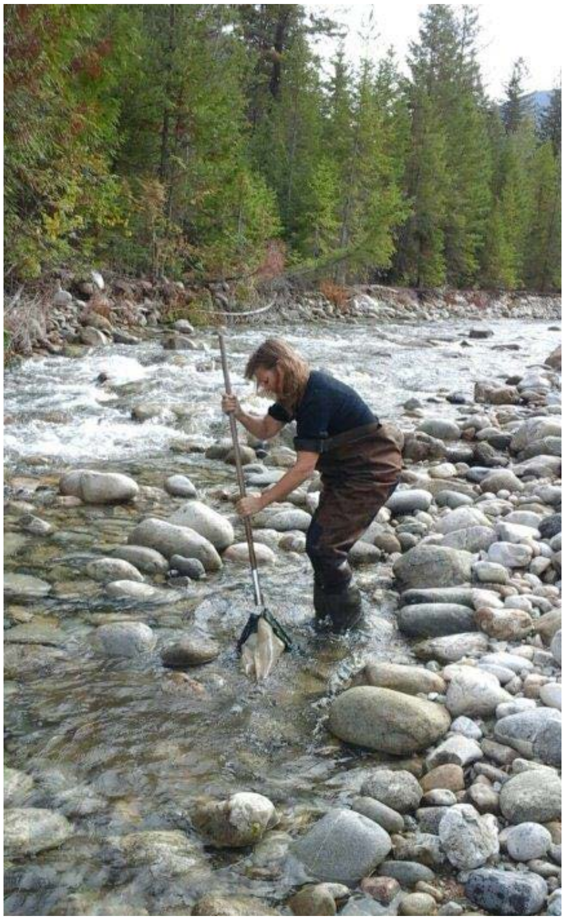
Lemon Creek Water Quality Monitoring Report 2016 – 2017



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Cover photo

Lemon Creek site NJLEM03, September 25, 2017

Project Highlights

The Columbia Basin Water Quality Monitoring Project (CBWQ) is an environmental stewardship project funded by the Columbia Basin Trust. Under the CBWQ, Mainstreams Environmental Society partnered with the Slocan River Streamkeepers Society to conduct baseline water quality monitoring in Lemon Creek from 2016 to 2017. Lemon Creek was identified to be a priority for monitoring, since it had high fisheries values, and is in an area with the potential for increased development pressures (i.e., logging activity, road-building, and mining). In addition, there was concern about effects from a fuel spill that occurred approximately 3 kilometers up the creek in July, 2013. Monitoring was conducted at site NJLEM03, located at the downstream end of the creek, near the confluence with the Slocan River. Three components were monitored: benthic macro-invertebrate community using Canadian Aquatic Biomonitoring Network (CABIN), water/sediment quality, and hydrologic characteristics (i.e., velocity and streamflow).

The benthic macro-invertebrate results identified NJLEM03 as being potentially stressed in both years sampled (2016-2017). This was evident through some (1-3 families) being absent that were expected based on reference group mean. As well, some metrics at NJLEM03 were minimally different than the reference group mean. Specifically, total abundance was higher in both years; percent of Ephemeroptera, Plecoptera, and Trichoptera orders (EPT) was lower in both years; and, the percent of two dominant taxa was higher in 2017. We noted that some community metrics at NJLEM03 indicated better conditions than that of the reference group mean (i.e., total abundance and taxa richness). Thus, the potentially stressed results may be an indication of the Preliminary Okanagan-Columbia Reference Model's limitations.

There were no indications from the water/sediment quality or the hydrometric results of the habitat being impaired. Only one parameter, pH, exceeded guidelines for the protection of aquatic life, and only in one sample. All others met the aquatic and drinking water guidelines. Streamflow followed a typical pattern of being high in the spring during freshet and decreasing throughout the summer to a base level.

The benthic invertebrate community appeared to have recovered from the 2013 gas spill. 2016 and 2017 values were similar to values upstream of the spill in 2013, for total abundance and number of EPT individuals.

Other CBWQ projects typically have had three instead of two years of monitoring data collected. Because of this we recommend a third year be completed, if possible. If this is not feasible, since the existing data showed stability in terms of aquatic health, it is still suitable as a baseline.

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1 Introduction

Community-based water quality monitoring in the Columbia River Basin plays an important role in gathering baseline information to understand watershed function and potential influences of concern. This information can help inform management decisions, to ensure that aquatic ecosystems are preserved, which in turn will contribute to maintaining sustainable communities. It is imperative that current and future water quality and quantity concerns be assessed in the Columbia River Basin as environmental change poses substantial risk to ecosystem and societal health. Changes in land use and climate change have the potential to substantially alter water quality and quantity in the Columbia River Basin (Carver 2017). Current and future reductions in snow accumulation (Barnett et al. 2008) and glacial ice (Jost et al. 2012) have been shown to result in reduced water supply in the Columbia Basin, particularly for the low flow summer periods (Burger et al. 2011). Lower streamflow leads to a reduced ability for streams to dilute pollution, potentially resulting in substantial water quality issues. In addition to climate change, the diverse land uses of the Columbia River Basin, including: recreational and industrial development, stream flow regulation, municipal and industrial waste water, and non-point source pollution present a challenge for community-based water quality management.

A first step in addressing present and future water quality and quantity issues is developing community awareness and involvement. The Columbia Basin Water Quality Monitoring Project (CBWQ) had its beginnings at a 2005 Watershed Stewardship Symposium sponsored by the Columbia Basin Trust (CBT), where the Columbia Basin Watershed Network was born. A key resolution from that meeting was for CBT to build capacity for watershed groups to monitor water quality in their watersheds. Consequently on a sunny weekend in June 2006 representatives from watershed groups from across the Columbia Basin met in Kimberley to attend a monitoring workshop with Dr. Hans Schreier and Dr. Ken Hall from UBC. At the end of the workshop Mainstreams agreed to coordinate the Columbia Basin Water Quality Monitoring Project and four groups began water quality monitoring in September 2007 with the following goals:

1. Develop a science-based model for community-based water quality monitoring;
2. Establish online accessibility to water quality data; and,
3. Link the monitoring project with community awareness activities.

All told, twelve watershed stewardship groups have participated in the project. Data collected by these groups can be found at the CBWQ website www.cbwq.ca.

In order to meet these goals the Slocan River Streamkeepers Society (SRSS or the stewardship group) conducted water quality monitoring in Lemon Creek from 2016 to 2017. Three components were monitored: benthic macro-invertebrate community using Canadian Aquatic Biomonitoring Network (CABIN) methods, water and sediment quality, and hydrologic characteristics (i.e., velocity and streamflow). This report presents the data, analyses the results, relates biological results to physical monitoring findings, and provides recommendations for future stream health monitoring.

Ongoing funding from the CBT has been and continues to be key to keeping this unique project, guided and administered by community watershed groups, operating until June 2018.

1.1 Lemon Creek background

Lemon Creek is a tributary of the Slocan River, which is situated approximately 20 km north-west of Nelson in southeast B.C. The mainstem is approximately 25 km long and originates in the southwest corner of Kokanee Glacier Provincial Park. Elevations in the watershed range from 550 m along the lower reach of the creek to 2,600 m within the park. Sapphire Lakes are the headwaters (Figure 1). The watershed encompasses several biogeoclimatic zones from Interior Cedar-Hemlock in the valley bottom, through to Engelmann Spruce-Subalpine and Alpine-Tundra at higher elevations (D'Eon. and Serrouya 2004).

Figure 1. Sapphire Lakes.

Fish and wildlife

Lemon Creek is considered one of the most diverse and productive watercourses for fish in the Slocan River Watershed. Eight species of fish are documented in Lemon Creek (Table 1). Three of these species are of conservation concern (BC Conservation Data Center [BC CDC] 2018). Umatilla Dace are listed as a threatened species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and are red-listed or endangered in BC. Both Bull Trout (interior lineage*)* and Shorthead Sculpin are listed as Species of Special Concern federally (COSEWIC) and in BC (Blue-listed).

Table 1. Fish species historically documented in Lemon Creek (Source: BC MoE 2018a)

Species - common name	Scientific name
Bull Trout	*Salvelinus confluentus*
Rainbow Trout	*Oncorhynchus mykiss*
Mountain Whitefish	*Prosopium williamsoni*
Umatilla Dace	*Rhinichthys umatilla*
Shorthead Sculpin	*Cottus confusus*
Slimy Sculpin	*Cottus cognatus*
Torrent Sculpin	*Cottus rhotheus*
Largescale Sucker	*Catostomus macrocheilus*

As a result of it its high elevation origin, Lemon Creek water temperature is especially cold. As such, it serves as an important "cold water input" to the relatively warm Slocan River. The cool water combined with the presence of good habitat downstream of the Lemon/Slocan confluence, has resulted in high fish presence. In 1998 - 2006, the Lemon/Slocan confluence was one of five index sites in the Slocan River Watershed, where catchable Rainbow Trout density (>30 cm) was monitored (Corbett 2007; Figure 2). In all years, the Lemon Creek site had more than three times the densities of fish than the other sites (Corbett 2007.

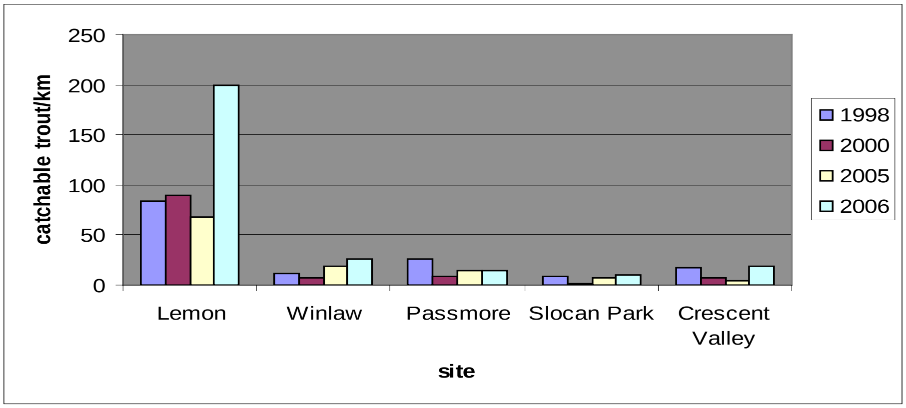

Figure 2. Catchable (> 30 cm) Rainbow Trout per km in various tributaries to the Slocan River (Corbett 2007).

Lemon Creek was historically known as one of the main spawning/rearing channels for Bull Trout in the Slocan River Watershed (Corbett 2007). A local fish biologist, Jeremy Baxter, intends to study Lemon Creek Bull Trout this year (2018). He plans to assess numbers, spawning activity, and install temperature sensors. This study is being completed as part of a larger program to understand Bull Trout population in the Slocan River Watershed.

The terrestrial and aquatic habitat in the Lemon Creek basin also supports a variety of wildlife species, including but not limited to: whitetail deer, elk, cougar, black bear grizzly, and marmot. The confluence with the Slocan River is a spring migration site for Trumpeter and Tundra swans.

Development

The Lemon Creek watershed has experienced logging and mining development. Logging, both clear-cut and selective, has altered the natural pattern of forest succession in many portions of Lemon Creek watershed. While Lemon has had extensive logging, and a road network development. Wildfire has been suppressed over much of the past half century, with few natural fires since the 1930's. Mining in the Lemon Creek watershed dates back to the 1800's. There are numerous claims in the upper portion of the watershed (Figure 3). While most claims are now inactive, the possibility remains for exploration and further mining development in the future (Pers. Comm. Popoff 2017).

