MINISTRY OF ENVIRONMENT

Water Quality Assessment and Objectives for Coldstream Creek

TECHNICAL REPORT

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EXECUTIVE SUMMARY

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

Coldstream Creek is the main tributary to Kalamalka Lake in the north Okanagan. Coldstream Creek serves as an important source of irrigation water, an indirect source of drinking water, and valuable aquatic habitat for rainbow trout, kokanee, and other aquatic species. Coldstream Creek flows down from its headwaters in Silver Star Provincial Park to Noble Canyon near Highway 6, flowing west through Lavington and Coldstream before entering Kalamalka Lake. Natural erosion, timber harvest, recreation and cattle grazing upstream of Noble Canyon and extensive agriculture and residential development in the valley bottom are potential influences on Coldstream Creek water quality. Although designated as a Community Watershed upstream of Noble Canyon, use of Coldstream Creek for domestic supply ceased in 1996 after severe storms degraded water quality. Water quality of Coldstream Creek and its influence on Kalamalka Lake, has also been a concern for many years. Although a number of studies have led to changes to agricultural practices and upgrades to community sewage collection, elevated bacteriological indicators, nutrients and turbidity in Coldstream Creek continue to be a concern to purveyors of drinking water supplied to 38,000 people from an intake in the north end of Kalamalka Lake.

BC Ministry of Environment water quality data collected up to spring of 2012 for sites between Noble Canyon and Kalamalka Lake were used in this assessment. Based on available data, water quality objectives are proposed for three parameters. *E. coli* bacteria and nitrate nitrogen are of immediate concern. Both are well studied in this drainage, are above BC water quality guidelines, and demonstrate increasing long term trends. A third parameter, turbidity, is elevated seasonally in Coldstream Creek. Water quality objectives for these three parameters are proposed taking into account the importance of aquatic life values within Coldstream Creek and drinking water use in Kalamalka Lake a short distance from where Coldstream Creek enters the lake. The water quality objective for *E.*

coli applies to Coldstream Creek at Kirkland Drive near Kalamalka Lake. The water quality objective for nitrate nitrogen and turbidity apply to all of Coldstream Creek below Noble Canyon. Additional efforts to understand and manage *E.coli* and nitrate inputs to the Coldstream Creek basin are required to protect aquatic life in Coldstream Creek and drinking water use in the north arm of Kalamalka Lake. Further efforts to reduce erosion of soils and stabilize stream banks within the drainage through riparian habitat protection are required. The water quality objectives proposed for Coldstream Creek are shown in Table 1 below. Other parameters, which have been assessed and are useful for determining Coldstream Creek water quality status and trends are: temperature, dissolved oxygen, specific conductance, sulfate, selenium and benthic invertebrate community composition. A monitoring program is proposed for future assessments to determine whether Coldstream Creek water quality objectives are being met.

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ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

1.1 BACKGROUND

Coldstream Creek is located in the Okanagan Valley near Vernon, B.C. Its headwaters originate in Silver Star Provincial Park and flow south through Noble Canyon then west through the communities of Lavington and Coldstream, before entering the north end of Kalamalka Lake (Figure 1). Coldstream Creek is the main tributary to Kalamalka Lake and serves as an important direct source of irrigation water and provides important aquatic life habitat. Approximately one kilometer from the mouth of Coldstream Creek, the Greater Vernon Water utility has an intake in Kalamalka Lake which supplies the main source of drinking water to approximately 38,000 customers in Vernon.

The upper portion of the Coldstream Creek basin, above Noble Canyon and the valley bottom, is largely forested with some logging and recreation activities; this portion of the watershed is a designated community watershed. Land use in the valley bottom is mainly agricultural and residential development. These land uses could contribute to the degradation of potable water quality and to the loss of fish and aquatic habitat. Indeed, water quality of Coldstream Creek and its influence on Kalamalka Lake, have been a concern for many years, and a number of studies have led to changes to agricultural practices, as well as upgrades to community sewage collection (Anon., 1978; BC Research. 1974; Haughton et al., 1974, Warrington, 1990). Despite these efforts, Coldstream Creek water quality remains a concern to local citizens and governments, and water quality and habitat studies and protection efforts are on-going (RDNO 2016).

To inform and support on-going water resource management, the Ministry of Environment (MOE) carries out long-term trend monitoring at one site at the mouth of Coldstream Creek. The Regional District of North Okanagan (RDNO) has also contributed capital dollars for the installation, operation and maintenance of a continuous water quality monitoring station at this same site. As well, the MOE recently completed several short-term water quality studies to provide additional spatial and temporal definition to the water quality issues in the creek (Ministry of Environment, 2009).

The purpose of this document is to briefly summarize the MOE water quality data for Coldstream Creek, to describe the status and trends of key water quality indicators, and to propose water quality objectives for parameters appropriate to water resource management of this watershed between Noble Canyon and its confluence with Kalamalka Lake near Kirkland Drive (Figure 1).

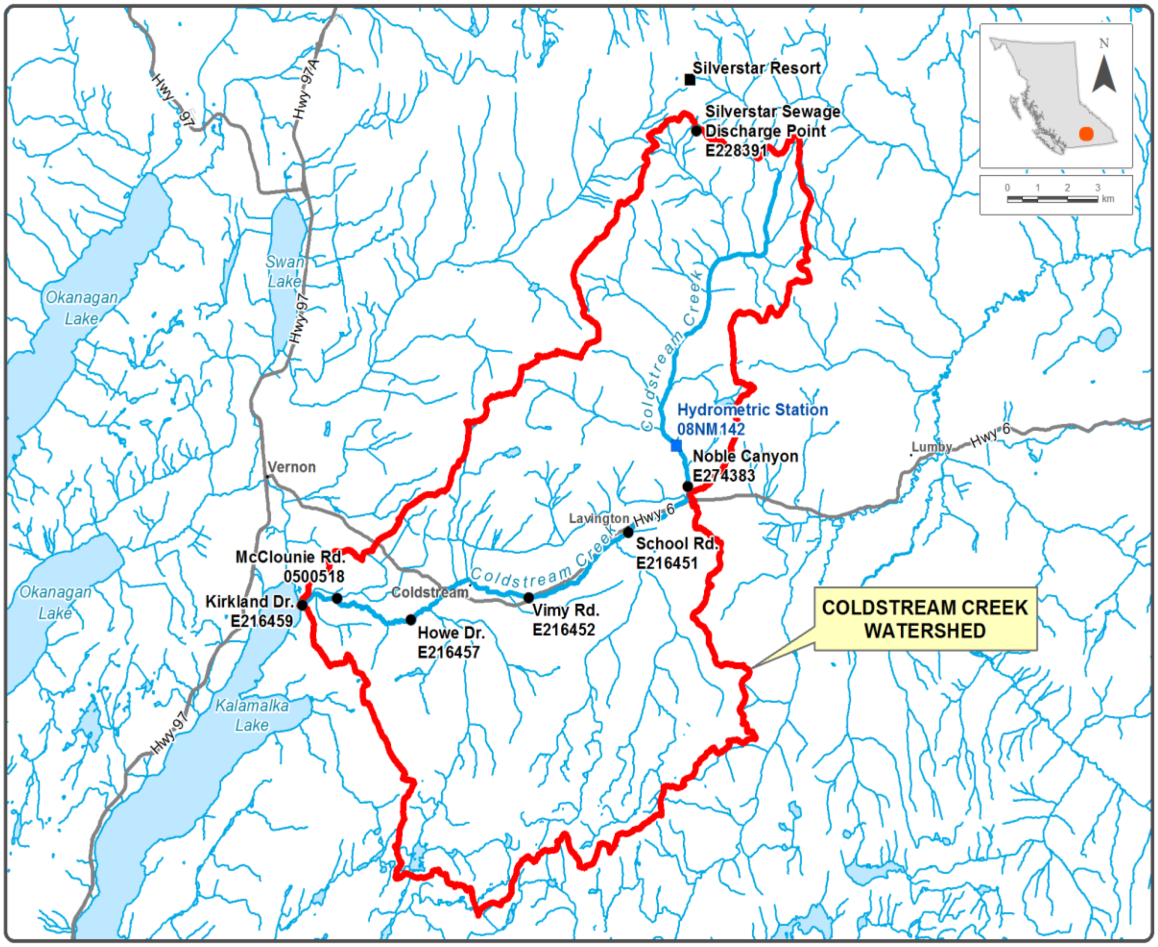

Figure 1. Location of Coldstream Creek watershed, discharge and sampling site locations.

1.2 WATER QUALITY OBJECTIVES

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

Water quality objectives are based on scientific guidelines that are safe limits of the physical, chemical, or biological characteristics of water, (including the water column), biota (plant and animal life), and sediments which protect water uses. In BC, objectives are established for waterbodies on a site-specific basis. They are often derived from the BC Water Quality Guidelines by considering local water quality, water uses, water movement, and waste discharges. Objectives are based on the best available science; however professional judgment may also influence how the objectives are expressed.

Water quality objectives are set to protect the most sensitive designated water use at a specific location. Designated water uses may include:

- source drinking water, public water supply and food processing;
- aquatic life and wildlife;
- recreation and aesthetics;
- agriculture (livestock watering and irrigation); and
- industrial water supplies.

By protecting the most sensitive water use, all designated uses for a given waterbody are also protected. There are three types of objectives: provisional, permanent, and short (interim) and long term. Provisional objectives are set where the information available about the local conditions (e.g., water quality, water use, aquatic life, waste discharges, etc.) and/or the water quality criteria for a substance are inadequate for the establishment of scientifically defensible objectives. Permanent objectives are established when the information available about the local conditions and water quality criteria is adequate. A monitoring program is specified with permanent objectives to assess the degree of their attainment. Both provisional and permanent objectives are subject to wide review before they are adopted, and permanent objectives will be reviewed from time to time and are subject to revision, as new information becomes available. Short-term and long-term objectives may be used where existing water quality does not suit all desired water uses, and it is feasible to improve the water quality over time. The short-term objectives would protect water uses to a certain degree until the long-term objectives can be achieved.

Water quality objectives provide policy direction for resource managers for the management and use of land and water in specific areas. Objectives may guide the evaluation of water quality, the issuance of permits, licenses and orders, the management of fisheries, and the province's land base. They also provide a reference against which the state of water quality in a particular water body can be checked, and help determine whether basin-wide water quality studies should be initiated. Water quality objectives and attainment monitoring results are reported to local stakeholders, and on a province-wide basis through forums such as State of the Environment reporting. These objectives may, in the future, also enable the calculation of a water quality index specific to Coldstream Creek.

2.0 WATERSHED PROFILE, CLIMATE, AND HYDROLOGY

2.1 PROFILE AND CLIMATE

Coldstream Creek is located in the Thompson-Okanagan Plateau. The watershed spans three biogeoclimatic zones: Engelmann Spruce-Subalpine Fir (ESSF) at the upper elevations, Interior Cedar Hemlock (ICH) at the mid-elevations and Interior Douglas Fir (IDF) at lower elevations (Dobson, 2001; Chapman, 1999).

The headwaters of Coldstream Creek occur in Silver Star Provincial Park. Its waters flow south through Crown land and enter the valley bottom after Noble Canyon, which is primarily private land (Figure 1). To satisfy irrigation demands, Coldstream Creek below Noble Canyon was diverted in 1906 to flow to Kalamalka Lake via Brewer and Caster creeks instead of the Shuswap (Larratt, 2011). From Noble Canyon, the creek travels west through the communities of Lavington and Coldstream and into the north arm of Kalamalka Lake. The creek is approximately 29.8km long from its headwaters to the confluence with Kalamalka Lake

(Ecoscape, 2009). The watershed drains an area of approximately 20,600 hectares, and approximately 68% of the watershed area occurs downstream of Noble Canyon. Elevations within the watershed range from 1,890 m at the headwaters in Silver Star Park, to 640 m at Noble Canyon, and 393 m at Kalamalka Lake.

Local bedrock varies from sedimentary rock in the northern portion of the watershed to volcanic rock types in the southern portion (Dobson, 2001). A variety of surficial materials overlay the bedrock; these include sandy silty till and lesser amounts of colluvial material (Chapman, 1999). Typical of most stream valleys, fluvial and glaciofluvial sediments are present and range in size from sand to cobble (Chapman, 1999).

Environment Canada operates a weather station at Vernon Coldstream Ranch (# 1128580) located approximately 7 km downstream from Noble Canyon at an elevation of 482 m (Environment Canada, 2012). Climate from this station are available from 1971 through to 2000 (Table 2). Average daily temperatures over this period ranged from -5 ^{o}C in January to 19.1 ^{o}C in July (Environment Canada, 2012). Average annual precipitation in the watershed is 484 mm, with 128 mm (water equivalent) of the precipitation falling as snow (Environment Canada, 2012). At higher elevations a larger portion of the total annual precipitation occurs as snowfall. Approximately 28% of the precipitation occurs from November to April as snow (Chapman, 1999).

Table 1. Climate (1971 – 2000) measured at Vernon Coldstream Ranch (Environment Canada Station #1128580) (Environment Canada, 2012).

Temperature:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Daily Average (°C)	-5	-2	3.3	8.4	12.8	16.4	19.1	18.7	13.7	7.3	0.6	-4.1
Standard Deviation	3.3	2.7	1.8	1.3	1.4	1.6	1.4	1.6	1.6	1	2.6	2.9
Daily Maximum (°C)	-1.9	1.6	8.4	14.7	19.4	23.1	26.6	26.2	20.2	12.1	3.7	-1.3
Daily Minimum (°C)	-8.1	-5.5	-1.8	2	6.1	9.6	11.6	11.3	7.2	2.5	-2.5	-6.9
Precipitation:	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall (mm)	7.3	12.1	19.7	28.7	46.5	53.9	40.7	42.8	37.3	32.1	25.3	10
Snowfall (cm)	32.9	22.2	6.1	0.4	0	0	0	0	0	1.2	22.8	42.4
Precipitation (mm)	40.2	34.3	25.8	29	46.5	53.9	40.7	42.8	37.3	33.3	48.1	52.4

2.2 HYDROLOGY

Coldstream Creek provides approximately 80% of the surface water inflow to Kalamalka Lake (BC Research 1974). Water Survey of Canada (WSC) has operated a hydrometric gauging station for the last 44 years (08NM142) at a site on Coldstream Creek just upstream of the District of Coldstream water intake in Noble Canyon. Coldstream Creek demonstrates a typical interior BC hydrographic profile dominated by spring snow melt freshet, and significant year to year variation (Figure 2). Valley bottom snow melt (downstream of Noble Canyon) typically occurs from late February to mid-April and has less influence on water quantity than on water quality. Maximum daily discharges recorded from 1971 to 2000 range from 0.54 m^3/s to 7.5 m^3/s (Water Survey of Canada, 2012). Mean annual discharge from Coldstream Creek also varies significantly from year-to-year with lows of less than 0.1 m^3/s in drought years such as 1970, to highs of over 0.5 m^3/s in the flood year of 1996 (Figure 3).

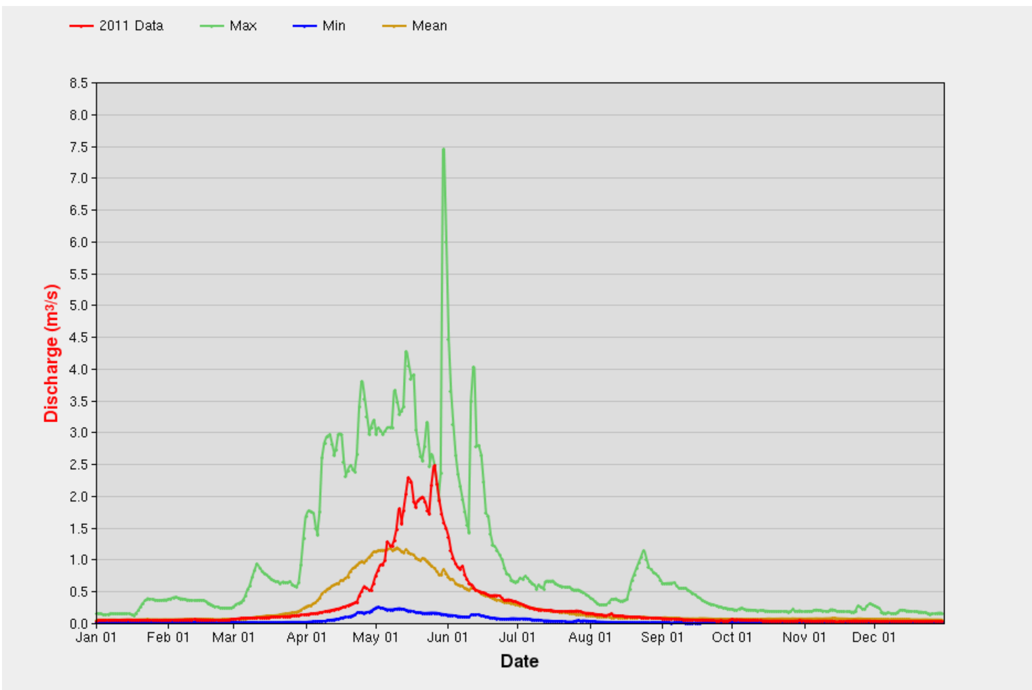

Figure 2. Coldstream Creek daily discharge record for 2011 (m3/s), and maximum, mean, and minimum daily discharge for the period of record 1967 to 2011 (Water Survey Canada site 08NM142).

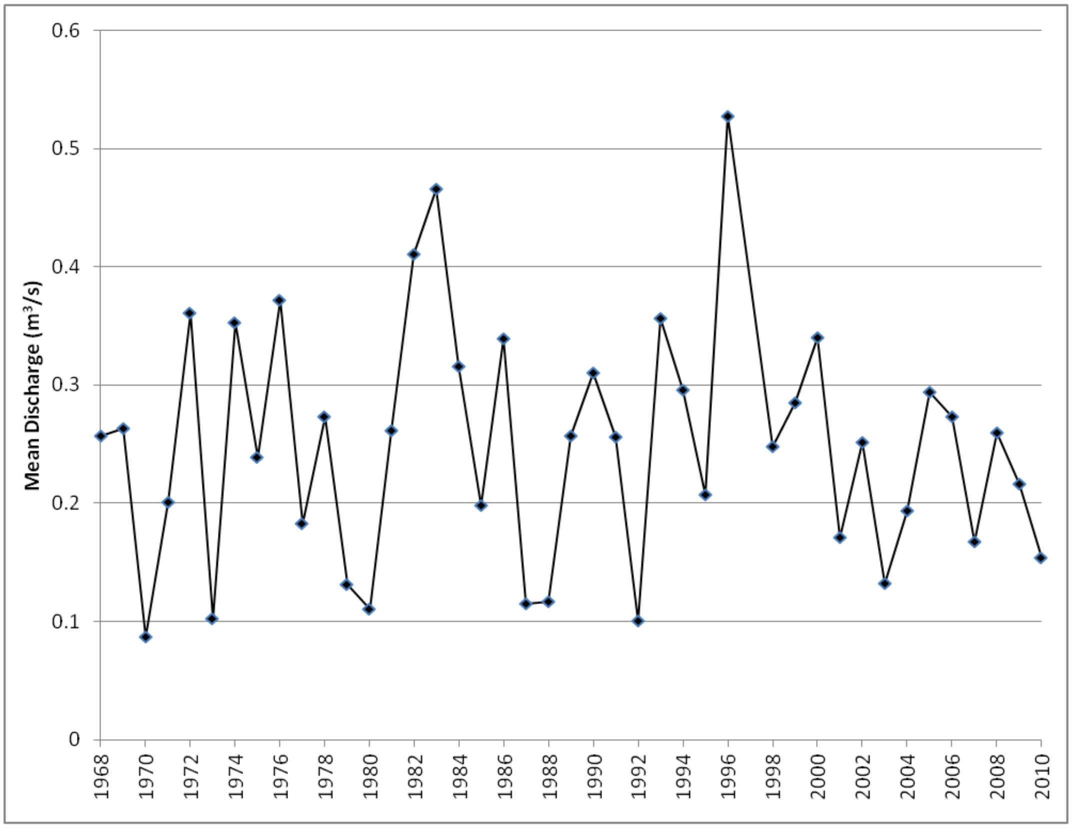

Figure 3. Annual mean discharge (m3/s) for Coldstream Creek for the period 1968 to 2010 (Water Survey Canada station 08NM142).

The influence of hydrology on the water quality of Coldstream Creek will be further explored in Sections 4 and 6.

3.0 DESIGNATED USES

3.1 WATER LICENSES

As of 2012, there were eight registered water withdrawal licenses recorded for Coldstream Creek (Table 3) (Reilly, pers. comm. 2014). The Regional District of the North Okanagan (RDNO) holds three water licenses for local waterworks and land improvement. The remaining water licenses are for irrigation, storage, and livestock watering (Reilly. pers. comm. 2014).

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

Withdrawal Purpose	Volume	Units	License Number	Licensee
Waterworks by Local Authority	414830.7	MY	C009359	Regional District of the North Okanagan
Storage - non power	17268.72	MY	C053949	Coldstream Ranch Ltd.
Land Improvement	0.17	MS	C069461	Regional District of the North Okanagan
Land Improvement	0	TF	C109777	Regional District of the North Okanagan
Irrigation	4933.92	MY	C059501	Private
Stockwatering	38.642	MD	F009238	Coldstream Ranch Ltd.
Irrigation	7400.88	MY	F018131	Private
Irrigation	1233.48	MY	F046750	Private

TF = Total Flow - The total flow of the stream is authorized to pass through the works. No water is diverted from the stream.

MD = cubic meters / day

MS = cubic meters / second

MY = cubic meters / year

The District of Coldstream maintained an intake on Coldstream Creek approximately 650 m off Highway-6 on Noble Canyon Road until 1996. Coldstream Creek above this point of diversion was designated as a community watershed in 1995, as defined under the *Forest Practices Code of British Columbia Act* ("the drainage area above the downstream point of diversion and which are licensed under the *Water Act* for waterworks purposes") . This designation was grandfathered in and continued under the *Forest and Range Practices Act* (FRPA) in 2004. The intake facility consisted of a small reservoir and chlorination facility. The District of Coldstream discontinued use of the water intake below Noble Canyon following the debris slides, erosion and high water turbidity in the very wet spring of 1996. The District retains the water license on Coldstream Creek, and the creek continues to be considered a community watershed, and as such it must be assumed that the license could at some future date be used for domestic or other purposes.

Significant licensed water withdrawal for domestic purposes occurs in Kalamalka Lake. Of importance to this assessment, the Greater Vernon Water Utility has licenses totaling 8.09M m^3/a, at an intake less than a kilometer from where Coldstream Creek enters Kalamalka Lake. Kalamalka Lake is used at the primary source of drinking water for the Greater Vernon urban area and serves a population of about 38,000. Water quality and taste and odour events and elevated turbidity at the Greater Vernon Water Utility (GVW) intake at the north end of Kalamalka Lake are linked to Coldstream Creek freshet and summer storms (Larratt, 2012).

Coldstream Creek responds within 24 hours to rain fall events, with higher flows and turbidity spikes, and local storm drain water and disturbed riparian areas on Coldstream Creek are thought to contribute to this rapid response to storms (Larratt, 2012). Minimizing turbidity and bacterial inputs though watershed controls is an on-going challenge for the GVW in order to be in compliance with BC Ministry of Health drinking water quality objectives for surface water, and optimize treatment costs.

