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Subject: Columbia Basin Water Quality Monitoring Program, 2015/2016 Alexander Creek - Data Summary

Lotic Environmental Ltd. (Lotic Environmental) has completed the review of data collected by the Elk River Alliance at Alexander Creek Site 3 (NGALX03), through the Columbia Basin Water Quality Monitoring Project (CBWQMP). This review included analysis of data collected in 2015 and 2016 of the four main components of the project: 1) water quality data, 2) continuous temperature data, 3) hydrometric data (velocity and flow), and 4) Canadian Aquatic Biomonitoring Network (CABIN) data. All data and initial analyses for these components were summarized by the Elk River Alliance. Lotic Environmental's objective was to conduct a QA/QC of data, compare water quality results to applicable guidelines, interpret results, and make recommendations.

1 Water Quality

Water quality data had been transposed into the master spreadsheet by the CBWQMP (see Excel attachment). The following data were collected in 2015/2016 at NGALX03:

a. Monthly (spring through fall) - total suspended solids (TSS), orthophosphate, total phosphorus, and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), temperature, specific conductivity, pH, turbidity, and air temperature.
b. Once per year (coinciding with CABIN monitoring) - in addition to data above, inorganics, full complement of nutrients, and metals.
c. One additional time annually (for a total of two sampling dates each year) – sulphate, total hardness, and metals.
d. In 2015, monthly from May to July at NABIR01 - *Escherichia coli* (E. coli).
e. Once in 2016 - a duplicate and a blank sample.

1.1 *Water Quality QA/QC*

Water quality data were first subjected to a quality control evaluation to assess the accuracy and precision of the laboratory and field methods.

The relative percent difference (RPD) was determined for the parameters sampled in duplicate (Province of BC 2003). All but one sample was below the alert level of 50%, indicating a high degree of precision in data collection and lab procedures. Although the RPD for turbidity was 127%, a field measured and lab analysed sample were compared. Greater than normal variability would be expected when comparing these two different techniques; particularly for turbidity which can be influenced by agitation/settling. Natural variability in turbidity in the water column is also likely.

Water quality field blanks were collected using laboratory issued de-ionized water. Field blank values two times greater than the reportable detection limit (RDL) were considered to be an alert level (Province of BC 2003). All field blank data were below the alert level, indicating that samples were contaminant free and analysed with precision.

1.2 *Guideline updates*

A guideline is a maximum and/or a minimum value for a characteristic of water, sediment or biota, which in order to prevent specified detrimental effects from occurring, should not be exceeded (BC Ministry of Environment [BC MoE] 2017). The guidelines for the protection of aquatic life, and drinking water were updated to reflect changes since 2012, when they were last summarized for the CBWQMP. This involved updating threshold values, where applicable, and streamlining the review process by just presenting one guideline per parameter for each use category. This was done by applying the following hierarchy to guideline determination (BC MoE 2016):

a. Use the BC Approved Water Quality Guideline (BC MoE 2017), and if one did not exist then use;
b. BC Working Water Quality Guidelines for British Columbia (BC MoE 2015), and if one did not exist then use;
c. The Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment [CCME] 2017), or Health Canada (2017).

When both a long-term (30- day average or chronic) and short-term (maximum acute) exposure guideline was available, the long-term guideline was used in the review, since sampling was assumed to have occurred under 'normal' conditions. Exceedances of these guideline thresholds were flagged to provide an understanding of the potential risks.

1.3 *Water quality results*

Water quality results met all but one aquatic life and/or drinking water guideline for the parameters assessed. It was noted that turbidity and TSS were low at this site for all but one spring freshet sample (May 19, 2016), indicating stable conditions.

