly Divergent	Mildly Divergent	Similar to Reference
	Water Quality	--	--	80.7 Good	93.6 Good	90.7 Good
Cowichan River downstream of Somenos Creek	CABIN (Gp 4)	--	Similar to Reference	Mildly Divergent	Mildly Divergent	Mildly Divergent
	Water Quality	--	--	81.7 Good	72.4 Fair	73.1 Fair
Koksilah River at Highway 1	CABIN (Gp 4)	--	Mildly Divergent	Mildly Divergent	Mildly Divergent	Similar to Reference
	Water Quality	--	--	83.4 Good	74.1 Fair	74.4 Fair
San Juan River at Island Road	CABIN (Gp 1)	Mildly Divergent	Mildly Divergent	Highly Divergent	Highly Divergent	Mildly Divergent
	Water Quality	--	--	100 Excellent	75.2 Fair	91.7 Good

Note: "--" indicates assessment result not available

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Appendix 1: Standard water quality analytical methods for GBAP water quality monitoring stations.

Parameter	Method	Method Detection Limit	Lab
MAJOR IONS			
Calcium, dissolved Magnesium, dissolved	Inductively Coupled Plasma Mass Spectrometer (ICP-MS)[1]	0.05 mg/L	Maxxam Analytics
Sulphate, dissolved Chloride, dissolved	Automated Colorimetric[1]	0.5 mg/L	Maxxam Analytics
TOTAL AND EXTRACTABLE TRACE METALS			
Aluminum	Inductively Coupled Plasma Sector Field Mass Spectrometer (ICP-SFMS)[2]	0.2 µg/L	NLET
Arsenic		0.01 µg/L	
Cadmium		0.001 µg/L	
Chromium		0.005 µg/L	
Copper		0.02 µg/L	
Lead		0.005 µg/L	
Iron		0.5 µg/L	
Molybdenum		0.005 µg/L	
Nickel		0.02 µg/L	
Selenium		0.05 µg/L	
Silver		0.001 µg/L	
Thallium		0.001 µg/L	
Zinc		0.05 µg/L	
HARDNESS	CALCULATED (Ca*2.497 + Mg*4.117)	0.5 mg/L	Maxxam
PH	Electrometric pH measurement[1]	0.1 pH UNITS	Maxxam
ALKALINITY	Auto potentiometric titration[1]	0.1 mg/L	Maxxam
TEMPERATURE	Field thermometer	0.5 deg C	Field
TURBIDITY	Laboratory nephelometer[1]	0.1 NTU	Maxxam
DISSOLVED OXYGEN	LaMotte kit – azide modification of the Winkler titration[3]	0.1 mg/L	Field
NUTRIENTS			
Nitrogen, nitrate/nitrite Nitrogen, total dissolved Phosphorus, total dissolved	Colorimetric[1]	0.002 mg/L 0.02 mg/L 0.002 mg/L	Maxxam
Phosphorus, total	Photometric[2]	0.5 µg/L	NLET

[1] Personal communication with Maxxam Analytics, Burnaby, B.C.

[2] National Laboratory for Environmental Testing (NLET) Schedule of Services 2008-2009 Environment Canada, Burlington, ON

[3] LaMotte Dissolved Oxygen Water Quality Test Kit Instruction Manual Code 5860

Appendix 2: Guidelines used to calculate the WQI.