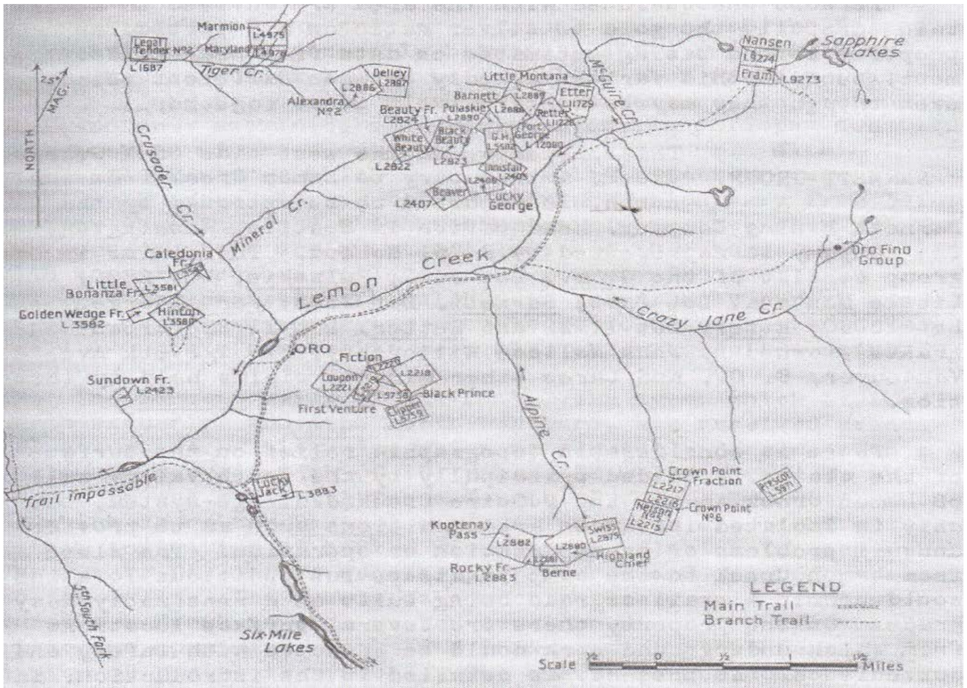

Figure 3. Lemon Creek mining claims (Maconachie 1940)

In the 1990's, the SRSS was asked to include Lemon Creek in the Slocan Valley Monitoring Program[1]. The request was triggered by residents, who in the spring, were experiencing turbid drinking water that was sourced from the creek. Sampling by a resident confirmed high turbidity (Pers. Comm. Peter Leach). The source was determined to be from numerous slides off a forestry road in one of the sub-basins. Currently, forestry operations have abated, and the water is less turbid.

There is also an active archaeological site near the confluence of Lemon Creek and the Slocan River, where First Nations people once resided. The site was an important natural feature (narrow passage), where fishing would have taken place (Figure 4).

[1] This was a program funded by the Provincial Government (Forest Renewal BC) that continued from 1997 – 2003, included 10- 14 creeks in the Slocan Valley, and was sponsored by the Winlaw Watershed committee. The data from the program resides in the Aquarius data base.

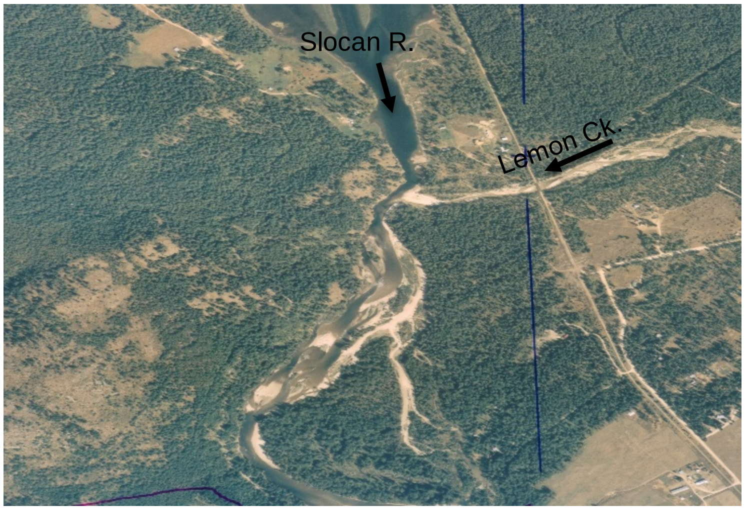

Figure 4. Confluence of Lemon Creek and the Slocan River (Google Earth 2014).

Historically, the lower portion of the Lemon Creek floodplain confined, with a berm built on either bank. This resulted in changes to the Slocan River. Below is a description of these events, as told by residents:

> *Lemon Creek was always an important cold water input into the Slocan River. In the late 1940's lower Lemon Creek was confined to one main channel to mitigate high spring run-off and associated channel movement from washing out the rail bridge. Lemon Creek entered the Slocan River at a site where the opposite bank was a bedrock wall, which created a constriction. Following berm installation, the stretch of Slocan River upstream of the confluence was further impounded and turned into a lake. Agriculture fields were flooded and some residents were compensated (Pers. Comm. Gary Burns).*
>
> *Once the lower Lemon Creek channel was confined, the Slocan River habitat changed. Immediately downstream of the Lemon Creek confluence, fish habitat improved. However, further downstream, when the grade leveled out, erosion increased. This situation remains today, with active erosion along banks downstream from Lemon Creek, from Perry Siding to Winlaw. Upstream from Lemon Creek, the fish habitat degraded, but it improved for birds.*

2013 Fuel spill

On July 26, 2013, approximately 35,000 liters of Jet A-1 fuel spilled into Lemon Creek (Figure 5). The driver didn't realize the condition of the road, or was lost. He had traveled up the main Lemon Forest Service Road and turned around. The truck went off the road on the way back to Highway 6. The event resulted in the evacuation of over 2,500 people from the Slocan Valley, as the fuel was carried downstream through the Slocan River to Brilliant Reservoir.

Figure 5. Overturned fuel truck in Lemon Creek (left), and fuel on the water surface (right), July 2013.

The event occurred at a time when water levels were moderately high. For this reason, the fuel went into side channels and into prime fish habitat in the Slocan River downstream of Lemon Creek. It settled into the stream substrate, woody debris, and river banks.

The SRSS was asked by the Regional District of Central Kootenay (RDCK) to collect drinking water samples for hydrocarbon testing. The SRSS also collected other environmental samples after the event and the following spring. This included benthic macro-invertebrate samples upstream and downstream of the spill site using CABIN techniques (Figure 6), and fish count data in side channels on the Slocan River downstream of Lemon Creek. Water sampling identified that hydrocarbons were still present the following spring (May), below Lemon Creek. The SRSS will continue to monitor benthic macro-invertebrates.

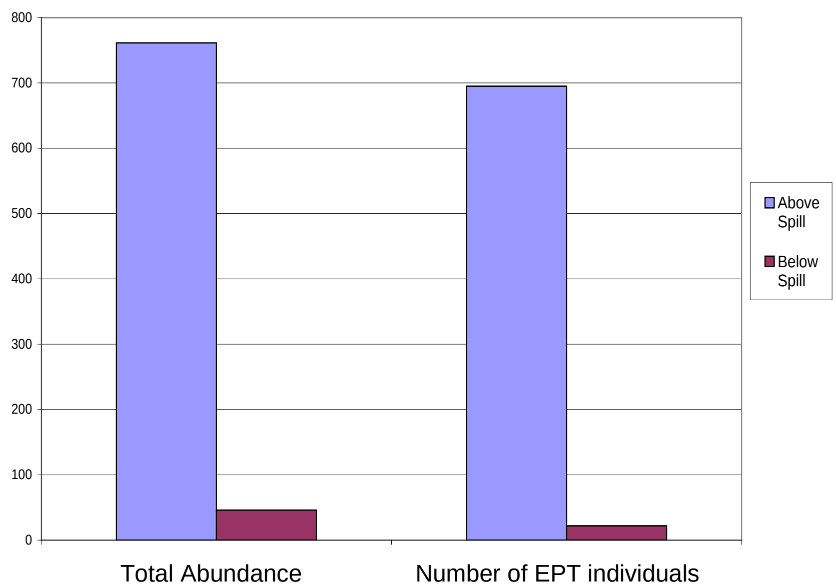

Figure 6. Lemon Creek invertebrate results, using CABIN techniques, October 2013 (SRSS 2013, and data is located in the CABIN database).

2016-2017 monitoring location

Monitoring was conducted at NGALX03. This site was located in the downstream section of the creek (Figure 7, Figure 8). The site was chosen so that any impacts associated with instream or landscape development throughout the watershed would be evident. The monitoring site was downstream of the 2013 fuel spill site.

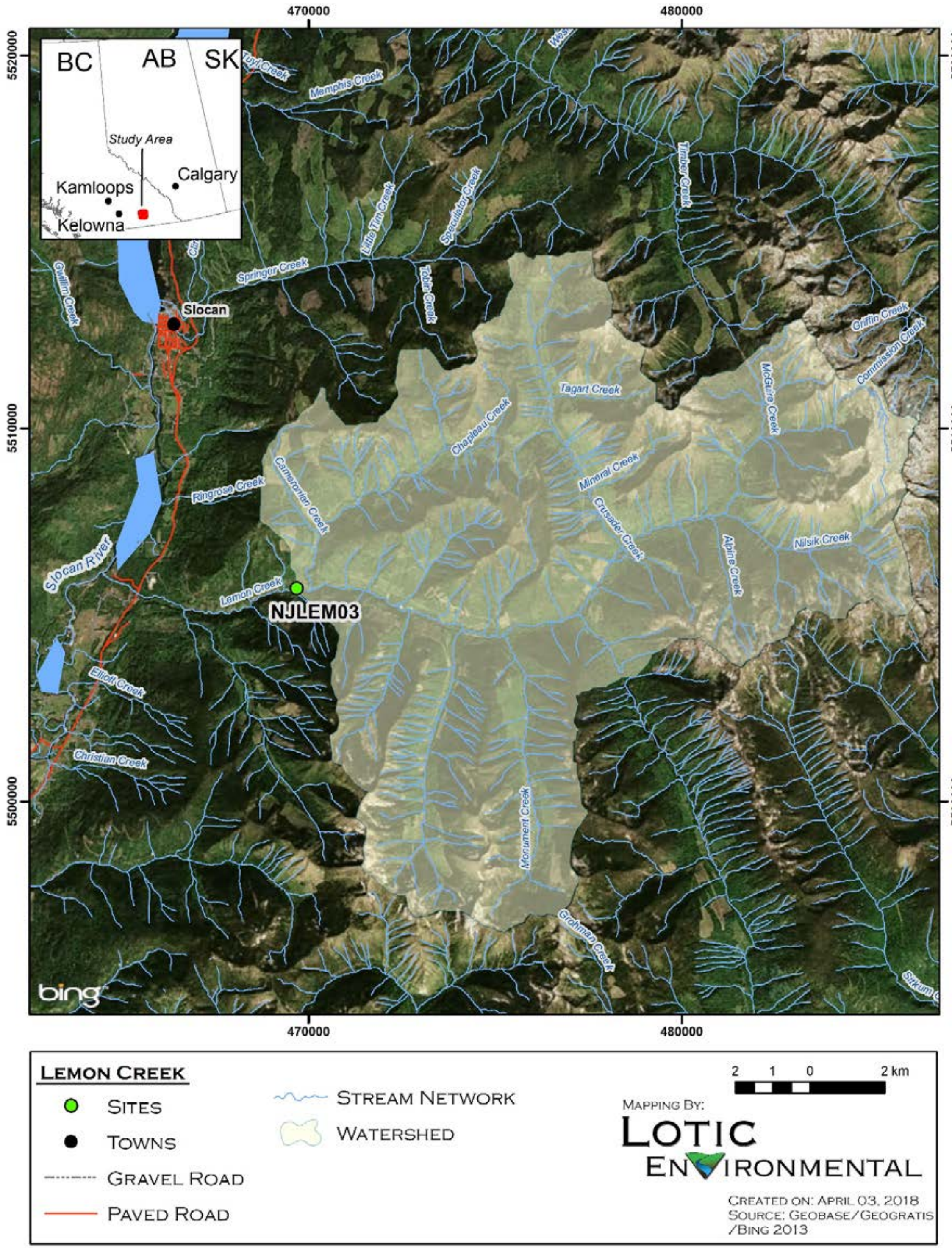

Figure 7. Lemon Creek monitoring location.

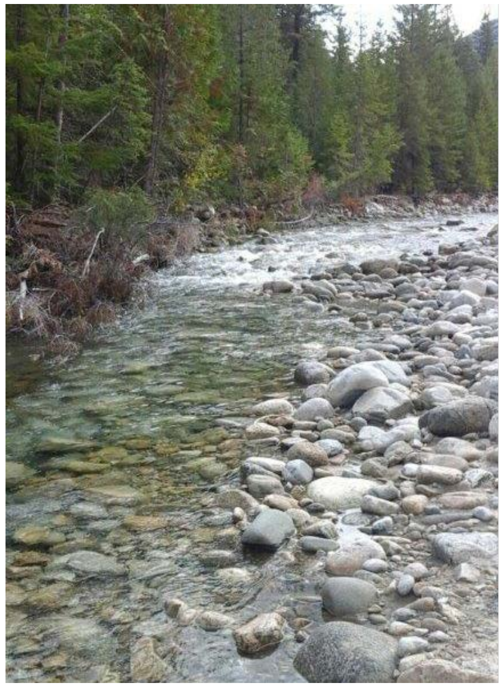

Figure 8.Upstream view from NJLEM03 monitoring site, September 25, 2017.