Total phosphorus: The total phosphorus guideline for the protection of aquatic life was not met in one out of the ten samples collected. Total phosphorus follows a framework-based approach where concentrations should not (i) exceed predefined 'trigger ranges'; and (ii) increase more than 50% over the baseline (reference) levels (CCME 2004). The trigger ranges are based on the range of phosphorus concentrations in water that define the reference productivity or trophic status[1] for the site (CCME 2004). Total phosphorus ranged from <0.005 - 0.0176 mg/L at NGALX03. Based on this data, the baseline range for total phosphorus was determined to be 0.004 - 0.010 mg/L, representing oligotrophic conditions. This is typical of unimpacted areas and

[1] Trophic status refers to the productivity of a waterbody, with eutrophic systems having high productivity and oligotrophic having low. Nutrient addition, primarily phosphorus, contributes to eutrophication, which is when the waterbody's productivity is accelerated from natural (Wetzel 2001).

generally supports diverse and abundant aquatic life and is self-sustaining (CCME 2004). Data was evaluated against the site specific guideline, calculated as 1.5 x the upper end of the baseline range, which is equivalent to 0.015 µg/L. The exceedance occurred in April 2015, with the May 2016 sample being the second highest value. Nutrient loading into a watercourse is anticipated during the spring, as a result of melting snow and rain events causing overland runoff. Since the exceedance was not prolonged and was only marginally higher than the guideline, aquatic life impacts are not expected. This data provides a valuable baseline for assessing long-term changes resulting from anthropogenic influences.

2 Stream Temperature

Temperature plays an important role in many biological, chemical, and physical processes. The effects of temperature on aquatic organisms are listed in the technical appendix for the BC MoE approved water quality guideline (Oliver & Fidler 2001), with the following generally occurring in aquatic organisms as water temperatures increase:

- Increased cardiovascular and respiratory functions, which in turn may increase the uptake of chemical toxins.
- Oxygen demand increases, while the dissolved oxygen content of water decreases, making swimming more difficult.
- In waters where dissolved gases are supersaturated, elevated water temperatures may worsen the effects of gas bubble trauma in fish.

The BC MoE stream temperature guidelines are specified by water use (i.e., drinking water, aquatic life, irrigation/livestock, and recreation/aesthetics). The aquatic life guidelines are dependent on the fish species (mostly salmonids) found in the stream for different life stages (rearing, spawning, and incubation). Bull Trout are especially sensitive to temperature changes, therefore streams with Bull Trout present have a separate set of more rigorous guidelines. The BC MoE also sets out temperature guidelines for streams with known fish distributions (mainly salmonids other than Bull Trout), and for streams with unknown fish distributions.

Fish species historically known to inhabit Alexander Creek include (BC MoE 2017a):

- Bull Trout (*Salvelinus confluentus*)
- Westslope Cutthroat Trout (*Oncorhynchus clarkia lewisi*)
- Rainbow Trout (*Oncorhynchus mykiss*)
- Brook Trout (*Salvelinus fontinalis*)

The special guidelines for streams with Bull Trout were used for reviewing the temperature data. In general, stream temperature did not exceed the maximum daily temperature of 15 ºC for Bull Trout in both years sampled (Figure 1 & Figure 2). The maximum daily temperature guideline reflects the optimal rearing temperatures for Bull Trout (6 ºC – 14 ºC). The water temperatures also did not exceed optimal Westslope Cutthroat rearing temperatures (7 ºC – 16 ºC).

Bull Trout spawning generally occurs from mid-September to late October and often is initiated when water temperatures drop below 9 ºC (McPhail 2007). The maximum daily temperatures in Alexander Creek did not exceed optimal spawning temperature guidelines (i.e. a max daily temperature of 10 ºC). However, it is unknown if fish spawn in the area of the temperature logger, as monitoring of spawning or potential for spawning (based on habitat including gravel size, flows, and depths) were not part of this study. Moreover, the eggs incubate overwinter when no temperature data is available. If spawning had occurred, the guideline for minimum temperature during incubation is 2 ºC. Temperatures in Alexander Creek did not meet the minimum guideline in October of 2016 and April of 2015. In April, eggs may have hatched but fry would still be in the gravel. Bull Trout egg incubation lasts 119-126 days at 2 ºC, 92-95 days at 6 ºC, 74-76 days at 6 ºC, 74-78 days at 8 ºC, and 70 days at 10 ºC (McPhail 2007). After hatching, fry remain in the gravel and generally emerge in June.