3.2 FISHERIES

Coldstream Creek provides important fish habitat to resident fish as well as spawning and rearing habitat for many Kalamalka Lake fish stocks. It is assumed that, with the exception of Lake Trout, all species present in Kalamalka Lake (kokanee, large scale sucker, mountain whitefish, northern pike minnow, perch sp., peamouth chub, pumpkin seed, rainbow trout, and redsided shiner) would be present in at least the lower reaches of the Coldstream Creek at certain times of the year (J. Mitchell, pers. comm. 2014). There is also a resident population of rainbow trout, which utilize the lower 19.8 km of the creek. Due to the presence of a migration barrier, migration of adfluvial fish species is limited to approximately 7.4 km upstream from Kalamalka Lake (Ecoscape, 2012). Below this barrier the creek provides very productive spawning and rearing habitat for Kalamalka Lake kokanee. Annual kokanee returns range from 15,000 to 25,000 spawners. Kokanee counts in 2011 of 19, 915 fish (Webster, 2012) represented an increase from the previous three years, however since reliable counts began in 1988, kokanee escapement to Coldstream Creek have been declining (Webster, 2012). Kalamalka Lake rainbow trout also use the lower 7.4 km of creek for spawning and rearing.

3.3 RECREATION

Water based recreation is important to the local residents and local economy of the North Okanagan. Although primary or secondary contact recreation in Coldstream Creek is unlikely or at least limited, Coldstream Creek enters Kalamalka Lake near private residences and important community swimming beaches. As such, the influence of Coldstream Creek water quality on recreation is relevant to this assessment.

3.4 DESIGNATED WATER USES

Designated water uses, are those water uses that are designated for protection in a specific watershed or waterbody. Water quality objectives are designed so that attainment with objectives ensures protection of the most sensitive designated water uses. Based on existing water uses within the watershed, water quality in Coldstream Creek should be protected for the following designated uses: aquatic life, source drinking water, recreation, irrigation and livestock watering.

4.0 INFLUENCES ON WATER QUALITY

There are no direct point source discharges of effluent direct into Coldstream Creek, however, many diffuse sources of contaminants or non-point source pollution may enter Coldstream Creek from natural and human land use activities. Natural influences include the biogeophysical nature of the soils, terrain and vegetation of the catchment itself. Land use activities that may affect water quality of the Coldstream Creek include a ski hill operation and related sewage disposal facility, timber harvest and roads, agriculture and range use, and rural and urban development, and recreation.

4.1 NATURAL INFLUENCES

Approximately 8% of the Coldstream Creek watershed has been classified as unstable, or potentially unstable, with the majority of this unstable terrain located upstream of the community water intake at Noble Canyon (Chapman, 1999). Twelve natural landslides have occurred in recent history in the watershed and were related to extreme soil wetness occurring during very wet spring conditions (Chapman, 1999). A large hillside slump occurred in May 1996, depositing a large amount of sediment into Coldstream Creek. This natural slide corresponded with Coldstream Creek's largest discharge on record and was the result of an intense rain event at the end of the snowmelt period (Dobson, 2001). While rehabilitation efforts at the landslide site on the main stem of Coldstream Creek have reduced the available sediment load, the site is still a contributor of fine sediment to the creek (Chapman, 1999; Dobson, 2001). Along the lower reaches of Coldstream Creek channel bank erosion and reworking of channel beds have been identified as naturally occurring influences on water quality (Dobson, 2001). Water quality parameters affected by erosion and sedimentation include increased suspended solids, turbidity and nutrients.

4.2 SKI HILL OPERATION AND SEWAGE DISCHARGE

Silver Star Mountain Resorts Ltd. holds a permit (PE-06738) under the Municipal Sewage Regulation (MSR) for the operation of a wastewater treatment and spray irrigation system in the headwaters of Coldstream Creek within Silver Star Provincial Park. For the past 10 years Silverhawk Utilities has operated the Silver Star Resort Class II Wastewater Treatment Facility (WWTF) which provides secondary treatment and discharges effluent through seepage to ground from storage lagoons, and effluent irrigation. Effluent flow rates of approximately 91,465 m^3 were reported for 2013, of which approximately 25,631 m^3 or approximately 28% was discharged by spray irrigation (Silverhawk Utilities, 2013).

Improvements to the WWTF have occurred several times over the years. Significant upgrades to the WWTF were initiated in 2010 and commissioned in fall of 2013 to comply with BC Municipal Sewage Regulation effluent quality requirements. Among other parameter limits and requirements, the effluent must meet limits of 10 mg/L total nitrogen and 45 mg/L BOD_5, (biochemical oxygen demand) at the point of discharge to the main exfiltration pond. A portion of the effluent evaporates from the lagoon; however the majority enters the groundwater flow that feeds Coldstream Creek. A smaller unknown quantity enters the headwaters of Vance Creek and flows to the Shuswap River drainage. Silverhawk Utilities is required to undertake extensive monitoring of the treatment system, groundwater and surface water, and report the results annually to the Ministry of Environment.

Groundwater monitoring by Silverhawk Utilities in the immediate vicinity of the main exfiltration pond has shown increasing ammonia nitrogen levels over the past decade, peaking in 2009. Surface water monitoring of upper tributaries of Coldstream Creek near to the lagoon have noted increasing nitrate nitrogen from 2005 through 2010. The changes in treatment plant design commissioned in 2013 are expected to provide greater effluent quality, specifically a reduction in total nitrogen and BOD_5 in the effluent. Silverhawk Utilities was in compliance with the Municipal Sewage Regulation in 2013 (Sokal, pers. comm. 2014).

Water quality parameters affected by municipal effluent are nutrients (nitrogen and phosphorus), coliform bacteria, chloride, sodium, suspended solids, and to a lesser extent metals, and sulphate.

4.3 TIMBER HARVEST AND ROADS

Forestry activities can impact both water quality and quantity. Removal of trees can decrease water retention time, resulting in a more rapid stream discharge response to precipitation, and which may create earlier and greater rain on snow events in the spring. Impacts from forestry may include changes to peak flows, landslides, surface erosion and changes to riparian function and channel stability.

Currently within the Coldstream Creek watershed, forest harvesting is aimed at controlling mountain pine beetle infestations. Dead pine dominated stands can have the same hydrological impacts as clear cuts, including increased peak flows and water yield, accelerated soil erosion, landslides, channel destabilization and nutrient losses (Dobson, 2001). Since 1974 a total of 2,225 ha or 33.3% of the upper watershed area has been harvested. Because of reforestation, the Equivalent Clearcut Area (ECA) for the watershed in 2001 was noted as approximately 10% (Dobson, 2001). BC Timber Sales (BCTS) harvested 1,216 ha between 1992 and 2008. Tolko was active in the watershed between 1978 and the early 1990's with 495 ha harvested, however only 17.6 ha were harvested to 2008. Vernon Fish & Game harvested 151 ha between 1985 and 2000, and another 76 ha in 2009. During the last 5 years, approximately 209 hectares (3.1% of the watershed) have been harvested, all by the smaller licensees.

Road construction associated with forest harvesting is also a potential factor impacting water quality in the watershed. Road density within the drainage is moderate to high and many abandoned roads were not deactivated as of 2001. The total length of roads in the watershed stands at 202 km for a road density of 0.03 km/ha. Approximately 3km of the Coldstream Creek Forest Service Road runs adjacent to Coldstream Creek, has been identified as a chronic source of sediments to Coldstream Creek (Dobson, 2001). As noted above, landslides have also been an issue within the watershed. Although the slides are primarily naturally occurring on unstable terrain, some are associated with slippage on forestry roads. High turbidity problems have plagued the intake ponds of the District of Coldstream community water intake, to the extent that the source is no longer used for human consumption (Dobson, 2001).

Principal water quality concerns typically associated with forest harvest include elevated turbidity and suspended solids.

4.4 AGRICULTURE AND RANGE USE

Approximately 10% of the entire Coldstream Creek watershed area is characterized by agricultural use. Seasonal cattle grazing occurs upstream of Noble Canyon. Two cattle grazing licenses are on record for the Coldstream Creek upper watershed area (Dobson, 2001) and it is not uncommon to observe cattle or evidence of cattle activity in and around Coldstream Creek in the Noble Canyon area. The total number of cattle on range in 2014 was 250 cow calf pairs and 14 bulls (Campbell, pers. comm. 2014). The cumulative effects of cattle on upper Coldstream Creek water quality have been noted as a concern in the past (Chapman Geoscience Ltd., 1999).

The majority of agricultural activity within the watershed, however, occurs in the valley bottom. Horse and cattle forage crop production predominate, followed by fruit orchards, and feedlot operations (see Sokal, 2009 for detailed mapping and tabulation). Agricultural land use increases incrementally through the valley bottom. For example, hectares of land used for cattle and horse forage crops increase steadily from Noble Canyon until reaching the higher density residential areas downstream at McClounie Road and Kirkland Drive near Kalamalka Lake (Figure 4).

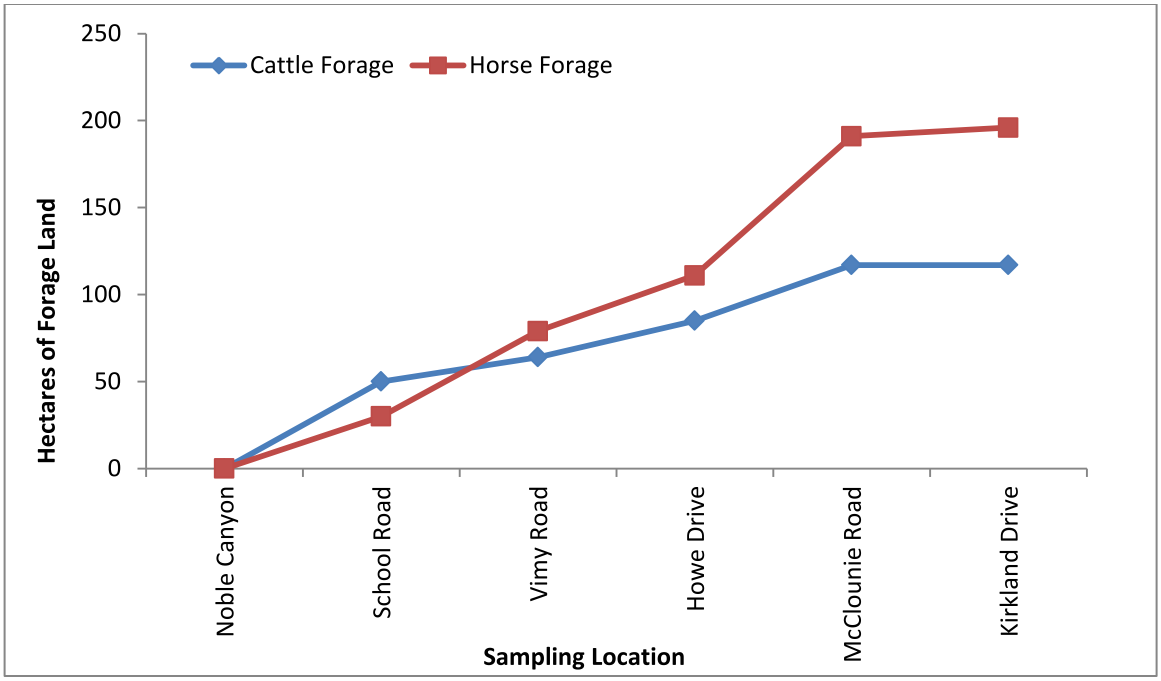

Figure 4. Coldstream Creek watershed land area (hectares) used for cattle and horse forage crop production. (See Sokal, 2009 for details and other agricultural land use data).

Significant efforts have been made over many years to reduce the impact of agriculture on water quality of surface and groundwater of the Coldstream Valley and Okanagan Basin (Jensen and Epp, 2002). Nonetheless, legacy and recent agricultural operations continue to impact surface and groundwater in the watershed. Sensitive habitat inventory and mapping (SHIM) on Coldstream Creek recently identified six agricultural runoff discharges to Coldstream Creek (Ecoscape, 2009). Also noted were extensive and persistent impacts to stream bank and riparian areas caused by unrestricted livestock access to 14% of the creek length surveyed (Ecoscape, 2009). Manure application on snow covered fields in the winter of 2010 caused contamination of Antwerp Spring, a shallow groundwater well providing drinking water to 3500 people in the Lavington area. As well, sites used for dairy operations in the past continue to strongly influence nitrate levels in surface and shallow groundwater in the Lavington area and efforts are on-going to understand and reduce nitrate inputs to surface and groundwater (Koch, 2012).

Agricultural practices are regulated by the Agricultural Waste Control Regulation (AWCR) under the BC *Environmental Management Act* (EMA). As with all activities regulated by the EMA, agricultural operations within the Coldstream Creek watershed must not cause pollution. More specifically, the Agricultural Waste Control Regulation specifically prohibits contaminated run-off from leaving the property boundary regardless of its level of impact. While commercial farms in the area contain large numbers of animals, smaller hobby farms with fewer animals can have an equal or greater impact on nearby water bodies if not properly managed (Sokal, 2009). In fall of 2010 the Ministry of Environment and Ministry of Agriculture and Lands cautioned residents and farmers of the Coldstream valley against application of animal waste on snow covered ground between November 1 and March 1 due to the high risk of contaminated run-off at snow melt.

The principal water quality concerns typically associated with agriculture are elevated nutrients (nitrogen and phosphorus), coliform bacteria, turbidity and suspended solids, and to a lesser extent pesticides and herbicides.

4.5 RURAL AND URBAN DEVELOPMENT

The lower portion of the watershed near Kalamalka Lake is dominated by higher density residential settlement. Approximately 60% of the properties within the district are on sewer (Reiley, pers. comm., 2014). The majority of these properties are within an area south of Hwy 6 and west of Coldstream Creek Road. This area is serviced by the City of Vernon sewer collection system with effluent disposal outside of the Coldstream drainage. Further east in the valley towards Lavington, residential settlement is more dispersed on larger properties using septic tanks and drain fields for sewage disposal.

Rural and urban development may also impact stream quality through changes to riparian vegetation and stormwater run-off. Recent Sensitive Habitat Inventory and Mapping (SHIM) determined that approximately 89% of the lower 19.8 km of Coldstream Creek is modified to some extent by urban, rural, and agricultural activities (Ecoscape, 2009). Within this area stormwater run-off may enter the creek from roadways and parking lots. Ecoscape (2009) recorded 11 storm drain pipes and 15 tile drains entering Coldstream Creek.

The water quality concerns typically associated with rural and urban development include elevated nutrients, coliform bacteria, turbidity and suspended solids, chloride, and to a lesser extent metals, herbicides, and pesticides.

4.6 RECREATION

Known recreational use within the Coldstream Creek watershed includes horseback riding, motorcycling, mountain biking, hiking, hunting, skiing, all-terrain vehicle use and snowmobiling.

A BC Hydro right of way which runs through the watershed approximately 3 km upstream of the abandoned community water intake in Noble Canyon is used for recreation (Dobson, 2001). There is a high density of trails throughout the watershed which are used for off road motorcycling and mountain biking. These trails, and the right of way, are characterized by disturbed, muddy surfaces and fine grained sediment, and could potentially affect water quality and may contribute to elevated turbidity in Coldstream Creek (Dobson, 2001; Chapman, 1999). In addition to sediment mobilization, recreational activities in the catchment can also contribute to increased fecal contamination due to improper disposal of human and animal wastes.

The principal water quality concerns typically associated with recreation are elevated turbidity and suspended solids, nutrients and coliform bacteria.

4.7 WILDLIFE

The Coldstream Creek watershed provides valuable habitat for a variety of warm-blooded wildlife species. Wildlife can influence water quality, as warm-blooded animals can carry pathogens such as *Giardia lamblia*, which causes giardiasis, or “beaver fever”, and *Cryptosporidium* oocysts, which cause the gastrointestinal disease cryptosporidiosis (Health Canada, 2012). Warm-blooded animals, including waterfowl, also excrete pathogens, including *Escherichia coli* (*E.coli)* in their feces, and can cause elevated levels of microbiological indicators in water. The water quality parameters of concern with respect to wildlife are fecal coliform bacteria, and *E.coli*.

5.0 DESCRIPTION OF WATER QUALITY MONITORING DATA

5.1 PREVIOUS OR OTHER WATER QUALITY STUDIES

Water quality studies on Coldstream Creek date back to at least the late 1960's. Studies in the 1960's and 1970's were part of multi-agency basin-wide investigations (BC Research. 1974; Haughton et al., 1974). Subsequently, the Ministry of Environment began sampling Coldstream Creek in the early 1970's. With funding from Forest Renewal BC program in the 1990's, the Ministry oversaw additional sampling on upper Coldstream Creek. Those results are summarized by Dobson (2001). As mentioned in Section 4.2 above, Silverhawk Utilities regularly samples and reports ground and surface water quality in proximity to their effluent disposal works. The Greater Vernon Water Utility has played an increasing role in water quality assessment and protection of Kalamalka Lake, and now more recently Coldstream Creek in order to provide safe drinking water (Clark, pers. comm. 2014)

No attempt has been made to directly incorporate data from earlier studies or that of local government work into this assessment unless that data was already contained within the Ministry of Environment database.

5.2 MINISTRY OF ENVIRONMENT WATER QUALITY STUDIES

This report primarily utilizes water quality data collected monthly by the Ministry of Environment at Kirkland Drive from 1972 to 1978 and from 2004 to 2011 or early-2012 (depending on parameter and site), and at McClounie Road from 1976 to 2003. McClounie Road is located a short distance (1.2km) upstream from Kirkland Drive, and both sites are within residential development and downstream of agricultural land use . Although some parameter concentrations are slightly lower at McClounie Road than Kirkland Drive, the data from both sites have been used in this assessment to examine long-term trends. Kirkland Drive has been chosen as the long term trend site for on-going monitoring, and it continues to be sampled monthly in low flow and weekly during freshet as part of a long-term trend assessment program.

Data was also collected between approximately November 2008 and March 2011 at four other sampling sites on Coldstream Creek - Noble Canyon, School Road, Vimy Road, and Howe Drive, to provide additional spatial and temporal definition to the water quality issues in the valley-bottom portion of Coldstream Creek. Noble Canyon is located below the forested portion of the watershed but above the valley bottom. Agricultural land use increases steadily and incrementally moving downstream to School Road to Vimy Road, to Howe Drive, McClounie Road and finally Kirkland Drive (Figure 4). Weekly sampling at these 6 sites occurred during the late winter valley bottom snow melt run-off, and during fall low-flows to estimate worst case conditions and evaluate water quality relative to BC Water Quality Guidelines. These six sampling sites are described further in Table 4.

Water sample analyses varied over time, but parameters usually included *E. coli*, fecal coliform bacteria, turbidity, specific conductance, total nitrogen, organic nitrogen, total Kjeldahl nitrogen, ammonia nitrogen, chloride, sulfate, total phosphorus, ortho-phosphorus, pH and hardness. Analyses periodically also included total and dissolved metals, total and suspended solids. On each sampling visit, field measurements for temperature, pH, turbidity, and dissolved oxygen (DO) were usually taken to augment laboratory analyses.

Table 3. Coldstream Creek water quality monitoring locations.

EMS ID	Site Name	Description	Lat/Long
E216459	Kirkland Drive	Upstream of Kirkland Dr. Bridge, about 100m upstream of Kalamalka Lake	50° 13' 27" N 119° 15' 43" W
0500518	McClounie Road	upstream of McClounie Rd. Culverts	50° 13' 30" N 119° 14' 53" W
E216457	Howe Drive	Downstream of Howe Dr. Bridge	50° 13' 1" N 119° 12' 44" W
E216452	Vimy Road	Upstream of culvert under Hwy. 6, east of Vimy Rd.	50° 13' 11" N 119° 9' 22" W
E216451	School Road	Downstream of School Rd. Bridge	50° 14' 6" N 119° 6' 27" W
E274383	Noble Canyon	Northwest of first bend in Noble Canyon Rd., about 500m north of Hwy. 6	50° 14' 46" N 119° 4' 40" W

5.3 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) procedures were incorporated into the sampling program. Quality assurance samples, consisting of replicate samples and field blanks, were collected periodically. The data set was screened for outliers and anomalous values, and checked against blanks and duplicate samples. Sample contamination is considered to have occurred when 5% or more of the blanks showed any levels above the method detection limit. For results at least 10 times the parameter detection limit, the maximum acceptable percent difference between duplicates was 25%. Surface grab samples were collected at each site according to the Resource Information Standards Committee (RISC) methodology (RISC, 1997). Samples were shipped within recommended holding times to government contract labs for analysis; most recently these were Maxxam Analytics and Cantest laboratories, both located in Burnaby, BC. All data collected has been archived in the MOE Environment Management System database.

6.0 WATER QUALITY ASSESSMENT AND PROPOSED OBJECTIVES

The British Columbia water quality guidelines (WQG) were used to screen and then assess Coldstream Creek water quality data relative to the water uses identified in Section 3 above. Parameters which demonstrated important trends, occurred at concentrations near or above guideline levels, or could be strongly influenced by identified land uses within the watershed were selected as potential candidates for establishing Coldstream Creek water quality objectives. From this screening, the parameters of interest to protect the identified water uses are: coliform bacteria, nitrate nitrogen, temperature, dissolved oxygen, turbidity, chloride, specific conductivity, selenium, and sulfate. Statistical summaries of all data collected at each site are provided in Appendices 1 to 6.

In this report, the sequence of assessment for each parameter begins with examining long-term trends as measured at Kirkland Drive and McClounie Road. Next, spatial and seasonal variation of a parameter is assessed using the recent data from all six sites. Finally, where appropriate, water quality objectives are proposed.

6.1 MICROBIOLOGICAL INDICATORS

Direct measures of waterborne pathogens are difficult due their low numbers, intermittent and unpredictable occurrence, and specific growth requirements (Krewski et al., 2004). Coliform bacteria such as fecal coliforms, *E coli,* and enterococci are indicators of the microbiological quality of surface water used by humans for drinking and recreational purposes.

Coliform bacteria such as fecal coliforms, *E coli,* and enterococci are present in large numbers in the intestines of warm blooded animals and are often used as indicators of fecal contamination in water. Coliform bacteria generally do not survive long in cold, fresh water (Brettar and Höfle, 1992), but can survive for prolonged periods in stream sediment, soils or fecal material, when associated with particulate matter, or in warmer water (Howell *et al.*, 1996; Tiedemann *et al.*, 1987). Due to its size, coliform bacteria move poorly through groundwater and inputs to stream water are therefore largely through movement in surface water or direct introduction. Coliform bacteria are often associated with particulate matter and are generally not uniformly dispersed in water. Even a small piece of fecal matter in a water sample can result in extremely high concentrations (i.e., >1,000 CFU/100 mL), which can skew the overall results for a particular site. For this reason, the 90^{th} percentile and geometric mean are typically used to ensure water quality results are within the guideline limits. It is recommended that the 90^{th} percentile concentrations be calculated using ten samples collected within thirty days and the geometric mean can be calculated from five samples collected within thirty days. In BC, due to sampling logistics, five samples collected over a thirty day period is recognized as acceptable protocol, instead of the recommended ten for microbiological indicators. For example, the BC drinking water guideline for raw waters receiving only disinfection is that the 90^{th} percentile of at least five weekly samples collected in a 30-day period should not exceed 10 CFU/100 mL for both fecal coliforms and *E. coli* (Warrington, 1988). *E. coli* became the bacteriological indicator of choice by 2001, however, fecal coliform bacteria and enterococci are provided here due to their longer time collection history and supportive role in water quality assessment in this study. An abbreviated version of the WQGs for drinking water and recreation is shown in Table 5. A complete list of microbiological guidelines for all water uses is available on the BC Ministry of Environment web site.