2 Methods

2.1 Data collection, data entry, and initial data presentation, completed by the CBWQ stewardship group

Overall, data were collected following the CBWQ Operating Procedures (CBWQ 2012) and the CABIN Field Procedures for Wadeable Streams (Environment Canada 2012a). The SRSS and Mainstreams completed all the field work, downloaded data into standard spreadsheets, and as applicable, conducted initial analyses (i.e., summary graphs, CABIN site reports).

Benthic macro-invertebrates

CABIN sampling was conducted once a year in the fall in 2016 and 2017. Benthic macro-invertebrate samples were analysed by Pina Viola Taxonomy following CABIN laboratory methods (Environment Canada 2012b). The data were entered into the online CABIN database and site reports were prepared using the CABIN analysis tools.

Water and sediment quality

Water quality laboratory analysis was completed by Maxxam (Burnaby, BC). The following water and sediment quality data were collected at NJLEM03:

a. 2016:
   - Monthly water quality (spring through fall) – orthophosphate, total phosphorus, total suspended solids (TSS), and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), water temperature, specific conductivity, pH, turbidity, and air temperature.
   - Water quality once in the fall, in addition to parameters above, inorganics (i.e., alkalinity, bicarbonate, carbonate and hydroxide), and metals.

- Sediment quality, once in the fall.

b. 2017:

- Monthly water quality (spring through fall) - orthophosphate, total nitrogen, total suspended solids (TSS), dissolved calcium, and *in situ* data.
- Water quality once in the summer and fall, in addition to parameters above, inorganics and metals.

The transpose add-in tool created by Devin Cairns (Blue Geosimulation) was used to automate the addition of new water quality data from Maxxam into the existing CBWQ datasets. The tool allowed users to open MS Excel files from Maxxam, and chose which MS Excel file to append the new data into. The add-in matched parameter names between files and converted units (e.g., between µm and mg), flagging the data cells that were successfully transferred.

Hydrometric data

Monthly streamflow and velocity data were collected from April to August in 2017. Velocity is the speed of water and is measured as a unit of distance per time (m/s). Streamflow, also known as discharge, is a measure of the volume of water moving through a stream channel in a given amount of time (m^3/s).

Streamflow and velocity were measured using the Velocity Tube method. Measurements were collected at regular length intervals across the stream using a Velocity Tube. At each interval, the Flowing Water Depth (cm) was measured from within the interior of the tube, as this area acts as a stilling well. The ‘head’ built up on the upstream side of the tube was also measured (Depth of Stagnation [cm]). The difference between the Flowing Water Depth and the Depth of Stagnation was inserted into Equation 1, to calculate Velocity

Equation 1. Water Velocity (V)

$$V = \sqrt{[2(\Delta D/100)*9.81]}$$

where ΔD was the average difference between the flowing water depth and the depth of stagnation

Flow was calculated using Equation 2, where the Average Stream Width and Average Depth was determined in the Stream Profile, and the Average Velocity was calculated above.

Equation 2: Stream flow (Q)

Q = Wetted Stream Width (m) x Average Depth (m) x Average Velocity (m/s).

2.2 Analysis overview

Following data collection and preparation described above completed by the CBWQ, Lotic Environmental Ltd. completed analyses and reporting. This included completing a quality assurance/quality control review (QA/QC) of data, comparing results to applicable guidelines, interpreting results, and providing recommendations.

The Reference Condition Approach (RCA) in CABIN was used to determine the condition of the benthic macro-invertebrate community at the test site (as sampled by the CBWQ group), by comparing the test site results to a group of reference sites with similar environmental characteristics. The Analytical Tools function in the CABIN database was used to run four analyses to review invertebrate test site data (Steps 1a – 1d in Figure 9): BEnthic Assessment of SedimenT (BEAST), River Invertebrate Prediction and Classification System (RIVPACS), community composition metrics, and habitat metrics. Water and sediment quality (Step 2), stream temperature (Step 3) and hydrometric (Step 4) analyses followed to provide an overall understanding of stream condition.

The reference model used in the RCA analysis was the Preliminary Okanagan-Columbia Reference Model (2010) provided in the online CABIN database. Because the model was still considered preliminary, with some potential data gaps, caution was exercised when interpreting RCA results (obtained from Steps 1a to 1d). Furthermore, it was important that all subsequent analyses (Steps 2 – 4) were conducted.

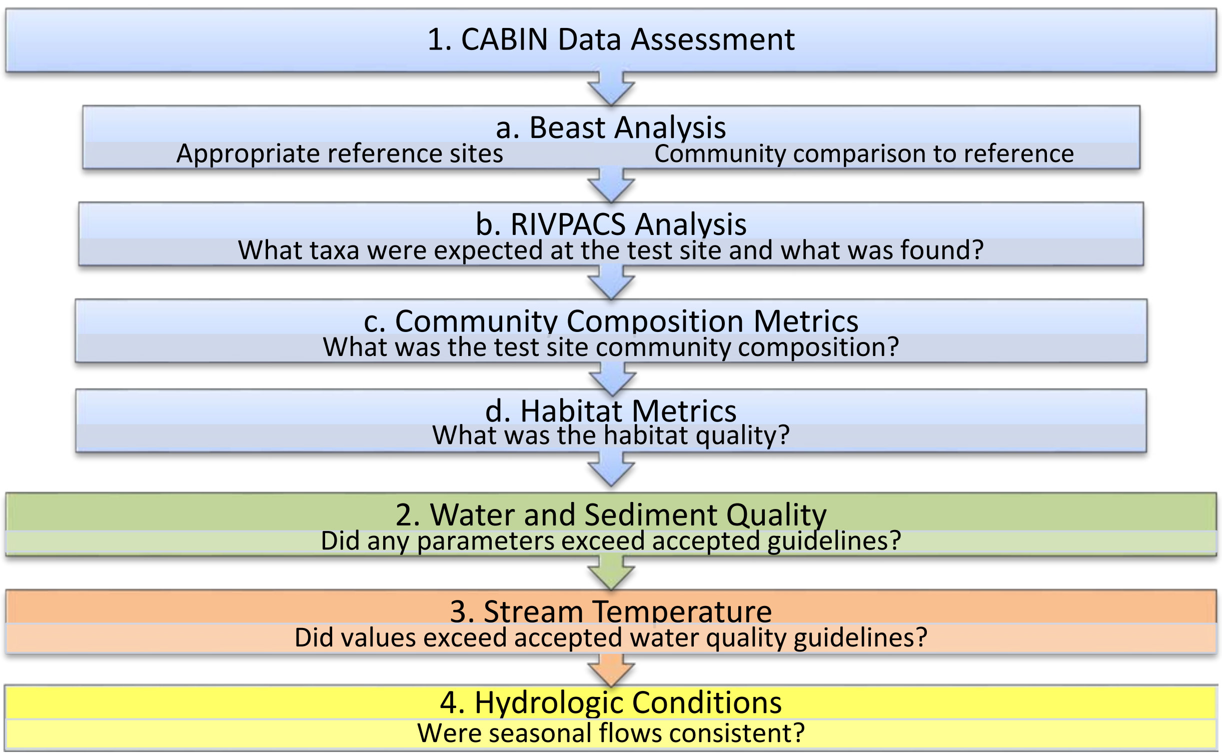

Figure 9. Stream condition analysis steps.

2.3 CABIN data analysis

2.3.1 Reference Condition Approach: BEAST analysis and site assessment

BEAST analysis was used to predict test sites to a reference group from the preliminary Okanagan-Columbia reference model provided by Environment Canada through the CABIN database. BEAST used a classification analysis that determined the probability of test site membership to a reference group based on habitat variables (Rosenberg *et al.* 1999). Habitat variables used to predict group membership in the Okanagan-Columbia reference model were latitude, longitude, percent area of watershed with a gradient <30%, percent area of watershed with permanent ice cover and average channel depth.

CABIN model hybrid multi-dimensional scaling ordination assessment was then used to evaluate benthic community stress based on divergence from reference condition. This analysis placed test sites into assessment bands corresponding to a stress level ranging from unstressed to severely stressed. In the ordination assessment, sites that were unstressed fell within the 90% confidence ellipse around the cloud of reference sites, which means that their communities were similar or equivalent to reference (Rosenberg *et al.* 1999). Potentially stressed, stressed and severely stressed sites indicate mild divergence, divergence, or high divergence of the benthic community from reference condition (Rosenberg *et al.* 1999).

2.3.2 RIVPACS analysis

RIVPACS ratios were calculated in the Analytical tools section of the CABIN database. RIVPACS analysis relied on presence/absence data for individual taxa. The RIVPACS ratio determined the ratio of observed taxa at test sites to taxa expected to be present at the test site based on their presence at reference sites. A RIVPACS ratio close to 1.00 indicated that a site was in good condition, as all taxa expected to be present were found at the test site. A RIVPACS ratio >1.00 could indicate community enrichment, while a ratio <1.00 could indicate that the benthic community was in poor condition.

2.3.3 Community composition metrics

Benthic community composition metrics were calculated in the CABIN database using the Metrics section of the Analytical Tools menu. A collection of relevant measures of community richness, abundance, diversity and composition were selected to describe the test site communities. Using metrics, indicator attributes were used to interpret the response to environmental disturbances. Metrics are complimentary to an RCA analysis.

2.4 Water and sediment quality data analysis

2.4.1 Guideline review

A guideline is a maximum and/or a minimum value for a characteristic of water, which in order to prevent specified detrimental effects from occurring, should not be exceeded (BC MoE 2018). Water quality results were compared to the applicable provincial and federal guidelines for the protection of aquatic life and drinking water. Exceedances of guidelines were flagged to provide an understanding of the potential impacts to aquatic life or drinking water.

When there was more than one guideline for a parameter, the following hierarchy was applied to determine the guideline that would apply (BC MoE 2016):

a. BC Approved Water Quality Guidelines (BC MoE 2018b)
b. BC Working Water Quality Guidelines (BC MoE 2017)
c. The Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment [CCME] 2017), or Health Canada (2017).

When both long-term and short-term exposure guidelines were available, the long-term guideline was reviewed, since sampling was assumed to have occurred under ‘normal’ conditions.

2.5 Hydrometric data analysis

Hydrometric data were reviewed for consistency and anomalies. Streamflow results were graphed, with seasonal patterns compared qualitatively amongst the years.

3 Results

3.1 CABIN results

3.1.1 Reference Condition Approach: BEAST analysis and site assessment

For NJLEM03, CABIN BEAST analysis determined the highest probability of reference group membership was to Group 4 (probabilities found in Table 2). The site was thus compared with Reference Group 4, which includes 12 streams, mostly from the Columbia Mountains and Highlands Ecoregion. The average channel depth of Reference Group 4 is 23.6 ± 11.1 cm (SD - standard deviation), which is near the test site's average depth of 35.75 cm. A comparison of other individual test site habitat attributes with those of the reference model, and the ordination plots are included in the Site Assessment Reports (Appendix A). The CABIN model assessed NJLEM03 as potentially stressed in both 2016 and 2017.

Table 2. CABIN model assessment of the test site against reference condition as defined by the preliminary Okanagan-Columbia reference model; assessment, prediction of reference group and probability of group membership.

Site	2016	2017
NJLEM03	**Potentially stressed** Group 4; 79.0%	**Potentially stressed** Group 4; 79.0%

3.1.2 RIVPACS analysis

The RIVPACS ratio at NJLEM03 was 0.97 in 2016 and 0.79 in 2017 (Table 3). These values indicate relatively good conditions at the test site, with only one family of taxa not present that was expected. The reduced ratio was explained by the taxa present. In 2016, only one family was absent at the test site that was expected based on the reference group. In 2017, three families were absent that were expected.

Table 3. RIVPACS Observed:Expected Ratios of taxa at test sites. Taxa listed had a probability of occurrence >0.70 at reference sites and were not observed at the test site. Condition indicated as shaded background*.