The stream temperatures did not exceed the drinking water temperature guideline of 15 ºC.

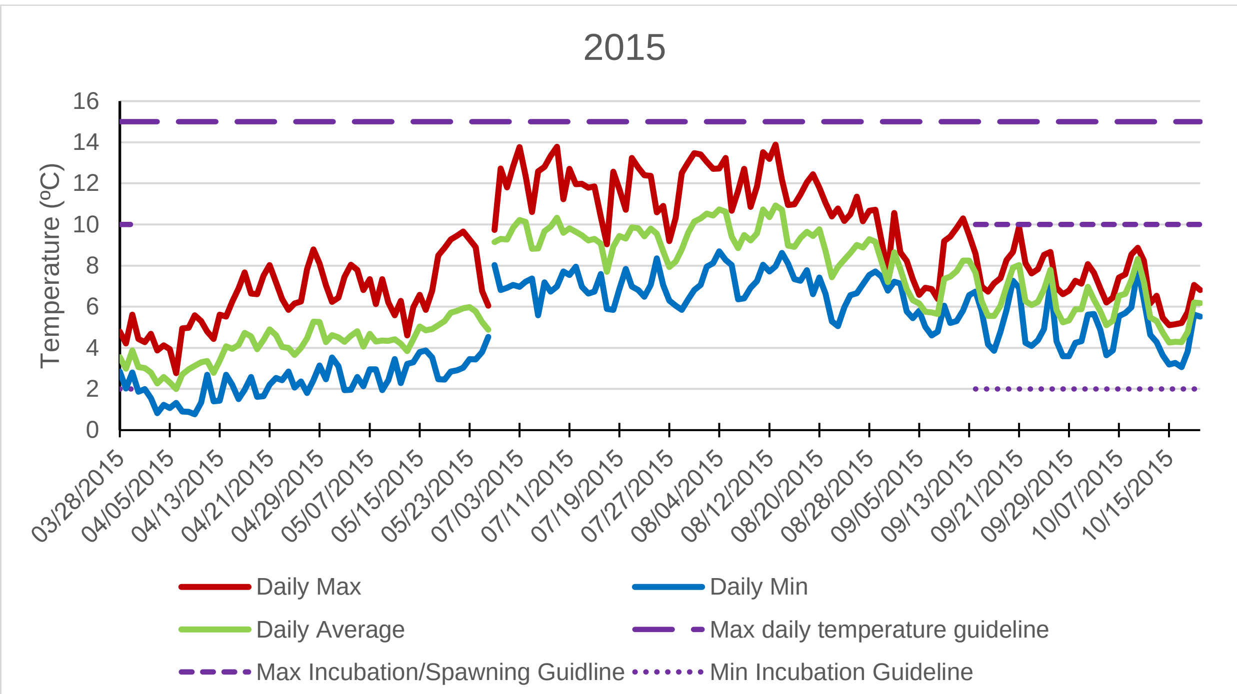

Figure 1. Stream water temperatures in Alexander Creek (site NGALX03) from March 28 to October 18, 2015. The logger was pulled during freshet (May 26 – June 29). The long dashed purple line indicates the BC MoE guideline for aquatic life for streams with Bull Trout present. The short dashes indicate maximum daily temperature during spawning and the dotted line indicates minimum daily water temperature during spawning and incubation.