Table 4. BC water quality guidelines for bacteriological indicators for the protection of drinking water and recreational use.

WATER USE	Level of Treatment/Contact	Guideline (100 CFU/100 mL)			Calculation
		Fecal Coliforms	*E.coli*	Enterococci	
RAW DRINKING WATER	None	0	0	0	Absolute value
	Disinfection Only	≤10	≤10	≤3	90th percentile
	Partial	≤100	≤100	≤25	
	Complete	N/A	N/A	N/A	N/A
RECREATION	Primary Contact	≤200	≤77	≤20	Geometric Mean

6.1.1 Fecal Coliforms

Fecal coliforms were used as the primary coliform bacteria indicator for Coldstream Creek from approximately 1975 until approximately 2008. Fecal coliform counts were highly variable over that time span and show no significant change for McClounie Road or Kirkland Drive sites (Figure 5).

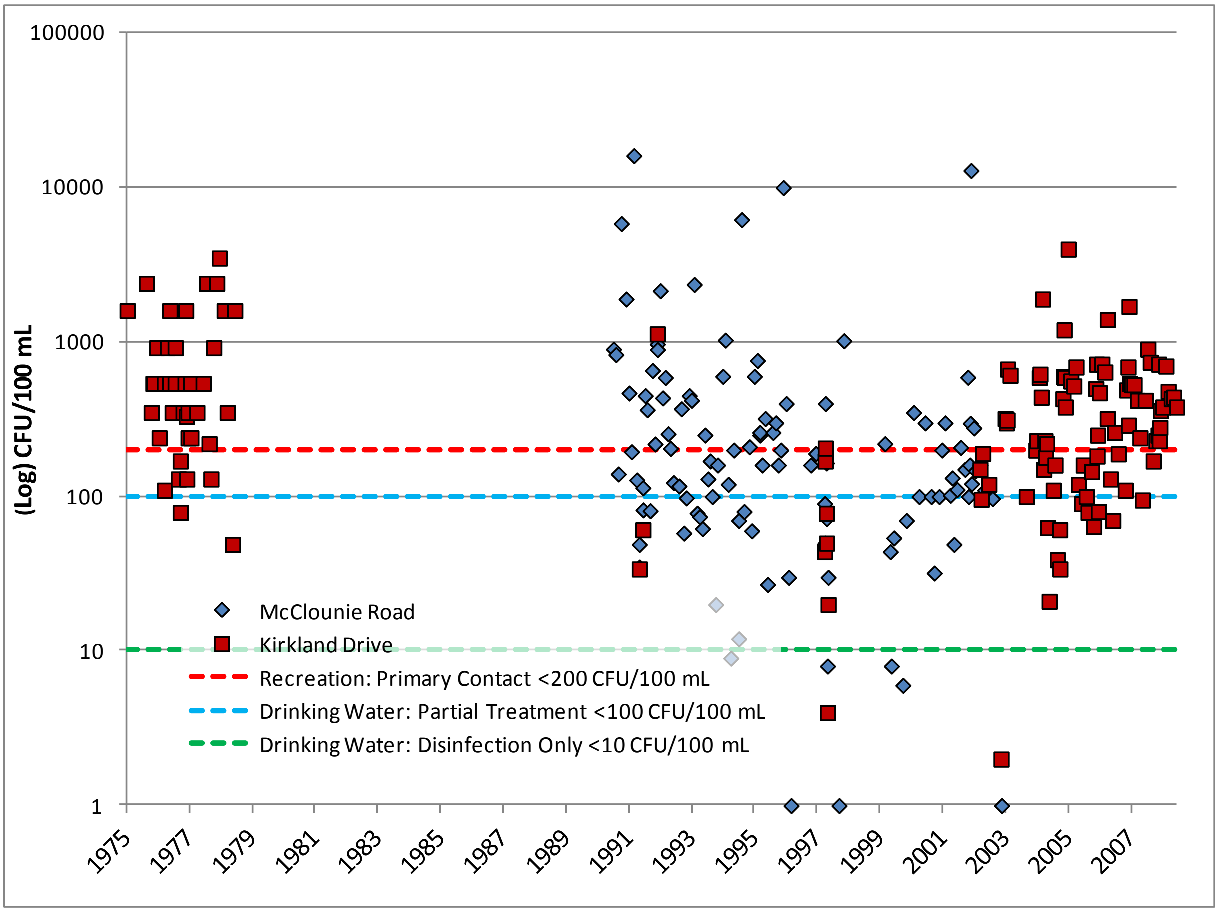

Figure 5. Coldstream Creek fecal coliform (CFU/100 mL) concentrations at Kirkland Drive and McClounie Road, 1975 to 2008.

Sample collection frequencies necessary to determine 90th percentiles and geometric means from 5 samples in 30 days are not available for the entire time series, however for the last two years of fecal coliform data, 90th percentiles were 1296 and 576 CFU/100mL in 2007 and 2008 respectively, well in excess of primary contact and drinking water guidelines.

6.1.2 *E. coli*

As early as the late nineties, water samples collected at McClounie Road and Kirkland Drive were also analyzed for *E.coli*, and *E. coli* became the indicator of choice by 2001. McClounie and Kirkland sites are downstream of agricultural influence but are within residential areas where storm water inputs may also contribute coliform bacteria to the stream. The relatively short time series for *E. coli* at McClounie Road precludes trend detection. The *E. coli* data for Kirkland Drive is also highly variable and no trend is apparent (Figure 6). However, it is clear that *E. coli* counts are often well above guidelines for the protection of drinking water with disinfection and partial treatment, as well as the guideline for primary contact recreation. In spring 2012 for example, the geometric mean and 90th percentile for *E. coli* were 270 CFU/100mL and 1350 CFU/100mL respectively.

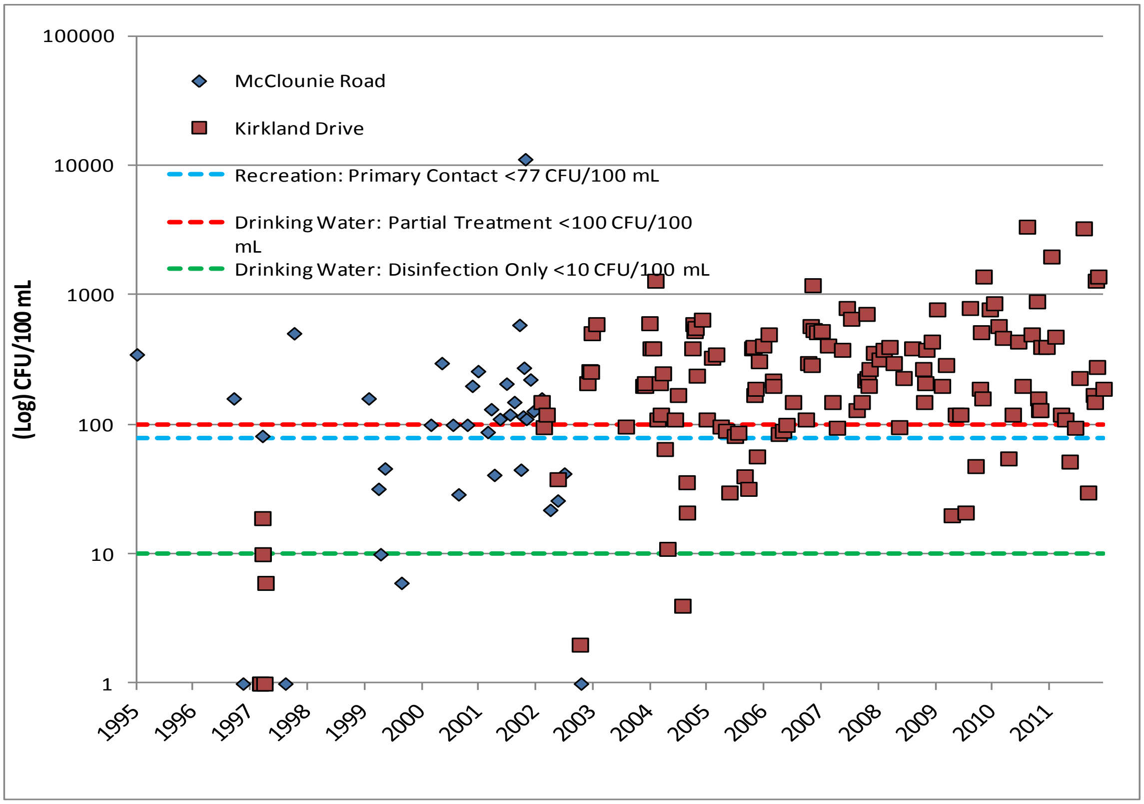

Figure 6. Coldstream Creek *E.coli* (CFU/100mL) concentrations at Kirkland Drive and McClounie Road, 1995 to 2012.

To examine spatial patterns and compare the data against BC water quality guidelines, *E. coli* was collected 5 times in 30 days at all six sites on Coldstream Creek in the spring and fall of 2009, fall 2010, and spring 2011. The 90^{th} percentiles (Figure 7) and geometric means (Figure 8) for *E. coli* were typically lowest at Noble Canyon and tended to increase moving downstream. Largest increases occurred between Noble Canyon and School Road, and again between Vimy Road and Howe Drive.

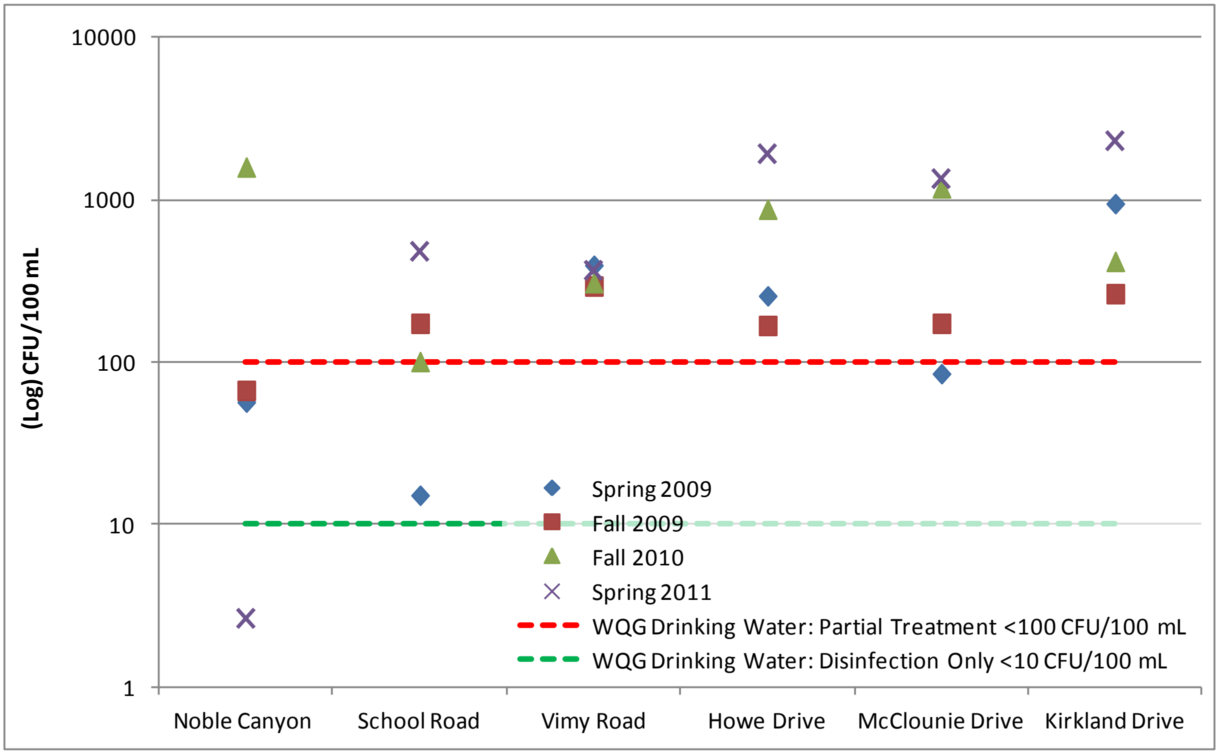

Figure 7. *E. coli* 90th percentiles (log CFU/100 mL) at six sites on Coldstream Creek compared to the BC WQGs for the protection of drinking water.

With the exception of the fall 2010 sampling period, *E. coli* results at Noble Canyon met the water quality guidelines for the protection of drinking water sources with partial treatment. *E.coli* concentrations increased with distance downstream (Figure 7), similar to the increases in agricultural land use between Noble Canyon and McClounie Road (Figure 4). *E. coli* exceeded guidelines for the protection of drinking water with partial treatment on all occasions but spring 2009 at School Road and McClounie Drive (Figure 7).

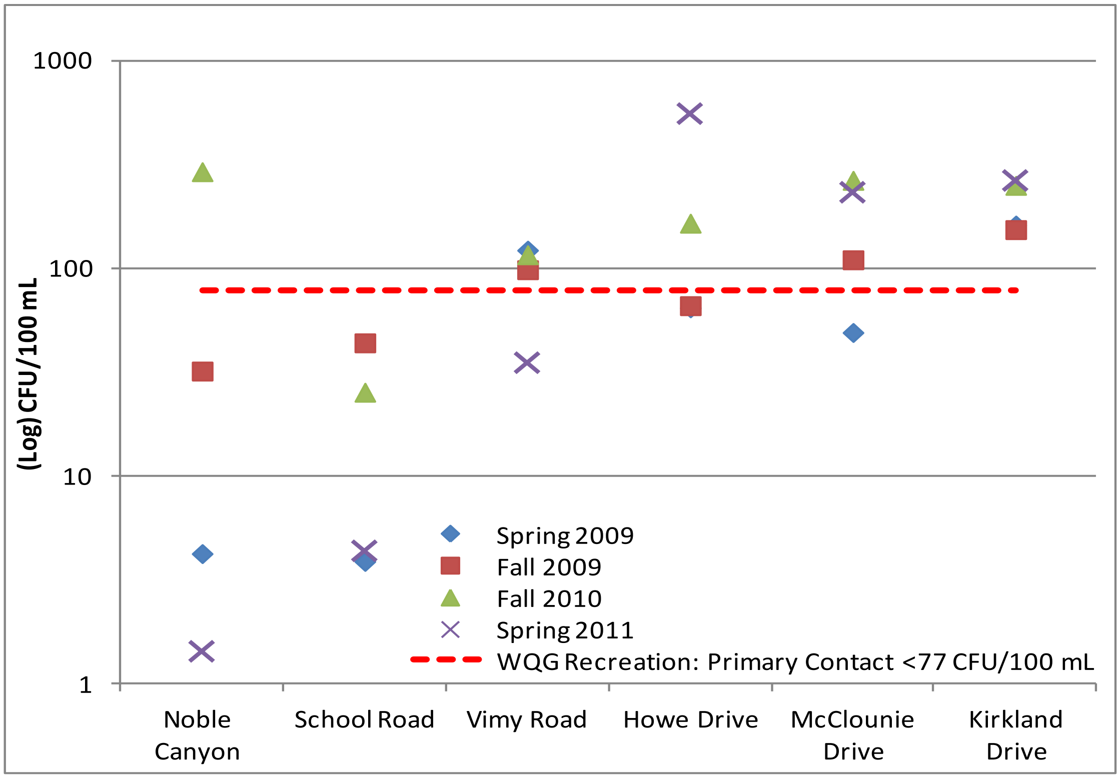

Figure 8. *E. coli* (log CFU/100 mL) geometric means at six Coldstream Creek sites compared to the BC WQG for the protection of primary contact recreation.

With the exception of the fall 2010 data, *E.coli* geometric mean concentrations were below the guideline for the protection of primary contact recreation at Noble Canyon and School Road on all sampling periods (Figure 8). Moving downstream, *E.coli* geometric mean concentrations usually exceeded the primary contact guideline at Vimy Road, and were above the guideline on all sampling events at Kirkland Drive.

6.1.3 Enterococci

Enterococci samples were collected at Kirkland Drive from 2004 to 2012. The data indicate no clear trend over time (Figure 9). Comparison of individual data points to guidelines, however, show that concentrations have been consistently and significantly above guidelines for the protection of drinking water and primary contact recreation.

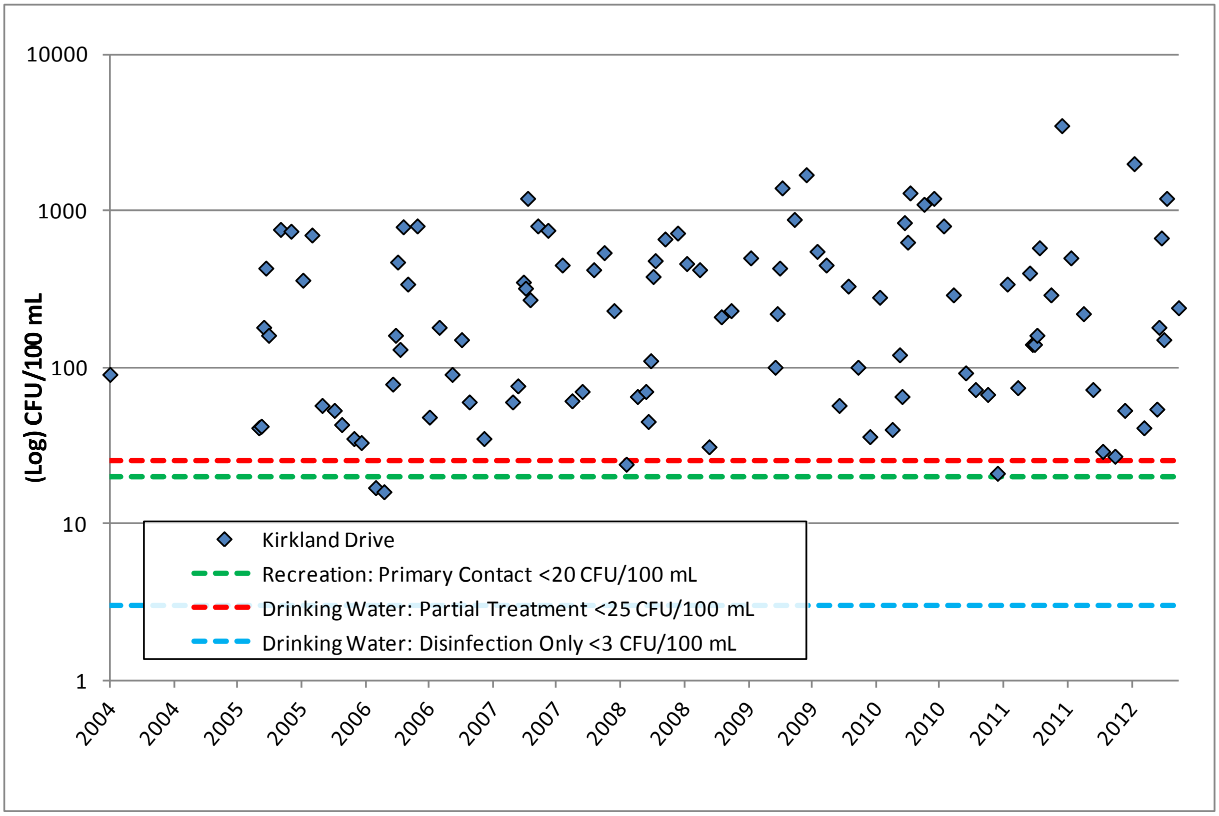

Figure 9. Enterococci (log CFU/100 mL) in Coldstream Creek at Kirkland Drive, 2004 to 2012.

To provide spatial and temporal information, enterococci were also analyzed on 3 to 5 dates over 30 day periods during the spring and fall of 2009 at all six monitoring sites on Coldstream Creek. Geometric mean and 90th percentile results show enterococci exceeded the guidelines for the protection of drinking water with partial treatment and disinfection (Figure 10), as well as the guideline for the protection of primary contact recreation (Figure 11) at all sites except Noble Canyon in the spring. Temporal patterns, with concentrations of enterococci higher during the fall, suggest higher stream flows in spring may dilute enterococci concentrations. Spatial patterns were similar to *E coli*, with concentrations increasing with distance downstream.

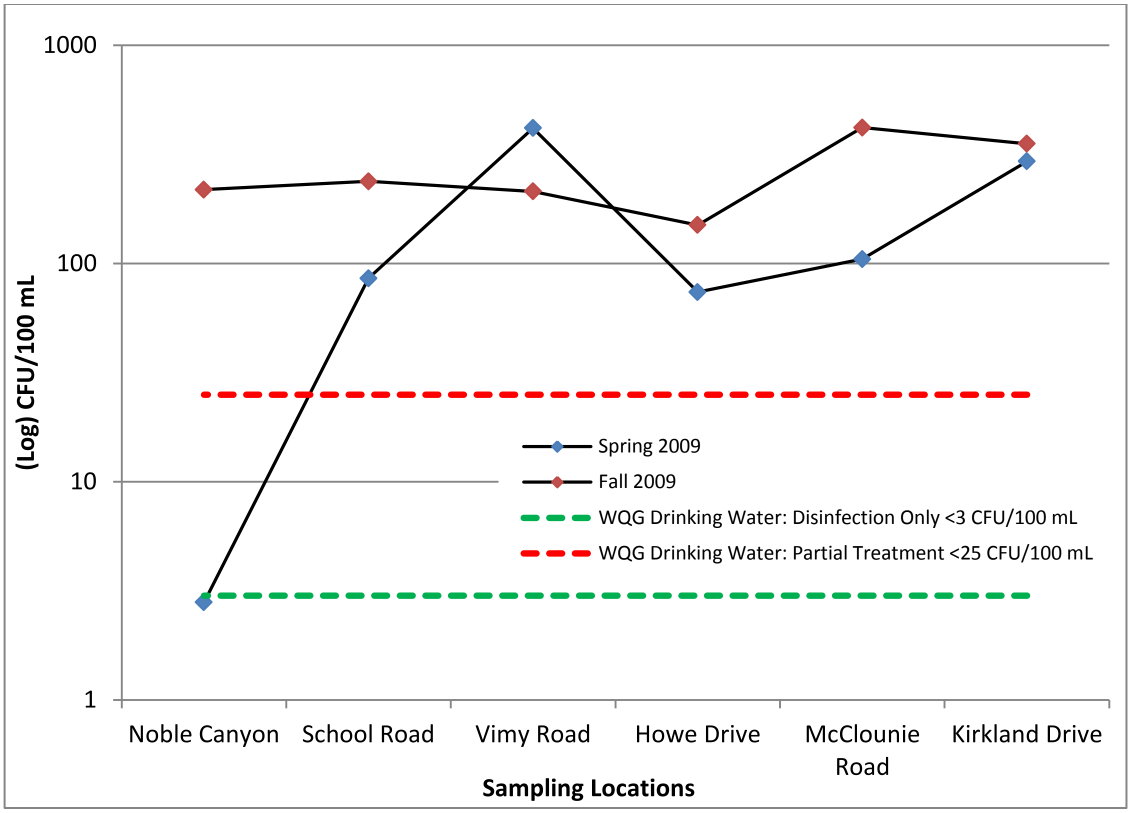

Figure 10. Enterococci 90th percentiles (log CFU/100mL) at six Coldstream Creek sites compared to BC drinking water guidelines.

