LOTIC ENVIRONMENTAL LTD
2193 MAZUR ROAD
CRANBROOK BC, V1C 6V9
P. 250.421.7802
WWW.LOTIC.CO

East Shore Fresh Water Habitat Society
Box 76, Kootenay Bay, BC
V0B 1X0
c/o Garth Norris (jagnorris@gmail.com)

June 14, 2017

Subject: Columbia Basin Water Quality Monitoring Program, 2015/2016 Crawford Creek - Data Review

Lotic Environmental Ltd. (Lotic Environmental) has completed the review of data collected by the East Shore Fresh Water Habitat Society (ESFHS) at Crawford Creek (NJCRA01), through the Columbia Basin Water Quality Monitoring Project (CBWQMP). This review included analysis of data collected in 2015 and 2016 for the four 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 ESFHS. Lotic Environmental's objective was to conduct a quality assurance/quality control (QA/QC) review 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 ESFHS (See Excel attachment). The following data were collected:

a. Monthly (spring through fall 2015/2016) - nutrients, total suspended solids (TSS), dissolved chloride, *Escherichia coli,* and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), temperature, specific conductivity, pH, turbidity, and air temperature.
b. Annually, in the fall (coinciding with CABIN monitoring) - in addition to data above, inorganics, and metals. However, metals were collected twice in 2015.
c. Once in 2016 - a duplicate and 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 parameter was below the concern level of 50%, indicating a high degree of precision (94%) in data collection and lab procedures.

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 but one field blank parameter analyzed was below the alert level, indicating that 94% of the sample was 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 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 three aquatic life and/or drinking water guidelines. Further details on the exceedances 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] 2017). The pH ranged from 6.1 to 7.91 pH units, and was below the guideline in one sample (May 2016). This value is not concerning as 93% of samples had a pH within the normal range. Also, low pH can occur naturally, and is only a concern if it is influenced by a particular anthropogenic discharge to the watercourse. If there are known discharges 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. Because of the low values, the stewardship group should ensure that their field meter is properly calibrated at the start of each sampling day.

E coli: The E coli drinking water guideline for raw untreated drinking water is 0 CFU/100 mL (BC MoE 2017). E. coli values ranged from <1 to 48 CFU/100 mL, with the guideline exceeded in 75% of samples. The criteria are based on bacteria present in human and animal feces (BC MoE 2017). Drinking water derived from surface water and shallow ground water sources should receive disinfection as a minimum treatment before human consumption (BC MoE 2017).

Total zinc: Zinc ranks fourth among metals of the world in annual consumption, and is found in an array of products (BC MoE 2017). Zinc is an essential element in trace amounts for plants and animals, but can be toxic in high concentrations (BC MoE 2017). Total zinc was 14.7 µg/L on September 28, 2015, exceeding the long-term (average) aquatic life guideline of 7.5 µg/L.

However, this value was considerably lower than the short term (maximum) guideline of 33 µg/L, and the two subsequent samples collected in 2016 were less than detectable levels.

Soluble or dissolved zinc is readily available for biological reactions and therefore considered most toxic (BC MoE 2017). The zinc guideline may also be interpreted in terms of the dissolved metal fraction when the total zinc concentration in the environment exceeds the guideline (BC MoE 2017). For this reason, if zinc is elevated in the future, sampling could include dissolved metal analysis to confirm if there is a potential for concern for aquatic life.

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 M0E 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 known to inhabit Crawford Creek include (BC MoE 2017a):

- Bull Trout (*Salvelinus confluentus*)
- Kokanee (*Oncorhynchus nerka*)
- Rainbow Trout (*Oncorhynchus mykiss*)
- Mountain Whitefish (*Prosopium williamsoni*)
- Prickly Sculpin (*Cottus asper*)

The special guidelines for streams with Bull Trout were used for reviewing the temperature data. In general, stream temperature exceeded the maximum daily temperature of 15 ºC for Bull Trout from mid-July to the end of September 2016 (with a gap in data for mid-August to mid-September; Figure 1). The maximum daily temperature guideline reflects the optimal rearing temperatures for Bull Trout (6.0 ºC – 14 ºC).

Bull Trout spawning generally occurs from mid-September to late October and is often initiated when water temperatures drop below 9 ºC (McPhail 2007). 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. If spawning had occurred, the guideline for minimum temperature during incubation is 2 ºC and maximum spawning/incubation temperatures are 10 ºC. Temperatures in Crawford Creek were below the minimum guideline in late November, and again in December of 2015 and early January of 2016. The stream temperatures also exceeded the maximum daily spawning guideline of 10 ºC in early October of 2015 and again in late September of 2016. The exceedances of the maximum spawning guidelines (especially in September of 2016) may have occurred shortly before Bull Trout spawning was initiated, as spawning usually does not start until temperatures are below 9 ºC (McPhail 2007).