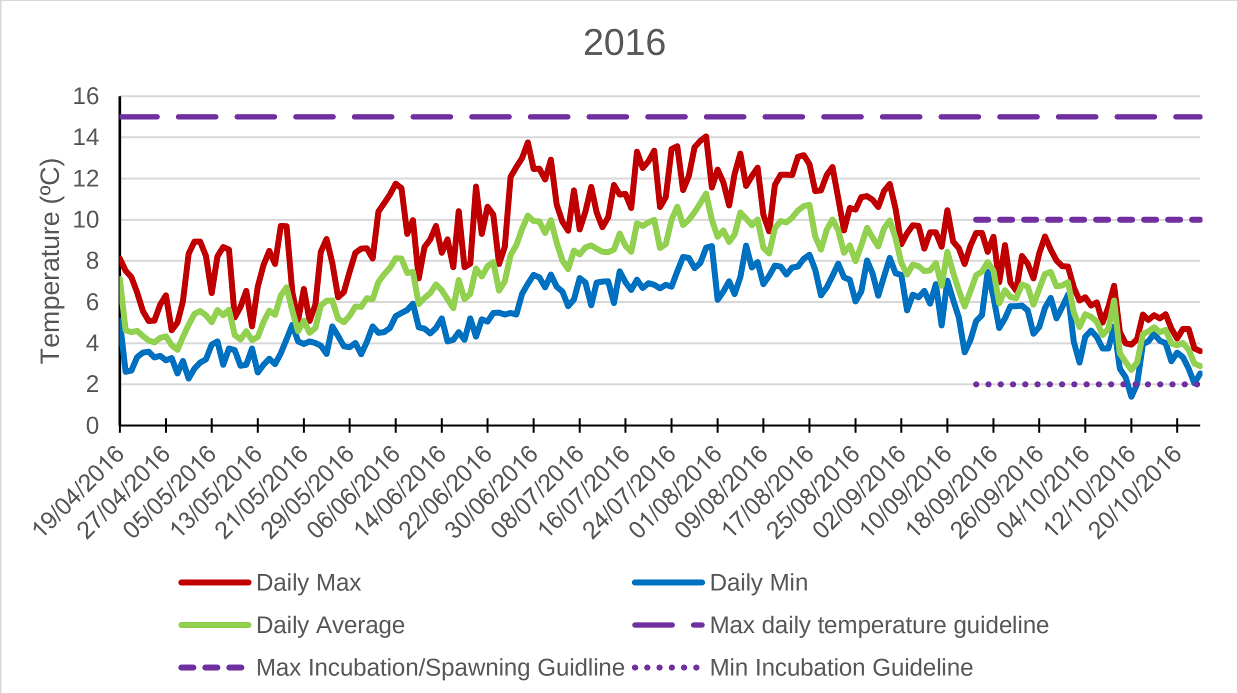

Figure 2. Stream water temperatures in Alexander Creek (site NGALX03) from April 19 to October 22, 2016. The long dashed purple line indicates the BC MoE guideline for aquatic life for streams with Bull Trout present. The short dashes indicate maximum daily temperature during spawning and the dotted line indicates minimum daily water temperature during spawning and incubation.

3 Hydrometric data (velocity and flow)

Stream flows play 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). Hydrometric data on Alexander Creek was collected as both a flow and a velocity. Both measure the amount of water moving past a point. Velocity is the speed of water and is measured as a unit of distance per time. Flow, also known as discharge, measures the volume of water moving through a point in a given amount of time, and is calculated by multiplying water velocity by the cross-sectional area.

The CBWQMP generally aimed to collect instantaneous velocity and flow data monthly from spring through fall. 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 detailed in a long term dataset. This would be best achieved using continuous level loggers and developing level-discharge (flow) relationships. Instantaneous flow measurements at one site cannot be directly related to fish habitat requirements, as water velocity 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 is still important as it shows changes in flow 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.

The results show consistencies in flow patterns between the two years sampled at Alexander Creek. Freshet (i.e. high flows due to snowmelt and/or heavy rain) occurred April – June, followed by decreasing flows and velocity (Figure 3 and Figure 4). In 2016, there was a slight increase in both flow and velocity in October, which may have been caused by precipitation.

