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

Lotic Environmental Ltd. (Lotic Environmental) has completed the review of data collected by Wildsight and the Lake Windermere Ambassadors at Windermere Creek Site 3 (NAWIN03) through the Columbia Basin Water Quality Monitoring Project (CBWQMP). This review included analysis of data collected in 2015 - 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 Bio Monitoring 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 and sediment quality

Water quality data had been transposed into the master spreadsheet by the CBWQMP (see Excel attachment). Generally, the following data were collected in 2015/16:

a. Monthly (spring through fall) - total suspended solids (TSS), nutrients, *Escherichia coli* (e. 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 summer and fall) - in addition to data above, inorganics and metals.
c. Once in 2016 - a duplicate and a blank sample.

Sediment quality data was not collected.

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 two parameters (86%) were below the alert level of 50%, indicating a high degree of precision in data collection and lab procedures. Turbidity was one of these parameters; however, 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.

A water quality field blank was 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 data (94%) 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 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 making updating threshold values, where applicable, and streamline 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 were generally good at NAWIN03. All but four parameters met the aquatic life and/or drinking water guidelines. Three of these only failed to meet the guideline only once each. Details of 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 NAWIN03 ranged from 8.1 to 9 pH units, and exceeded the upper guideline in one sample. This value is not concerning as it was an isolated reading. Additionally, the geology of the watershed lends itself to having an elevated pH. There is a gypsum mine in the watershed, and the rock has a lot of limestone in it, which is on the basic end of the scale.

Dissolved oxygen: DO ranged from 5.5 – 13 mg/L. The BC Approved water quality guideline for aquatic life to protect all fish life stages other than buried embryo /alevin, is a minimum of 8 mg/L, as a long-term average. This guideline was not met in one sample, collected on November 2, 2015. However, this value is not concerning as it was an isolated reading, and the instantaneous minimum of 5 mg/L was met. However, if there is a known human caused reason for the reduced DO, then the parameter should be monitored more thoroughly in accordance with the BC guidelines to ensure there are no impacts on the aquatic environment. The stewardship group is reminded to ensure that their field meter is properly calibrated each day that it is in use. Also, if the DO probe is the type that consumes oxygen at the membrane (not an optic probe), then the probe is to be gently swayed through the water column when sampling in a standing water environment.

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 - 0.0187 mg/L at NAWIN03. 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 on June 8, 2015. The elevated value occurred during the spring freshet period when nutrient loading into a watercourse is anticipated as a result of 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). E. coli ranged from <1 - 39 CFU/100 mL, with the guideline exceeded in all 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).

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

[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).

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

- Bull Trout (*Salvelinus confluentus*)
- Westslope Cutthroat Trout (*Oncorhynchus clarkia lewisi*)
- Rainbow Trout (*Oncorhynchus mykiss*)
- Brook Trout (*Salvelinus fontinalis*)
- Burbot (*Lota lota*)
- Kokanee (*Oncorhynchus nerka*)
- Mountain Whitefish (*Prosopium williamsoni*)
- Mottled Sculpin (*Cottus bairdii*)
- Slimy Sculpin (*Cottus cognatus*)
- Spoonhead Sculpin (*Cottus ricei*)

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 except on four occasions in late June/July, when the temperature exceeded the guideline by less than 1 ºC (Figure 1). The maximum daily temperature guideline reflects the optimal rearing temperatures for Bull Trout (6.0 ºC – 14 ºC). The water temperatures did not exceed optimal Westslope Cutthroat rearing temperatures (7 ºC – 16 ºC) or Burbot (15.6 – 18.3 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 Windermere Creek did not exceed optimal spawning temperature guidelines (i.e. a max daily temperature of 10 ºC), except briefly in early fall and in early October. However, these increases may have occurred prior to the initiation of spawning in the creek (when temperatures regularly drop below 9 ºC). Moreover, 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. 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 Windermere Creek dropped below this guideline in late November.

