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

Lotic Environmental Ltd. (Lotic Environmental) has completed the review of data collected by Wildsight at Birchland Creek sites 1 and 2 (NABIR01 and NABIR02), through the Columbia Basin Water Quality Monitoring Project (CBWQMP). This review included analysis of data collected in 2015 and 2016 for the four main components of the project: 1) water quality data, 2) continual 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 Wildsight. 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 Wildsight (See Excel attachment). Water quality monitoring was conducted at NABIR01 in 2015 and at NABIR02 in 2016. In general, the following data were collected:

a. Monthly 2015/2016 (spring through fall) - nutrients, total suspended solids (TSS), dissolved chloride, and *in situ* (field measured) data. *In situ data* were dissolved oxygen (DO), temperature, specific conductivity, pH, turbidity, and air temperature.
b. In 2015, monthly from May to July at NABIR01 - *Escherichia coli* (E. coli).
c. Once per year - in addition to data above, inorganics, and metals.
d. 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 parameter was below the concern level of 50%, indicating a high degree of precision (93%) in data collection and lab procedures. Although the RPD for turbidity was 109%, 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 are 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 were 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 five aquatic life and/or drinking water guidelines at NABIR01, and all but one guideline at NABIR02. 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). pH at NABIR01 ranged from 8.13 to 9.45 pH units, and exceeded the upper guideline in 37% of samples. The pH at NABIR02 ranged from 8.18 to 9.4 pH units, and exceeded the upper guideline in 29% of samples. These values are not concerning if they reflect background conditions and are not elevated as a result of a particular anthropogenic influence/discharge to the watercourse. However, if there is a discharge into the systems, then pH and carbon dioxide 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 high values, the stewardship group is to ensure that their field meter is properly calibrated each day that it is in use.

Total Phosphorus: The total phosphorus guideline for the protection of aquatic life was not met in one out of the three samples collected at NABIR01. 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 - 0.0192 mg/L at NABIR01, and <0.005 - 0.0103 mg/L at NABIR02. 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 generally supports diverse and abundant aquatic life and is self-sustaining (CCME 2004). Data were evaluated against the site specific guideline, calculated as 1.5 x the upper end of the baseline range, which is equivalent to 0.015 mg/L. The exceedance occurred in June 2015 at NABIR01, with a value of 0.0192 mg/L. 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.

E coli: The E. coli drinking water guideline for raw untreated drinking water is 0 CFU/100 mL (BC MoE 2017). The guideline was exceeded on July 29, 2015 at NABIR01, where the value was 8 CFU/100 mL. The other four monthly samples had E. coli values within the guideline. 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).

Aluminum: Total aluminum at NABIR01 was 69.9 µg/L, whereas the BC Approved long-term dissolved aluminum aquatic life guideline was 50 µg/L (long term). Since only the total fraction was analysed, it is unknown if the long-term guideline, which protects aquatic organisms from the bio-available form, was exceeded. If there is reason to believe that aluminum discharge may be a concern in this waterbody, then it would be prudent to analyse the dissolved metal fraction in the future. The short term/maximum aquatic life guideline for dissolved aluminum (100 µg/L) was met.

Total Iron: Total iron at NABIR01 was 374 µg/L, exceeding the drinking water guideline of 300 µg/L. The guideline is in place for aesthetic reasons, as it is based on taste and staining of laundry and plumbing fixtures; with no evidence of dietary iron toxicity in the general population (Health Canada 2017).

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.

[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).

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.

There was no fish data available for Birchland Creek on Habitat Wizard (BC MoE 2017a). However, the following fish species were found in the Columbia River near (i.e, within 4 km) Birchland Creek, with no known obstacles to fish migration evident between the site and the Columbia River.

- Bull Trout (*Salvelinus confluentus*)
- Rainbow Trout (*Oncorhynchus mykiss*)
- Brook Trout (*Salvelinus fontinalis*)

Since the fish species distribution is not known for Birchland Creek specifically, the temperature guideline for streams with unknown fish distributions was used. This guideline states that the mean weekly maximum temperature (MWMT), defined as the average of the daily maximum temperatures over seven consecutive days, cannot exceed 18 ºC and the maximum daily temperature cannot exceed 19 ºC. Temperatures cannot change by more than 1 ºC per hour. Additionally, maximum daily temperature during times that fish eggs are incubating (i.e. the spring and fall) cannot exceed 12 ºC. Since Bull Trout were found in the vicinity of Birchland Creek, the maximum daily temperature guideline for Bull Trout rearing (15 ºC) was also included in this analysis.