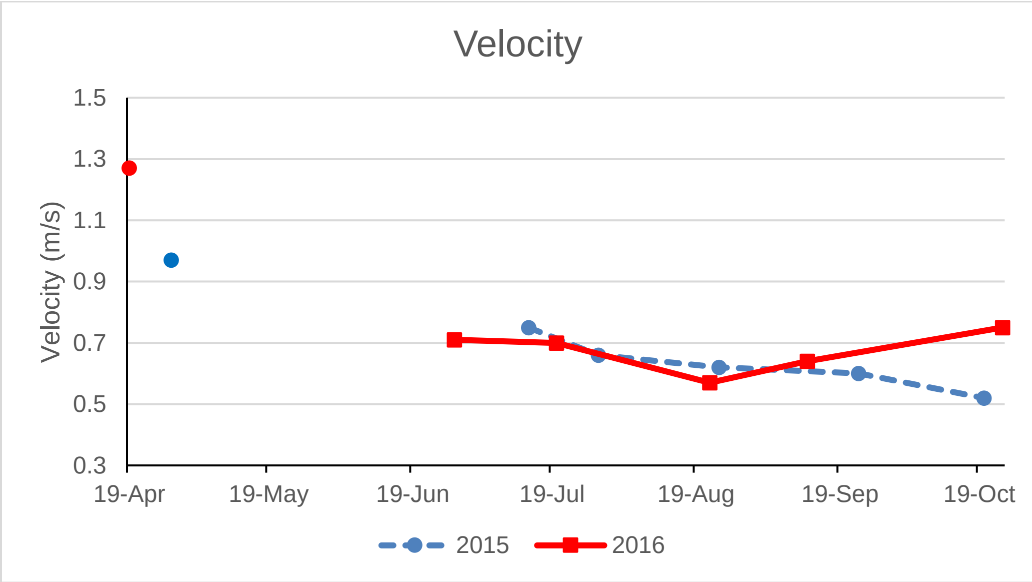

Figure 3. Water velocity at NGALX03 in 2015 and 2016. No measurements were taken in May for both years and in June of 2015 due to safety concerns during high flows.

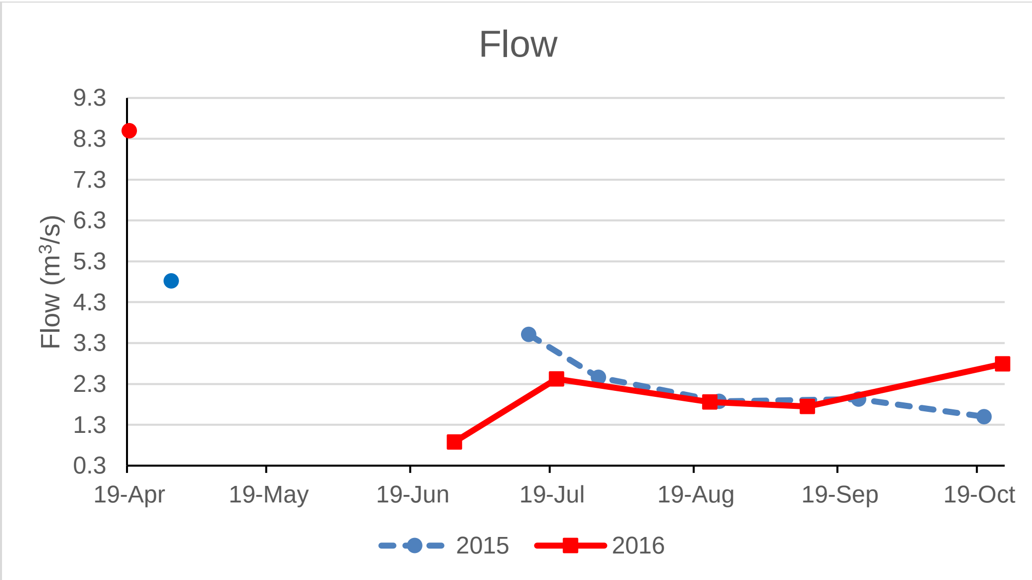

Figure 4. Water flow at NGALX03 in 2015 and 2016. No measurements were taken in May for both years and in June of 2015 due to safety concerns during high flows.