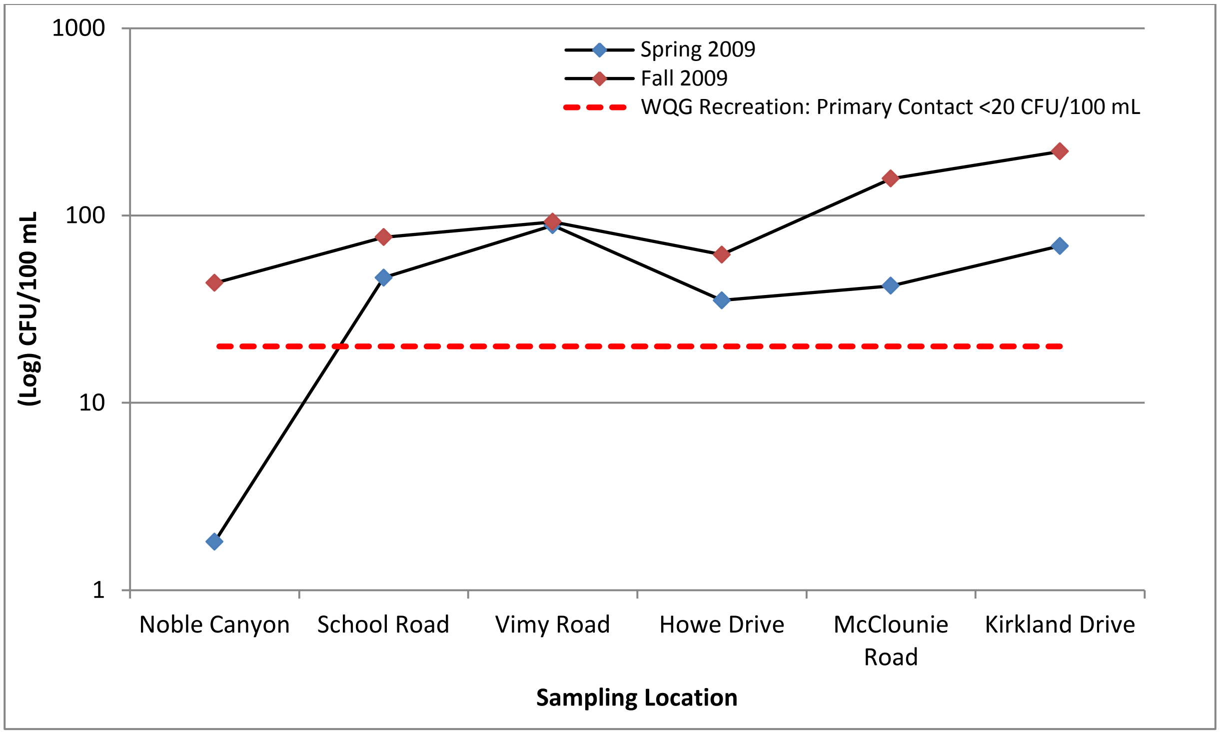

Figure 11. Enterococci geometric means (log CFU/100 mL) at six Coldstream Creek sites compared to BC water quality guideline for primary contact recreation.

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To further assess spatial and temporal patterns of all three bacteriological indicators, all results from the Kirkland Drive site were pooled by month over the history of data collection (Figure 12). From this information, seasonal patterns, likely driven by changes in hydrology, become more apparent. *E coli* and enterococci indicators increased sharply during the transition from frozen valley bottom conditions in January and February to low elevation snow melt period in March. *E. coli* and enterococci bacteria then decreased briefly during freshet period of April and May, and then steadily increased during the summer months, peaking in August, likely a result of increased concentration under low flow conditions, or greater animal reliance on direct access to the stream for water. While fecal coliform concentrations decreased in March and peaked earlier in June, they generally followed the pattern of *E. coli* and enterococci.

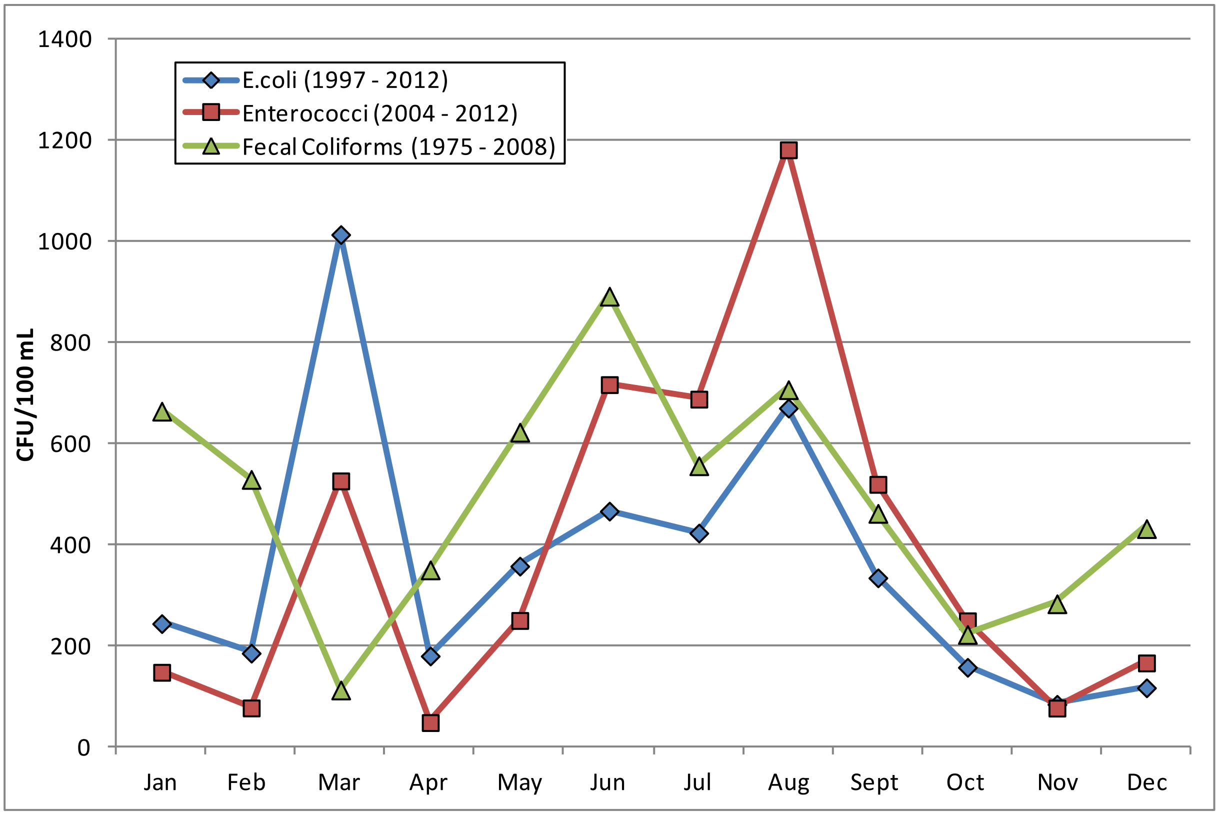

Figure 12. Monthly averages of all data for *E.coli*, Enterococci and Fecal Coliforms (CFU/100mL) at Kirkland Drive on Coldstream Creek.

E.coli has been recommended as the indicator organism of choice to protect freshwater systems in B.C., and enterococci has been recommended as a marine water recreation indicator (Rieberger, 2010). *E.coli*, concentrations in Coldstream Creek have for many years, if not decades, been well above guidelines for the protection of drinking water with disinfection and partial treatment, as well as above the guideline for primary contact recreation. Seasonal patterns indicate that bacteria concentrations peak in Coldstream Creek during valley bottom snowmelt in spring, and again during summer months. The spring peak coincides with rapid movement of Coldstream Creek water across Kalamalka Lake and over the Greater Vernon Water (GVW) utility intake. The summer *E. coli* peak coincides with the peak recreational use period on waters of Kalamalka Lake. Kalamalka Lake bacteria counts at the GVW intake show a relationship to Coldstream Creek quality and discharge (Larratt, 2012). GVW drinking water receives disinfection using ultraviolet light and chlorine before distribution. To date, filtration deferral has conditional support by the Ministry of Health provided microbiological source control and other water quality protection efforts are successful (Clark, pers. comm. 2014).

Although no drinking water use is known to occur directly from Coldstream Creek at this time, it does occur less than a kilometer away in Kalamalka Lake. The influence of Coldstream Creek on water quality at the GVW's north arm intake is a noted concern (Larratt, 2012). For this reason **it is proposed that a long term water quality objective (10 years) be set for *E. coli* as ≤100 CFU/100 mL for the protection of drinking water sources. Attainment should be determined as a 90th percentile based on 5 samples over 30 days during early spring and summer low flow periods at Kirkland Drive.** Should drinking water use be re-established at Noble Canyon, these objectives should be re-assessed.

This objective will be very difficult to achieve in the short term but offers reasonable long-term water quality protection for the established water uses and supports the GVW watershed control strategies. Considerable effort to reduce animal access and overland flow of contaminated waters to Coldstream Creek will be required to reduce coliform bacteria inputs. Additional effort will also be required to identify bacteria source inputs to Coldstream Creek. It has been shown that coliform bacteria inputs to Coldstream Creek may come from many diffuse human related sources as well as natural sources. Bacterial source tracking using genetic "finger print" techniques on Coldstream Creek samples was carried out on three occasions in 2009 (Sokal, 2009). While this testing is relatively new and costly, the data suggested multiple sources of fecal contamination including human, livestock (cows and horse), dog and avian (waterfowl, gulls and songbirds) was entering the creek. Fecal contamination of waters from human sources is generally regarded as a greater risk to human health than contamination from non-human sources, as they are more likely to contain human-specific enteric pathogens. At that time, the majority of fecal contamination was attributed to the avian component, with lesser amounts of dog and livestock bacteria, indicating that wildlife are impacting the water quality of Coldstream Creek (Sokal, 2009). Water quality assessments, objective setting, and source control will benefit as new methods of bacterial source identification become more accessible.

6.2 NUTRIENTS (NITROGEN AND PHOSPHORUS)

Nitrogen (N) and phosphorus (P) are important and often limiting nutrients in freshwater ecosystems. N and P occur naturally but can increase in streams and lakes through inputs of sewage, septic tank seepage, from agricultural inputs via manure or fertilizers, or from erosion of soils to downstream waters. The environmental consequences of excessive N and P concentrations in aquatic ecosystems is eutrophication, and the associated increased incidence of nuisance or toxic algal blooms, fish mortality due to anoxia, increased costs of drinking water treatment, reduced water clarity, loss of recreational appeal and reduced tourism.

Phosphorus is measured in freshwater in various forms; for stream water this is often as ortho-phosphorus, total dissolved P and total P. Due to rapid uptake and recycling of P in streams, there are no BC Guidelines for phosphorus in streams, rather, the productivity arising from P inputs and utilization is measured as algal periphyton chlorophyll-*a*. As such, the phosphorus data for Coldstream Creek, which is routinely collected at Kirkland Drive, will not be assessed in this document. Nevertheless, it is important to note that phosphorus export from Coldstream Creek to Kalamalka Lake is very important to Kalamalka Lake water quality variation (BC Research, 1975; Anon., 1985) and water usage of Kalamalka Lake in terms of recreation (Sokal, 2014. pers. comm.) and drinking water supply (Larratt, 2012). Continued collection of P data at Kirkland Drive will be useful to determine Kalamalka Lake response to P loading and changes in climate.

Nitrogen occurs in many forms in freshwater. The most important forms in primary production are the inorganic forms, ammonia and nitrate (Nordin, 1985). The most reduced inorganic form of nitrogen found in water is ammonia, which can be present as ammonia (NH_3) or ammonium (NH_4^+), depending on environmental conditions (Nordin & Pommen, 1986). Ammonia concentrations are usually low in the environment due to rapid nitrification to nitrate (NO_3^-). Indeed, ammonia is generally low (< 0.1 mg/L) in Coldstream Creek, however increased concentrations (3.6 mg/L) were measured at Kirkland Drive during weeks of higher spring flows in spring 2011. While not above guideline levels, the high ammonia levels coincided with elevated phosphorus levels, indicating high overall nutrient loading to the creek during the early snow melt period. During that period, many agricultural fields in the vicinity of Howe Drive were flooded and run-off from fields and ditches was observed flowing into the creek (Sokal, 2009). Sporadic ammonia sample collection, and generally low levels, suggests that the BC WQGs for ammonia, for the protection of aquatic life (Meays, 2009) are appropriate for Coldstream Creek protection.

Nitrite (NO_2^-) is another intermediary form of nitrogen, which can be very toxic to aquatic life. However, this form is quite unstable and rapidly converts to nitrate in the presence of oxygen. Nitrate is dissolved in water and has low affinity or reactivity with soils and therefore is highly mobile in groundwater. Nitrogen in Coldstream Creek was analyzed as nitrate + nitrite on all sampling sites. Due to the unstable nature of nitrite, nitrate + nitrite results are typically the same as results of nitrate analysis on its own, therefore, nitrate + nitrite will be referred to as nitrate in this document.

The BC WQG for nitrate in source drinking water is 10.0 mg/L (Nordin & Pommen, 1986). For the protection of aquatic life the 30-day average concentration should not exceed 3.0 mg/L and the maximum guideline concentration is 32.8 mg/L (Meays, 2009). The 30-day average concentration is based on the chronic effects of nitrate on the Pacific Tree frog (*Pseudacris regill*). As well, a study of acute and chronic toxicity of nitrate on early life stages of lake trout (*Salvelinus namaycush*) and lake whitefish (*Coregonus clupeaformis*) also supports the validity of the nitrate guideline for freshwater life by showing that the early life stages of these species were susceptible to sub-lethal effects at levels similar to those affecting early life stages of the Pacific tree frog. This amphibian is endemic throughout central and southern BC (BC Frogwatch Program). Mean background nitrate + nitrite concentrations in lotic systems throughout BC fall below 0.5 mg/L (Meays, 2009). Therefore, a guideline of 3.0 mg/L nitrate (as N) allows an increase of 6 times over background concentrations (Meays, 2009).

To assess long term trends in Coldstream Creek, all nitrate data from the McClounie Road and Kirkland Drive sampling sites were used as the sites are close together and influenced by the same land use (Figure 13). In recent years, maximum nitrate concentrations exceeded the water quality guideline. These levels are not typical in nearby drainages. For example, this concentration range is well above what has been recorded for Bessette (max. 0.2 mg/L) and Duteau (max. 0.28 mg/L) creeks, located nearby and having substantial agricultural land use.

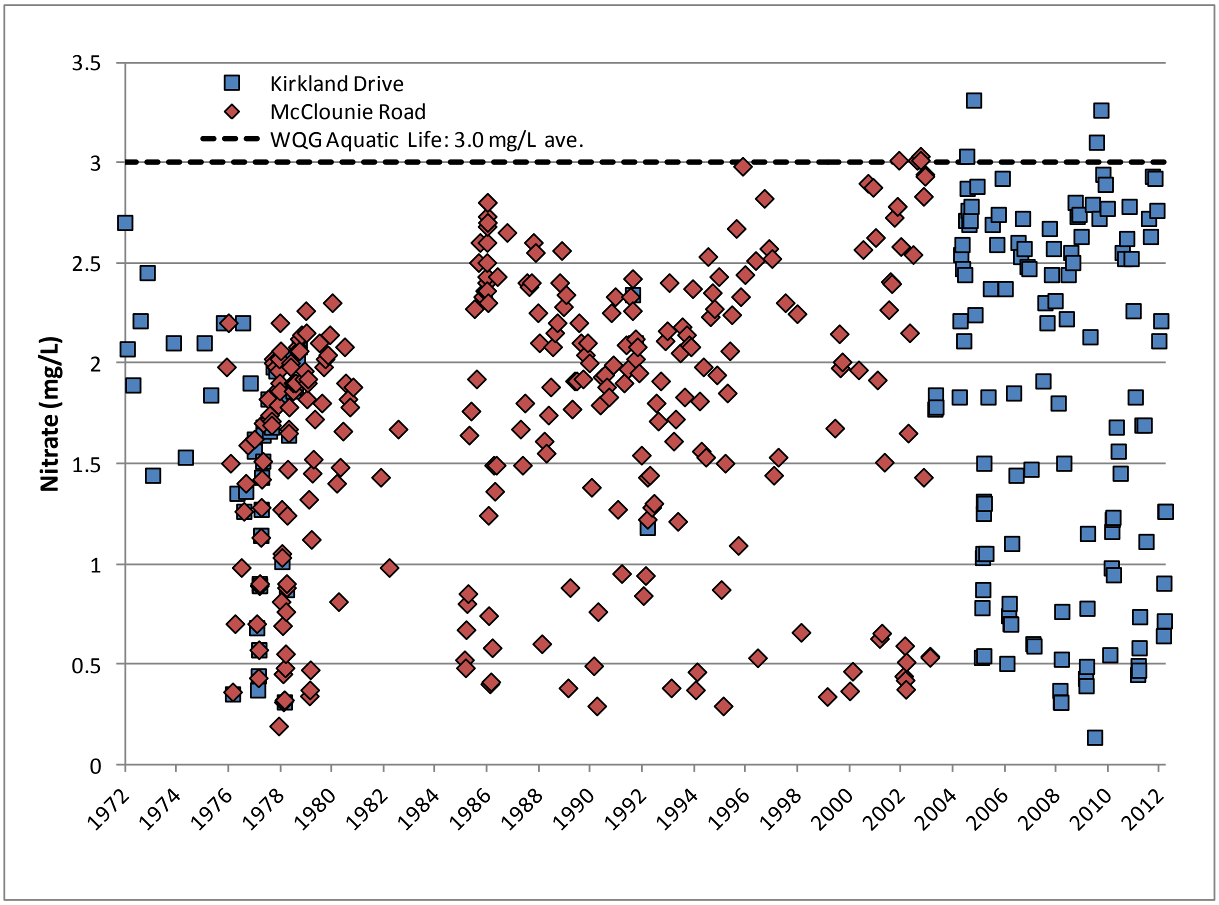

Figure 13. Nitrate nitrogen (mg/L) concentrations in Coldstream Creek at Kirkland Drive and McClounie Road between 1972 and 2012.

To assess nitrate seasonal and spatial patterns, weekly samples were collected from the six Coldstream Creek sites on three recent occasions, spring 2009, fall 2010 and spring 2011. The 30-day mean concentrations are summarized in Table 6 and are plotted in Figure 14.

Table 5. Mean nitrate concentrations (mg/L) at six Coldstream Creek sampling sites.

	Noble Canyon	School Road	Vimy Road	Howe Drive	McClounie	Kirkland
Spring 2009	0.190*	5.899*	3.110*	2.812	2.532	2.496
Fall 2010	0.030	1.750	**3.158**	**3.154**	2.718	2.678
Spring 2011	0.290	2.082	2.910	2.612	2.332	2.274

*n=3, could not compare to BC WQG.
Bold values exceed BC WQG (3.0 mg/L).

Notwithstanding significant nitrate inputs to ground from Silver Star sewage works in the upper Coldstream Creek catchment, nitrate concentrations at Noble Canyon are uniformly very low during 2009-2011 (Table 6). Downstream of Noble Canyon, Coldstream Creek nitrate increases dramatically, generally peaking at Vimy Road and remaining high downstream to the confluence with Kalamalka Lake. Low volume surface and groundwater drainage from an old dairy farm (no longer in operation) upstream from School Road is known to be a significant nitrate N input to Coldstream Creek in this area. Unpublished MOE analyses in 2011using caffeine and nitrogen isotopes suggested the source was manure. The nitrogen isotope data indicated that the source of nitrate could be nitrified manure, septic effluent, and soil nitrate. However, the absence of caffeine in the drainage ruled out septic sources. It remains unclear whether or not the elevated concentrations are a legacy or current land use issue (Sokal, pers. comm. 2014). Efforts to further quantify these inputs and develop mitigation measures are being investigated by the District of Coldstream (Koch, 2012). As nitrate concentrations remain elevated downstream of School Road it is likely that other inputs of nitrate to Coldstream Creek occur farther downstream within the drainage due to historic and present land use patterns.

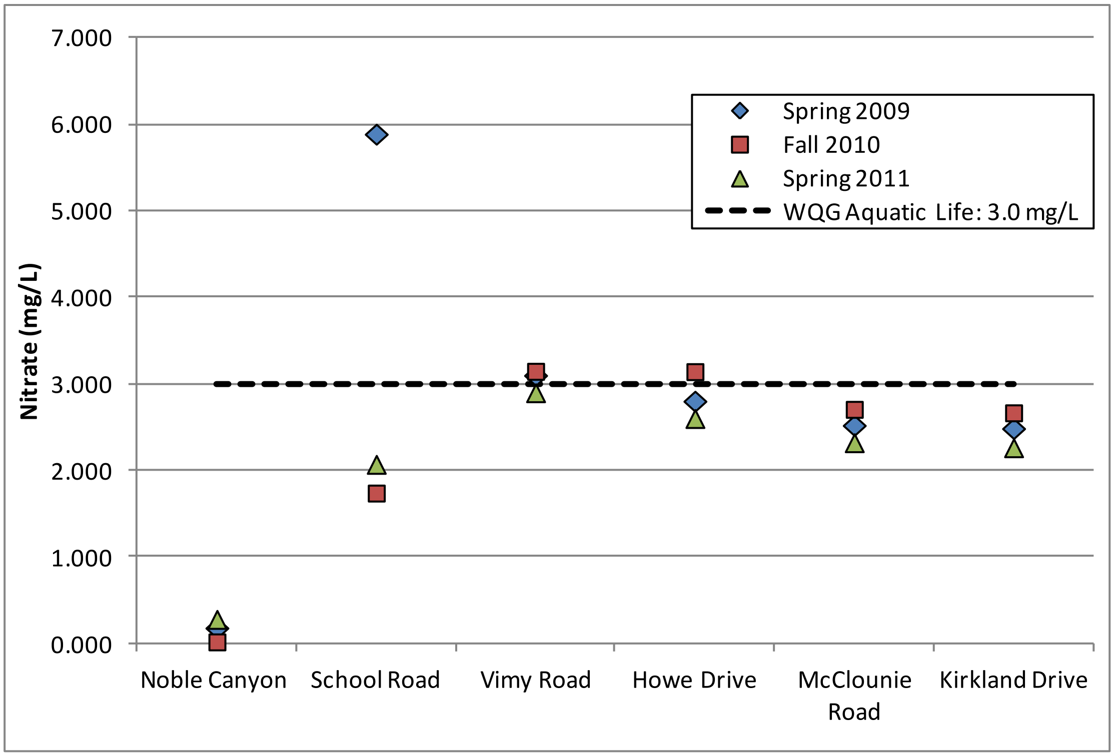

Figure 14. Nitrate mean concentrations (mg/L) at six sites on Coldstream Creek from sampling conducted during spring 2009, fall 2010, and spring 2011.