The stream temperatures exceeded the drinking water temperature guideline of 15 ºC in the summer and early fall of 2016. The drinking water guideline is an aesthetic objective. Temperature indirectly affects health and aesthetics through impacts on disinfection, corrosion control and formation of biofilms in the distribution system (Health Canada 2017).

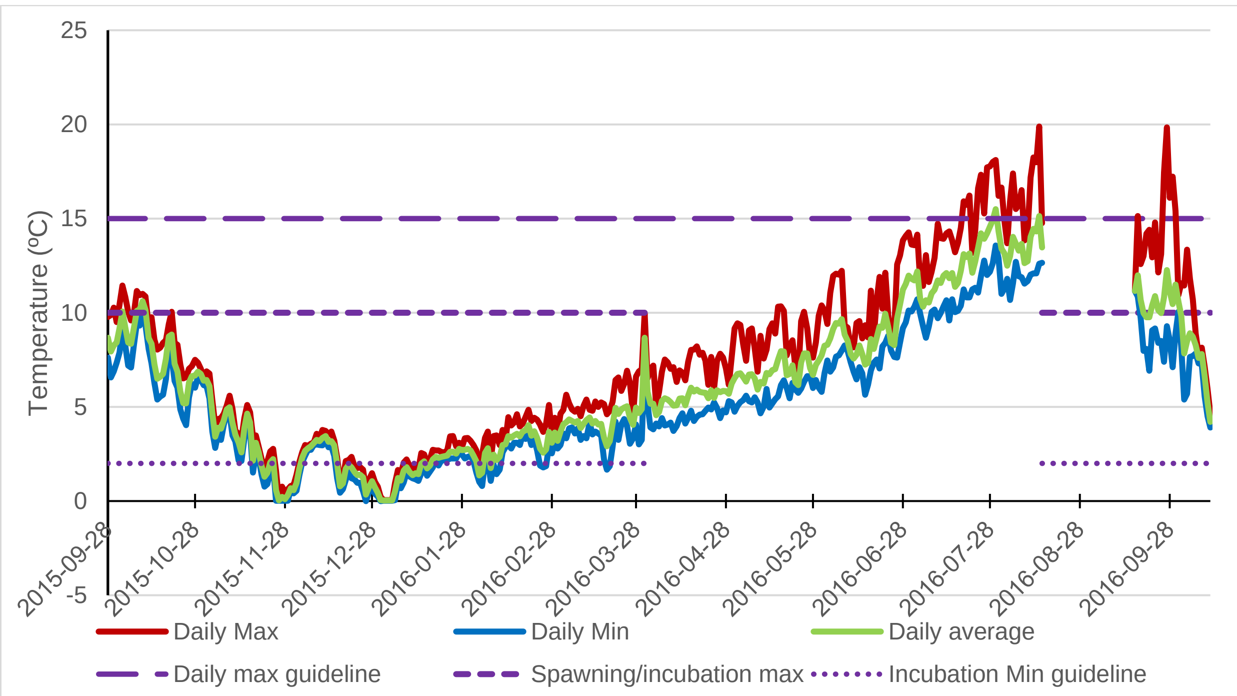

Figure 1. Stream water temperatures in Crawford Creek from September 28, 2015 to October 12, 2016. The logger was pulled out of water from August 16 to September 16, 2016. The long dashed purple line indicates the BC MoE guideline for aquatic life for streams with Bull Trout present. The short dashes indicate maximum daily water 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 Crawford 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 some consistencies in flow patterns between the two years sampled at Crawford Creek in spring/early summer and a diversion in the hydrometric pattern in late summer/early fall. Freshet (i.e. high flows due to snowmelt and/or heavy rain) occurred May – June, followed by decreasing flows and velocity (Figure 2 and Figure 3). In 2016, there was a notable drop in both flow and velocity in September of 2016, before increasing again in October. This dip in flow and velocity may have been a measurement error, as discharge measured during CABIN sampling (see Section 4) on the same day in September of 2016 was actually 2.74 m^3/s (vs. 0.102 m^3/s discharge calculated as part of the monthly hydrometric sampling). The discharge measurement taken during CABIN in 2015 was similar to the discharge (flow) measurement taken that same day as part of the monthly hydrometric sampling (1.6 m^3/s in CABIN vs 1.9 m^3/s during hydrometric sampling).