4 CABIN

CABIN data were collected following standard methods in the CABIN Field Protocols Manual (Environment Canada 2012) at NGALX03 in the fall of 2015 and 2016. The CBWQMP completed a RCA analysis on collected CABIN data using the Analytical tools in the CABIN database. Here, we reviewed the CABIN output, and summarized and interpreted the results.

4.1 *Reference Condition Approach: BEAST Analysis and Site Assessment*

The Reference Condition Approach (RCA) in CABIN is used to determine the condition of the benthic invertebrate community at the test sites (as sampled by CBWQMP groups), by comparing each site to a group of reference sites with similar environmental characteristics. The RCA in CABIN determines whether the benthic community at the test sites falls within the normal range of community variability defined by pristine sites, or sites in "reference condition".

The Benthic Assessment of Sediment tool (BEAST) was used to predict sites to a reference group from the preliminary Okanagan-Columbia reference model. BEAST uses a classification analysis that determines 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 include: latitude, longitude, percent of watershed with a gradient <30, percent of watershed with permanent ice cover, and average channel depth (cm).

The reference model used in the RCA analysis was the Preliminary Okanagan-Columbia Reference Model provided in the online CABIN database (Environment Canada 2010). Because the model is still considered preliminary, with some potential data gaps, caution must be exercised when interpreting RCA results. However, CABIN results can be investigated in multiple ways, including by examining the test site's water chemistry, habitat and invertebrate community metrics. These additional assessments are used to supplement ordination assessments, and they provide essential information for evaluating the CABIN model outputs.

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

For Alexander Creek Site 3 (NGALX03), CABIN BEAST analysis determined the highest probability of reference group membership in both 2015 and 2016 was to Group 3 (probabilities found in Table 1). The site was thus compared with Reference Group 3, which includes 17 streams, mostly from the Northern Continental Divide Ecoregion. The average channel depth of Reference Group 3 is 22.5 +/- 10 cm, which is near the test site's average depth of 34.4 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. The CABIN model assessed NGALX03 as unstressed in both 2015 and 2016.

Table 1. 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	Description	2015	2016
NGALX03	Alexander Creek, Site 3	**Unstressed** Group 3; 85.5%	**Unstressed** Group 3; 85.9%

4.2 *RIVPACS Analysis*

River Invertebrate Prediction and Classification System (RIVPACS) ratios were calculated in the Analytics tools section of the CABIN database. RIVPACS is a measure that describes the presence or absence of specific taxa. The RIVPACS ratio determines the ratio of observed taxa at test sites, relative to taxa expected to be present (at a >70% probability) at reference sites. A RIVPACS ratio close to 1.00 indicates that a site is in good condition, as all or most taxa expected were found at the test site. A RIVPACS ratio >1.00 can indicate community enrichment, while a ratio <1.00 can indicate that a benthic community is in poor condition.

The RIVPACS ratio at NGALX03 was 1.05 in both 2015 and 2016. This value indicates good conditions at the test site, with all taxa present that were expected to be present.

4.3 *Community Composition Metrics*

Benthic community composition metrics were calculated in the CABIN database using the Analytical Tools. A collection of measures (metrics) of community richness, abundance, diversity and composition were selected to describe the test site communities and are summarized in the Site Assessment Reports. The following metrics of special interest were reviewed in further detail (Table 2): total abundance; percent composition of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) orders (EPT); percent composition of Chironomidae (midges) taxa; percent composition of the two dominant taxa; and total number of taxa.