The 2015 data shows very high temperatures in the summer (Figure 1). This may be due to low flows which are known to increase instream temperatures. At low flows, the logger may also have been in very shallow water, or even out of the water completely (and logging air temperatures). If the logger was actually reflecting stream temperatures, then all temperature guidelines were exceeded in the summer months of 2015. The Creek also experienced high temperatures in October of 2015, which exceeded daily maximum and spawning temperature guidelines. Additionally, the large differences between the minimum and maximum daily temperatures in October suggest high temperature fluctuations.

Stream temperature in 2016 were noticeably lower than in 2015 (Figure 2) and did not exceed the daily temperature guidelines for streams with unknown fish distributions, but regularly exceeded the Bull Trout daily maximum temperature guideline 15 ºC. Additionally, the temperatures in early June 2016, during the Westslope Cutthroat and Rainbow Trout spawning seasons, exceeded the maximum daily temperature guideline for incubation in streams with unknown fish distributions.

The stream temperatures exceeded the drinking water temperature guideline of 15 ºC multiple times throughout the summer in both years sampled and in the fall of 2015. 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).

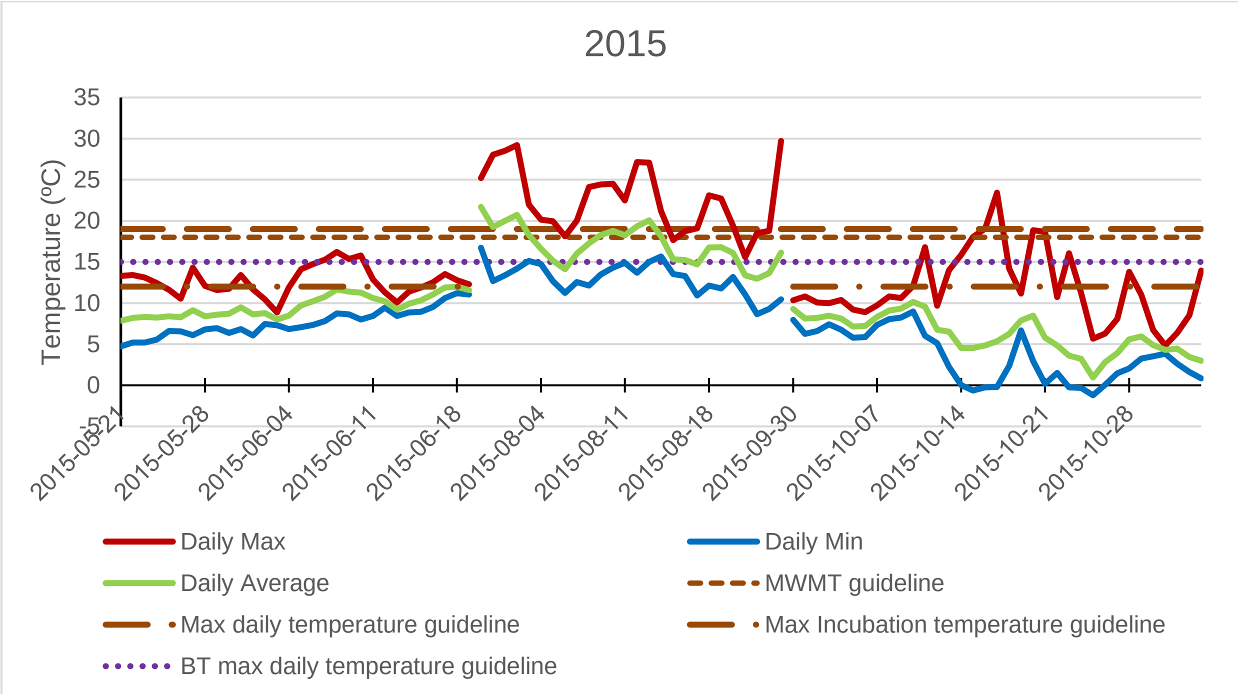

Figure 1. Stream water temperatures in Birchland Creek (site NABIR02) from May 21 to November 3, 2015. Data was missing from June 19 to July 30, and again from August 24 to September 30. The dashed brown lines represent BC MoE temperature guidelines for streams with unknown fish distributions. MWMT = Mean Weekly Maximum Temperature represents the average of the daily maximum temperatures over seven consecutive days. The dotted purple line indicates the BC MoE daily maximum temperature guideline for aquatic life for streams with Bull Trout (BT) present.