Site	2016	2017
NJLEM03	0.97 Capniidae	0.79 Capniidae, Perlidae, Taeniopterygidae

***CABIN model condition:** unstressed, potentially stressed, stressed, severely stressed.

3.1.3 Community composition metrics

Key metrics that were reviewed in detail include (Table 4): total abundance; percent composition of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) orders (EPT); percent composition of Chironomidae (non-biting midges) taxa; percent composition of the two dominant taxa; and total number of taxa.

Table 4. Benthic macro-invertebrate community composition metrics measured in 3 min kicknet samples, 2015 to 2017 at NJLEM03. Condition indicated as shaded background*

Metric	Reference Group 4 (Mean ± SD)	NJLEM03	
		2016	2017
Total abundance	587.4 ± 299.1	1031.3	913.9
% EPT taxa	87.7 ± 7.4	74.8	69.3
% Chironomidae	7.4 ± 6.4	10.6	9.7
% of 2 dominant taxa	57.9 ± 14.2	47.6	31.9
Total number of taxa	19.3 ± 3.7	25	29

*__CABIN model condition:__ unstressed, potentially stressed, stressed, severely stressed.

Total abundance of organisms found at the test site can be influenced by many factors including type of stress and the organisms involved (Rosenberg and Resh 1984). Abundance may increase due to nutrient enrichment but decrease in response to toxic effects such as metals contamination or changes in pH, conductivity and dissolved oxygen. Total abundance at NJLEM03 in both 2016 and 2017 (1031.3 and 913.9 organisms, respectively), was slightly higher than the reference group mean (587.4 ± 299.1 organisms). This likely influenced the site being assessed as potentially stressed. However, there was no evidence of nutrient enrichment in the water quality results.

The percent of the community made up by individuals of any taxon, either at the family or order level, will vary depending on the taxon's tolerance to pollution, feeding strategy and habitat requirements (Rosenberg and Resh 1984). EPT orders of insects are typically indicators of good water quality. Percent EPT at NJLEM03 was slightly lower in both years (74.8 and 69.3%, respectively) than the reference group mean (87.7 ± 7.4 %). This too, likely contributed to the assessment outcome. Conversely, the Chironomidae family of insect (non-biting midges) are generally tolerant of pollution. Percent Chironomidae at the test site in both years (10.6 and 9.7%) was within the reference group mean (7.4 ± 6.4 %).

The relative occurrence of the two most abundant taxon is a metric that can relate to impacted streams since only a few taxa end up dominating the community as diversity decreases (Environment Canada 2012c). Opportunistic taxa that are less particular about where they live replace taxa that require special foods or particular types of physical habitat (Environment Canada 2012c). The percent of two dominant taxa at the test site in 2016 (47.6 %) was within the reference group mean (57.9 ± 14.2 %). However, in 2017, this metric was slightly lower (31.9%) than the reference group mean.

Taxa richness is the total number of taxa present for a given taxonomic level. There is usually a decrease of intolerant taxa and an increase of tolerant taxa with instream disturbance. However, overall biodiversity of a stream typically declines with disturbance (Environment Canada 2012c). Taxa richness at the test site in 2016 and 2017 (25 and 29 taxa, respectively) were slightly higher than the reference mean (19.3 ± 3.7 taxa). These results further indicate why the benthic invertebrate community at NJLEM03 was assessed to be potentially stressed.

3.1.4 Habitat conditions

Key physical habitat conditions that could influence benthic macro-invertebrate community health were reviewed amongst the sampling years (Table 5). Conditions were similar amongst both years monitored. Average velocity in 2016 and average depth in 2017 were slightly higher than the reference group mean. However, these values did not appear to alter the substrate proportions, as they were all within the reference group mean. Overall, habitat conditions of depth and velocity may have had a small influence on the assessment outcome of the invertebrate community being potentially stressed.

Table 5. Select physical habitat characteristics for the predicted reference group, and NJLEM03.

Parameter	Reference group mean ± SD	2016	2017
Average depth (cm)	23.6 ± 11.1	31.8	39.7
Average velocity (m/s)	0.48 ± 0.22	0.74	0.67
% Cobble (6.4 - 25.6 cm)	51 ± 15	66	59
% Pebble (1.6 – 6.4 cm)	37 ± 20	24	19
% Gravel (0.2 – 1.6 cm)	3 ± 3	0	7
% Sand (0.1 – 0.2 cm)	0 ± 0	0	0
% silt and clay (<0.1 cm)	0 ± 0	0	0

3.2 Water and sediment quality results

Overall, water and sediment quality results for NJLEM03 were very good. Water quality results met all but one aquatic life and/or drinking water guidelines for the non-metal parameters reviewed (Appendix B). It was noted that turbidity was very low (< 1.0 NTU) even during the high flow or spring freshet period. This is indicative of a stable system. The one guideline exceedance was pH, and details are as follows:

- **pH**: The BC approved water quality guideline for the protection of aquatic life for pH allows for an unrestricted change within the range of 6.5-9.0 (BC Ministry of Environment [BC MoE] 2018b). The pH ranged from 6.2 to 7.6 pH units, and was below the guideline in one sample (6.2 pH units on April 26, 2016). This value is not concerning if it reflected background conditions and was not low as a result of a particular anthropogenic influence/discharge to the watercourse. However, if there is a discharge into the watercourse, then pH should be monitored more thoroughly in accordance with the BC guidelines to ensure guidelines are met and there are no impacts on the aquatic environment.

All guidelines for metal water quality parameters and for sediment quality were met (Appendix B2, and B3, respectively). Total aluminum in the water column was flagged on June 14, 2017 as being high. However, the BC guideline is for the dissolved fraction. Dissolved aluminum, although not analysed, was likely lower than total aluminum. If this was a parameter of recurring concern, which it does not appear to be, then it would be recommended dissolved aluminum also be reviewed to confirm if there were exceedances.

3.3 Hydrometric results

Stream flow plays an important role in stream ecosystems, influencing aquatic species distributions, water quality (especially turbidity, dissolved oxygen content and stream temperature), physical habitat (especially substrate characteristics), and fish life history traits (e.g. spawning time).

At NJLEM03, instantaneous streamflow data were collected on a monthly basis from April to August in 2017. The results show that freshet (i.e. high flow due to snowmelt and/or heavy rain) occurred from April thru June, and this was followed by decreasing flows through to mid-July (Figure 10). After which, streamflow stabilized at a base level. These results were consistent with the normal flow regime in the region in the region.

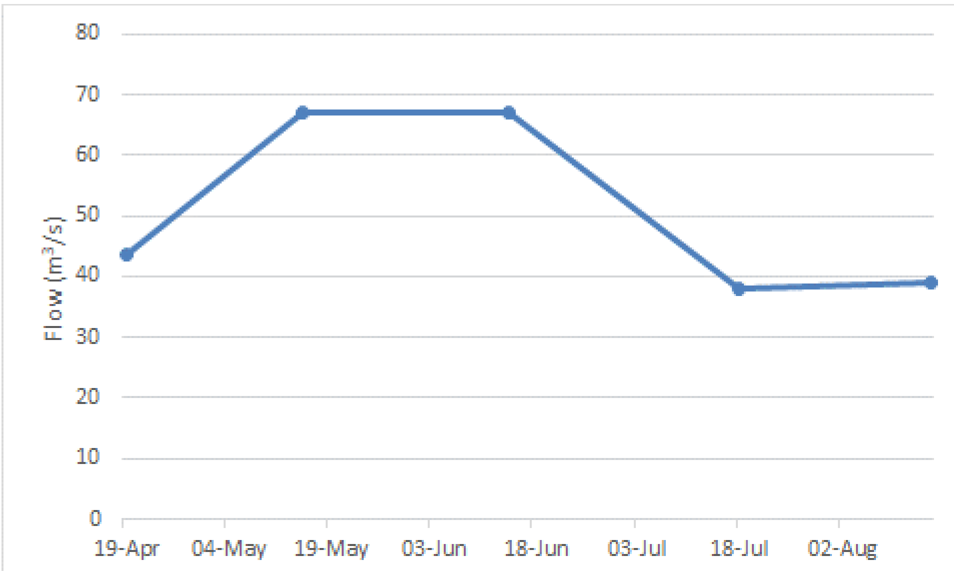

Figure 10. Monthly streamflow at NJLEM03 from April to August 2017.

Provincial instream flow guidelines to protect aquatic ecosystems are usually set relative to natural historic flows of each stream. In order to develop these criteria, the annual hydrologic regime of the stream would need to be thoroughly described using a long-term dataset. This would be best achieved using continuous level loggers and developing level streamflow relationships. Instantaneous flow measurements at one site cannot be directly related to fish habitat requirements, as flow will vary with channel morphology, and fish can swim to more suitable habitats within the stream. Nevertheless, the hydrometric data collected as part of this project are still important as they can be used to evaluate changes in streamflow patterns with time. This information can also explain changes in water quality (e.g., turbidity can increase during high flows) and biological changes such as fish/invertebrate/periphyton species population distributions.

4 Conclusions

The CABIN analysis of the benthic macro-invertebrate monitoring results identified NJLEM03 as being potentially stressed in both years sampled (2016-2017). This was evident through with one to three families, depending on the year, being absent that were expected based on reference group. As well, some metrics were minimally different than the reference group mean; specifically at NJLEM03, total abundance was higher in both years, percent EPT was lower in both years, and the percent of two dominant taxa was higher in 2017. We noted that some community metrics at NJLEM03 indicated that conditions were better than the reference group's (i.e., total abundance and taxa richness). Thus, the potentially stressed results may be an indication of the Preliminary Okanagan-Columbia Reference Model's limitations.

There were no indications from the water/sediment quality or the hydrometric results, of the habitat being impaired. Only one parameter, pH, exceeded guidelines for the protection of aquatic life, and this occurred in only one sample. All other parameters met their respective aquatic and/or drinking water quality guidelines. Streamflow followed a typical pattern of being high in the spring during freshet and decreasing throughout the summer to a base level.

The benthic macro-invertebrate results indicated that the Lemon Creek benthic invertebrate community recovered from the 2013 gas spill. Total abundance and number of EPT individuals were similar to values collected upstream of the spill in 2013 (Figure 11).

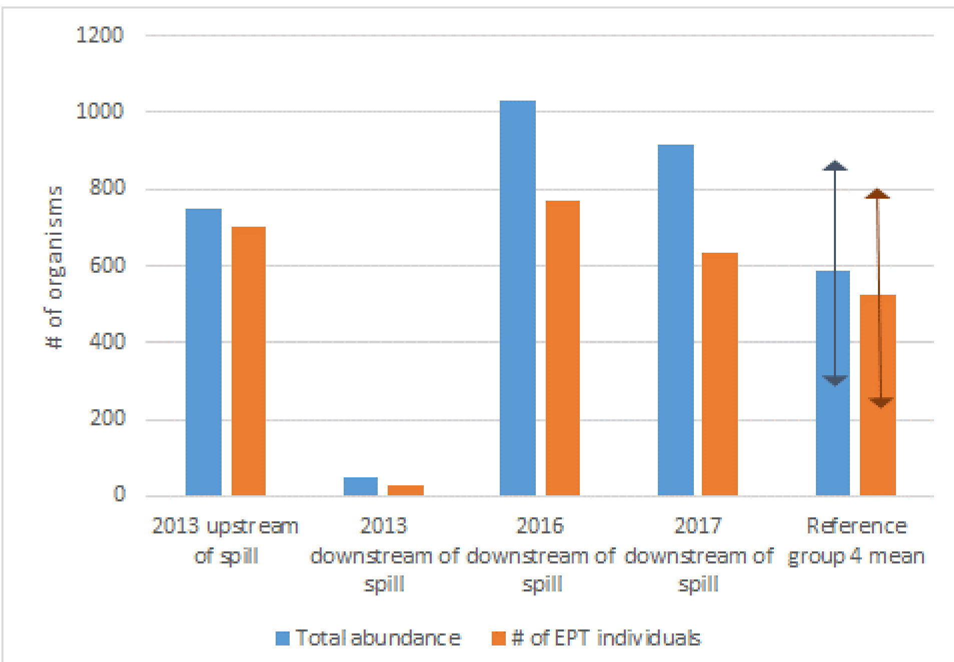

Figure 11. Benthic macro-invertebrate results using CABIN methods from before and after the 2013 gas spill into Lemon Creek (2013 data is from SRSS 2013). The arrows on the reference group mean represent the standard deviation.