	Station	Variable	Value	Guideline	Source
UPPER CHEAKAMUS RIVER WATERSHEDS	Callaghan Creek below Callaghan Lake	Water temperature	>13°C Nov-Mar >19°C Mar-Nov	B.C.	Oliver and Fidler, 2001
		Nitrogen, total dissolved	>0.7 mg/L	Canada	GC, 2008
		Copper, total	>2 µg/L		
		Lead, total	>1 µg/L		
		Zinc, total	>7.5 µg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Chloride, dissolved	>150 mg/L	BCMOE	Nagpal et al., 2003
		Cadmium, total	>0.015 µg/L	SSG	Swain, 2009a
		Phosphorous, total	>0.009 mg/L		
	Callaghan Creek at Highway 99	Water temperature	>13°C Nov-Mar >19°C Mar-Nov	B.C.	Oliver and Fidler, 2001
		Phosphorous, total	>0.025 mg/L	Canada	GC, 2008
		Copper, total	>2 µg/L		
		Lead, total	>1 µg/L		
		Zinc, total	>7.5 µg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Chloride, dissolved	>150 mg/L	BCMOE	Nagpal et al., 2003
		Cadmium, total	>0.015 µg/L	SSG	Swain, 2009a
		Silver, total	>0.05 µg/L	BCMOE	Warrington, 1996
	Cheakamus River at Daisy Lake Forest Road	Water temperature	>13°C Nov-Mar >19°C Mar-Nov	B.C.	Oliver and Fidler, 2001
		Phosphorous, total	> 0.025 mg/L	Canada	GC, 2008
		Copper, total	>2 µg/L		
		Lead, total	>1 µg/L		
		Zinc, total	>7.5 µg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Chloride, dissolved	>150 mg/L	SSG	Swain, 2009a
		Cadmium, total	>0.013 µg/L	SSG	Swain, 2009a

	Station	Variable	Value	Guideline	Source
LOWER FRASER RIVER	Fraser River at Hope	Water temperature	>19°C	B.C.	Oliver and Fidler, 2001
		Silver, total	>0.05µg/L		Warrington, 1996
		Zinc, total	>7.5µg/L		Nagpal, 1999
		Oxygen, dissolved	<8mg/L		BCMOE, 1997
		Copper, total	>2µg/L	Canada	GC, 2008
		Phosphorus, total dissolved	>0.025mg/L		
		Nitrogen, total dissolved	>0.7mg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Arsenic, total	>5µg/L		
		Thallium, total	>5 µg/L		
	Sumas River at Interantional Boundary	Water temperature	>19°C	B.C.	Oliver and Fidler, 2001
		Zinc, total	≥7.5 µg/L when $CaCO_3$ ≤90 mg/L, 7.5+(0.75*(water hardness-90) µg/L when > 90mg/L		Nagpal, 1999
		Sulphate, dissolved	>50 mg/L		Singleton, 2000
		Copper, total	$>0.2(e^{[0.8545(ln[hardness])-1.465]}$ µg/L when $[CaCO_3]$ > 90mg/L	Canada	GC, 2008
		Lead, total	$>e^{(1.273(ln*[hardness])-4.705)}$ µg/L when $[CaCO_3]$ > 50mg/L		
		Nickel, total	$>e^{(0.76[ln*(hardness)+1.06)}$ µg/L		
		Phosphorus, total	>0.025mg/L		
		Cadmium, total	$\geq 10^{(0.86[log(hardness)]-3.2)}$ µg/L when $CaCO_3$ > 50mg/L	CCME	CCME, 2007
		pH	>6.5, <9		
		Molybdenum, total	>73µg/L		
		Nitrate, dissolved	>2.93mg/L		
		Chromium, total	>28.6µg/L	SSG	Swain, 2005
		Oxygen, dissolved	<6mg/L		
	North Alouette River at 132nd Avenue and Edge Street	Water temperature	>13°C Nov-Mar >19°C Mar-Nov	B.C.	Oliver and Fidler, 2001
		Oxygen, dissolved	<8mg/L		BCMOE, 1997
		Copper, total	>2µg/L	Canada	GC, 2008
		Lead, total	>1µg/L		
		Zinc, total	>7.5µg/L		
		Nitrogen, total dissolved	>0.7mg/L		
		pH	>6.5, <9	CCME	CCME 2007
		Cadmium, total	>0.011µg/L	SSG	Ryan, 2009
		Phosphorous, total	>0.025mg/L		