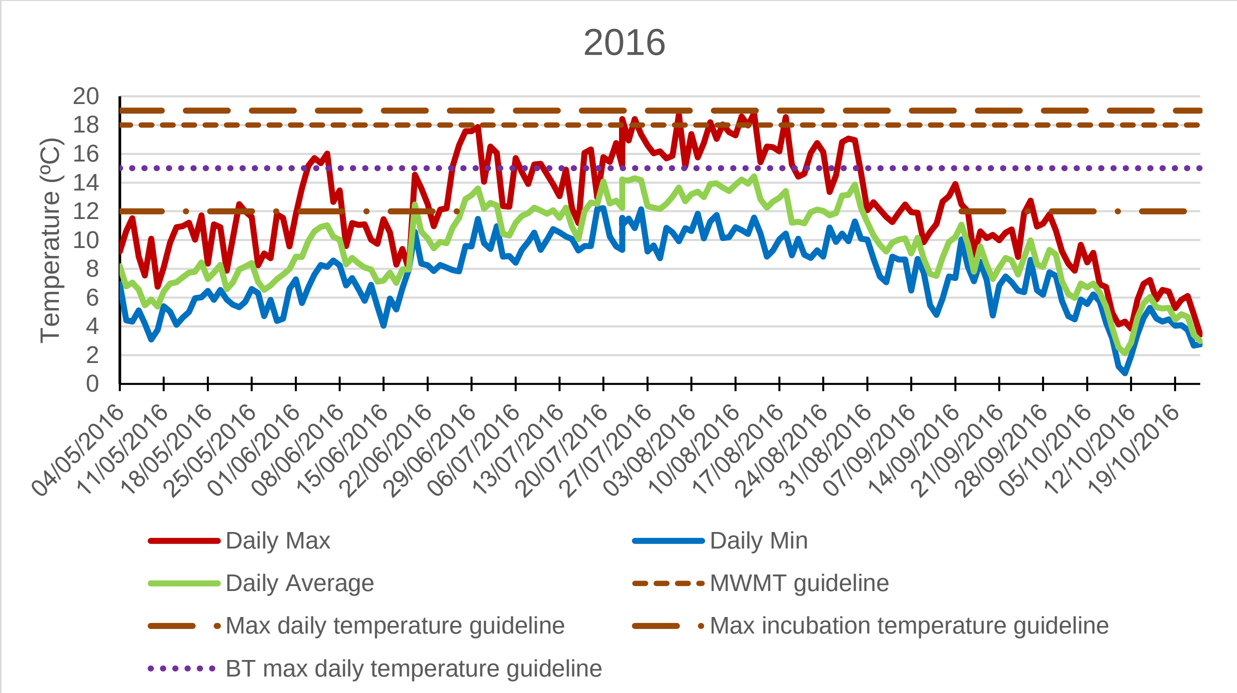

Figure 2. Stream water temperatures in Birchland Creek (site NABIR02) from April 5 to October 23, 2016. The dashed brown lines represent BC MoE temperature guidelines for streams with unknown fish distributions. MWMT = Mean Weekly Maximum Temperature represents the average of the daily maximum temperatures over seven consecutive days. The dotted purple line indicates the BC MoE daily maximum temperature guideline for aquatic life for streams with Bull Trout (BT) present.

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 Birchland 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 the 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 water 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.

Flow/velocity data on Birchland Creek was collected at NABIRO1 in the late April - August 2015 and at NABIRO2 in October 2015, as well as May - October 2016. The results show that 2016 generally had higher flows and velocity. This can also be a result of changing measurement locations, as sites lower in the watershed tend to have higher flows (discharge). However, the October 2015 measurements taken at NABIRO2 still show lower flows and velocity in 2015. May flows were higher in 2015 than 2016, this could be due to an earlier freshet peak in 2016.