The stream temperatures did not exceed the drinking water temperature guideline of 15 ºC, except for the two days in July when temperatures exceeded the guideline by less than 1 ºC. 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).

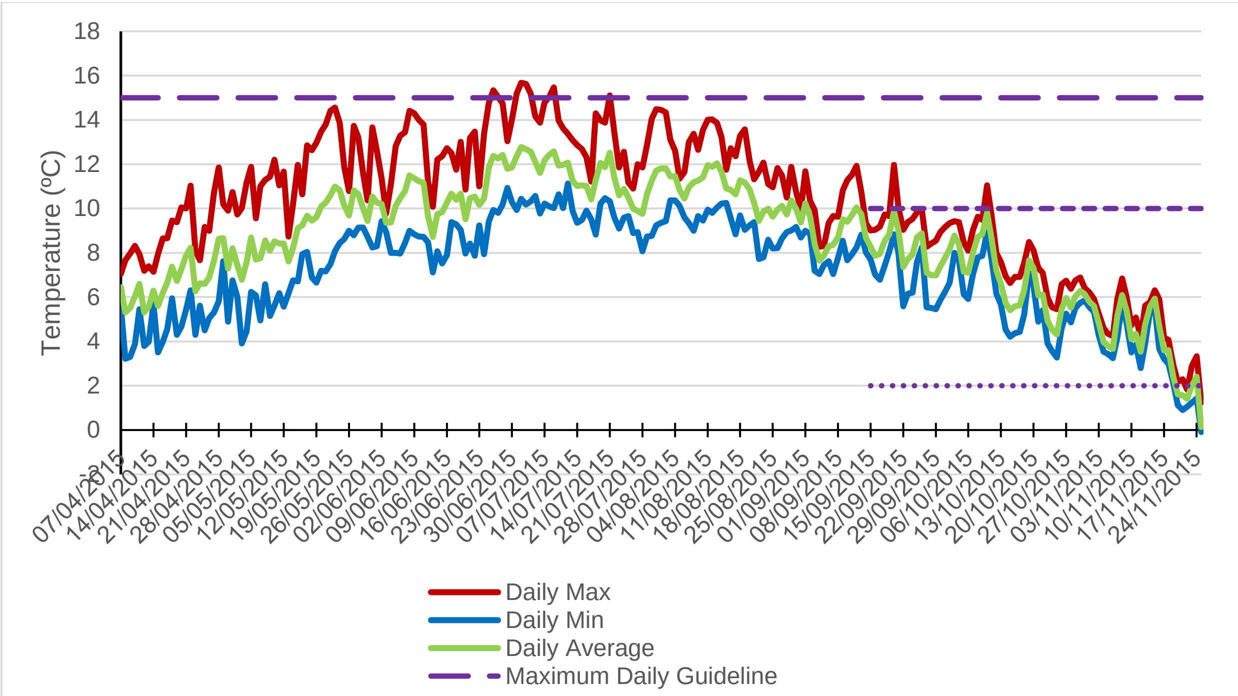

Figure 1. Stream water temperatures in Windermere Creek (site NAWIN03) from April 7 to November 25, 2015. The long dashed purple line indicates the BC MOE guideline for aquatic life for streams with Bull Trout present. The short dashes indicate maximum daily temperature during spawning, and the dotted 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 Windermere Creek was collected monthly from spring through fall, as both a velocity and a flow (Figure 2, Figure 3). 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.

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 2015/16 hydrometric data only shows a slight freshet period (i.e. high flows due to snowmelt and/or heavy rain). This is likely due to a high dominance of groundwater inflows (MacDonald and Berzins 2009), and the construction of an inlet catch basin/drain system as part of restoration projects on the creek (Crowley 1998). Hydrometric data was not collected in September – October of 2016. The available data from 2015 and 2016 show little variation in the data between months and a similar pattern for flow/velocity between years.