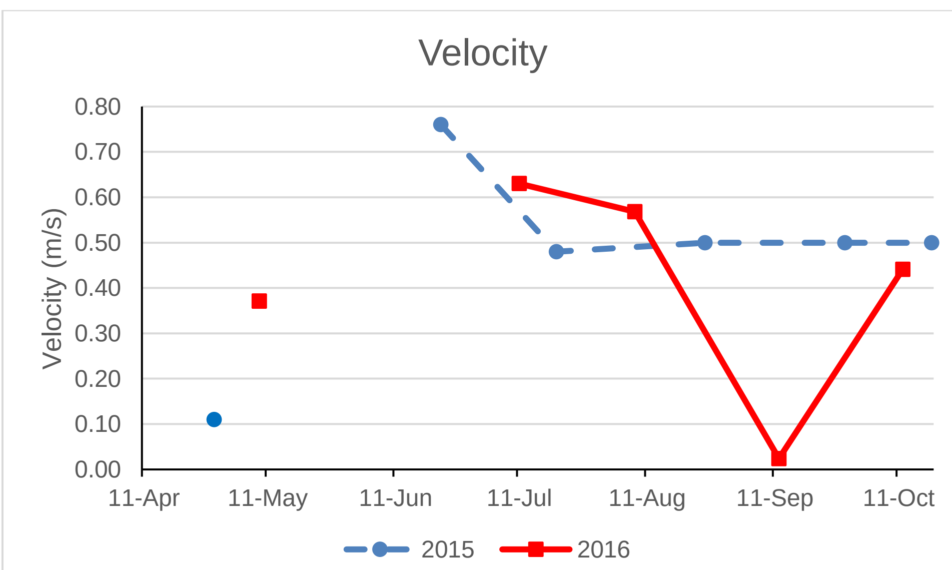

Figure 2. Water velocity at Crawford Creek (NJCRA01) in 2015 and 2016. No measurements were taken in May 2015 and in April and June of 2016 due to safety concerns during high flows

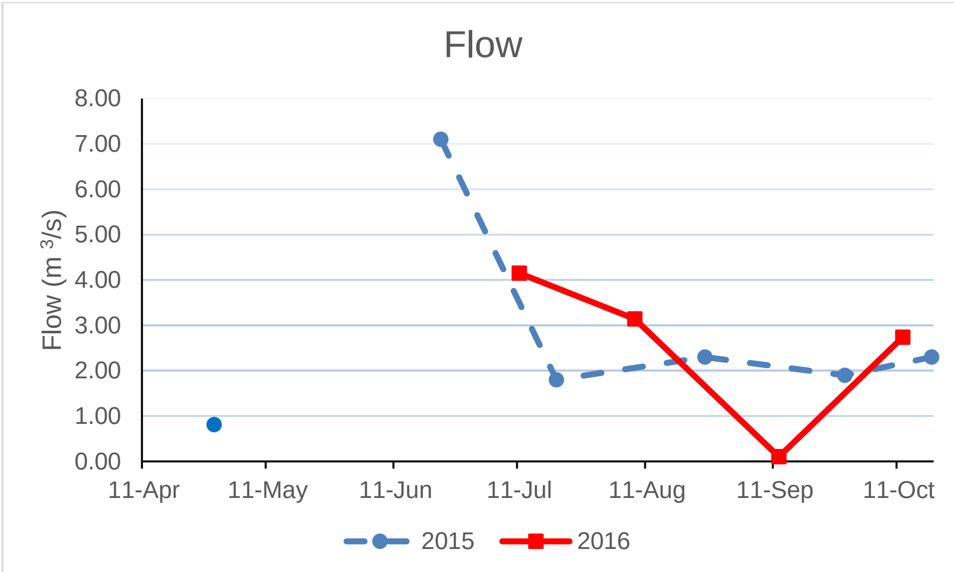

Figure 3. Water flow (discharge) at Crawford Creek (NJCRA01) in 2015 and 2016. No measurements were taken in May of both years and in April – June of 2016 due to safety concerns during high flows.

4 CABIN

CABIN data was collected following standard methods in the CABIN Field Protocols Manual (Environment Canada 2012) at NJCRA01 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. 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 NJCRA01, CABIN BEAST analysis determined the highest probability of reference group membership was to Group 4 in both 2015 and 2016 (probabilities found in Table 1). The site was thus compared with Reference Group 4, which includes 12 streams, mostly from the Columbia Mountain and Highlands Ecoregion. The average channel depth of Reference Group 4 is 23.6 ± 11.1 cm (SD - standard deviation), which is similar to the test sites' average depth of 23.6 cm in 2015. In 2016, the depth appears to have been entered incorrectly as 0.4 cm; if this is corrected, the probability of membership to Group 4 will likely increase. A comparison of other individual test site habitat attributes with the reference model means, and the ordination plots are included in the Site Assessment Reports. The CABIN model assessed NJCRA01, as unstressed in 2015 and potentially stressed in 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
NJCRA01	Crawford Creek, Site 1	**Unstressed** Group 4; 73.6%	**Potentially stressed** Group 4; 68.6%

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 NJCRA01 was 0.80 in both 2015 and 2016. This indicates that most families expected to be present, based on the reference group, were found at the test site. In both years there were three families not present at the test site that were expected.