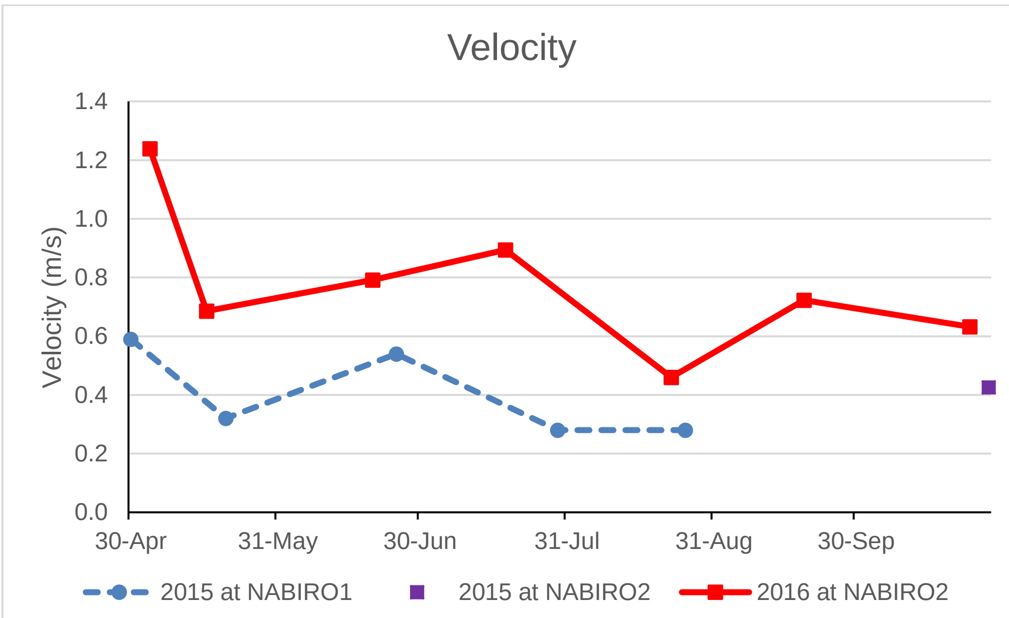

Figure 3. Water velocity at NABIRO1 in 2015 as well as NABIRO2 in October of 2015 and spring-fall of 2016. No measurements were taken in May for both years and in June of 2015 due to safety concerns during high flows.

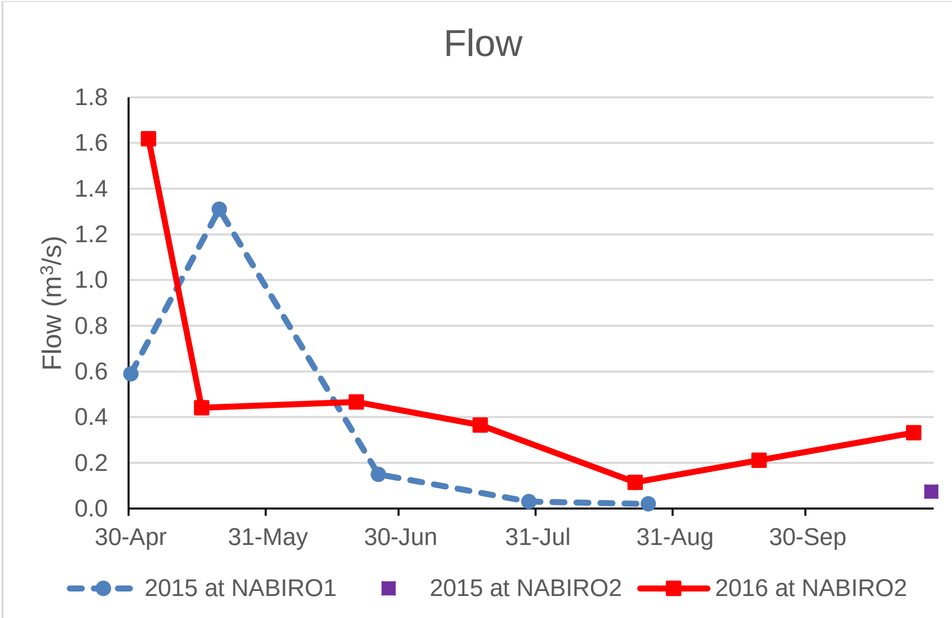

Figure 4. Water flow (discharge) at NABIRO1 in 2015 as well as NABIRO2 in October of 2015 and spring-fall of 2016.