	Station	Variable	Value	Guideline	Source
VANCOUVER ISLAND WATERSHEDS	Quinsam River near the mouth	Water temperature	>19°C	B.C.	Oliver and Fidler, 2001
		Zinc, total	≥7.5 µg/L when $CaCO_3$ ≤90 mg/L		Nagpal, 1999
		Copper, total	>2µg/L when [$CaCO_3$] < 90mg/L	Canada	GC, 2008
		Lead, total	>$e^{(1.273(\ln*[hardness])-4.705)}$ µg/L when [$CaCO_3$] > 50mg/L, 1 µg/L when $CaCO_3$ < 50mg/L		
		Nitrogen, total dissolved	>0.7mg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Arsenic, total	>5µg/L		
		Iron, total	>300mg/L		
		Alkalinity, total	>20mg/L	SSG	Ryan, 2004
		Phosphorus, total dissolved	>0.025mg/L		
	Tsolum River below Murex Creek	Sulphate, dissolved	>50mg/L	B.C.	Singleton, 2000
		Selenium, total	>0.002mg/L		Nagpal and Howell, 2001
		Aluminum, dissolved	>0.05mg/L		Butcher, 1988
		pH	>6.5, <9	CCME	CCME, 2007
		Cadmium, total	≥$10^{(0.86[\log(hardness)]-3.2)}$ µg/L when $CaCO_3$ > 50mg/L		
		Lead, total	>$e^{(1.273(\ln*[hardness])-4.705)}$ µg/L when [$CaCO_3$] > 50mg/L		
		Zinc, total	≥7.5 µg/L when $CaCO_3$ ≤90 mg/L		
		Copper, total	> 11 µg/L	SSG	Deniseger, 1995
	Englishman River at Highway 19	Zinc, total	≥7.5 µg/L when $CaCO_3$ ≤90 mg/L	B.C.	Nagpal, 1999
		Copper, total	>2 µg/L when $CaCO_3$ <90mg/L	Canada	GC, 2008
		Lead, total	>1 µg/L when $CaCO_3$ <50mg/L		
		Nitrogen, total dissolved	>0.7mg/L		
		Phosphorus, total	>0.025mg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Cadmium, total	≥0.019 µg/L when $CaCO_3$ <50 mg/L		
		Water temperature	>10°C Jan 1 - May 15 and Nov 16 - Dec 31 >15°C May 16 -Jun 30 >20°C Jul 01-Nov 15	SSG	BCMOE, 2007
		Turbidity	>5NTU		

Region	Station	Variable	Value	Guideline	Source
VANCOUVER ISLAND WATERSHEDS	Cowichan River Downstream of Somenos Creek	Water temperature	>19°C	B.C.	Oliver and Fidler, 2001
		Zinc, total	>33µg/L		Nagpal, 1999
		Phosphorus, total	>0.025mg/L	Canada	GC, 2008
		pH	>6.5, <9	CCME	CCME, 2007
		Oxygen, dissolved	<8mg/L Oct-May <11.2 mg/L Jun-Sept	SSG	McKean, C.J.P., 1989
		Lead, total	>8µg/L		
		Copper, total	>4µg/L		
	Koksilah River at Highway 1	Water temperature	>10°C Nov 16 - May 15 >13°C Sept 01 - May 15 >16°C May 16 - Aug 31	B.C.	Oliver and Fidler, 2001
		Phosphorus, total	>0.025mg/L	Canada	GC, 2008
		pH	>6.5, <9	CCME	CCME, 2007
		Oxygen, dissolved	<8mg/L Oct-May <11.2 mg/L Jun-Sept	SSG	McKean, C.J.P., 1989
		Lead, total	>8µg/L		
		Zinc, total	>180µg/L		
		Copper, total	>4µg/L		
	San Juan River at Island Road	Water temperature	>16°C	B.C.	Swain, 2009b
		Copper, total	>2 µg/L when $CaCO_3$ <90mg/L	Canada	GC, 2008
		Lead, total	>1 µg/L when $CaCO_3$ <50mg/L		
		Phosphorus, total dissolved	>0.025mg/L		
		pH	>6.5, <9	CCME	CCME, 2007
		Cadmium, total	$\geq 10^{(0.86[\log(hardness)]-3.2)}$ µg/L when $CaCO_3$ > 50mg/L, ≥0.019µg/L when $CaCO_3$ < 50mg/L		
		Chromium, total	>1µg/L		