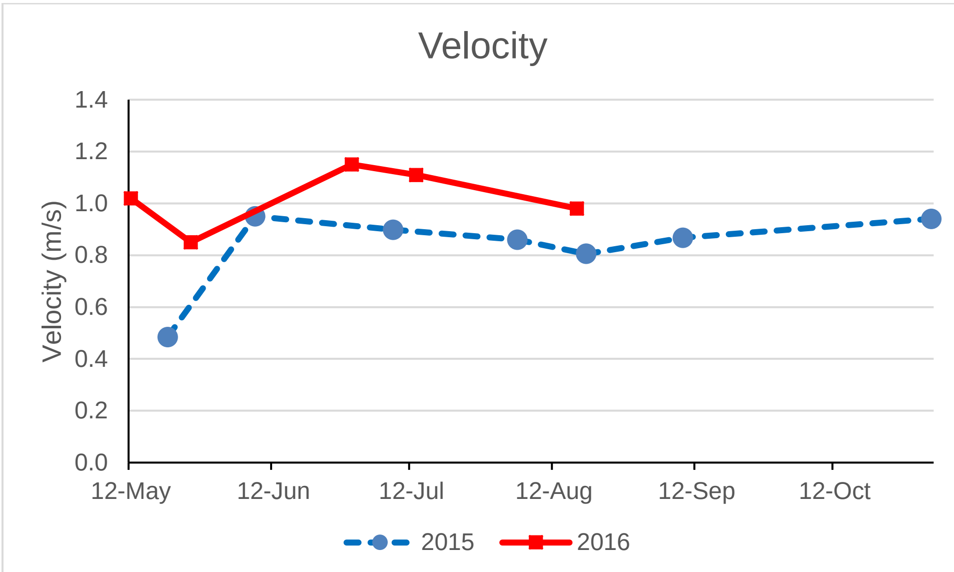

Figure 2. Water velocity at NAWIN03 in 2015 and 2016.

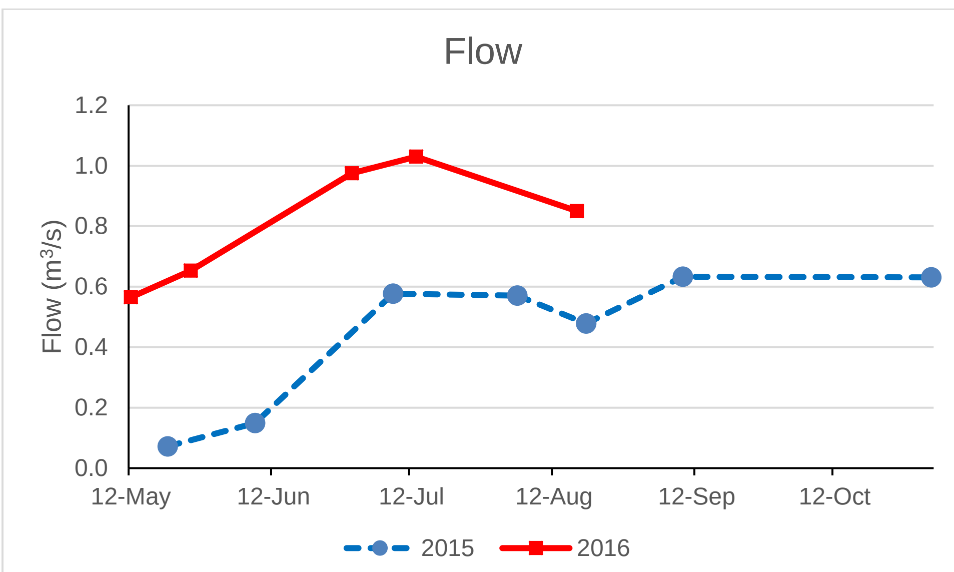

Figure 3. Water flow at NAWIN03 in 2015 and 2016.