Mean concentrations of nitrate at Kirkland Drive exhibit strong seasonality, with greater concentrations in fall and winter and reduced concentrations in spring and early summer (Figure 15).

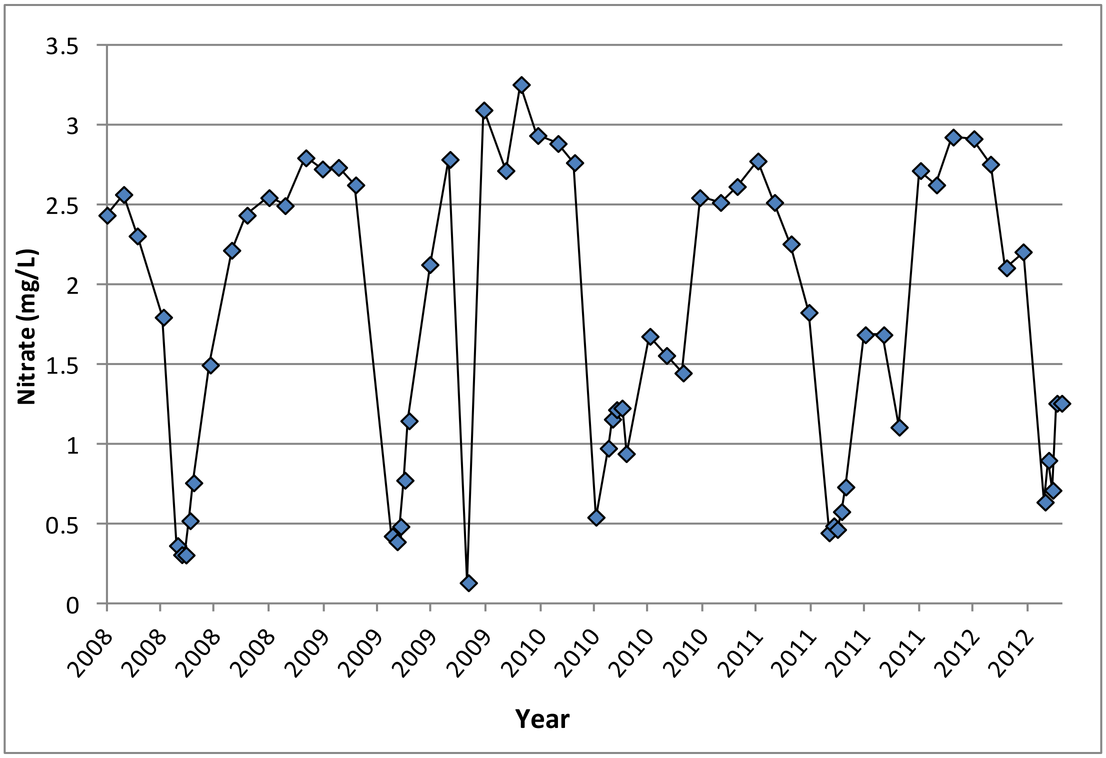

Figure 15. Nitrate seasonal variation in Coldstream Creek at Kirkland Drive, 2008 to 2012.

These seasonal patterns are likely related to stream discharge; however, other factors such as the timing of fertilizer application could be important as well. Of most concern is that nitrate concentrations in Coldstream Creek have been increasing over time.

Mean nitrate concentrations at monitoring locations downstream of Vimy Road are approaching, or periodically exceeding the WQG for the protection of aquatic life (3.0 mg/L) during fall and winter low flow conditions. This coincides with the time of year when kokanee eggs and fry are incubating in Coldstream Creek. **In the short-term (3 years), a water quality objective of 3.0 mg/L for nitrate is proposed for the protection of aquatic life**. **Water quality objective applies to Coldstream Creek below Noble Canyon, and attainment of the objective should be determined as the average of five samples collected in 30 days during worst case conditions of fall and winter low flow period.**

A long term water quality objective for nitrate is appropriate given the increasing trend in nitrate and the apparent loss of assimilative capacity given that the WQG of 3.0 mg/L is periodically exceeded. Water quality objectives may be set based on background or historic data when available and reasonable (MacDonald Environmental Sciences Ltd. 1997). Nitrate data is available for McClounie and Kirkland sites in the 1970s. The 95th percentile of that data set is approximately 2.0 mg/L. **Therefore, a long-term water quality objective (10 years) for nitrate of 2.0 mg/L is proposed for Coldstream Creek below Noble Canyon. Attainment of the objective should be determined as the average of five samples collected in 30 days during worst case conditions of fall and winter low flow period. This long term water quality objective should provide a realistic incentive to better manage nutrient inputs, particularly nitrate N within the catchment.** This value is still greater than what occurs in similar nearby drainages, and in Coldstream Creek at Noble Canyon. Further data is required to establish nitrate norms for Coldstream Creek above Noble Canyon. Further assessment of nitrate loading to Coldstream Creek valley bottom lands and Coldstream Creek is required to identify and reduce inputs and better develop water quality goals for this stream. As with all non-point source pollution, a multi-faceted approach (surface and groundwater, both quality and quantity) will be required to develop an action plan to reverse this chronic water quality issue.

6.3 TEMPERATURE

Land use activities such as forest harvesting, agriculture or urban development, can increase stream temperatures through decreases in stream shading or reductions in water levels due to water withdrawals. These changes may exacerbate those attributable to climate change or variability. Coldstream Creek is a relatively cool waterbody, with maximum temperatures at Kirkland Drive rarely exceeding 18 ^{o}C in recent history (Figure 16).

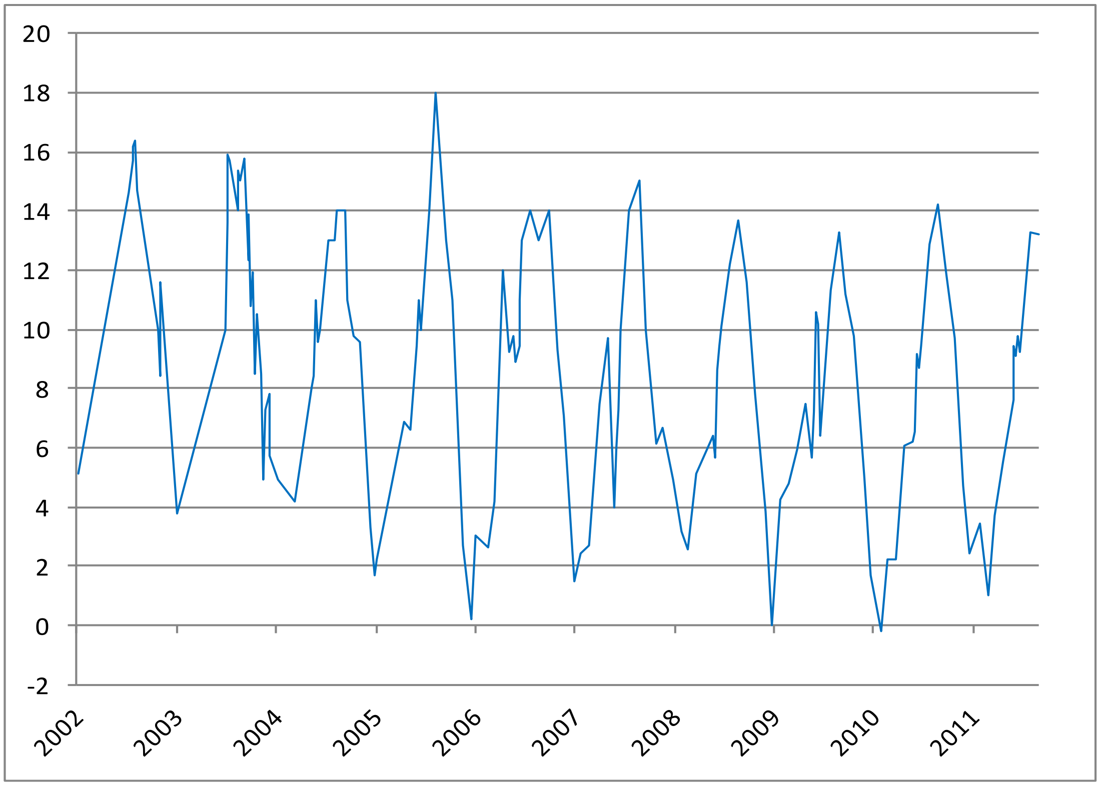

Figure 16. Temperatures in Coldstream Creek at Kirkland Drive.

Water quality guidelines for temperature have been developed for several water uses. For drinking water supplies, it is recommended that water temperature be less than 15^{o}C to protect the aesthetic quality of the water. For the protection of aquatic life in streams of known species distribution, the guidelines restrict temperature change to + or - 1 degree Celsius beyond specific optimum temperature ranges for specific life history stages of the fish species present (Oliver and Fidler, 2001). Coldstream Creek serves as an important spawning and rearing habitat for resident and Kalamalka Lake fish species, most notably kokanee. For the protection of kokanee, the guideline for incubation is 4.0 – 13.0^{o}C. Incubation typically occurs anywhere from mid-August through to May. During the summer months, when temperatures in Coldstream Creek are expected to reach their peak, the most sensitive life history stage present would be migration and spawning. Temperature guidelines for these stages range from 7.2 – 15.6 ^{o}C and 10.6 – 12.8 ^{o}C respectively.

Coldstream Creek temperature measurement periods have not typically targeted sensitive life history stages for Coldstream Creek kokanee. As such there is difficulty applying the temperature guidelines for the protection of aquatic life to the data available on Coldstream Creek (St. Hilaire, pers. comm. 2014). Water temperature for Coldstream Creek at Kirkland Drive (1972 to 1978 and 2002 to 2012) and McClounie Drive (1976 to 2003) were assessed by month using 95th percentile values to reflect maximum temperatures without the influence of outliers. This data suggests that stream temperatures remain within the appropriate range for the protection of the most sensitive life stages for kokanee (Figure 17).

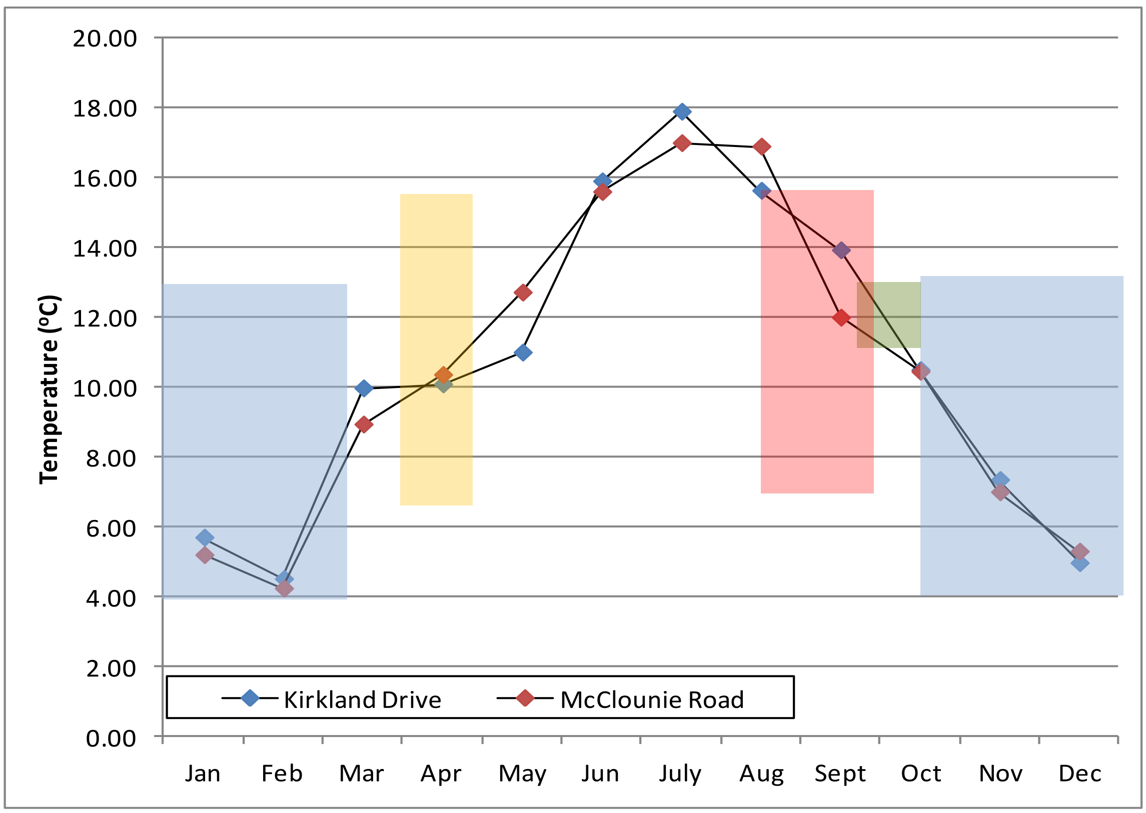

Figure 17. Water temperature (95th percentile) of Coldstream Creek at Kirkland Drive (1972 – 1978 & 2002 – 2012) and McClounie Road (1976 – 2003) compared to the WQG for the protection of aquatic life. Shaded areas denote WQG ranges for specific life stages of kokanee in Coldstream Creek (blue boxes = egg incubation period, green box = spawning period, red box = adult outmigration period, yellow box = juvenile outmigration period).

Water temperatures at these lower sites were within the optimal range during the fall migration period, but were cooler than the optimal range for kokanee migration (7.2 – 15.6 ^{o}C ±1) during spring sampling events. However, sampling events typically occurred in late-fall and early-spring, therefore the results represent cooler temperatures than would likely be experienced during the peak migration of kokanee (adult migration in mid-August through September and juvenile out migration in April) (St. Hilaire, 2009). Based on the long term data from Kirkland Drive it appears that during kokanee migration, temperatures were within the optimal range during the fall migration and were within the optimal range during the juvenile out migration.

Optimal temperatures for kokanee spawning are 10.6 – 12.8 ^{o}C ±1. Spawning typically occurs in Coldstream Creek from mid-September to mid-October, again fall sampling targeted October/November and did not capture the peak spawning period. Temperatures are typically cooler in October/November than September/October and therefore were much cooler than the optimal temperature range for spawning. The optimal temperature for kokanee egg incubation is 4.0 – 13.0 ^{o}C ±1. The egg incubation period in Coldstream Creek is mid-October through to early March.

Weekly temperature records (5 dates in 30 days) for all sampling sites during the spring and fall sampling events (2009 – 2011) show mean temperatures increase downstream from Noble Canyon and peak at Howe Drive then decrease to Kirkland Drive (Figure 18). These spatial patterns maybe due to reduced riparian canopy and more direct solar radiation. However other factors, such as changes in stream discharge, channel depth, or changes in the relative contribution of groundwater to stream flow may also be important regulatory factors.

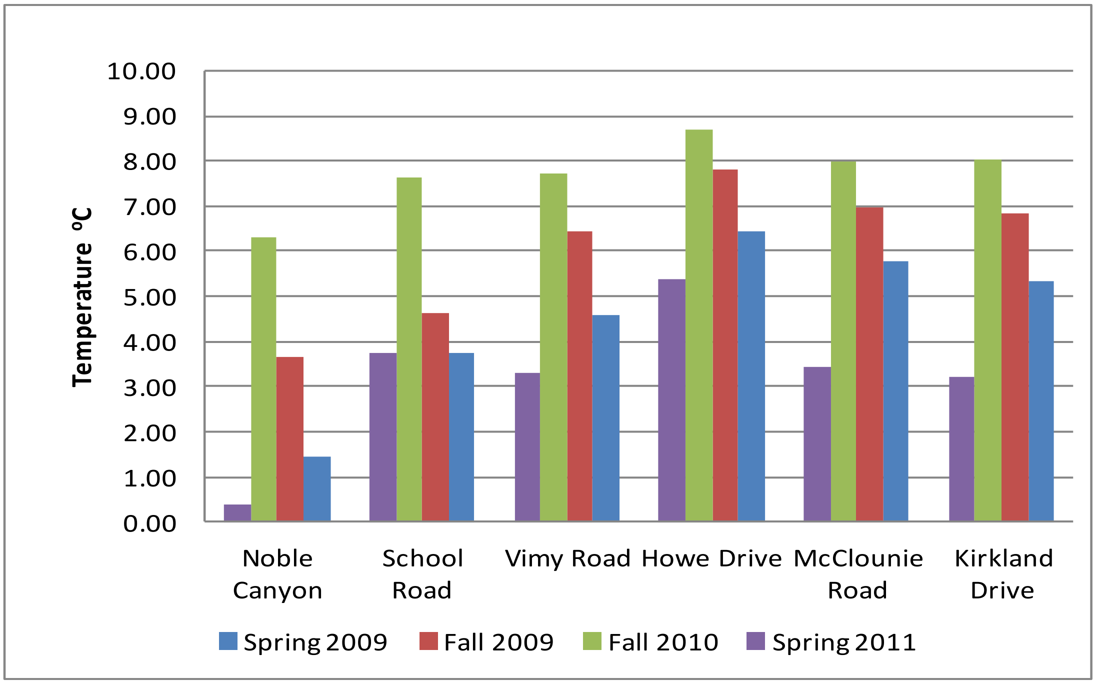

Figure 18.Temperature mean values at six Coldstream Creek sites, 2009 to 2011.

Nevertheless, given that water quality results are within the optimal range for sensitive life stages of kokanee in Coldstream Creek, **a water quality objective is not warranted at this time**. The BC water quality guidelines for the protection of aquatic life are protective of all water uses in the watershed. Continuous water temperature measurement at Kirkland Drive is required to properly assess Coldstream Creek water quality relative to the guideline. With the establishment of the continuous water quality station at Kirkland Drive by RDNO in 2015, this data may be reviewed and assessed in the future.

6.4 DISSOLVED OXYGEN

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in water. It is dependent on photosynthetic activity, respiration rates of organisms, temperature, salinity, turbulence, mixing, and atmospheric pressure. DO in surface water typically ranges from 0 to 15 mg/L, while concentrations in flowing surface water are generally less than 10 mg/L. The capacity of water to hold oxygen is inversely proportional to water temperature, meaning that during warm weather conditions the DO concentration of water is expected to be lower.

DO levels are important for the survival of aquatic organisms, especially those sensitive to reduced oxygen levels, such as salmonids. The BC water quality guideline for the protection of aquatic life (all life stages) is an instantaneous minimum of 5 mg/L and a 30-day average of ≥8 mg/L (Ministry of Environment, 1997).

Long-term trend data for Kirkland Drive shows that with few exceptions, DO concentrations range from 8 to 14 mg/L. A seasonal pattern is also evident in the data with DO concentrations diminishing during the summer months when stream flow is low and the water is warmer, thus having a reduced ability to hold oxygen.

Seasonal data collection at the six monitoring sites on Coldstream Creek show DO ranged from 8.78 to 13.0 mg/L with concentrations generally greater in spring than fall (Figure 20). A consistent spatial pattern is evident during the 3 study periods, with depressed DO concentrations at Vimy Road, and slight recovery by Kirkland Drive.

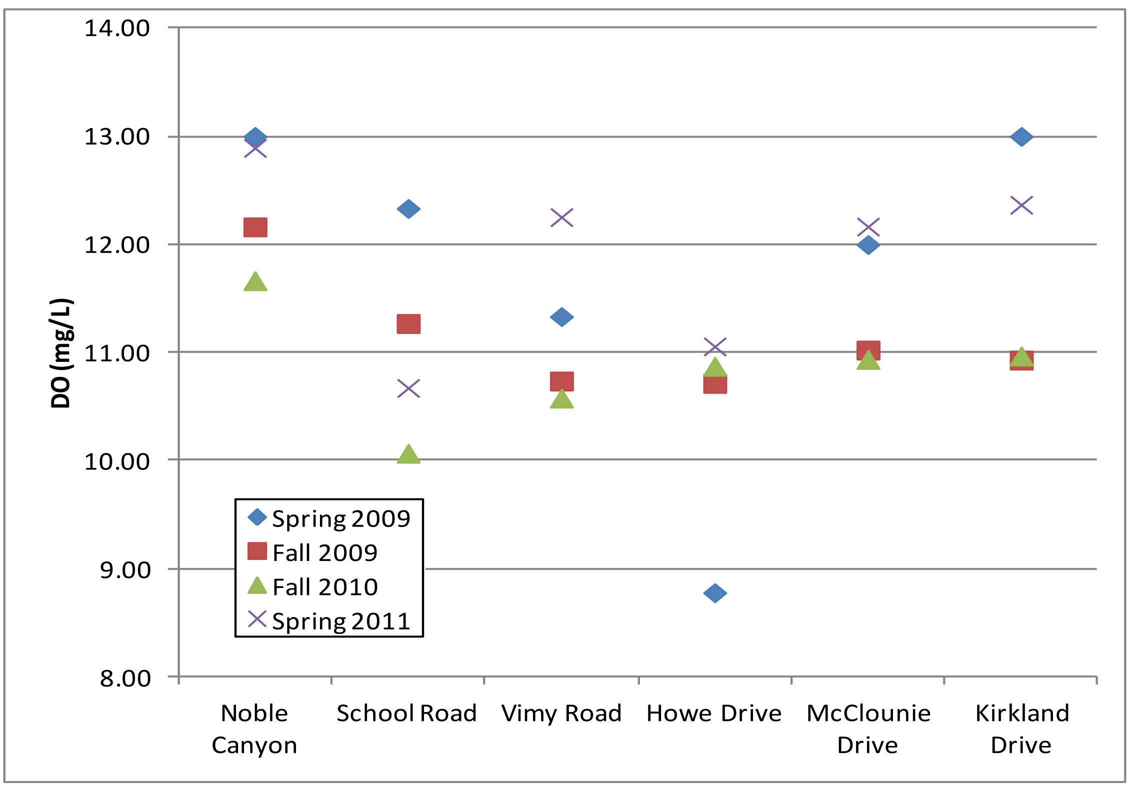

Figure 19. Dissolved oxygen in Coldstream Creek at six sites, spring 2009 to spring 2011.

DO concentrations were within the guidelines for the protection of aquatic life of ≥8 mg/L during all sampling events. **Given this, no water quality objective is proposed for DO at this time.** Collection of DO data at Kirkland Drive should continue to complement water chemistry and biological data and support ongoing water quality assessment of Coldstream Creek.

6.5 TURBIDITY

Turbidity is used as an indicator of the clarity or cloudiness of water. Turbidity is expressed as nephelometric turbidity units (NTU). Turbidity measurements increase with the amount of light scattered, or diffracted in the sample. Particles suspended in a water sample may include clay, silt, fine sand, decaying organics, algae and other microorganisms (Dobson, 2001). These particles may carry pathogens and chemicals with them. The deposition of these fine particles can be detrimental to aquatic organisms by reducing the amount of available oxygen and light penetration into stream beds thus impacting primary and secondary production. Direct effects on fish include clogging and abrasion of gills, behavioral effects and smothering of stream habitat (Caux et al., 1997). From a drinking water perspective, domestic water supplies with elevated turbidity levels can be aesthetically unpleasing for the consumer. More importantly, elevated turbidity reduces the effectiveness of water treatment and disinfection processes. In order to ensure proper treatment of the potentially higher bacteria concentrations and to account for the absorption of chlorine by the suspended particles in water, water purveyors must use higher levels of chemical disinfectants, such as chlorine, or use UV disinfection.