Appendix 3: Detailed Statistical Summaries

Upper Cheakamus River

Callaghan Creek below Callaghan Lake												
2004 - 2007									Percentile Values			
		N	Average	Median	Max	Min	Standard Deviation	10^{th}	25^{th}	75^{th}	90^{th}
Water temperature	ºC	70	7.5	6.0	21.0	-0.5	5.9	1.0	2.0	12.0	16.0
pH	pH units	71	7.0	7.1	8.4	6.3	0.3	6.5	6.7	7.2	7.3
Specific conductivity	uS/cm	71	31	24	95	18	15	20	23	36	47
Turbidity	NTU	70	2.1	0.4	15.0	0.1	3.6	0.1	0.2	2.0	6.2
Alkalinity	mg/L	71	9.2	7.3	28.3	5.1	4.6	5.8	6.6	10.8	13.7
Chloride, dissolved	mg/L	70	0.6	0.5	1.5	0.5	0.2	0.5	0.5	0.5	0.9
Phosphorus, total dissolved	mg/L	70	0.003	0.002	0.015	0.002	0.002	0.002	0.002	0.003	0.004
Phosphorus, total	mg/L	69	0.003	0.002	0.044	0.001	0.007	0.001	0.001	0.003	0.004
Arsenic, total	ug/L	69	0.05	0.05	0.16	0.01	0.02	0.04	0.04	0.05	0.07
Cadmium, total	ug/L	71	0.008	0.008	0.014	0.001	0.003	0.005	0.007	0.009	0.011
Copper, total	ug/L	71	0.63	0.58	2.34	0.26	0.32	0.48	0.52	0.62	0.66
Lead, total	ug/L	70	0.020	0.009	0.220	0.005	0.039	0.005	0.005	0.016	0.024
Zinc, total	ug/L	70	0.83	0.69	3.73	0.05	0.58	0.43	0.53	0.89	1.21
Fecal coliforms	C/100mL	66	1.2	1.0	7.0	1.0	0.9	1.0	1.0	1.0	1.0

Callaghan Creek at Highway 99												
2004 - 2007									Percentile Values			
		N	Average	Median	Max	Min	Standard Deviation	10^{th}	25^{th}	75^{th}	90^{th}
Water temperature	ºC	97	5.9	5.5	14.0	-0.5	4.0	1.0	2.0	9.0	11.4
pH	pH units	99	7.0	7.2	7.6	5.9	0.4	6.5	6.8	7.3	7.5
Specific conductivity	uS/cm	99	44	38	86	1	18	24	30	55	70
Turbidity	NTU	99	6.6	2.3	119.0	0.1	14.8	0.4	0.8	6.9	16.1
Alkalinity	mg/L	99	13.2	11.4	26.1	5.3	5.3	7.3	9.5	15.9	21.4
Chloride, dissolved	mg/L	99	0.7	0.5	6.7	0.5	0.7	0.5	0.5	0.7	1.2
Phosphorus, total dissolved	mg/L	98	0.005	0.004	0.041	0.002	0.006	0.002	0.002	0.006	0.010
Phosphorus, total	mg/L	92	0.021	0.009	0.387	0.001	0.047	0.003	0.004	0.019	0.040
Arsenic, total	ug/L	96	0.08	0.07	0.55	0.01	0.06	0.05	0.06	0.09	0.10
Cadmium, total	ug/L	96	0.011	0.008	0.202	0.001	0.020	0.005	0.006	0.010	0.013
Copper, total	ug/L	96	1.10	0.69	21.80	0.37	2.21	0.51	0.58	0.89	1.71
Lead, total	ug/L	96	0.130	0.064	3.500	0.005	0.363	0.019	0.033	0.126	0.195
Zinc, total	ug/L	96	1.69	1.14	27.80	0.48	2.89	0.74	0.87	1.50	2.25
Fecal coliforms	C/100mL	97	5	1	160	1	21	1	1	1	3