5 Recommendations

The existing monitoring program provides a good picture of aquatic invertebrate health and water quality, assuming that the years captured were relatively representative of general conditions in the watershed, and there were no changes in land-use. Other CBWQ projects typically have had three instead of two years of monitoring data collected. Because of this we recommend a third year be completed, if possible. If this is not feasible, since the existing data showed stability in terms of aquatic health, it is still suitable as a baseline. This information can be used in the future to identify if there are any water quality or benthic macro-invertebrate changes caused by increased disturbance. Once baseline data have been attained, sampling should focus on other locations experiencing ongoing development pressures.

There is a variety of other information, which was outside of the scope of this monitoring project that could be potentially collected to support a baseline understanding of a watershed. This may include, but not be limited to: 1) determining the hydrologic regime of the stream, using continuous level loggers, 2) conducting fish habitat assessments, 3) conducting fish assessments (e.g., composition, abundance and life-history use). The stewardship group would need to look at existing data available, to determine information gaps needing to be filled. The results of the Bull Trout study planned in 2018 will be very informative and important to gain an increased understanding of the value of Lemon Creek and its tributaries, to the larger Slocan River Watershed.

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Personal Communications

Popoff, Walter. 2017. Area H Director, Regional District of Central Kootenay.

Appendix A. CABIN data

Site Description

Study Name	CBWQ-Slocan
Site	NJLEM03
Sampling Date	Sep 28 2016
Know Your Watershed Basin	Slocan
Province / Territory	British Columbia
Terrestrial Ecological Classification	Montane Cordillera EcoZone Columbia Mountains and Highlands EcoRegion
Coordinates (decimal degrees)	49.70649 N, 117.49236 W
Altitude	1778
Local Basin Name	Lemon Creek
	Slocan
Stream Order	4

Figure 1. Location Map

Across Reach (No image found)
Down Stream (No image found)
Field Sheet (No image found)
Miscellaneous (No image found)
Substrate (No image found)
Up Stream (No image found)

Cabin Assessment Results

Reference Model Summary	
Model	Columbia-Okanagan Preliminary March 2010
Analysis Date	February 27, 2017
Taxonomic Level	Family
Predictive Model Variables	Depth-Avg Latitude Longitude Reg-Ice Reg-SlopeLT30%

Reference Groups	**1**	**2**	**3**	**4**	**5**
Number of Reference Sites	9	43	17	12	33
Group Error Rate	22.2%	24.5%	22.2%	25.0%	32.4%
Overall Model Error Rate			26.4%		
Probability of Group Membership	0.6%	3.5%	7.7%	79.0%	9.3%
CABIN Assessment of NJLEM03 on Sep 28, 2016			Mildly Divergent		

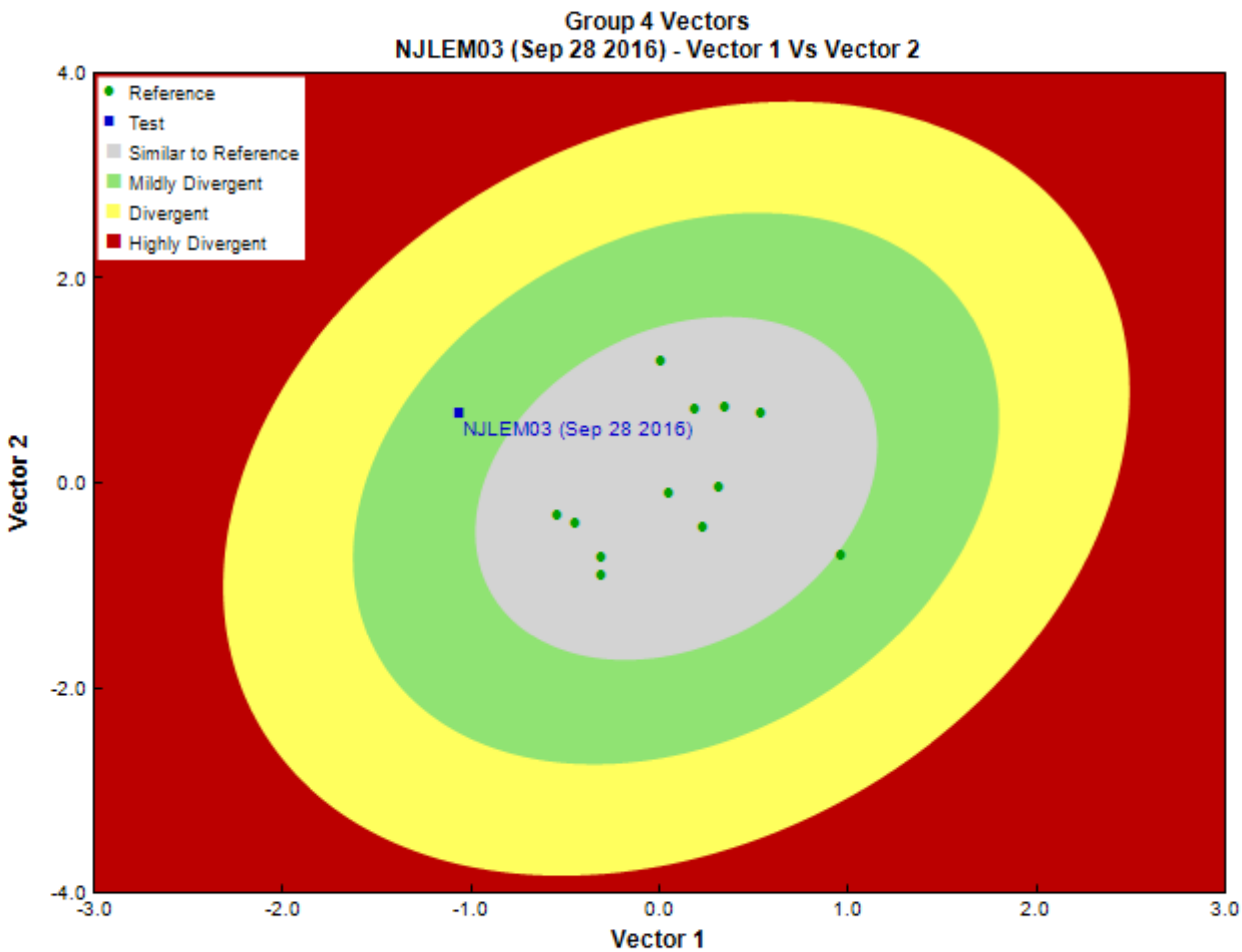

Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	-
Date Taxonomy Completed	-
	-
Sub-Sample Proportion	32/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Oligochaeta	Enchytraeida	Enchytraeidae	14	43.8
Arthropoda	Arachnida	Trombidiformes	Aturidae	1	3.1
			Hygrobatidae	2	6.3
			Lebertiidae	4	12.5
			Sperchontidae	1	3.1
			Torrenticolidae	1	3.1
	Insecta	Diptera	Chironomidae	35	109.4
			Empididae	22	68.7
			Simuliidae	2	6.2
			Tipulidae	1	3.1
		Ephemeroptera	Ameletidae	1	3.1
			Baetidae	76	237.5
			Ephemerellidae	17	53.2
			Heptageniidae	23	71.9
			Leptophlebiidae	4	12.5

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
		Plecoptera	Chloroperlidae	1	3.1
			Nemouridae	10	31.2
			Perlidae	1	3.1
			Perlodidae	5	15.6
			Taeniopterygidae	1	3.1
		Trichoptera	Brachycentridae	1	3.1
			Hydropsychidae	81	253.1
			Hydroptilidae	4	12.5
			Lepidostomatidae	10	31.3
			Rhyacophilidae	12	37.5
			Total	330	1,031.1

Metrics

Name	NJLEM03	Predicted Group Reference Mean ±SD
Bray-Curtis Distance	0.59	0.4 ± 0.1
Biotic Indices		
Hilsenhoff Family index (North-West)	4.2	3.2 ± 0.3
Intolerant taxa	--	
Long-lived taxa	1.0	2.1 ± 1.0
Tolerant individuals (%)	--	0.8 ± 0.3
Functional Measures		
% Filterers	25.5	2.2 ± 1.8
% Gatherers	27.0	38.4 ± 12.4
% Predatores	50.9	19.0 ± 8.5
% Scrapers	32.4	63.2 ± 19.7
% Shredder	7.0	27.6 ± 15.2
No. Clinger Taxa	24.0	23.2 ± 6.3
Number Of Individuals		
% Chironomidae	10.6	7.4 ± 6.4
% Coleoptera	0.0	1.5 ± 3.9
% Diptera + Non-insects	25.2	10.8 ± 7.6
% Ephemeroptera	36.7	51.7 ± 18.8
% Ephemeroptera that are Baetidae	62.8	40.6 ± 30.0
% EPT Individuals	74.8	87.7 ± 7.4
% Odonata	0.0	0.0 ± 0.0
% of 2 dominant taxa	47.6	57.9 ± 14.2
% of 5 dominant taxa	71.8	81.6 ± 7.9
% of dominant taxa	24.5	39.8 ± 14.9
% Plecoptera	5.5	31.4 ± 15.4
% Tribe Tanyatarisini	--	
% Trichoptera that are Hydropsychida	75.0	27.0 ± 26.2
% Tricoptera	32.7	4.5 ± 2.8
No. EPT individuals/Chironomids+EPT Individuals	0.9	0.9 ± 0.1
Total Abundance	1031.3	587.4 ± 299.1
Richness		
Chironomidae taxa (genus level only)	1.0	1.0 ± 0.0
Coleoptera taxa	0.0	0.4 ± 0.5
Diptera taxa	4.0	3.3 ± 1.0
Ephemeroptera taxa	5.0	3.8 ± 0.8
EPT Individuals (Sum)	771.9	526.0 ± 285.8
EPT taxa (no)	15.0	13.3 ± 2.7
Odonata taxa	0.0	0.0 ± 0.0
Pielou's Evenness	0.7	0.7 ± 0.1
Plecoptera taxa	5.0	6.3 ± 1.1
Shannon-Wiener Diversity	2.4	1.9 ± 0.4
Simpson's Diversity	0.9	0.8 ± 0.1
Simpson's Evenness	0.3	0.3 ± 0.1
Total No. of Taxa	25.0	19.3 ± 3.7
Trichoptera taxa	5.0	3.2 ± 1.4

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJLEM03
	Group 1	Group 2	Group 3	Group 4	Group 5	
Baetidae	100%	100%	100%	100%	97%	1.00
Capniidae	78%	55%	50%	92%	68%	0.85
Chironomidae	100%	100%	100%	100%	95%	0.99
Chloroperlidae	78%	88%	94%	100%	100%	0.99
Ephemerellidae	78%	100%	100%	100%	100%	1.00
Heptageniidae	100%	100%	100%	100%	100%	1.00
Hydropsychidae	11%	92%	78%	92%	86%	0.90
Nemouridae	100%	100%	100%	100%	100%	1.00
Perlidae	11%	84%	33%	100%	3%	0.85
Perlodidae	78%	78%	89%	92%	81%	0.90
Rhyacophilidae	100%	92%	100%	100%	95%	0.99
Taeniopterygidae	89%	49%	100%	92%	97%	0.91

RIVPACS Ratios

RIVPACS : Expected taxa P>0.50	13.79
RIVPACS : Observed taxa P>0.50	14.00
RIVPACS : O:E (p > 0.5)	1.02
RIVPACS : Expected taxa P>0.70	11.38
RIVPACS : Observed taxa P>0.70	11.00
RIVPACS : O:E (p > 0.7)	0.97