Table 2. Summary of select metrics of interest for reference and test sites

Metric	Reference Group 3 (Mean +/- SD)	NGALX03	
		2015	2016
Total abundance	5780 +/- 4895	5212	7100
% EPT taxa	84.9 +/- 14.3	81.7	82.9
% Chironomidae	8.2 +/- 13.6	6.0	9.2
% of 2 dominant taxa	58.9 +/- 10.0	37	45.4
Total number of taxa	17.7 +/- 2.6	20	25

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. The total abundance at NGALX03 (5212 and 7100 organisms, in 2015 and 2016 respectively) was within the reference condition mean (5780 ± 4895 organisms).

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 the test site in 2015 and 2016 (81.7 and 82.9 %, respectively), were similar to the reference group mean (84.9 ±14.3 %). Conversely, the Chironomidae family of insect (non-biting midges), are generally tolerant of pollution. Their percentages were low in both years at the test site (6.0 and 9.2 %), and also similar to the reference mean, further supporting the unstressed determination for the site.

Relative occurrence of the two most abundant taxon is a metric that can relate to impacted streams, since as diversity declines, a few taxa end up dominating the community. Opportunistic taxa that are less particular about where they live replace taxa that require special foods or particular types of physical habitat (Environment Canada 2012b). At this test site, the percent of two dominant taxa (37 and 45.4 %), were actually in lower than the reference site (58.5 ±10 %), indicating a healthy community.

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 disturbance. However, overall biodiversity of a stream typically declines with disturbance (Environment Canada 2012b). Taxa richness at the test site (20 and 25 taxa, respectively) was slightly higher than the reference mean (17.7 ± 2.6 taxa), further supporting the unstressed condition of NGALX03.

5 Conclusions

Overall, the water quality was good at the Alexander Creek Site 3, with only one nominal aquatic life guideline exceedance (total phosphorus). Water temperatures between spring and fall were normal, not exceeding the guidelines for drinking water and the protection of aquatic life. Velocities and flows followed a typical pattern of being high in the spring during freshet and decreasing throughout the summer season in both years measured. These results corresponded with the CABIN model determination of the site being unstressed.

6 Recommendations

Overall, the program you are undertaking is really good for developing a baseline. Three years should provide a good picture of aquatic invertebrate health and water quality, assuming relatively representative years are captured, and there are no change in land-use during the 3 year period. This information will identify if there are water quality or benthic invertebrate changes as a result of a major disturbance. Obtaining data over a longer period, of course, would help provide an understanding of natural variance in the system over time, but we recognize that resources are limited, and a three year period is realistic and achievable. Once baseline data has been attained, sampling should be focussed to locations experiencing ongoing development pressures.

General recommendations for the CBWQMP to consider, to improve the baseline monitoring program are:

1. The current level of flow monitoring is limited to providing context for CABIN and water quality results. However, continuous hydrologic monitoring would provide much more robust datasets to work with. The effort required for this is low, and would involve adding a pressure transducer and developing a rating curve. Additional ideas regarding flow data collection:
   a. In terms of regional assessment, it would be interesting to tie these sites in with Water Survey of Canada data to develop hydrographs over longer time periods. This would allow for an assessment of regional trends, and differences in hydrologic regime between larger areas, etc.
   b. The Water Sustainability Act has a component that is trying to mirror the Alberta Watershed Planning and Advisory Council approach. This is where stewardship actually plays a role in decision making. Because there is relatively little hydrologic monitoring in the province, water licencing in BC could benefit from these data. It could provide a basis for water allocation and for understanding trends (link with regional analysis above).
2. Sample CABIN in triplicate (three sites) in every third year, to get a sense of spatial variability in the stream.
3. It would be good if the duplicate and blank were collected annually at least once, and for all parameters (during the fall), if funding allowed.

Closing

The Elk River Alliance has completed very good monitoring work, which will be a valuable base to measure changes over time. We hope that this review provides useful information to help your organization with understanding the results of your efforts, and planning for future monitoring.

Sincerely,

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