Cheakamus River at Daisy Lake Forest Road												
2004 - 2007								Percentile Values				
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
Water temperature	ºC	104	8.2	8.5	15.0	0.5	4.0	3.0	5.0	11.0	14.0
pH	pH units	104	7.1	7.3	7.6	6.4	0.3	6.5	6.8	7.4	7.5
Specific conductivity	uS/cm	104	49	46	92	23	15	32	37	58	70
Turbidity	NTU	104	2.7	1.5	53.1	0.1	5.7	0.6	0.8	2.4	4.2
Alkalinity	mg/L	106	14.0	14.0	21.9	6.8	3.2	10.0	11.4	16.2	18.0
Chloride, dissolved	mg/L	104	1.8	1.0	9.2	0.5	1.8	0.5	0.5	2.5	4.1
Phosphorus, total dissolved	mg/L	104	0.007	0.006	0.023	0.002	0.005	0.002	0.002	0.008	0.014
Phosphorus, total	mg/L	106	0.021	0.011	0.727	0.007	0.070	0.008	0.009	0.018	0.025
Arsenic, total	ug/L	101	0.11	0.09	1.19	0.06	0.12	0.07	0.08	0.11	0.12
Cadmium, total	ug/L	100	0.007	0.006	0.094	0.001	0.009	0.004	0.005	0.007	0.010
Copper, total	ug/L	101	1.31	1.00	24.10	0.54	2.33	0.74	0.85	1.16	1.48
Lead, total	ug/L	100	0.068	0.034	2.280	0.005	0.229	0.011	0.020	0.052	0.088
Zinc, total	ug/L	99	1.15	0.68	33.30	0.20	3.32	0.37	0.55	0.90	1.38
Fecal coliforms	C/100mL	106	128.8	2.0	2200.0	1.0	315.8	1.0	1.0	54.5	415.0

Lower Fraser River

North Alouette at 132nd Avenue and Edge Street											
2004 - 2007								Percentile Values			
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
Water temperature	ºC	105	9.4	9.0	21.0	1.0	4.9	4.0	5.0	13.0	16.0
pH	pH units	107	6.7	6.6	7.5	6.1	0.3	6.3	6.4	6.9	7.1
Specific conductivity	uS/cm	107	18	17	33	9	6	12	14	20	29
Turbidity	NTU	107	0.4	0.3	2.9	0.1	0.4	0.2	0.2	0.4	0.7
Oxygen, dissolved	mg/L	37	10.8	11.0	13.0	8.1	1.4	9.0	9.9	12.0	13.0
Alkalinity	mg/L	107	4.3	3.7	9.9	1.0	2.2	2.0	2.9	5.0	8.1
Chloride, dissolved	mg/L	106	0.77	0.70	3.40	0.50	0.36	0.50	0.50	0.90	1.15
Phosphorus, total dissolved	mg/L	105	0.003	0.002	0.008	0.002	0.001	0.002	0.002	0.003	0.005
Phosphorus, total	mg/L	97	0.003	0.002	0.019	0.001	0.003	0.001	0.001	0.003	0.006
Arsenic, total	ug/L	103	0.17	0.16	0.31	0.08	0.05	0.12	0.14	0.18	0.24
Cadmium, total	ug/L	103	0.007	0.007	0.024	0.001	0.003	0.005	0.006	0.008	0.011
Chromium, total	ug/L	103	0.058	0.052	0.306	0.021	0.034	0.030	0.041	0.065	0.087
Copper, total	ug/L	99	0.45	0.42	1.09	0.19	0.12	0.33	0.37	0.50	0.61
Lead, total	ug/L	100	0.083	0.065	0.320	0.011	0.059	0.030	0.046	0.096	0.182
Zinc, total	ug/L	98	0.86	0.67	4.83	0.20	0.65	0.40	0.53	0.95	1.38
Fecal coliforms	C/100mL	104	28	8	380	1	55	1	2	28	64