Habitat Description

Variable	NJLEM03	Predicted Group Reference Mean ±SD
Channel		
Depth-Avg (cm)	31.8	23.6 ± 11.1
Depth-Max (cm)	43.0	34.6 ± 12.3
Discharge (m^3/s)	0.770	0.000 ± 0.000
Macrophyte (PercentRange)	1	0 ± 0
Reach-%CanopyCoverage (PercentRange)	2.00	1.33 ± 0.78
Reach-%Logging (PercentRange)	0	0 ± 0
Reach-DomStreamsideVeg (Category (1-4))	4	4 ± 1
Reach-Pools (Binary)	1	1 ± 0
Reach-Rapids (Binary)	1	0 ± 0
Reach-Riffles (Binary)	1	1 ± 0
Reach-StraightRun (Binary)	1	1 ± 1
Slope (m/m)	2.3400000	0.0546683 ± 0.0376269
Veg-Coniferous (Binary)	1	1 ± 0
Veg-Deciduous (Binary)	1	1 ± 0
Veg-GrassesFerns (Binary)	1	1 ± 0
Veg-Shrubs (Binary)	1	1 ± 0
Velocity-Avg (m/s)	0.74	0.48 ± 0.22
Velocity-Max (m/s)	1.33	0.76 ± 0.36
Width-Bankfull (m)	56.0	13.4 ± 9.9
Width-Wetted (m)	12.6	8.5 ± 5.8
XSEC-VelMethod (Category (1-3))	1	1 ± 0
Landcover		
Reg-Ice (%)	0.00000	0.02487 ± 0.06034
Substrate Data		
%Bedrock (%)	0	0 ± 0
%Boulder (%)	10	9 ± 9
%Cobble (%)	66	51 ± 15
%Gravel (%)	0	3 ± 3
%Pebble (%)	24	37 ± 20
%Sand (%)	0	0 ± 0
%Silt+Clay (%)	0	0 ± 0
D50 (cm)	11.00	15.12 ± 14.26
Dg (cm)	10.2	8.2 ± 2.8
Dominant-1st (Category(0-9))	6	7 ± 1
Dominant-2nd (Category(0-9))	7	7 ± 1

Habitat Description

Variable	NJLEM03	Predicted Group Reference Mean ±SD
Embeddedness (Category(1-5))	4	5 ± 1
PeriphytonCoverage (Category(1-5))	2	1 ± 0
SurroundingMaterial (Category(0-9))	6	4 ± 1
Topography		
Reg-SlopeLT30% (%)	15.28600	18.88386 ± 9.29866
Water Chemistry		
Ag (mg/L)	0.0100000	0.0000050
Al (mg/L)	6.8000000	0.0049000
As (mg/L)	0.0050000	0.0002700
B (mg/L)	50.0000000	0.0500000
Ba (mg/L)	10.0000000	0.0682000
Be (mg/L)	0.0500000	0.0000100
Bi (mg/L)	0.5000000	0.0000050
Ca (mg/L)	12.7000000	21.1083333 ± 16.8005659
Cd (mg/L)	0.0120000	0.0000050
Chloride-Dissolved (mg/L)	1.7000000	0.9750000 ± 2.6309780
Co (mg/L)	0.2500000	0.0000100
CO3 (mg/L)	0.2500000	0.0000000 ± 0.0000000
Cr (6) (µg/L)	0.5000000	0.0000000 ± 0.0000000
Cu (mg/L)	0.2500000	0.0001000
Fe (mg/L)	5.0000000	0.0080000
General-Alkalinity (mg/L)	38.3000000	71.7000000 ± 53.9231440
General-Conductivity (µS/cm)	76.4000000	121.8083333 ± 87.6800844
General-DO (mg/L)	11.0000000	11.4175000 ± 0.7986708
General-Hardness (mg/L)	36.9000000	84.2750000 ± 70.6251066
General-pH (pH)	7.0	7.9 ± 0.4
General-SolidsTSS (mg/L)	2.0000000	0.8849836 ± 1.2378575
General-TempAir (Degrees Celsius)	12.5	26.0
General-TempWater (Degrees Celsius)	8.0000000	7.3183333 ± 2.7240839
General-Turbidity (NTU)	0.2000000	0.2020000
HCO3 (mg/L)	46.8000000	0.0000000 ± 0.0000000
Hg (ng/L)	0.0050000	0.0000000 ± 0.0000000
K (mg/L)	0.8130000	0.6141667 ± 0.4056971
Li (mg/L)	2.5000000	0.0011000
Mg (mg/L)	1.2500000	7.6666667 ± 7.9748848
Mn (mg/L)	0.5000000	0.0006100
Mo (mg/L)	2.0000000	0.0006900
Na (mg/L)	1.4400000	1.5383333 ± 1.2751459
Ni (mg/L)	0.5000000	0.0003000
Nitrogen-NO2 (mg/L)	0.0050000	0.0027500 ± 0.0062831
Nitrogen-NO3 (mg/L)	0.0200000	0.0546667 ± 0.0498148
Pb (mg/L)	0.1000000	0.0000520
Phosphorus-OrthoP (mg/L)	0.0025000	0.0002727 ± 0.0004671
Phosphorus-TP (mg/L)	0.0025000	0.0045833 ± 0.0049992
S (mg/L)	1.5000000	5.0000000
Sb (mg/L)	0.2500000	0.0000700
Se (mg/L)	0.0500000	0.0001200
Si (mg/L)	3680.0000000	3.1516667 ± 1.2277017
Sn (mg/L)	2.5000000	0.0000100
SO4 (mg/L)	2.2000000	17.2250000 ± 25.9966125
Sr (mg/L)	98.9000000	0.0443000
Tl (mg/L)	0.0250000	0.0000020
U (mg/L)	1.9700000	0.0011700
V (mg/L)	2.5000000	0.0002000
Zn (mg/L)	2.5000000	0.0010000
Zr (mg/L)	0.2500000	0.0000000 ± 0.0000000

Site Description

Study Name	CBWQ-Slocan
Site	NJLEM03
Sampling Date	Sep 25 2017
Know Your Watershed Basin	Slocan
Province / Territory	British Columbia
Terrestrial Ecological Classification	Montane Cordillera EcoZone Columbia Mountains and Highlands EcoRegion
Coordinates (decimal degrees)	49.70167 N, 117.41972 W
Altitude	1794
Local Basin Name	Lemon Creek
	Slocan
Stream Order	4

Figure 1. Location Map

Across Reach (No image found)
Aerial (No image found)

Down Stream
Field Sheet (No image found)
Miscellaneous (No image found)

Substrate

Up Stream

Cabin Assessment Results

Reference Model Summary	
Model	Columbia-Okanagan Preliminary March 2010
Analysis Date	January 30, 2018
Taxonomic Level	Family
Predictive Model Variables	Depth-Avg Latitude Longitude Reg-Ice Reg-SlopeLT30%

Reference Groups	**1**	**2**	**3**	**4**	**5**
Number of Reference Sites	9	43	17	12	33
Group Error Rate	22.2%	24.5%	22.2%	25.0%	32.4%
Overall Model Error Rate	26.4%				
Probability of Group Membership	2.1%	2.6%	7.8%	79.0%	8.5%
CABIN Assessment of NJLEM03 on Sep 25, 2017	Mildly Divergent				

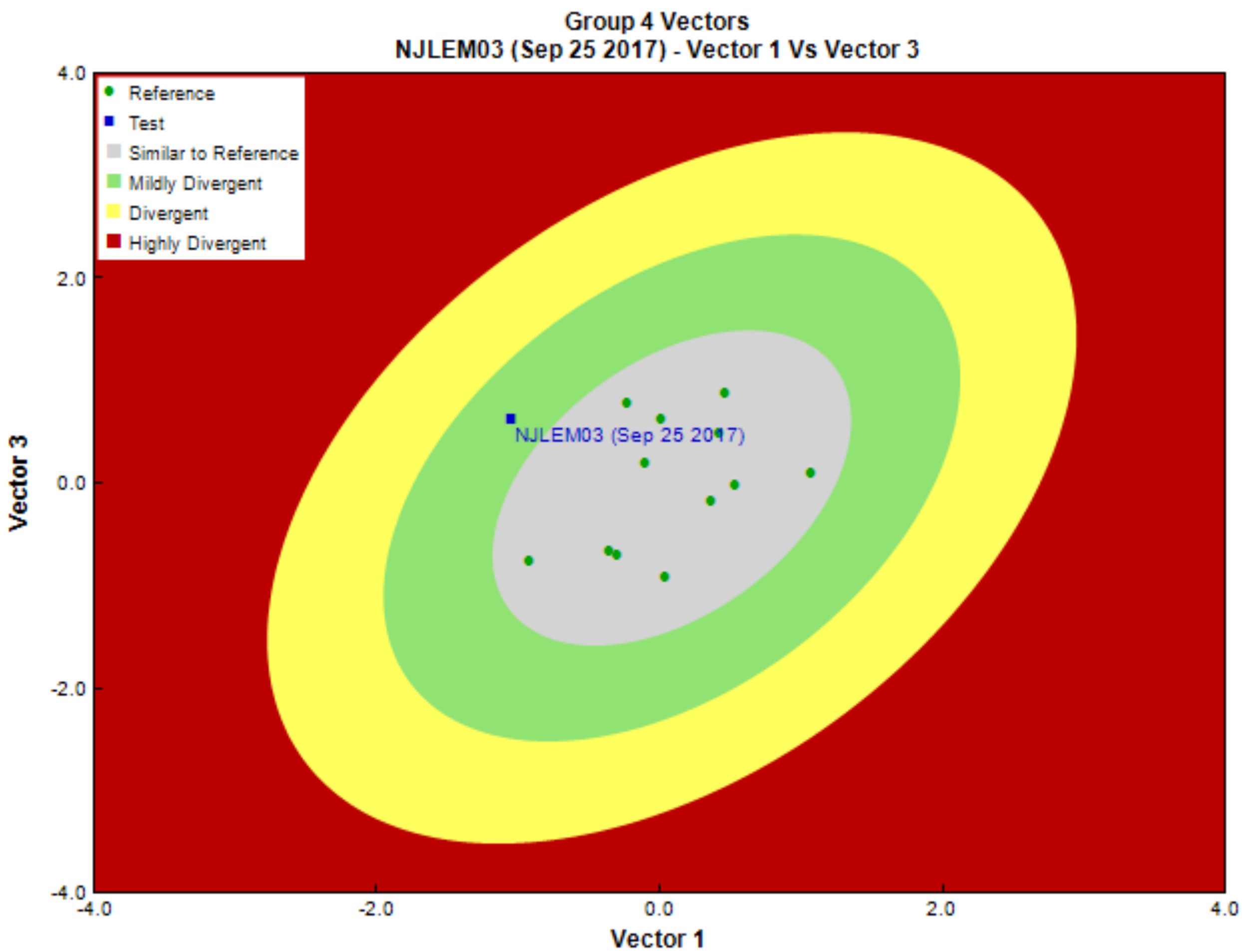

Figure 3. CABIN ordination assessment of the test site with the predicted group of reference sites. Each axis represents the relative abundance of the entire benthic invertebrate community with different organisms weighted differently on each axis.

Sample Information

Sampling Device	Kick Net
Mesh Size	400
Sampling Time	3
Taxonomist	Pina Viola, Consultant
Date Taxonomy Completed	December 03, 2017
	Marchant Box
Sub-Sample Proportion	36/100

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
Annelida	Oligochaeta	Enchytraeida	Enchytraeidae	1	2.8
		Tubificida	Naididae	4	11.1
Arthropoda	Arachnida	Trombidiformes	Aturidae	3	8.3
			Hydryphantidae	1	2.8
			Hygrobatidae	25	69.5
			Lebertiidae	4	11.1
			Sperchontidae	2	5.6
			Torrenticolidae	3	8.4
	Insecta	Coleoptera	Dytiscidae	1	2.8
			Elmidae	2	5.6
		Diptera	Ceratopogonidae	1	2.8
			Chironomidae	32	88.9
			Empididae	12	33.4
			Psychodidae	8	22.2
			Simuliidae	1	2.8

Community Structure

Phylum	Class	Order	Family	Raw Count	Total Count
			Tipulidae	1	2.8
		Ephemeroptera	Ameletidae	21	58.3
			Baetidae	61	169.4
			Ephemerellidae	13	36.1
			Heptageniidae	44	122.3
			Leptophlebiidae	24	66.7
		Plecoptera	Chloroperlidae	6	16.7
			Nemouridae	5	13.9
			Perlodidae	1	2.8
		Trichoptera	Brachycentridae	1	2.8
			Hydropsychidae	19	52.7
			Hydroptilidae	1	2.8
			Lepidostomatidae	28	77.8
			Rhyacophilidae	4	11.1
			Total	329	914.3