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 here (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 site

Metric	Reference Group 4 (Mean +/- SD)	NJCRA01	
		2015	2016
Total abundance	587.4 ± 299.1	1282.1	2087.5
% EPT taxa	87.7 ± 7.4	73.0	48.3
% Chironomidae	7.4 ± 6.4	7.8	39.6
% of 2 dominant taxa	57.9 ± 14.2	52.9	75.4
Total number of taxa	19.3 ± 3.7	21.0	21.0

Total abundance of organisms 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 NJCRA01 (1282.1 and 2087.5 organisms, respectively in 2015 and 2016) was higher than the reference group mean (587.4 ± 299.1 organisms). Values were notably higher in 2016, likely influencing the potentially stressed outcome. There was no evidence of nutrient enrichment in the water quality results at the site to cause the high values.

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. The % EPT was similar to the reference group (87.7 ± 7.4 %) in 2015 (73 %), but dropped in 2016 (48.3 %). Chironomidae (non-biting midges) are generally tolerant of pollution. In 2015, there was only a small percentage of Chironomidae at the test site (7.8 %), similar to the reference group mean (7.4 ± 6.4 %). However in 2016, Chironomidae increased at the test site (39.6 %), indicating potential declining conditions in accordance with the CABIN model output of potentially stressed.

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). In 2015, at the test site, the percent of the two dominant taxa (52.9 %) were also similar to the reference group (57.9 ±14.2 %). In 2016, this metric increased (75.4 %), also indicating diminishing conditions.

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 (Environment Canada 2012b). However, overall biodiversity of a stream typically declines with disturbance (Environment Canada 2012b). Taxa richness in both years at the test site (21 taxa) were similar to the reference group (19.3 ± 3.7 taxa), supporting the model outputs.

Overall, total abundance, percent Chironomidae, and percent of 2 dominant taxa metrics support the CABIN model analysis of the site transitioning from unstressed to potentially stressed between 2015 and 2016.

5 Conclusions

Overall, the water quality was fairly good at this site, exceeding two aquatic life guidelines for only a short period (pH one monthly sample in 2016), zinc (one sample in 2015), and one drinking water guideline (E. coli – regularly). As outlined in the results, the guideline exceedances should only be reviewed further if there is concern of anthropogenic influences relating to them in the watershed. Otherwise they may simply represent normal background conditions.

Temperature was measured from late September 2015 to October 2016 with a gap in measurements in the late summer of 2016. Temperatures in the summer and early fall of 2016 regularly exceeded guidelines for the protection of aquatic life. Velocity and flows appeared more variable in 2016 than in 2015, mainly due to a notable drop in both flows and velocity in September of 2016 before increasing again in October. However, it is unclear if this drop was a measurement error, as flows measured during CABIN on the same day were higher.

The CABIN model determined the site to be unstressed in 2015 and potentially stressed in 2016. This was reflected in the poorer invertebrate community composition metrics in 2016 compared to 2015. It is unclear what caused the changes in invertebrate community. Temperatures were higher in the fall of 2016 than 2015; however, continuous temperature data for summer/early fall of 2015 was not measured so an accurate comparison of the thermal regime in the creek between the years is not possible. The change could potentially be related to an increase in discharge (flows) seen during CABIN sampling. In 2015 when CABIN sampling was conducted discharge was 1.6 m^3/s, and in 2016 it was 2.7 m^3/s. However, the large discrepancy in discharge measurements between CABIN and the monthly hydrometric measurements taken in September of 2016 makes the flow results unclear. It could also be the result of other variables not reviewed here, or natural variability in the benthic invertebrate community.

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.

Project specific recommendations for the East Shore Freshwater Habitat Society are to:

- Ensure the calibration of the field meter is checked daily during sampling against known concentrations of pH (calibration solution).
- Update the average depth from 0.4 cm to 30 cm in the CABIN database, if it has not already been done.
- Ensure accuracy in collecting flow and velocity measurements.

Other 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.

7 Closing

The East Shore Fresh Water Habitat Society 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,

Sherri McPherson
Senior Aquatic Ecologist (BSc, RPBio)
250.464.4564
sherri.mcpherson@lotic.co

Kamila Baranowska
Aquatic Biologist, (MSc, RPBio)
705.977.0306
kamila.baranowska@lotic.co

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