Vancouver Island

Tsolum River below Murex Creek												
2005 - 2007								Percentile Values				
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
pH	pH units	35	6.9	6.8	7.6	6.4	0.4	6.5	6.6	7.2	7.4
Specific conductivity	uS/cm	22	31	26	56	21	11	21	23	36	46
Alkalinity	mg/L	32	10.0	9.0	20.6	3.2	4.4	5.5	6.8	12.4	16.4
Arsenic, total	ug/L	271	0.90	0.80	4.80	0.10	0.37	0.60	0.70	1.00	1.30
Cadmium, total	ug/L	253	0.070	0.020	4.370	0.003	0.302	0.010	0.010	0.040	0.090
Copper, total	ug/L	272	12.99	9.20	57.20	0.70	10.15	4.60	6.08	16.85	26.40
Copper, dissolved	ug/L	39	5.91	4.22	24.30	0.43	4.96	2.26	2.78	7.16	13.44
Lead, total	ug/L	251	0.074	0.050	0.690	0.010	0.080	0.020	0.030	0.090	0.160
Zinc, total	ug/L	274	2.16	1.60	21.80	0.20	2.17	0.80	1.10	2.40	3.87

Note: Total metals sample collected daily during certain periods using an automated sampler.

Englishman River at Highway 19											
2005 - 2007								Percentile Values			
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
Water temperature	ºC	84	9.0	8.0	22.0	1.0	5.0	3.0	5.0	13.3	16.0
pH	pH units	84	7.4	7.5	7.9	6.6	0.3	7.0	7.3	7.6	7.7
Specific conductivity	uS/cm	84	66	57	136	23	27	37	45	91	104
Turbidity	NTU	84	3.3	0.8	92.1	0.3	13.1	0.4	0.5	1.3	3.7
Phosphorus, total dissolved	mg/L	84	0.004	0.003	0.024	0.002	0.004	0.002	0.002	0.005	0.009
Phosphorus, total	mg/L	78	0.007	0.003	0.182	0.001	0.021	0.002	0.002	0.006	0.011
Nitrate + Nitrite	mg/L	84	0.029	0.020	0.100	0.002	0.026	0.003	0.009	0.049	0.070
Arsenic, total	ug/L	83	0.21	0.15	3.26	0.10	0.40	0.12	0.13	0.16	0.19
Cadmium, total	ug/L	83	0.004	0.002	0.078	0.001	0.012	0.001	0.001	0.002	0.004
Copper, total	ug/L	83	1.33	0.71	28.00	0.49	3.48	0.58	0.63	0.89	1.22
Lead, total	ug/L	83	0.079	0.022	2.250	0.005	0.282	0.006	0.010	0.046	0.107
Zinc, total	ug/L	83	1.03	0.26	37.30	0.05	4.53	0.08	0.15	0.44	0.94
Fecal coliforms	C/100mL	81	44	20	370	1	74	3	8	43	64

Cowichan River downstream of Somenos Creek											
2005 - 2007								Percentile Values			
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
Water temperature	ºC	84	9.4	8.1	20.0	-2.0	6.0	2.0	5.0	14.3	18.7
pH	pH units	74	7.5	7.6	7.9	6.9	0.2	7.3	7.4	7.7	7.8
Specific conductivity	uS/cm	83	60	57	86	43	9	50	53	67	71
Turbidity	NTU	84	5.4	1.5	44.6	0.1	9.6	0.5	0.8	4.9	15.0
Phosphorus, total dissolved	mg/L	84	0.015	0.015	0.038	0.002	0.006	0.007	0.010	0.018	0.022
Phosphorus, total	mg/L	71	0.033	0.028	0.104	0.011	0.019	0.018	0.021	0.035	0.058
Arsenic, total	ug/L	71	0.20	0.17	0.66	0.08	0.10	0.12	0.14	0.21	0.31
Cadmium, total	ug/L	71	0.004	0.003	0.041	0.001	0.006	0.001	0.002	0.004	0.008
Copper, total	ug/L	71	1.16	0.69	6.06	0.49	1.09	0.56	0.59	1.25	2.52
Lead, total	ug/L	71	0.075	0.035	0.471	0.007	0.09	0.014	0.020	0.088	0.190
Zinc, total	ug/L	71	1.07	0.60	6.21	0.05	1.28	0.18	0.29	1.30	2.66
Fecal coliforms	C/100mL	81	42	14	700	1	97	1	4	33	90