Metrics

Name	NJLEM03	Predicted Group Reference Mean ±SD
Bray-Curtis Distance	0.51	0.4 ± 0.1
Biotic Indices		
Hilsenhoff Family index (North-West)	4.3	3.2 ± 0.3
Intolerant taxa	--	
Long-lived taxa	2.0	2.1 ± 1.0
Tolerant individuals (%)	0.3	0.8 ± 0.3
Functional Measures		
% Filterers	6.4	2.2 ± 1.8
% Gatherers	36.5	38.4 ± 12.4
% Predatores	35.0	19.0 ± 8.5
% Scrapers	35.3	63.2 ± 19.7
% Shredder	11.2	27.6 ± 15.2
No. Clinger Taxa	24.0	23.2 ± 6.3
Number Of Individuals		
% Chironomidae	9.7	7.4 ± 6.4
% Coleoptera	0.9	1.5 ± 3.9
% Diptera + Non-insects	29.8	10.8 ± 7.6
% Ephemeroptera	49.5	51.7 ± 18.8
% Ephemeroptera that are Baetidae	37.4	40.6 ± 30.0
% EPT Individuals	69.3	87.7 ± 7.4
% Odonata	0.0	0.0 ± 0.0
% of 2 dominant taxa	31.9	57.9 ± 14.2
% of 5 dominant taxa	57.8	81.6 ± 7.9
% of dominant taxa	18.5	39.8 ± 14.9
% Plecoptera	3.6	31.4 ± 15.4
% Tribe Tanyatarisini	--	
% Trichoptera that are Hydropsychida	35.8	27.0 ± 26.2
% Tricoptera	16.1	4.5 ± 2.8
No. EPT individuals/Chironomids+EPT Individuals	0.9	0.9 ± 0.1
Total Abundance	913.9	587.4 ± 299.1
Richness		
Chironomidae taxa (genus level only)	1.0	1.0 ± 0.0
Coleoptera taxa	2.0	0.4 ± 0.5
Diptera taxa	6.0	3.3 ± 1.0
Ephemeroptera taxa	5.0	3.8 ± 0.8
EPT Individuals (Sum)	633.3	526.0 ± 285.8
EPT taxa (no)	13.0	13.3 ± 2.7
Odonata taxa	0.0	0.0 ± 0.0
Pielou's Evenness	0.8	0.7 ± 0.1
Plecoptera taxa	3.0	6.3 ± 1.1
Shannon-Wiener Diversity	2.7	1.9 ± 0.4
Simpson's Diversity	0.9	0.8 ± 0.1
Simpson's Evenness	0.4	0.3 ± 0.1

Metrics

Name	NJLEM03	Predicted Group Reference Mean ±SD
Total No. of Taxa	29.0	19.3 ± 3.7
Trichoptera taxa	5.0	3.2 ± 1.4

Frequency and Probability of Taxa Occurrence

Reference Model Taxa	Frequency of Occurrence in Reference Sites					Probability Of Occurrence at NJLEM03
	Group 1	Group 2	Group 3	Group 4	Group 5	
Baetidae	100%	100%	100%	100%	97%	1.00
Capniidae	78%	55%	50%	92%	68%	0.85
Chironomidae	100%	100%	100%	100%	95%	1.00
Chloroperlidae	78%	88%	94%	100%	100%	0.99
Ephemerellidae	78%	100%	100%	100%	100%	1.00
Heptageniidae	100%	100%	100%	100%	100%	1.00
Hydropsychidae	11%	92%	78%	92%	86%	0.88
Nemouridae	100%	100%	100%	100%	100%	1.00
Perlidae	11%	84%	33%	100%	3%	0.84
Perlodidae	78%	78%	89%	92%	81%	0.90
Rhyacophilidae	100%	92%	100%	100%	95%	0.99
Taeniopterygidae	89%	49%	100%	92%	97%	0.92

RIVPACS Ratios

RIVPACS : Expected taxa P>0.50	13.78
RIVPACS : Observed taxa P>0.50	12.00
RIVPACS : O:E (p > 0.5)	0.87
RIVPACS : Expected taxa P>0.70	11.36
RIVPACS : Observed taxa P>0.70	9.00
RIVPACS : O:E (p > 0.7)	0.79

Habitat Description

Variable	NJLEM03	Predicted Group Reference Mean ±SD
Channel		
Depth-Avg (cm)	39.7	23.6 ± 11.1
Depth-BankfullMinusWetted (cm)	29.60	51.38 ± 29.42
Depth-Max (cm)	54.2	34.6 ± 12.3
Macrophyte (PercentRange)	0	0 ± 0
Reach-%CanopyCoverage (PercentRange)	1.00	1.33 ± 0.78
Reach-%Logging (PercentRange)	0	0 ± 0
Reach-DomStreamsideVeg (Category(1-4))	4	4 ± 1
Reach-Pools (Binary)	1	1 ± 0
Reach-Rapids (Binary)	1	0 ± 0
Reach-Riffles (Binary)	1	1 ± 0
Reach-StraightRun (Binary)	1	1 ± 1
Slope (m/m)	0.0200000	0.0546683 ± 0.0376269
Veg-Coniferous (Binary)	1	1 ± 0
Veg-Deciduous (Binary)	1	1 ± 0
Veg-GrassesFerns (Binary)	1	1 ± 0
Veg-Shrubs (Binary)	1	1 ± 0
Velocity-Avg (m/s)	0.67	0.48 ± 0.22
Velocity-Max (m/s)	0.98	0.76 ± 0.36
Width-Bankfull (m)	30.0	13.4 ± 9.9
Width-Wetted (m)	9.6	8.5 ± 5.8
XSEC-VelMethod (Category(1-3))	1	1 ± 0
Landcover		
Reg-Ice (%)	0.00000	0.02487 ± 0.06034
Substrate Data		
%Bedrock (%)	0	0 ± 0
%Boulder (%)	14	9 ± 9
%Cobble (%)	59	51 ± 15
%Gravel (%)	7	3 ± 3

Habitat Description

Variable	NJLEM03	Predicted Group Reference Mean ±SD
%Pebble (%)	19	37 ± 20
%Sand (%)	0	0 ± 0
%Silt+Clay (%)	0	0 ± 0
D50 (cm)	11.00	15.12 ± 14.26
Dg (cm)	9.6	8.2 ± 2.8
Dominant-1st (Category(0-9))	6	7 ± 1
Dominant-2nd (Category(0-9))	7	7 ± 1
Embeddedness (Category(1-5))	4	5 ± 1
PeriphytonCoverage (Category(1-5))	2	1 ± 0
SurroundingMaterial (Category(0-9))	7	4 ± 1
Topography		
Reg-SlopeLT30% (%)	15.22000	18.88386 ± 9.29866
Water Chemistry		
Ag (mg/L)	0.0000200	0.0000050
Al (mg/L)	0.0064000	0.0049000
As (mg/L)	0.0001000	0.0002700
B (mg/L)	0.0250000	0.0500000
Ba (mg/L)	0.0105000	0.0682000
Be (mg/L)	0.0001000	0.0000100
Bi (mg/L)	0.0005000	0.0000050
Ca (mg/L)	13.8000000	21.1083333 ± 16.8005659
Cd (mg/L)	0.0000050	0.0000050
Co (mg/L)	0.0002000	0.0000100
Cr (6) (µg/L)	1.0000000	0.0000000 ± 0.0000000
Cu (mg/L)	0.0005000	0.0001000
Fe (mg/L)	0.0100000	0.0080000
General-Alkalinity (mg/L)	45.7000000	71.7000000 ± 53.9231440
General-DO (mg/L)	11.0000000	11.4175000 ± 0.7986708
General-Hardness (mg/L)	40.0000000	84.2750000 ± 70.6251066
General-pH (pH)	7.4	7.9 ± 0.4
General-SolidsTSS (mg/L)	4.0000000	0.8849836 ± 1.2378575
General-SpCond (µS/cm)	82.9000000	168.9833333 ± 123.7858182
General-TempAir (Degrees Celsius)	11.0	26.0
General-TempWater (Degrees Celsius)	7.0000000	7.3183333 ± 2.7240839
General-Turbidity (NTU)	0.1500000	0.2020000
HCO3 (mg/L)	55.8000000	0.0000000 ± 0.0000000
Hg (ng/L)	10.0000000	0.0000000 ± 0.0000000
K (mg/L)	0.7350000	0.6141667 ± 0.4056971
Li (mg/L)	0.0020000	0.0011000
Mg (mg/L)	1.3700000	7.6666667 ± 7.9748848
Mn (mg/L)	0.0010000	0.0006100
Mo (mg/L)	0.0024000	0.0006900
Na (mg/L)	1.5100000	1.5383333 ± 1.2751459
Ni (mg/L)	0.0010000	0.0003000
Pb (mg/L)	0.0002000	0.0000520
Phosphorus-OrthoP (mg/L)	0.0050000	0.0002727 ± 0.0004671
Phosphorus-TP (mg/L)	0.0050000	0.0045833 ± 0.0049992
S (mg/L)	3.0000000	5.0000000
Sb (mg/L)	0.0005000	0.0000700
Se (mg/L)	0.0001000	0.0001200
Si (mg/L)	3.8500000	3.1516667 ± 1.2277017
Sn (mg/L)	2.5000000	0.0000100
SO4 (mg/L)	3.1000000	17.2250000 ± 25.9966125
Sr (mg/L)	0.1070000	0.0443000
Ti (mg/L)	0.0050000	0.0005000
Tl (mg/L)	0.0000100	0.0000020
U (mg/L)	0.0030800	0.0011700
V (mg/L)	0.0050000	0.0002000
Zn (mg/L)	0.0050000	0.0010000
Zr (mg/L)	0.0001000	0.0000000 ± 0.0000000

Appendix B. Water and sediment quality data

B1 – Water quality, non-metals

B2 – Water quality, metals

Water quality legend

Abbreviation/ symbol	Description
1	Guidelines relevant to background not assessed, as they are intended to be monitored during construction/discharge activity.
(1)	RDL raised due to matrix effects
AO	Aesthetic objective
BC App	BC approved water quality guidelines (BC MoE 2018b).
BC Work	BC working water quality guidelines (BC MoE 2017)
CCME	Canadian environmental quality guidelines (CCME 2018)
HC	Health Canada drinking water guidelines (Health Canada 2017)
Red font	Field collected data
ISQG	Interim sediment quality guideline; below which adverse biological effects are expected to rarely occur.
PEL	Probable effect level for sediment, above which adverse effects are expected to occur frequently.
Green highlight	Exceedance of guideline for the protection of aquatic life
Blue highlight	Exceedance of drinking water guideline

Appendix B1 - Water quality, non metals

Stewardship Group	Sample Date (dd/mm/yy)	Site Code	Site Name	Nitrite (N)	Nitrate (N)	Alkalinity (Total as CaCO3)	Alkalinity (PP as CaCO3)	Bicarbonate (HCO3)	Carbonate (CO3)	Hydroxide (OH)	Orthophosphate (P)	Nitrate plus Nitrite (N)
			Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
			Guideline for protection of aquatic life[avg]	BC App: 0.02 when chloride <2 mg/L (or see Guideline Table)	BC App: 3	-	-	-	-	-	-	BC App: 3
			Guideline for drinking water[max]	HC: 1	HC: 10	-	-	-	-	-	-	BC App: 10
SRSS	26/04/2016	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	25/05/2016	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	28/06/2016	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	26/07/2016	NJLEM03	Lemon 03	-	-	-	-	-	-	-	-	-
SRSS	23/08/2016	NJLEM03	Lemon 03	-	-	-	-	-	-	-	-	-
SRSS	28/09/2016	NJLEM03	Lemon 03	<0.0050	<0.020	38.3	<0.50	46.8	<0.50	<0.50	<0.0050	<0.020
SRSS	26/10/2016	NJLEM03	Lemon 03	-	-	-	-	-	-	-	-	-
SRSS	19/04/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	-	-
SRSS	15/05/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	14/06/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	18/07/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	15/08/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	<0.0050	-
SRSS	20/09/2017	NJLEM03	Lemon 03	-	-	45.7	<1.0	55.8	<1.0	<1.0	<0.0050	-
SRSS	25/09/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	0.005	-
SRSS	25/10/2017	NJLEM03	Lemon 03	-	-	-	-	-	-	-	-	-