4 CABIN

CABIN data was collected following standard methods in the CABIN Field Protocols Manual (Environment Canada 2012) at NABIR02 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).

CABIN sampling was conducted at NABIR02, in both 2015 and 2016. CABIN sampling was not completed at NABIR01. This is because the substrate was sandy and Wildsight was advised by Stephanie Strachan (Environmental Monitoring Scientist, Environment & Climate Change Canada) that that they would not be able to use the data for comparison with the Columbia CABIN model. However, Wildsight collected water samples at the lower site (NABIR01) in October 2015.

For NABIR02, CABIN BEAST analysis determined the highest probability of reference group membership was to Group 5 in both 2015 and 2016 (probabilities found in Table 1). The site was thus compared with Reference Group 5, which includes 33 streams, mostly from the Columbia Mountain and Highlands and Western Continental Ranges ecoregions. The average channel depth of Reference Group 5 is 21.5 +/- 9.7 cm (SD - standard deviation), which is higher than the test site's average depth of 7 cm. 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 NABIR02, as potentially stressed in 2015 and unstressed 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
NABIR02	Birchland Creek, Site 2	**Potentially stressed** Group 5; 72.5%	**Unstressed** Group 5; 72.5%

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 NABIR02 was 0.63 in 2015 and 0.94 in 2016. These values support the model results above, indicating improvement in the invertebrate community from 2015 to 2016. In 2015 there were four families that were not present at the test site that were expected based on the reference group; while in 2016, only one family of taxa was not present that was 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 (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 5 (Mean +/- SD)	NABIR02	
		2015	2016
Total abundance	2163.6 ± 1274.4	1631.8	2285.7
% EPT taxa	93.7 ± 5.3	99.4	95.0
% Chironomidae	4.6 ± 5.0	0.0	3.4
% of 2 dominant taxa	60.2 ± 11.4	89.7	62.4
Total number of taxa	16.0 ± 3.0	10	16

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 NABIR02 was lower in 2015 (1631.8 organisms) than in 2016 (2285.7 organisms); these values were within the reference group mean (2163.6 ± 1274.4 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. The % EPT was high in both years at the test site, with values similar to that of the reference site. Chironomidae (non-biting midges), are generally tolerant of pollution. There were no Chironomidae at the test site in 2015, and only a small percentage in 2016 (3.4 %), in accordance with the low reference group mean (4.6 ± 5.0 %).

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 the two dominant taxa decreased over time (89.7 % to 62.4 %), indicating an improvement, in accordance with the model output.

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 at the test site also improved over the study period (from 10 - 16 taxa), further supporting the model outputs of potentially stressed in 2015 and unstressed in 2016.

5 Conclusions

Overall, the water quality was good at this site exceeding two drinking water guidelines and three aquatic life parameters. 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. Instream temperatures in 2015 were high and regularly exceeded temperature guidelines for the protection of aquatic life and drinking water. On the other hand, temperatures in 2016 were lower and only exceeded spawning temperature guidelines in June, as well as daily temperature guidelines for Bull Trout in the summer. Temperatures in 2016 did not exceed daily or weekly maximum temperatures for streams with unknown fish distributions, which is what Birchland Creek was considered to be. The higher temperatures in 2015 may be reflective of the low flows in 2015 compared to 2016. These results correspond with the CABIN model determination of the site being potentially stressed in 2015 and unstressed in 2016.

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.

A few project specific recommendations for Wildsight are to:

1. Ensure the calibration of the field meter is checked daily during sampling against known concentrations of pH (calibration solution).
2. Analyse the dissolved fraction of aluminum, if there is reason to believe that aluminum discharge may be occurring, to confirm if there is a potential for impacts on aquatic life.
3. Update water quality data entered into the CABIN database for accuracy in units. In particular, we noted that 2016 NABIR02 metal results were entered as µg/L (as provided by the lab), and that most should have been converted to mg/L.

4. Check that the temperature loggers are installed in a location that is representative of the reach in terms of flow, depth, and shade (i.e. riparian cover).
5. Ensure the site selection is suitable for the full complement of the water quality monitoring program. Since NABIR01 was too sandy, CABIN analysis was not conducted, as the CABIN model would not be applicable. If such sites require monitoring, it is possible to conduct CABIN monitoring, whereby the model portion would be omitted, but community composition metrics could be included and available as the baseline.

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

Wildsight 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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