Koksilah River at Highway 1											
2005 - 2007								Percentile Values			
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
Water temperature	ºC	133	7.9	7.0	19.0	0.0	5.1	2.0	4.0	12.0	16.0
pH	pH units	74	7.6	7.6	7.9	7.0	0.2	7.3	7.5	7.7	7.8
Specific conductivity	uS/cm	103	112	101	195	43	43	60	77	158	170
Turbidity	NTU	137	2.2	1.0	34.3	0.1	4.3	0.5	0.6	2.0	3.7
Oxygen dissolved	mg/L	55	10.5	11	14	5.8	2.3	7.5	8.6	12	13
Phosphorus, total dissolved	mg/L	137	0.008	0.006	0.041	0.002	0.006	0.003	0.004	0.011	0.014
Phosphorus, total	mg/L	75	0.018	0.013	0.093	0.006	0.017	0.009	0.010	0.016	0.024
Arsenic, total	ug/L	71	0.26	0.26	0.58	0.12	0.09	0.14	0.18	0.31	0.35
Cadmium, total	ug/L	71	0.005	0.004	0.024	0.001	0.004	0.002	0.003	0.005	0.009
Copper, total	ug/L	71	0.97	0.69	5.83	0.40	0.92	0.52	0.59	0.87	1.67
Lead, total	ug/L	71	0.113	0.046	1.670	0.005	0.218	0.019	0.029	0.129	0.227
Zinc, total	ug/L	71	1.20	0.68	7.66	0.05	1.40	0.36	0.45	1.09	2.62
Fecal coliforms	C/100mL	104	44	14	1500	1	150	1	5	37	64

San Juan River at Island Road												
2005 - 2007								Percentile Values				
		N	Average	Median	Max	Min	Standard Deviation	10th	25th	75th	90th
Water temperature	ºC	53	8.6	7.0	16.0	0.5	4.3	4.0	6.0	12.0	14.8
pH	pH units	55	7.3	7.3	8.0	6.5	0.4	6.8	7.1	7.5	7.7
Specific conductivity	uS/cm	55	60	61	102	34	16	40	49	68	81
Turbidity	NTU	55	1.3	0.6	17.2	0.1	2.5	0.2	0.3	1.1	2.9
Alkalinity	mg/L	54	21.9	21.1	44.1	11.0	6.8	14.9	16.3	26.6	27.8
Nitrate + Nitrite	mg/L	55	0.061	0.060	0.158	0.013	0.029	0.027	0.041	0.076	0.094
Phosphorus, total dissolved	mg/L	55	0.004	0.003	0.015	0.002	0.002	0.002	0.002	0.004	0.006
Phosphorus, total	mg/L	55	0.006	0.003	0.049	0.001	0.008	0.002	0.002	0.006	0.010
Arsenic, total	ug/L	54	0.20	0.17	0.75	0.11	0.10	0.13	0.15	0.25	0.27
Cadmium, total	ug/L	54	0.004	0.003	0.026	0.001	0.004	0.001	0.002	0.004	0.005
Copper, total	ug/L	54	0.53	0.40	3.26	0.09	0.48	0.24	0.30	0.62	0.86
Lead, total	ug/L	55	0.047	0.018	0.415	0.005	0.082	0.005	0.007	0.050	0.096
Zinc, total	ug/L	54	0.44	0.20	5.04	0.05	0.74	0.08	0.13	0.43	0.75
Fecal coliforms	C/100mL	50	12	3	94	1	20	1	1	12	31