4 CABIN

CABIN data were collected following standard methods in the CABIN Field Protocols Manual (Environment Canada 2012) at NAWIN03 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 NAWIN03 in both 2015 and 2016, CABIN BEAST analysis determined the highest probability of reference group membership 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 depths of 22.8 cm (2015) and 21.1 cm (2016) 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 NAWIN03 as potentially stressed in 2015 and severely stressed in 2016. Below, we will explore the CABIN outputs more, to try gain a better understanding of why the site was given this assessment.

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
NAWIN03	Windermere Creek, Site 3	**Potentially Stressed** Group 3; 35.5%	**Severely stressed** Group 3; 35.6%

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 NAWIN03 was 0.83 in 2015 and 0.94 in 2016. This is a quite good, as it indicates that most families of taxa were present that were expected based on the reference group in both years. In 2015, there were two families not present at the test site, while in 2016, there was only one absent.

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)	NAWIN03	
		2015	**2016**
Total abundance	5780 ± 4895	1171.4	202.0
% EPT taxa	84.9 ± 14.3	68.3	70.8
% Chironomidae	8.2 ± 13.6	24.1	5.9
% of 2 dominant taxa	58.9 ± 10.0	53.4	45.5
Total number of taxa	17.7 ± 2.6	17	18

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 NAWIN03 dropped substantially between 2015 and 2016 (1171.4 organisms and 202.0 organisms, respectively). The 2016 value was substantially below the reference group mean (5780 ± 4895 organisms), and appears to be the key determiner of the severely stressed rating in 2016. However, water quality does not appear to be related to this change (i.e., metals were not high in either year relative to guidelines).

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. At the test site, percent EPT was similar in both 2015 and 2016 (68.3 % and 70.8 %, respectively). Both values were close to the reference group mean of 84.9 ± 14.3 %. Conversely, the Chironomidae family of insect (non-biting midges) are generally tolerant of pollution. Chironomidae contributed to the community less in 2016 (5.9 % versus 24.1 % in 2015). Both values were within the reference group mean (8.2 ± 13.6 %). The higher percent EPT and lower percent Chironomidae in 2016, indicates an improvement.

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 were similar between the years (53.4 % and 45.5 %, respectively in 2015 and 2016), and were close to the reference group mean (58.9 ± 10 %). The slight drop in 2016, indicates an improvement.

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 was similar in 2015 and 2016 (17 taxa and 18 taxa, respectively). These values were also both similar reference mean (17.7 ± 2.6 taxa), indicating good conditions.

5 Conclusions

Overall, the water quality was good at this site, with three guidelines for the protection of aquatic life (pH, total phosphorus, and dissolved oxygen) incidentally not being met, and one drinking water guideline not being met (albeit this was for *E. coli*, which is normal to be naturally influenced). Water temperature data was collected in 2015 and did not exceed guidelines for the protection of aquatic life or drinking water guidelines except for two occasions in July when temperatures exceeded the guideline by less than 1 ºC. Flow and velocity data shows that this is a groundwater fed stream with little variation between months and years.

Overall, the very low total abundance of benthic invertebrates in 2016 appears to be the key reason the site went from being assessed as potentially stressed in 2015 to severely stressed in 2016. It is not certain what led to the low abundance. A simple comparison of the physical habitat descriptors did not show any obvious changes between the years that would reduce abundance. For example, the depths and velocities, the percent of fine substrates (sand, and silt and clay), and turbidity were similar between the years. Embeddedness even showed an improvement, going from a score of 3 (1/2 embedded) to a score of 4 (1/4 embedded). The particle size that 50% of the pebble count samples were equal to or smaller than (D50) increased from 1.8 cm to 3.5 cm between the years, but the reference group mean is also variable (79.45 ± 47.98 cm). Perhaps, Wildsight has some knowledge of an influence not evident here. Without another explanation, it is possible that the results relate to changes in sampler techniques between the years. The 2017 results will be very interesting to see.

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.

One project specific recommendation for Wildsight is to:

1. Ensure the calibration of the field meter is checked daily during sampling, against known concentrations of pH (calibration solution), and DO.

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.

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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