Now withstanding the past influence of turbidity on Coldstream Creek drinking water use, aquatic life is the most sensitive water use at present with respect to turbidity increases in Coldstream Creek. Therefore the BC WQGs to protect aquatic life are appropriate for Coldstream Creek turbidity assessment. However, the BC WQG for aquatic life will also assist turbidity reduction and therefore drinking water protection in the north arm of Kalamalka Lake.

BC WQGs for aquatic life during periods of normally clear flow (July to April) recommend that no change from background of 8 NTU at any one time for a duration of 24 hours, or no increase of 2 NTU or more over background over a duration of 30 days. During turbid flow (May-June) and normally higher turbidities (8-50 NTU), the WQG recommends no change of 5 NTU or more at any time, or an increase of 10% over background when values are greater than 50 NTU (Caux et al., 1997; Singelton, 2001).

In recent history, Coldstream Creek is generally low in turbidity at Kirkland Drive (Figure 21) and, typical of interior streams with snow melt hydrographs, maximum turbidities occur in spring. Between 2003 and 2012, turbidity averaged 7.38 NTU overall, and during clear flow periods (July to April) and turbid (May June) flow periods, turbidity averaged 3.8 NTU and 16.3 NTU respectively. Evaluation of the Kirkland Drive site relative to the BC WQGs for aquatic life is not feasible as only one site was typically sampled historically, and a background site is needed for comparison.

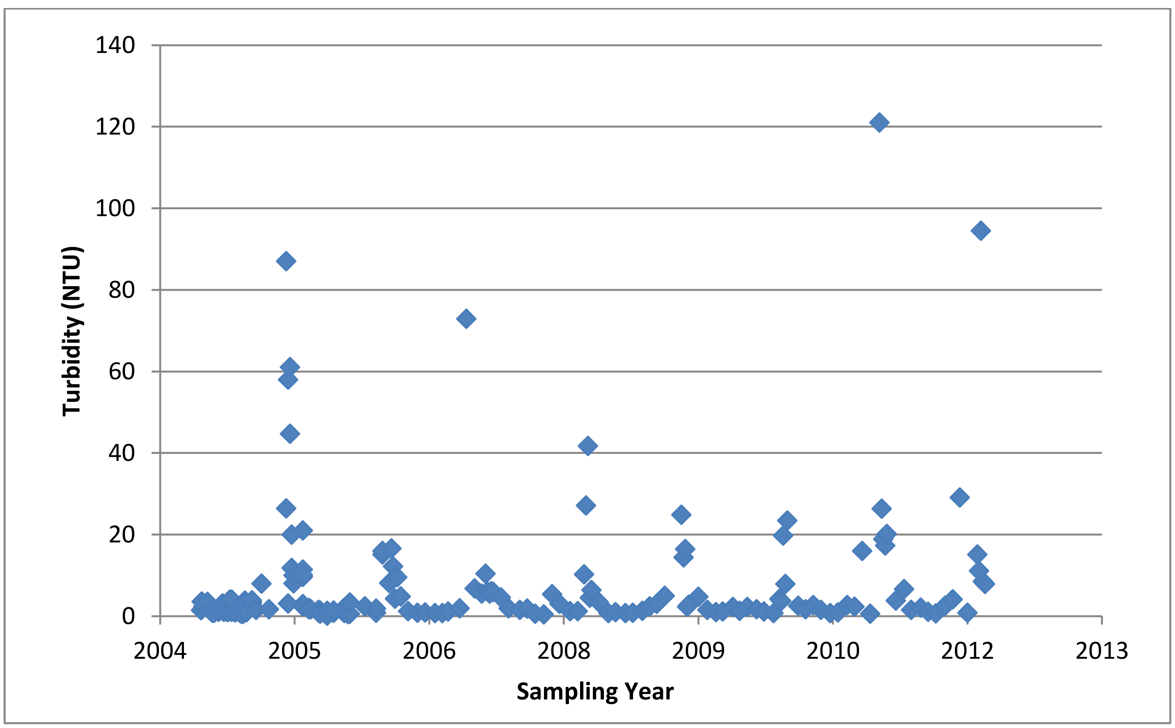

Figure 20. Turbidity (NTU) in Coldstream Creek at Kirkland Drive, 2004 to 2012.

Assessment of turbidity increase between pairs of sites is possible however for the period 2009 to 2011 when the six monitoring locations were sampled during the spring and fall monitoring periods. Spring sampling in this data strived to assess the period of elevated coliform counts during the low elevation snow melt, which generally precedes the April-May freshet period. Turbidity generally increased between Noble Canyon and School Road, decreased at Vimy Road before increasing again at Howe Drive and remaining elevated through to Kirkland Drive (Figure 22). This pattern suggests Coldstream Creek above Noble canyon was generally not a source of turbidity during the recent sampling events. This is reasonable given that the collection period proceeded the main freshet period of May and June. It also suggests that the area between School Road and Vimy Road is perhaps a depositional area, and that erosional processes increase again below Vimy Road. For the 2009 to 2011 data set, all data could be considered clear flow given the timing of collection and background values below 8 NTU. Given this, only the turbidity increase between Howe Drive and McClounie Road in February 2011 and between Vimy Road and Howe Drive in March 2011 were more than the 8 NTU limit. For all other spring and fall dates, turbidities, or increases in turbidity were less than 8 NTU. Recognizing the limitations of the data to judge turbidity relative to the WQG 30 day average, it appears that between Noble Canyon and School Road in spring and fall 2009 and fall 2010, between Vimy Road and Howe Drive in spring turbidity exceeded the allowable average increase of 2 NTU over 30 days. More frequent sampling would be required to determine average changes in turbidity between sites.

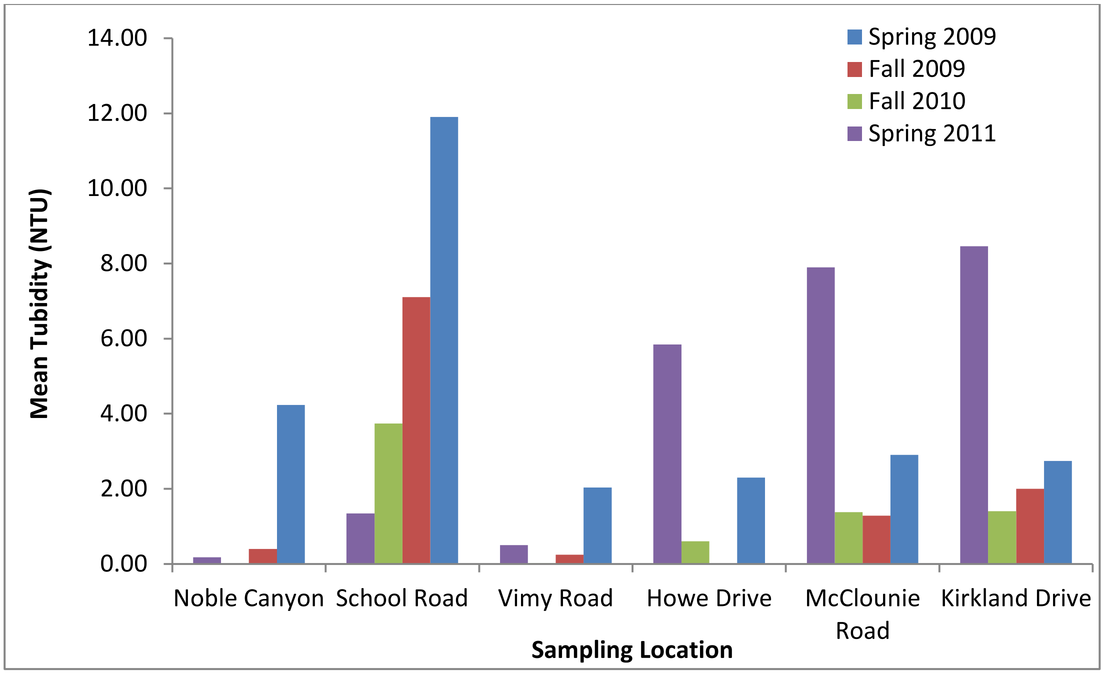

Figure 21. Turbidity (NTU) in Coldstream Creek at six sites, spring 2009 to spring 2011.

Multiple site sampling during the main freshet period of April and May would also be required to more thoroughly assess turbidity in Coldstream Creek relative to the BC WQG for aquatic life protection. Continuous turbidity monitoring would also provide better definition of clear and turbid flow periods, and help determine the suitability of grab samples to determine attainment.

Given the importance of low turbidity to aquatic life protection in Coldstream Creek and drinking water supply concerns in Kalamalka Lake, water quality objectives for turbidity are proposed for Coldstream Creek. The water quality objectives proposed for aquatic life will also function to protect drinking water sources in Kalamalka Lake. **The water quality objectives for turbidity in Coldstream Creek will be consistent with the BC WQGs for aquatic life protection. In other words, between any two sampling sites from Noble Canyon to Kirkland Drive, turbidity during clear flow should not increase by more than 8 NTU at any one time for 24 hours, or increase by more than 2 NTU over a 30 day period. During turbid flow (8-50 NTU), there should be no change of 5 NTU at any time, or an increase of more than 10% between sites when the NTU is greater than 50 NTU.**

Key locations of assessing downstream increases are between Noble Canyon and School Road, and between Vimy Drive and Kirkland Drive.

6.6 CHLORIDE

Chloride in water can serve as an excellent indicator of human influences on water quality. Chloride ions, once dissolved, tend to remain in solution and are not degraded in the environment. Sources of chloride include road salt, sewage, irrigation drainage, industrial effluents and dissolution of natural salt deposits (Nagpal et al., 2003). The largest source of chloride to freshwaters in BC is generally associated with the storage and application of road salt which then enter water, soil, and ground water during snowmelt. For freshwater, natural background concentrations of chloride are on the order of 1 to 100 mg/L, with maximum observed concentrations in B.C. in the range of 13 to 140 mg/L (Bright and Addison, 2002). BC water quality guidelines for chloride have been established to protect aquatic life (600 mg/L max and ≤150 mg/L 30-d average) and drinking water (250 mg/L max) (Nagpal et al., 2003).

Long term trend data for dissolved chloride data is available for the Kirkland Drive and McClounie Road sites from 1972 to 1978 and from 2005 to 2012 (Figure 23). This data shows chloride concentrations in Coldstream Creek, near its confluence with Kalamalka Lake, are increasing over time but remain well below the BC guidelines and fall within the range reported for BC.

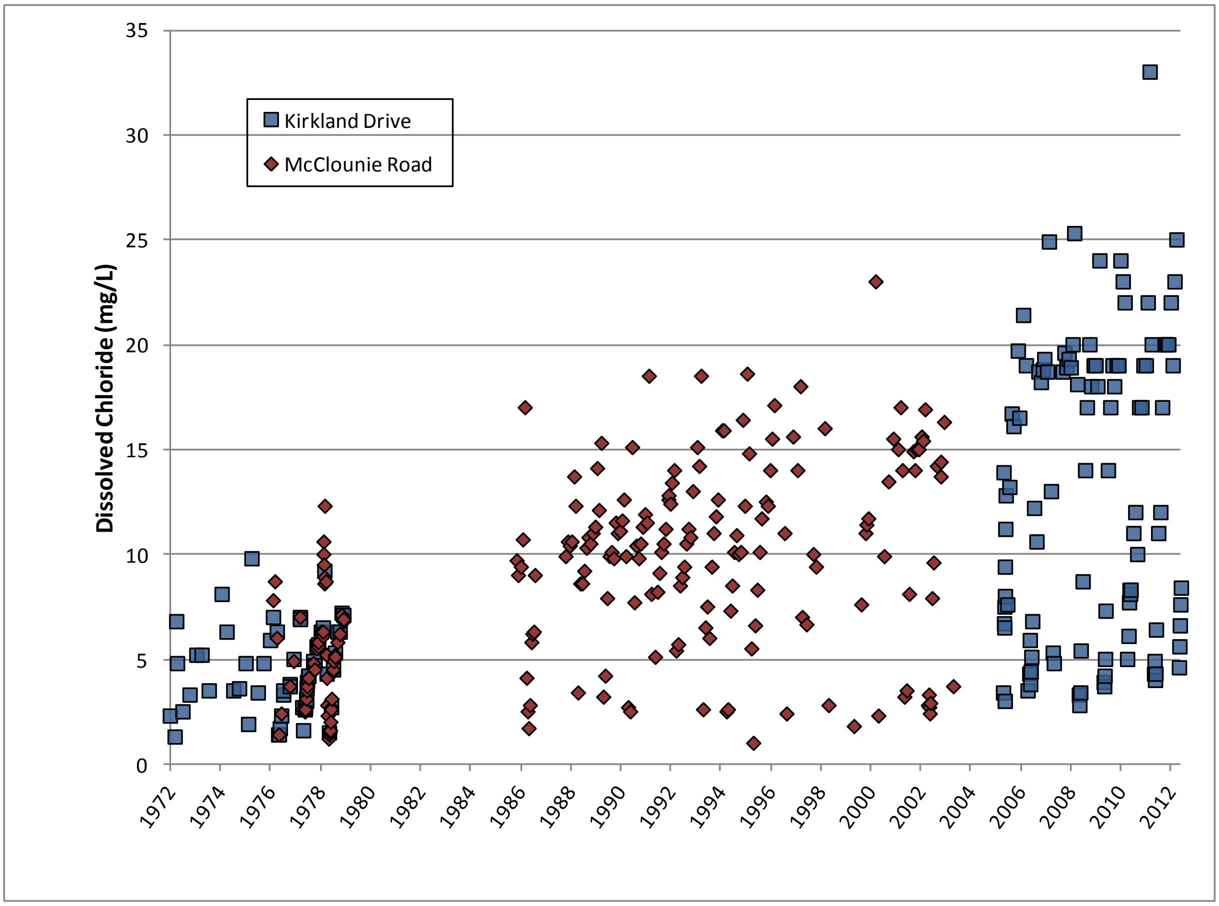

Figure 22. Dissolved Chloride in Coldstream Creek at Kirkland Drive and McClounie Road, 1972 to 2012.

Although chloride was not regularly monitored as part of the seasonal monitoring, limited data is available from the spring of 2009. This data should be used with caution, as only three samples were analyzed at Vimy Road, School Road and Noble Canyon. Nevertheless, the 2009 data suggests that the chloride concentration increases markedly between Noble Canyon and School Road and then continues to increase gradually with distance downstream (Figure 24). The large increase between the first two sampling sites is interesting, and seems to follow the general spatial pattern observed for coliform bacteria, nitrate and turbidity. While chloride concentrations did increase moving downstream, the guidelines for the protection of aquatic life (600 mg/L instantaneous maximum; 150 mg/L 30 day average) and for the protection of drinking water (250 mg/L maximum) were not threatened at any of the sampling sites.

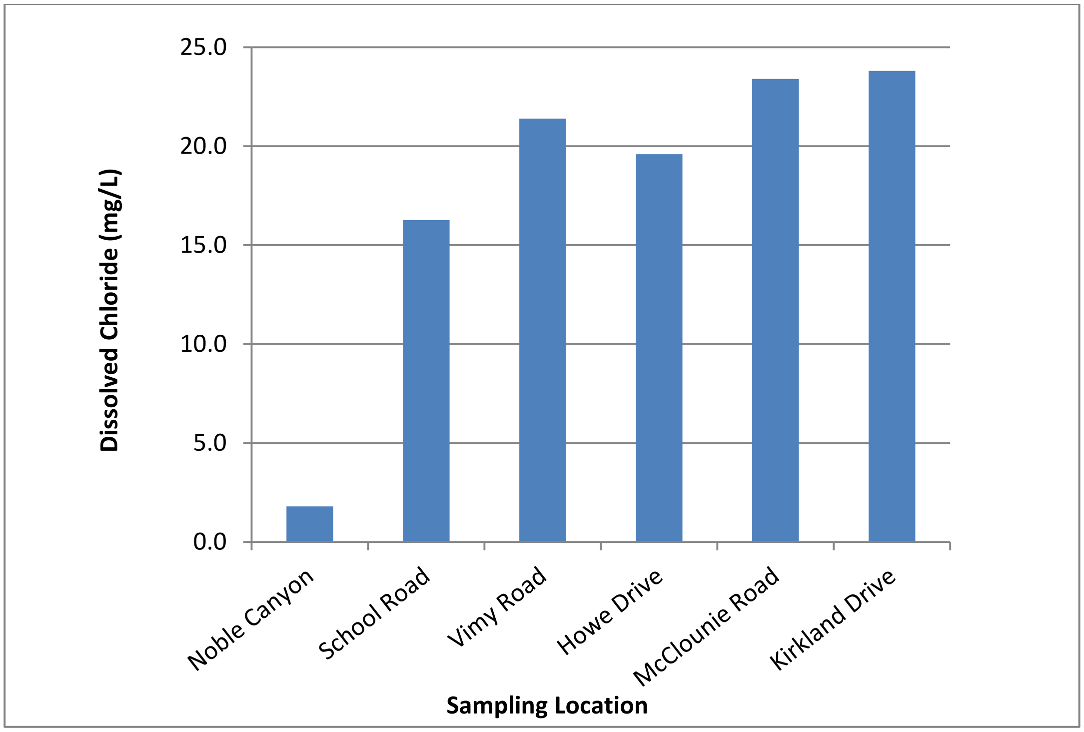

Figure 23. Dissolved chloride (mg/L) mean concentrations at six Coldstream Creek sites in 2009.

Given the high aquatic life values of Coldstream Creek, the WQGs for the protection of aquatic life (600 mg/L max and ≤150 mg/L 30-day average) are the most appropriate reference guidelines. However, given the relatively low concentrations observed to date, and low risk in the foreseeable future, **no water quality objective for dissolved chloride is proposed at this time for Coldstream Creek.** Nevertheless, it is recommended that chloride be monitored on Coldstream Creek to further assess the increasing trend noted at Kirkland Drive.

6.7 CONDUCTIVITY

Conductivity refers to the ability of a water sample to conduct an electric current. The conductivity of a water sample gives a measure of the amount of dissolved substances (calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulfate, and nitrate) in water (Health Canada, 2012). As temperature affects the conductivity of water (a 1ºC increase in temperature results in approximately a 2% increase in conductivity), specific conductivity is usually reported to compensate for temperature. Specific conductivity is measured in units of microsiemens per centimeter (μS/cm). Natural waters vary between 50 μS/cm and 1,500 μS/cm. Water level and specific conductance tend to be inversely related, with specific conductivity decreasing during periods of increased flows (such as spring snow melt, or summer storm events) when the ionic concentration of water may become diluted. Conversely, warm summer temperatures, or groundwater input to streams in winter can result in higher specific conductance values. In situations where landslides or runoff from anthropogenic sources introduce high levels of dissolved and suspended solids to a water body, specific conductance levels tend to increase. Therefore, as with chloride, changes in specific conductance can be used as a general indicator of cumulative changes to water quality from both land use activities and natural occurrences.

Due to its natural variability, there are no BC WQGs for specific conductance. However, for the protection of drinking water quality, high specific conductance levels are aesthetically unpleasant. A federal aesthetic drinking water guideline for total dissolved solids is ≤500 mg/L (Health Canada, 2012). This correlates to a specific conductance of approximately 700 μS/cm (Ministry of Environment, 2006).

Measurements for specific conductance were obtained at the Coldstream Creek monitoring locations on the majority of sampling trips. A long-term data set for specific conductance is available at the Kirkland Drive and McClounie Road sites. Long term trend data for Kirkland Drive and McClounie Road sites show specific conductivity maximums above 700 μS/cm for a number of decades and may be normal for this catchment (Figure 25). A slight increasing trend is apparent and maybe attributed to an increase in urban development, and long term irrigation leaching salts from agricultural soils.

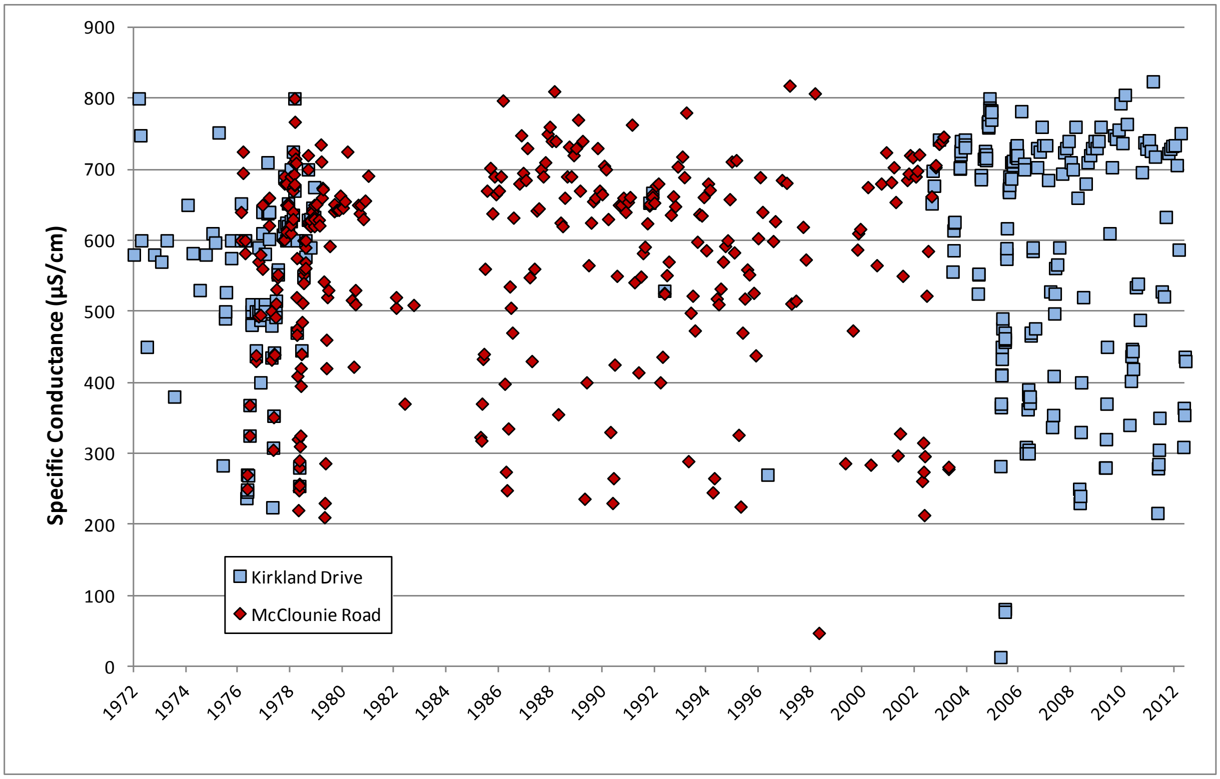

Figure 24. Specific conductance (µS/cm) in Coldstream Creek at Kirkland Drive and McClounie Road, 1972 to 2012.

Spatial patterns of specific conductance were also studied in 2009, 2010 and 2011. Average specific conductance was lowest at Noble Canyon (390 to 420 µS/cm), and were highest downstream at Kirkland Drive (685-800 µS/cm) (Figure 26).