Appendix B1 - Water quality, non metals

Sample Date (dd/mm/yy)	Dissolved Oxygen	Specific Conductivity	pH	Turbidity	Water Temperature	Air Temperature	Total Hardness (CaCO3)	Total Phosphorus (P)
	mg/L	uS/cm		NTU	C	C	mg/L	
	BC App (**minimum**): 8 all stages other than buried embryo. 11 buried embryo not assessed, as spawning confirmation required.	-	BC App: 6.5-9.0.	BC App[1]: Change from background of 8 during clear flow period, and change of 5 during turbid flows.	BC App: 19 max.	-	-	CCME: Based on this data, the site is oligotrophic (0.004-0.01); exceedances of 1.5 times the upper value (or 0.015) indicates a potential problem.
	-	-	HC: 7-10.5	BC App[1]: Change of 1 when background is <5 NTU; change of 5 when background is >5 and <50; change of 10% when background is >50.	BC App[AO]: 15	-	-	-
26/04/2016	*12*	*50.8*	*6.2*	*0.3*	*5*	*11*	-	-
25/05/2016	*12*	*37*	*7.2*	*0.4*	*6*	*13*	-	<0.0050
28/06/2016	*10*	*42.6*	*6.8*	*0.25*	*10*	*32*	-	<0.0050
26/07/2016	*11*	*53*	*-*	*0.25*	*12*	*20*	-	-
23/08/2016	*11*	*78.5*	*6.8*	*0.2*	*11*	*20*	-	-
28/09/2016	*11*	*76.4*	*7*	*0.2*	*8*	*12.5*	36.9	<0.0050
26/10/2016	*13*	-	-	-	*4*	*8*	-	-
19/04/2017	*13*	*84*	*6.6*	*0.35*	*4.5*	*10*	-	-
15/05/2017	*13*	*54*	*6.8*	*0.3*	*3.5*	*6*	-	0.0065
14/06/2017	*13*	*34.7*	*7.3*	*0.25*	*5*	*18*	15.8	0.0107
18/07/2017	*11*	*56.6*	*7.6*	*0.45*	*10*	*20*	-	<0.0050
15/08/2017	*11*	*70.1*	*7.5*	*0.25*	*10*	*13*	-	<0.0050
20/09/2017	*12*	*81.9*	*7.4*	*0.4*	*6*	*9*	40	<0.0050
25/09/2017	*11*	*82.9*	*7.5*	*0.15*	*7*	*11*	-	-
25/10/2017	*12*	*84.75*	*7.4*	*0.2*	*3*	*5*	-	-

Appendix B1 - Water quality, non metals

Sample Date (dd/mm/yy)	Total Nitrogen (N)	Total Suspended Solids	Dissolved Calcium (Ca)	Dissolved Magnesium (Mg)	Dissolved Sulphate (SO4)	Dissolved Chloride (Cl)
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
	-	BC App[1]: Change from background of: ≤ 25 for 24 hr during clear flow, or 10 for 24 hr during turbid period (when natural water is 25-100)	-	-	BC App: hardness 0-3 = 128, hardness 31-75 = 218, hardness 76-180 = 309, hardness 181-250 = 429	BC App (total chloride): 150
	-	-	-	-	HC[AO]: 500	BC App[AO]: 250
26/04/2016	-	-	-	-	-	-
25/05/2016	-	<4.0	-	-	-	-
28/06/2016	-	<4.0	-	-	2.42	-
26/07/2016	-	-	-	-	-	-
23/08/2016	-	<4.0	-	-	-	-
28/09/2016	<0.020	<4.0	12.7	1.25	-	1.7
26/10/2016	-	<4.0	-	-	-	-
19/04/2017	-	<4.0	-	-	-	-
15/05/2017	-	<4.0	-	-	-	-
14/06/2017	-	<4.0	-	-	-	-
18/07/2017	-	<4.0	-	-	-	-
15/08/2017	-	<4.0	-	-	-	-
20/09/2017	-	<4.0	-	-	-	-
25/09/2017	0.005	-	<4.0	-	-	-
25/10/2017	-	<4.0	-	-	-	-

Appendix B2 - Water quality, metals

Stewardship Group	Sample Date (dd/mm/yy)	Site Code	Site Name	pH	Total Hardness (CaCO3)	Total Aluminum (Al)	Total Antimony (Sb)	Total Arsenic (As)	Total Barium (Ba)
			Units	ph units	mg/L	µg/L	µg/L	µg/L	µg/L
			Guideline for protection of aquatic life[avg]	BC App:6.5-9.0	-	BC App (**dissolved Al**): when pH is <6.5 = e[1.6-3.327 (median pH) + 0.402 (median pH)^2]. When pH ≥ 6.5 = 50.	BC Work: 9 (**antimony III**).	BC App: 5 (max)	BC Work: 1000
			Calculated aquatic life guideline (where required)	-	-	50	-	-	-
			Guideline for drinking water[max]	HC: 7-10.5	-	BC App[AO]: 200	HC: 6	BC App: 10	HC: 1000
SRSS	28/06/2016	NJLEM03	Lemon 03	-	18.8	23	<0.50	<0.10	7.6
SRSS	28/09/2016	NJLEM03	Lemon 03	7	36.9	6.8	<0.50	<0.10	10
SRSS	14/06/2017	NJLEM03	Lemon 03	*7.3*	15.8	75.9	<0.50	<0.10	5.8
SRSS	25/09/2017	NJLEM03	Lemon 03	*7.5*	40	6.4	<0.50	<0.10	10.5

Appendix B2 - Water quality, metals

Sample Date (dd/mm/yy)	Total Beryllium (Be)	Total Bismuth (Bi)	Total Boron (B)	Total Cadmium (Cd)	Total Calcium (Ca)	Total Chromium (Cr)	Total Cobalt (Co)	Total Copper (Cu)	Total Iron (Fe)	Total Lead (Pb)	Total Lithium (Li)	Total Magnesium (Mg)
	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
	BC Work: 0.13	-	BC App: 1200	CCME: 10{0.83(log[hardness]) – 2.46}	-	BC Work: 8.9 (**chromium III**)	BC App: 4.0	BC App: when hardness <50 = 2. Hardness >50 = (0.04 x hardness)	BC App^{max}: 1000	BC App: when hardness >8 = (3.31 + e(1.273 In [hardness] - 4.704).	-	-
	-	-	-	0.05	-	-	-	2	-	3.94	-	-
	-		BC App: 5000	HC: 5	-	HC: 50	-	BC App^{AO}: 1000	BCApp^{AO}: 300	BC App: 10	-	-
28/06/2016	<0.10	<1.0	<50	0.013	6.49	<1.0	<0.50	0.78	13	<0.20	<5.0	0.62
28/09/2016	<0.10	<1.0	<50	0.012	12.7	<1.0	<0.50	<0.50	<10	<0.20	<5.0	1.25
14/06/2017	<0.10	<1.0	<50	0.012	5.46	<1.0	<0.20	<0.50	67	<0.20	<2.0	0.53
25/09/2017	<0.10	<1.0	<50	<0.010	13.8	<1.0	<0.20	<0.50	<10	<0.20	<2.0	1.37

Appendix B2 - Water quality, metals

Sample Date (dd/mm/yy)	Total Manganese (Mn)	Total Mercury (Hg)	Total Molybdenum (Mo)	Total Nickel (Ni)	Total Potassium (K)	Total Selenium (Se)	Total Silicon (Si)	Total Silver (Ag)	Total Sodium (Na)	Total Strontium (Sr)	Total Sulphur (S)	Total Thallium (Tl)
	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L
	BC App: (0.0044 x hardness + 0.605)x1000	CCME 0.026	BC App: 1000	CCME: when hardness 0 to ≤ 60 = 25. Hardness > 60 to ≤ 180 = e{0.76[ln(hardness)]+1.06}. Hardness >180 = 150.	-	BC App. 2.0	-	BC App: when hardness <100 = 0.05. Hardness >100 = 1.5.	-	-	-	BC Work: 0.8
	605.12	-	-	25	-	-	-	0.05	-	-	-	-
	BC App[AO]: 50	BC App: 1	BC App: 250	-	-	BC App: 10	-	-	HC[AO]: 200	-	-	-
28/06/2016	<1.0	<0.010	1.2	<1.0	0.424	<0.10	2580	<0.020	0.796	57	<3.0	<0.050
28/09/2016	<1.0	<0.010	2	<1.0	0.813	<0.10	3680	<0.020	1.44	98.9	<3.0	<0.050
14/06/2017	3	<0.010	<1.0	<1.0	0.438	<0.10	2650	<0.020	0.623	47.4	<3.0	<0.010
25/09/2017	<1.0	<0.010	2.4	<1.0	0.735	<0.10	3850	<0.020	1.51	107	<3.0	<0.010

Appendix B2 - Water quality, metals

Sample Date (dd/mm/yy)	Total Tin (Sn)	Total Titanium (Ti)	Total Uranium (U)	Total Vanadium (V)	Total Zinc (Zn)	Total Zirconium (Zr)
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
	-	-	BC Work: 8.5	-	BC App: hardness <90 = 7.5. Hardness 90 - 330 = 7.5 + 0.75 x (hardness - 90)	-
	-	-	-	-	7.5	-
	-	-	HC: 20	-	BC App[AO]: 5000	-
28/06/2016	<5.0	<5.0	0.82	<5.0	<5.0	<0.50
28/09/2016	<5.0	<5.0	1.97	<5.0	<5.0	<0.50
14/06/2017	<5.0	<5.0	0.77	<5.0	<5.0	<0.10
25/09/2017	<5.0	<5.0	3.08	<5.0	<5.0	<0.10

Appendix B3 - Sediment quality

Stewardship Group	Sample Date (dd/mm/yy)	Site Code	Site Name	Soluble (2:1) pH	Total Aluminum (Al)	Total Antimony (Sb)	Total Arsenic (As)	Total Barium (Ba)
			Units	pH Units	mg/kg	mg/kg	mg/kg	mg/kg
SRSS	28/09/2016	NJLEM03	Lemon 03	7	6.8	<0.50	<0.10	10

Aquatic Life Guideline					
	ISQG or Low Effect	-	-	Wk: 5.9	-
	PEL or Severe Effect	-	-	Wk: 17	-
	General	-	-	-	-

Appendix B3 - Sediment quality

Sample Date (dd/mm/yy)	Total Beryllium (Be)	Total Bismuth (Bi)	Total Cadmium (Cd)	Total Calcium (Ca)	Total Chromium (Cr)	Total Cobalt (Co)	Total Copper (Cu)	Total Iron (Fe)
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
28/09/2016	<0.10	<1.0	0.012	12.7	<1.0	<0.50	<0.50	<10

ISQG or Low Effect	-	-	Wk: 0.6	-	Wk: 37.3	-	Wk: 35.7	Wk: 21,200
PEL or Severe Effect	-	-	Wk: 3.5	-	Wk: 90	-	Wk: 197	Wk: 43,766
General	-	-	-	-	-	-	-	-

Appendix B3 - Sediment quality

Sample Date (dd/mm/yy)	Total Lead (Pb)	Total Lithium (Li)	Total Magnesium (Mg)	Total Manganese (Mn)	Total Mercury (Hg)	Total Molybdenum (Mo)	Total Nickel (Ni)	Total Phosphorus (P)
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
28/09/2016	<0.20	<5.0	1.25	<1.0	-	2	<1.0	<0.0050

ISQG or Low Effect	Wk: 35	-	-	Wk: 460	Wk: 0.17	-	Wk: 16	-
PEL or Severe Effect	Wk: 91.3	-	-	Wk: 1100	Wk: 0.486	-	Wk: 75	-
General	-	-	-	-	-	-	-	-

Appendix B3 - Sediment quality

Sample Date (dd/mm/yy)	Total Potassium (K)	Total Selenium (Se)	Total Silver (Ag)	Total Sodium (Na)	Total Strontium (Sr)	Total Thallium (Tl)	Total Tin (Sn)	Total Titanium (Ti)
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
28/09/2016	0.813	<0.10	<0.020	1.44	98.9	<0.050	<5.0	<5.0

ISQG or Low Effect	-	-	Wk: 0.5	-	-	-	-	-
PEL or Severe Effect	-	-	-	-	-	-	-	-
General	-	BC: 2	-	-	-	-	-	-

Appendix B3 - Sediment quality

Sample Date (dd/mm/yy)	Total Uranium (U)	Total Vanadium (V)	Total Zinc (Zn)	Total Zirconium (Zr)
	mg/kg	mg/kg	mg/kg	mg/kg
28/09/2016	1.97	<5.0	<5.0	<0.50

ISQG or Low Effect	-	-	Wk: 123	-
PEL or Severe Effect	-	-	Wk: 315	-
General	-	-	-	-