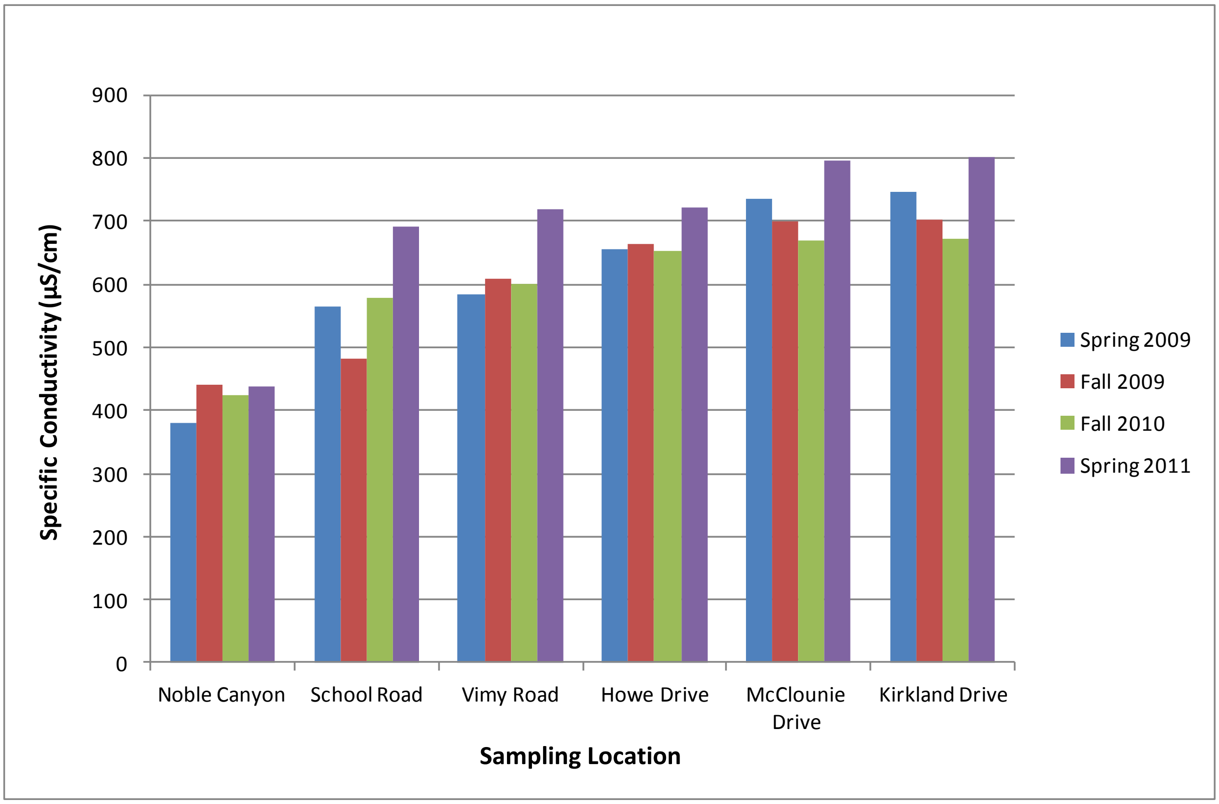

Figure 25. Specific conductivity (µS/cm) mean values at all sites on Coldstream Creek, spring 2009 to spring 2011.

Given that no BC water quality guideline exists for specific conductance, **a water quality objective is not proposed at this time for Coldstream Creek.** Nevertheless, it is recommended that specific conductance continue to be monitored on Coldstream Creek to further assess the increasing trend and high values noted at Kirkland Drive.

6.8 METALS AND SULFATE

Metals have only been measured on Coldstream Creek water a few times. The most consistent data from 2004 and 2005 indicate that all metals, with the exception of selenium, are well below the water quality guidelines for the protection of aquatic life. In most cases, the hard water (250 mg/L) of Coldstream Creek would ameliorate the effects of most metals on aquatic life. Water hardness however, does not affect selenium uptake by organisms. Selenium (Se) is a relatively rare trace element, but may be elevated in areas with soils that originate from marine sedimentary deposits. Selenium is mobilized in the watershed by erosion or more commonly from mining activity. In the aquatic environment, Se accumulates in sediments and biota, and can continue to cycle and persist for many years where it has many adverse effects on fish such as reductions in growth, behavioral changes, increased deformity, and increased mortality in early life stages. Birds that feed in aquatic environments are also affected by reduced egg hatchability followed by deformity in offspring. As is often the case in Se toxicity, the adult organism may not appear affected; however, overall reproductive success and productivity may be negatively impacted. These effects occur at very low selenium concentrations (Beatty and Russo, 2014). Accordingly, the BC water quality alert and guideline values for selenium are 1 μg/L and 2 μg/L respectively (Beatty and Russo, 2014). The limited data for Coldstream Creek at Kirkland Drive from October 2004 to February 2005 averages 3.5 μg/L. **Given the small data set, a water quality objective is not proposed for selenium. However, further testing of water during low flow conditions is warranted to determine whether selenium is a water quality concern.**

Similar to most metals, the effects of sulfate on aquatic life are reduced by higher water hardness. Sulfate has been collected sporadically on Coldstream Creek at Kirkland Drive. The average sulfate concentration is 65 mg/L. The BC water quality guideline to protect aquatic life is 429 mg/L in freshwaters with an average hardness of 250 mg/L. Thus, Coldstream Creek aquatic life is likely protected by the BC guideline, however, further sampling is warranted to determine seasonal variability and determine whether a water quality objective is necessary.

6.9 BIOLOGICAL INDICATORS

Biological monitoring is essential to assessing and protecting biological resources. Chemical measurements, or habitat assessments, are useful to aquatic resource management, but the primary sentinels requiring protection are often the organisms living in the stream. For this reason, biological monitoring has become increasingly useful in assessing stream health (Karr and Chu, 1999). Benthic invertebrates are useful integrators of various stressors and are widely acknowledged as useful cumulative effects indicators. Multi-metric and multivariate analyses allow comparison of stream health against regionally developed models describing reference conditions. Preliminary work with these indicator tools has been carried out in the Okanagan valley, and continues through collaboration with Environment Canada to refine these indicator tools. To date, this work using a multi-metric index suggests stream health is good at both Kirkland Drive and Noble Canyon. Further work is necessary to refine this indicator.

7.0 MONITORING RECOMMENDATIONS

The short-term and long-term water quality objectives proposed for Coldstream Creek are summarized in Table 7. The water quality objectives proposed for Coldstream Creek are to protect aquatic life, and secondarily, to aid the protection of drinking water in the north end of Kalamalka Lake.

Table 6. Summary of water quality objectives proposed for Coldstream Creek.

Variable	Objective Value	Sites
Nitrate	Long term: 1.5 mg/L (10 years) Short term: 3.0 mg/L (3 years)	Kirkland Drive (E216459) Howe Drive (E215457) School Road (E216451)
E.coli	Long-term: <100 CFU/100mL (10 years)	Kirkland Drive (E216459)
Turbidity	Clear flow: < 8 NTU increase in 24 hrs, or < 2 NTU increase as 30 day average Turbid flow: <5 NTU or 10% increase	Kirkland Drive (E216459) Howe Drive (E215457) School Road (E216451)

This report has identified that non-point sources of pollution is an on-going concern to water quality of Coldstream Creek and Kalamalka Lake. Further effort will be required to understand and manage coliform bacteria and nitrate N inputs to Coldstream Creek, if the objectives for these parameters are to be met consistently. For nitrate, the development of a nutrient budget may be useful to account for sources and losses within the drainage.

Information on groundwater quality and its influence on Coldstream Creek water quality and quantity are lacking, and a study identifying groundwater quality is recommended to better determine whether or not this is an important pathway for nutrients to enter Coldstream Creek.

8.0 SUMMARY OF PROPOSED WATER QUALITY OBJECTIVES AND MONITORING SCHEDULE

Monitoring to determine whether these water quality objectives are met or attained, should occur at least every 3-5 years during three, 5 dates in 30-day time periods, once in the late fall or early winter low flow period, and preferably twice in the spring (Table 8). The fall-winter period targets the maximum time period for nitrate. Attainment monitoring in spring should target the period of valley-bottom snow melt when *E.coli* is often highest due to runoff from agricultural lands and urban areas in the valley-bottom. Sampling during higher elevation snow melt and spring freshet (May-June) targets turbidity worst case conditions. If only one spring sampling period is feasible it should be based on further assessment of worst case conditions relative to the GVW Utility intake. Benthic invertebrate sampling should occur in late-summer or early-fall to match the timing of wider regional programs. The monitoring recommended here is in addition to the long-term trend monitoring that should continue to occur at Kirkland Drive. A recently installed (2015) remote automated water quality station (measuring temperature, turbidity, conductivity and water level) has been installed at Kirkland Drive by RDNO to fully assess the effects of episodic events during spring and rain storm driven run-off.

Table 7. Proposed monitoring schedule for Coldstream Creek.

Parameter	Site	Frequency & Timing
Turbidity	Kirkland Drive (E216459) Howe Drive (E216457) School Road (E216451) Noble Canyon (E274383)	Five times in 30 days during freshet
Dissolved metals Selenium **Hardness and Sulphate**	Kirkland Drive (E216459)	Fall low flow
***E.coli*, nitrate, ammonia, chloride**	Kirkland Drive (E216459) Howe Drive (E216457) School Road (E216451) Noble Canyon (E274383)	Five times in 30 days during spring valley bottom snow melt and fall low flow periods.
Benthic Invertebrates	Kirkland Drive (E216459) Noble Canyon (E274383)	Late-August through September.

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APPENDICES

Appendix 1. Summary of water quality data for Coldstream Creek at Noble Canyon.

COLDSTREAM CR @ NOBLE CANYON RD (EMS# E272383)						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Ammonia Diss. (mg/L)	Nov 2008 - Apr 2009	4	< 0.005	0.043	0.015	0.019
Chloride Diss. (mg/L)	Mar - Apr 2009	3	1.1	2.2	1.8	0.61
Fecal Coliforms (CFU/100mL)	Nov 2008 - Apr 2009	4	< 1	70	20	33.5
Dissolved Oxygen (mg/L)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	12.52	13.31	12.94	0.24
E. coli (CFU/100mL)	Nov 2008 - Mar 2011	19	< 1	1900	234.1	499.0
Enterococci (CFU/100mL)	Nov 2008 - Nov 2009	9	1.1	87	16.01	27.23
Total Kjeldahl Nitrogen (mg/L)	Nov 2008 - Apr 2009	4	< 0.02	0.09	0.05	0.033
Nitrate + Nitrite Diss. (mg/L)	Nov 2008 - Apr 2009 Oct 2010 - Mar 2011	14	0.014	0.387	0.157	0.138
Nitrogen Organic-Total (mg/L)	Nov 2008 - Apr 2009	4	< 0.02	0.05	0.035	0.017
Nitrogen Total (mg/L)	Nov 2008 - Apr 2009	4	0.05	0.25	0.195	0.097
Ortho-Phosphate Dissolved (mg/L)	Nov 2008 - Apr 2009	4	0.001	0.007	0.0038	0.003
Tot. Phosphorus (mg/L)	Nov 2008 - Apr 2009	4	0.003	0.008	0.0058	0.003
Tot. Dissolved Phosphorus (mg/L)	Nov 2008 - Apr 2009	4	0.003	0.008	0.0055	0.002
Specific Conductance (µS/cm)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	311	498	416	61.6
Temp (°C)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	0.01	2.2	0.81	0.685
Turbidity (NTU)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	< 0.1	7.6	1.61	2.64
pH (pH units)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	7.62	8.90	8.47	0.39

* Summary statistics were calculated using all data points for a given parameter. Multiple date ranges represent, generally, the time periods of data collection and provide an indication of the age and continuity of the dataset.

Appendix 2. Summary of water quality data for Coldstream Creek at School Road.

COLDSTREAM CR @ SCHOOL RD (EMS# E216451)						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Ammonia Diss. (mg/L)	May 1992 Nov 2008 - Apr 2009	5	<0.005	0.067	0.022	0.026
Chloride Diss. (mg/L)	Mar - Apr 2009	3	1.8	35	16.27	17.01
Fecal Coliforms (CFU/100mL)	Oct 1991 - May 1992 Nov 2008 - Apr 2009	6	5	83	46.17	33.60
Dissolved Oxygen (mg/L)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	9.92	15	11.34	1.65
E. coli (CFU/100mL)	Nov 2008 - Mar 2011	18	<1	190	36.22	55.47
Enterococci (CFU/100mL)	Nov 2008 - Nov 2009	8	7	250	88.50	93.03
Total Kjeldahl Nitrogen (mg/L)	Oct 1991 - May 1992 Nov 2008 - Apr 2009	6	0.09	0.3	0.158	0.086
Nitrate + Nitrite Diss. (mg/L)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Oct 2010 - Mar 2011	16	0.32	12.2	2.44	2.82
Nitrogen Organic-Total (mg/L)	Nov 2008 - Apr 2009	4	0.02	0.3	0.125	0.121
Nitrogen Total (mg/L)	Nov 2008 - Apr 2009	4	0.53	12.2	4.96	5.26
Ortho-Phosphate Dissolved (mg/L)	May 1992 Nov 2008 - Apr 2009	5	<0.003	0.201	0.053	0.084
Tot. Phosphorus (mg/L)	Oct 1991 - May 1992 Nov 2008 - Apr 2009	6	0.009	0.205	0.052	0.076
Tot. Dissolved Phosphorus (mg/L)	May 1992 Nov 2008 - Apr 2009	5	0.006	0.204	0.054	0.085
Specific Conductance (µS/cm)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Feb - Mar 2011	11	350	850	593.0	158.8
Temp (°C)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	1.9	5.9	3.56	1.42
Turbidity (NTU)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Feb - Mar 2011	11	0.2	18	5.68	7.06
pH (pH units)	May 1992 Nov 2008 - Apr 2009 Feb - Mar 2011	10	7.33	8.90	8.09	0.50

* Summary statistics were calculated using all data points for a given parameter. Multiple date ranges represent, generally, the time periods of data collection and provide an indication of the age and continuity of the dataset.

Appendix 3. Summary of water quality data for Coldstream Creek at Vimy Road.

COLDSTREAM CR @ VIMY RD (EMS# E216452)						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Ammonia Diss. (mg/L)	May 1992 Nov 2008 - Apr 2009	5	<0.005	0.031	0.013	0.011
Chloride Diss. (mg/L)	Mar - Apr 2009	3	7.2	29	21.4	12.31
Fecal Coliforms (CFU/100mL)	Oct 1991 - May 1992 Nov 2008 - Apr 2009	6	1	640	222.3	268.9
Dissolved Oxygen (mg/L)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	11	12.76	11.86	0.65
E. coli (CFU/100mL)	Nov 2008 - Mar 2011	19	<1	540	153.1	160.6
Enterococci (CFU/100mL)	Nov 2008 - Nov 2009	9	22	1000	244.6	323.1
Total Kjeldahl Nitrogen (mg/L)	Oct 1991 - May 1992 Nov 2008 - Apr 2009	6	0.15	0.32	0.233	0.066
Nitrate + Nitrite Diss. (mg/L)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Oct 2010 - Mar 2011	16	1.07	4.4	2.86	0.88
Nitrogen Organic-Total (mg/L)	Nov 2008 - Apr 2009	4	0.14	0.32	0.22	0.08
Nitrogen Total (mg/L)	Nov 2008 - Apr 2009	4	1.23	4.5	3.23	1.46
Ortho-Phosphate Dissolved (mg/L)	May 1992 Nov 2008 - Apr 2009	5	0.012	0.027	0.018	0.006
Tot. Phosphorus (mg/L)	Oct 1991 - May 1992 Nov 2008 - Apr 2009	6	0.015	0.033	0.024	0.007
Tot. Dissolved Phosphorus (mg/L)	May 1992 Nov 2008 - Apr 2009	5	0.014	0.027	0.020	0.005
Specific Conductance (µS/cm)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Feb 2011 - Mar 2011	11	420	766	629.2	114.9
Temp (°C)	Nov 2008 - Apr 2009 Feb - Mar 2011	9	1.64	5.9	3.83	1.22
Turbidity (NTU)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Feb 2011 - Mar 2011	11	<0.1	3.8	1.05	1.02
pH (pH units)	May 1992 Nov 2008 - Apr 2009 Feb 2011 - Mar 2011	10	7.47	8.90	8.26	0.388

* Summary statistics were calculated using all data points for a given parameter. Multiple date ranges represent, generally, the time periods of data collection and provide an indication of the age and continuity of the dataset.

Appendix 4. Summary of water quality data for Coldstream Creek at Howe Drive.

COLDSTREAM CR @ HOWE DRIVE (EMS # E216457)						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Ammonia Diss. (mg/L)	Dec 1991 - Aug 1992 Nov 2008 - Apr 2009	13	<0.005	0.479	0.071	0.131
Ammonia Tot. (mg/L)	Nov 2008 - Apr 2009	6	0.01	0.5	0.14	0.18
Chloride Diss. (mg/L)	Dec 1991 - Aug 1992 Mar - Apr 2009	11	7.2	26	13.68	6.75
Fecal Coliforms (CFU/100mL)	Oct 1991 -Aug 1992 Sep - Nov 1997 Feb 2007 - Jul 2009 Oct 2009 & Oct 2010	30	<1	3200	431.8	747.4
Dissolved Oxygen (mg/L)	Jul - Aug 1992 Nov 2008 - Apr 2009 Feb - Mar 2011	13	9.8	13	11.38	0.95
E. coli (CFU/100mL)	Sep - Nov 1997 Nov 2008 - Mar 2011	27	1	2600	276.8	546.8
Enterococci (CFU/100mL)	Jul - Aug 1992 Nov 2008 - Nov 2009	16	12	1440	204.1	371.0
Total Kjeldahl Nitrogen (mg/L)	Oct 1992 - May 1992 Feb 2007 - Jul 2009 Oct 2009 & Oct 2010	19	0.16	2.8	0.50	0.61
Nitrate Diss. (mg/L)	Feb 2007 - Jul 2009 Oct 2009 & Oct 2010	10	1.89	3.66	2.63	0.61
Nitrate + Nitrite Diss. (mg/L)	Oct 1991 - Aug 1992 Feb 2007 - Oct 2009 Feb 2010 - Mar 2011	34	1.23	3.67	2.55	0.68
Nitrite Diss. (mg/L)	Dec 1991 - Aug 1992 Feb 2007 - Feb 2009 Jul 2009 - Feb 2010	17	0.005	0.02	0.010	0.004
Nitrogen Organic-Total (mg/L)	Nov 2008 - Apr 2009	6	0.16	0.8	0.46	0.28
Nitrogen Total (mg/L)	Feb 2007 - Jul 2009 Oct 2009 - Feb 2010	16	1.97	5.55	3.26	0.95
Ortho-Phosphate Diss. (mg/L)	Dec 1991 - May 1992 Nov 2008 - Apr 2009	8	0.01	0.102	0.03	0.03
Tot. Phosphorus (mg/L)	Oct 1991 - Aug 1992 Feb 2007 - Jul 2009 Oct 2009 - Feb 2010	24	0.01	0.35	0.05	0.069
Tot. Dissolved Phosphorus (mg/L)	Dec 1991 - Aug 1992 Nov 2008 - Apr 2009	13	0.015	0.131	0.03	0.030
Residue Non-filterable TSS (mg/L)	Jul - Aug 1992	5	2	17.0	5.20	6.61
Specific Conductance (µS/cm)	Oct 1991 - Aug 1992 Nov 2008 - Apr 2009 Feb - Mar 2011	19	475	748	624.7	92.2
Temp (°C)	Jul - Aug 1992 Nov 2008 - Apr 2009 Feb - Mar 2012	14	4.46	16	7.78	3.77
Turbidity (NTU)	Oct 1991 - May 1992 Nov 2008 - Apr 2009 Feb - Mar 2012	14	0.6	19.2	3.38	4.78
pH (pH units)	Dec 1991 - May 1992 Nov 2008 - Apr 2009 Feb - Mar 2012	8	7.55	9.1	8.51	0.48

* Summary statistics were calculated using all data points for a given parameter. Multiple date ranges represent, generally, the time periods of data collection and provide an indication of the age and continuity of the dataset.

Appendix 5. Summary of water quality data for Coldstream Creek at McClounie Road.

COLDSTREAM CR @ McCLOUNIE ROAD BRIDGE (EMS# 0500518)						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Alkalinity Total 4.5 (mg/L)	Feb 1976 - Sep 1980 Oct 1985 - Feb 1987 Aug 1991	93	87.9	289	217.41	51.42
Alkalinity pH 8.3 (mg/L)	Mar 1976 - Sep 1980	34	<0.5	12	4.28	2.68
Ammonia Diss. (mg/L)	Feb 1976 - Oct 1982 May 1985 - Apr 2003 Mar - Apr 2009	298	<0.005	1.58	0.040	0.137
Bromide Diss. (mg/L)	Aug 1996 - Dec 2001	31	<0.05	0.3	0.060	0.045
Carbon Total Inorganic (mg/L)	Feb 1976 - Mar 1979 May - Jul 1985	48	25	69	53.17	11.36
Carbon Total Organic (mg/L)	Feb 1976 - Jul - 1979 Dec 2002 - Apr 2004	79	<1	112	5.06	12.88
Chloride Diss. (mg/L)	Feb 1976 - Dec 1978 Nov 1985 - Apr 2003 Mar - Apr 2009	225	1	27	9.05	5.09
Fecal Coliforms (CFU/100mL)	Jan 1991 - May 2003 Mar - Apr 2009	120	0	16100	680.0	2184.7
Fecal Coliforms (MPN)	Feb 1976 - Oct 1982	80	17	5400	833.4	896.2
Total Coliforms (CFU/100mL)	May 1992 Jul 1994 - Jun 1997 Oct 1999 - Jan 2003	47	38	18000	1246.9	3153.1
Total Coliforms (MPN)	Feb 1976 - Jul 1979	66	230	7900	1619.9	1268.0
Color True (TCU)	Feb 1976 - Jul 1979 Dec 2002 - Feb 2003	24	<5	40	11.25	10.14
Color TAC (TAC)	Sep 1976 - Sep 1980	45	<1	64	11.0	11.8
Dissolved Oxygen (mg/L)	May 1985 - Oct 1987 Mar - Apr 2009 Feb - Mar 2011	35	9.2	13.4	11.78	1.12
E. coli (CFU/100mL)	Aug 1995 - May 2003 Mar 2009 - Mar 2011	63	<1	11300	360.4	1436.1
Enterococci (CFU/100mL)	Mar - Nov 2009	10	17	500	135.4	152.1
Fluoride Tot. (mg/L)	Aug 1996 - Dec 1999	16	0.07	0.39	0.208	0.083
Fluoride Diss. (mg/L)	Mar 2000 - Dec 2001	15	<0.01	0.31	0.225	0.090
Hardness Diss. (mg/L)	Feb 1976 - Sep 1980	48	108	335	258.9	63.0
Total Kjeldahl Nitrogen (mg/L)	Feb 1976 - Mar 1996 Mar - Apr 2009	253	0.04	20	0.47	1.29
Nitrate Tot. (mg/L)	Feb 1978 - Oct 1982	31	0.11	2.28	1.78	0.46
Nitrate Diss. (mg/L)	Feb 1990 Aug 1996 - Apr 2003	51	0.332	3.006	1.860	0.939
Nitrate + Nitrite Diss. (mg/L)	Feb 1976 - Oct 1982 May 1985 - Apr 2003 Mar 2009 - Mar 2011	313	0.19	3.03	1.750	0.727
Nitrite Tot. (mg/L)	Aug 1986 - Nov 1997	9	<0.005	0.005	0.005	0.000
Nitrite Diss. (mg/L)	Feb 1978 Nov 1978 - Oct 1982 May 1985 - Aug 1986 Oct 1987 - Mar 1996 Mar 1998 - Apr 2003	195	<0.002	0.08	0.010	0.009

COLDSTREAM CR @ McCLOUNIE ROAD BRIDGE (EMS# 0500518)… Continued						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Total Organic Nitrogen(mg/L)	Feb 1976 - Jun 1982 Feb 1990 Mar - Apr 2009	110	0.06	18.42	0.59	1.75
Total Nitrogen (mg/L)	Feb 1976 - Oct 1982 Feb 1990 Aug 1996 - Apr 2003 Mar - Apr 2009	159	0.27	20.19	2.17	1.65
Ortho-Phosphate Diss. (mg/L)	Feb 1976 - Mar 1979 May 1985 - Aug 1986 Dec 1991 - May 1992 Jun 1997 - Sep 2002 Mar - Apr 2009	90	<0.001	0.3	0.039	0.044
Total Phosphorus (mg/L)	Feb 1976 - Oct 1982 May 1985 - Apr 2003 Mar - Apr 2009	317	0.012	3.64	0.092	0.236
Total Dissolved Phosphorus (mg/L)	Apr 1976 - Oct 1982 May 1985 - Apr 2003 Mar - Apr 2009	311	0.003	0.428	0.033	0.040
Residue Total (mg/L)	Apr 1978 May 1985 - Mar 1986 Feb - Jul 1991 Aug 1996 - Apr 2003	59	197	969	410.3	127.0
Residue Total: Fixed (mg/L)	May 1985 - Mar 1986	11	194	408	279.5	63.9
Residue Filterable 1.0u (mg/L)	Feb 1976 - Sep 1980 May 1985 - Aug 1986 Aug 1987 - Apr 2003	214	148	550	370.8	94.2
Residue Fixed Non-filterable(mg/L)	Mar 1992 Jun 1994	2	6	16	11.0	7.1
Residue Non-filterable TSS (mg/L)	Feb 1976 - Sep 1980 Jan 1986 - Apr 2003	215	1	765	34.5	81.1
Silica Diss. (mg/L)	Feb 1976 - Sep 1979 May - Jul 1985	59	15.2	20	17.9	1.4
Specific Conductance (µS/cm)	Feb 1976 - Oct 1982 May 1985 - Apr 2003 Mar - Apr 2009 Feb - Mar 2011	346	47	860	576.7	148.7
Sulphate Diss. (mg/L)	Feb 1976 - Sep 1979 Mar 1998 - Dec 2001	79	15	127	68.3	27.6
Sulphate Tot. (mg/L)	Aug 1996 - Nov 1997	9	13	156	69.1	37.9
Tannin Lignin Tot. (mg/L)	Feb 1978 - Jan 1980	33	<0.1	12.5	0.98	2.17
Temp. (°C)	Feb 1976 - Oct 1982 May 1985 - Oct 1992 Jun - Nov 1995 Mar 1998 - Apr 2003 Mar - Apr 2009 Feb - Mar 2011	184	0	19	7.88	4.40
pH (pH units)	Feb 1976 - Oct 1982 May 1985 - May 2003 Mar - Apr 2009 Feb - Mar 2011	336	7.4	9.2	8.30	0.22
Turbidity (NTU)	Feb 1976 - Oct 1982 Jan 1986 - Apr 2003 Mar - Apr 2009 Feb - Mar 2011	300	0.4	270	13.4	30.3

COLDSTREAM CR @ McCLOUNIE ROAD BRIDGE (EMS# 0500518)… continued						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Metals - Total						
Aluminum Tot. (mg/L)	May - Jul 1985 Apr 1986 Jun 1990	6	0.14	4.01	1.42	1.45
Arsenic Tot. (mg/L)	May - Jul 1979 May 1985 -Apr 1986	10	<0.005	0.25	0.128	0.129
Calcium Tot. (mg/L)	Feb 1976 - Dec 1978 May 1985 - Apr 1986 Jun 1990	53	38.2	92	70.0	14.9
Cadmium Tot. (mg/L)	Feb - Mar 1979 May - Jun 1985 Apr 1986	9	<0.0005	0.01	0.007	0.005
Cobalt Tot. (mg/L)	May - Jun 1985 Apr 1986 Jun 1990	6	<0.1	0.1	0.10	0.00
Chromium Tot. (mg/L)	May - Jul 1979 May - Jul 1985 Apr 1986 Jun 1990	11	<0.005	0.01	0.008	0.003
Carbon Tot. (mg/L)	May - Jul 1985	5	36	57	45.2	8.5
Copper Tot. (mg/L)	Feb - Mar 1979 May - Jun 1985 Apr 1986 Jun 1990	9	<0.001	0.02	0.009	0.005
Iron Tot. (mg/L)	Feb - Mar 1976 Feb - Mar 1979 May - Jun 1985 Apr 1986 Jun 1990	11	0.2	6.59	1.65	1.92
Mercury Tot. (mg/L)	Feb - Mar 1979	3	<0.00005	0.00005	0.00005	0.00
Magnesium Tot. (mg/L)	Feb 1976 - Dec 1978 May 1985 - Apr 1986 Jun 1990	50	8	28.3	19.26	5.71
Manganese Tot. (mg/L)	Mar 1979 May - Jun 1985 Apr 1986 Jun 1990	8	0.03	0.29	0.098	0.087
Molybdenum Tot.(mg/L)	Feb - Mar 1979 May - Jun 1985 Apr 1986 Jun 1990	9	0.0061	0.01	0.009	0.002
Nickel Tot. (mg/L)	May - Jun 1985 Apr 1986 Jun 1990	6	<0.05	0.05	0.05	0.00
Lead Tot. (mg/L)	Feb - Mar 1979 May - Jun 1985 Apr 1986 Jun 1990	9	<0.001	0.1	0.067	0.049
Vanadium Tot. (mg/L)	May - Jul 1985 Apr 1986 Jun 1990	6	0.01	0.01	0.010	0.000
Zinc Tot. (mg/L)	Feb - Mar 1979 May - Jun 1985 Apr 1986 Jun 1990	9	<0.005	0.05	0.017	0.014

COLDSTREAM CR @ McCLOUNIE ROAD BRIDGE (EMS# 0500518)… continued						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Metals - Dissolved						
Boron Diss. (mg/L)	May - Jul 1979	5	<0.1	0.1	0.1	0.0
Calcium Diss. (mg/L)	Feb 1976 - Sep 1980	49	30.7	89	69.9	15.2
Iron Diss. (mg/L)	Feb - Sep 1980	4	<0.01	0.51	0.14	0.25
Potassium Diss. (mg/L)	Feb 1976 - Sep 1980 Oct 1987 - Jul 1991	115	1.4	13.7	5.42	1.98
Magnesium Diss. (mg/L)	Feb 1976 - Sep 1980	48	7.2	31	20.63	6.31
Manganese Diss. (mg/L)	Feb - Sep 1980	4	<0.01	0.02	0.013	0.005
Sodium Diss. (mg/L)	Feb 1976 - Jul 1979 Aug - Dec 1991	52	4.6	27.4	14.51	6.02

* Summary statistics were calculated using all data points for a given parameter. Multiple date ranges represent, generally, the time periods of data collection and provide an indication of the age and continuity of the dataset.

Appendix 6. Summary of water quality data for Coldstream Creek at Kirkland Drive.

COLDSTREAM CR @ KIRKLAND DRIVE (EMS# E216459)						
Parameter (Units)	**Sampling Period(s)***	**Number of Samples**	**Min.**	**Max.**	**Avg.**	**Std. Dev.**
Alkalinity Total 4.5 (mg/L)	Jan 1972 - Dec 1978	67	102	280	214.0	42.8
Alkalinity pH 8.3 (mg/L)	Oct 1972 - Oct 1978	33	0.5	9.5	4.35	2.19
Ammonia Diss. (mg/L)	Dec 1991 - Apr 1992 Jul 2003 - Aug 2012	132	<0.005	3.6	0.07	0.34
Ammonia Tot. (mg/L)	Apr 1972 - Dec 1978 Nov 2007 - Aug 2012	130	0	3.6	0.07	0.34
Biological Oxygen Demand (mg/L)	Jan 1972 - May 1977	4	0.5	10	7.63	4.75
Bromide Diss. (mg/L)	Apr 2005 - Aug 2010	62	<0.1	0.8	0.21	0.15
Carbon Total Inorganic (mg/L)	May 1975 - Dec 1978	40	25	68	51.1	10.3
Carbon Total Organic (mg/L)	Apr 1972 - Dec 1978 Jul 2003 - Jan 2005 Sep 2009	80	<1	21	3.54	3.39
Chloride Diss. (mg/L)	Jan 1972 - Dec 1978 Dec 1991 Apr 2005 - Aug 2012	178	1.3	33	10.45	7.36
Fecal Coliforms (CFU/100mL)	Jul 1975 - Dec 1978 Oct 1991 - May 1992 Sep - Nov 1997 Sep 2002 - Jun 1010	167	<2	4000	488.8	589.7
Total Coliforms (CFU/100mL)	Jul 1975 - Dec 1978 May 1992 Sep 2002 - Dec 2002	44	96	3500	1180.6	881.4
Color True (TCU)	Jan 1972 - May 1977	34	5	50	13.68	12.63
Color TAC (TAC)	Sep 1976 - Sep 1979	19	2	19	8.21	5.29
Dissolved Oxygen (mg/L)	Jan 1972 - Jan 1976 May 2005 - Aug 2012	131	5.9	15	11.55	1.51
E. coli (CFU/100mL)	Sep - Nov 1997 Sep 2002 - Aug 2012	162	<1	3400	335.2	443.3
Enterococci (CFU/100mL)	Feb 2004 - Aug 2012	121	16	3500	373.9	476.1
Fluoride Diss. (mg/L)	Mar 1972 - May 1977	11	0.13	0.46	0.31	0.08
Hardness Total (mg/L)	Jan 1972 - Dec 1978 May 2008 - Aug 2012	124	91.3	434	258.7	82.4
Kjeldahl Nitrogen Tot. (mg/L)	Jan 1972 - Dec 1978 Oct 1991 - May 1992 Nov 2007 - Aug 2012	147	<0.02	6.6	0.40	0.60
Kjeldahl Nitrogen Tot. Diss. (mg/L)	Feb 2005 - Apr 2009	62	<0.02	1	0.27	0.18
Nitrate + Nitrite Tot. (mg/L)	Mar 1972 - Dec 1978 Nov 2007 - Aug 2012	139	0.14	3.2	1.65	0.82

COLDSTREAM CR @ KIRKLAND DRIVE (EMS# E216459) … continued

Parameter (Units)	Sampling Period(s)*	Number of Samples	Min.	Max.	Avg.	Std. Dev.
Nitrate + Nitrite Diss. (mg/L)	Oct 1991 - May 1992 Jul 2003 - Aug 2012	151	0.134	3.31	1.92	0.86
Nitrate Diss. (mg/L)	Apr 1972 - Nov 1978 Jul 2003 - Feb 2005 Feb 2009 - Feb 2010	34	0.37	3.306	2.26	0.64
Nitrite Diss. (mg/L)	Apr 1972 - Nov 1978 Dec 1991 - May 1992 Jul 2003 - Feb 2005 Feb 2009 - Feb 2010	36	0.003	0.012	0.010	0.002
Total Organic Nitrogen(mg/L)	Apr 1972 - Dec 1978 Feb 2005 - Aug 2012	180	<0.02	3.0	0.31	0.32
Total Nitrogen (mg/L)	Jan 1972 - Dec 1978 Jul 2003 - Aug 2012	217	0.27	8.9	2.11	1.01
Nitrogen Total Dissolved (mg/L)	Feb 2005 - Mar 2008	43	0.842	3.72	1.95	0.78
Ortho-Phosphate Diss. (mg/L)	Dec 1991 - May 1992 Jun 2004 - Feb 2005 Nov 2008 - Jan 2010	27	0.005	0.132	0.03	0.03
Total Phosphorus (mg/L)	Jan 1972 - Dec 1978 Oct 1991 - May 1992 Jul 2003 - Aug 2012	214	0.005	1.21	0.05	0.11
Ortho-Phosphate (mg/L)	Oct 1975 - Dec 1978	40	0.01	0.032	0.020	0.004
Total Dissolved Phosphorus (mg/L)	Mar 1972 - Dec 1978 Dec 1991 - May 1992 Jul 2003 - Feb 2005 Nov 2008 - Jan 2010	83	0.003	0.152	0.030	0.020
Residue Filterable 1.0u (mg/L)	Apr 1972 - Dec 1978 Sep 2009	45	170	462	332.1	81.8
Residue Non-filterable (mg/L)	Jan 1972 - Dec 1978 Jul 2003 - Feb 2005	74	1	510	23.5	62.4
Silica Tot. (mg/L)	Mar 1972 - Dec 1978	54	14.1	19.8	17.7	1.4
Specific Conductance (µS/cm)	Jan 1972 - Dec 1978 Oct 1991 - May 1992 Sep 2002 - Aug 2012	310	13	870	572.4	164.3
Sulphate Diss. (mg/L)	Jan 1972 - Dec 1978 Apr 2005 - Aug 2012	170	16	161	62.5	26.5
Sulfur Tot. (mg/L)	May - Nov 2008	8	6	31	21.4	10.3
Tannin Lignin Tot. (mg/L)	Mar 1972 - Apr 1973	5	0.1	1	0.32	0.38
Temp. (C)	Jan 1972 - Dec 1978 May 1996 Dec 2002 - Aug 2012	221	0	21	8.42	4.35
Turbidity (NTU)	Jan 1972 - Dec 1978 Oct 1991 - May 1992 Sep 2002 - Aug 2012	276	0.1	121	7.62	15.91

COLDSTREAM CR @ KIRKLAND DRIVE (EMS# E216459) … continued

Parameter (Units)	Sampling Period(s)*	Number of Samples	Min.	Max.	Avg.	Std. Dev.
pH (pH units)	Jan 1972 - Dec 1978 Oct 1991 - May 1992 Jul 2003 - Sep 2004 May 2007 - Aug 2012	190	7.26	9.30	8.35	0.26
Metals - Total						
Silver Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	<0.000005	0.00002	0.00002	0.00001
Aluminum Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.0033	0.126	0.029	0.041
Arsenic Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.0013	0.0018	0.0010	0.0002
Barium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.0374	0.0515	0.048	0.005
Beryllium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	<0.00001	0.00002	0.00002	0.00000
Bismuth Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	<0.000005	0.00002	0.00002	0.00001
Calcium Tot. (mg/L)	Feb 1976 - Dec 1978 May 2008 - Aug 2012	105	25.5	122	72.51	20.58
Cadmium Tot. (mg/L)	May 1977 Oct 2004 - Feb 2005 Sep 2009	9	0.000014	0.0005	0.0001	0.0002
Cobalt Tot. (mg/L)	Oct 204 - Feb 2005 Sep 2009	8	0.000012	0.000158	0.00005	0.00005
Chromium Tot. (mg/L)	May 1977 Oct 2004 - Feb 2005 Sep 2009	9	<0.0002	0.008	0.0012	0.0026
Copper Tot. (mg/L)	May 1977 Oct 2004 - Feb 2005 Sep 2009	9	0.00049	0.008	0.0016	0.0024
Mercury Tot. (mg/L)	Apr 1972 - May 1977	9	<0.05	0.17	0.06	0.04
Potassium Tot. (mg/L)	May - Nov 2008	8	1.82	8.71	5.35	2.63
Lithium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.00745	0.0101	0.0083	0.0009
Magnesium Tot. (mg/L)	Oct 1974 - Dec 1978 May 2008 - Aug 2012	104	6.58	34.7	20.02	7.51
Manganese Tot. (mg/L)	May 1977 Oct 2004 - Feb 2005 Sep 2009	9	0.00024	0.13	0.025	0.041
Molybdenum Tot.(mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.0049	0.0066	0.0058	0.0006
Sodium Tot. (mg/L)	May - Nov 2008	8	3.89	20.7	13.64	7.34

COLDSTREAM CR @ KIRKLAND DRIVE (EMS# E216459) … continued

Parameter (Units)	Sampling Period(s)*	Number of Samples	Min.	Max.	Avg.	Std. Dev.
Nickel Tot. (mg/L)	May 1977 Oct 2004 - Feb 2005 Sep 2009	9	<0.00005	0.01	0.00	0.00
Lead Tot. (mg/L)	May 1977 Oct 2004 - Feb 2005 Sep 2009	9	<0.00001	0.001	0.00	0.00
Antimony Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.000031	0.000063	0.00	0.00
Selenium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.00244	0.0045	0.00	0.00
Tin Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	<0.00001	0.00002	0.00	0.00
Strontium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.642	0.819	0.74	0.07
Thallium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	<0.000002	0.000009	0.00	0.00
Uranium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.00411	0.00568	0.01	0.00
Vanadium Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	8	0.00041	0.00126	0.00	0.00
Zinc Tot. (mg/L)	Oct 2004 - Feb 2005 Sep 2009	9	<0.0001	0.014	0.00	0.00
Metals - Dissolved						
Calcium Diss. (mg/L)	Mar 1972 - Dec 1978 May 2008	61	31.4	98.9	67.05	15.82
Cadmium Diss. (mg/L)	Mar 1972 - Oct 1976	8	0.0001	0.0005	0.0003	0.0002
Chromium Diss. (mg/L)	Mar 1972 - Oct 1976	8	<0.005	0.005	0.005	0.000
Copper Diss. (mg/L)	Mar 1972 - Oct 1976	8	0.001	0.019	0.006	0.006
Iron Diss. (mg/L)	Mar 1972 - Oct 1976	15	<0.04	0.7	0.11	0.16
Potassium Diss. (mg/L)	Mar 1972 - Dec 1978 May 2008	67	2.1	14.8	5.02	1.88
Magnesium Diss. (mg/L)	Mar 1972 - Dec 1978 May 2008	62	7.2	33	19.91	6.29
Manganese Diss. (mg/L)	Mar 1972 - Oct 1976	8	<0.01	0.04	0.02	0.01
Sodium Diss. (mg/L)	Mar 1972 - Dec 1978 Dec 1991 May 2008	55	4.45	34	14.79	6.10
Nickel Diss.(mg/L)	Mar 1972 - Oct 1976	9	<0.01	0.01	0.01	0.00
Lead Diss.(mg/L)	Mar 1972 - Oct 1976	8	<0.001	0.003	0.002	0.001
Zinc Diss. (mg/L)	Mar 1972 - Oct 1976	8	<0.005	0.07	0.022	0.025

* Summary statistics were calculated using all data points for a given parameter. Multiple date ranges represent, generally, the time periods of data collection and provide an indication of the age and continuity of the dataset.

GLOSSARY

Adfluvial
Migrating between lakes, rivers and streams.

Ambient
Refers to conditions in the surrounding environment.

Ammonia
A measure of the most reduced inorganic form of nitrogen in water and includes dissolved ammonia (NH3) and the ammonium ion (NH4+).

Chlorphyll-*a*
The primary green-coloured pigment found in plants and algae which traps and converts light energy to chemically stored energy.

Designated water use
A water use that is to be protected at a specific location.

Disinfection
The process of killing or rendering harmless microbiological organisms in water which cause disease by the application of a disinfectant (e.g., chlorine, chloramines, ozone, ultraviolet radiation).

Disinfection by-products
Chemicals (e.g., trihalomethanes) formed when a disinfectant (e.g., chlorine) is added to water containing organic matter. Such by-products are suspected to be human carcinogens.

Dissolved oxygen (DO)
Oxygen dissolved in water and essential for respiration by most aquatic organisms.

Environment Management System (EMS)
BC Environment environmental data storage system.

***Escherichia coli* (*E. coli*)**
A coliform bacteria inhabiting the gut of humans and other warm blooded animals which are used as an indicator of water contamination. Some forms are pathenogenic (e.g., O157:H7).

Eutrophic
A body of water, commonly a lake or pond, of high primary productivity due to excessive nutrients and is subject to algal blooms resulting in poor water quality. The bottom waters of such bodies are commonly deficient in oxygen.

Eutrophication
Increasing nutrient content in a body of water over time. This natural process may be accelerated by nutrient-rich discharges from agriculture or sewage, resulting in algal blooms, excessive growth of macrophytes or undesirable changes in water quality.

Geometric mean
The Nth root of the product of N observations.

Grab sample
A single sample taken at a given place and time.

Hardness
The hardness of water is generally due to the presence of calcium and magnesium in the water. Hardness is reported in terms of calcium carbonate as mg/L. Waters with values exceeding 120 mg/L are considered hard while values below 60 mg/L are considered soft.

Kjeldahl nitrogen
A measure of both the ammonia and the organic forms of nitrogen.

µg/L
Micrograms per litre or parts per billion

mg/L
Milligrams per liter or parts per million

MOE
BC Ministry of Environment

Morphometry
The physical characteristics of a lake such as size and shape of a lake basin, mean depth, maximum depth, volume, drainage area, and flushing rate.

90th percentile
The value in a data set at which 90% of the results fall below. For example, a data set consisting of 10 samples are ranked from lowest to highest with the 9th highest value representing the 90th percentile.

Nitrate + nitrite (NO3 + NO2)
A measure of the most oxidized and stable form of N in a water body (NO3) and an intermediate form (NO2) that occurs in the biological conversion of NH4 to NO3.

Non-point source contamination (NPS)
Contaminants enter air or water from many different (often individually small) sources with no specific solution to rectify the problem, making it difficult to regulate. Agriculture, urban

run-off, septic tank seepage are often categorized as NPS. NPS is the leading cause of water pollution.

Okanagan Basin Study (OBS)
A federal – provincial water resource study of water resources in the Okanagan basin from 1971-1974. Follow-up studies were conducted under the Okanagan Basin Implementation Agreement from 1976-79.

Ortho-phosphorus
A measure of the inorganic oxidized and biologically available form of soluble phosphorus.

pH
A measure of the hydrogen ion concentration of a solution which provides a quantitative expression of its acidity or alkalinity ranging, from 0 to 14. pH 7 is neutral, less than 7 is acidic and more than 7 is alkaline or basic.

Point source contamination
Contaminants that enter air or water from direct site specific sources such as a sewer or effluent discharge pipe. More easily quantified and regulated than NPS.

ppm
Parts per million or mg/L.

ppb
Parts per billion or µg/L.

Recreational primary contact
Activities like swimming and water sports where a person has or risks direct contact with water through
immersion or ingestion.

Specific conductance
A quantitative measure of the ability of water to conduct an electrical current, related to the type and concentration of ions in solution. Specific conductance can be used for approximating the total dissolved solids concentration in water.

Total nitrogen (TN)
A measure of all forms of nitrogen (organic and inorganic).

Total Phosphorus (TP)
A measure of all forms of phosphorus (organic and inorganic).

Water Quality Guideline
Numerical value(s) for a physical, chemical or biological characteristics of water, biota or sediment which must not be exceeded to prevent specified detrimental effects from occurring to water use.

Water Quality Objective
A water quality guideline adapted to protect the most sensitive designated water use at a specified location with an adequate degree of safety, taking local circumstances into account.

Watershed
All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream.