Appendix C: Coldstream Creek EFN Memo

This document is meant as a component of a larger more comprehensive EFN assessment for Coldstream Creek as well as other streams as a part of the Okanagan EFN. Background information, discussion, recommendations and conclusions have not been included as they will be completed separately.

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Field Work completed by: Okanagan Nation Alliance

Limitations

This preliminary assessment does not represent a complete detailed habitat based EFN assessment described in Lewis et al. (2004) and Hatfield et al. (2003) for several important reasons;

1) **The change in fish habitat over the entire stream or reach was not calculated for different management scenarios**. While this data is important, the purpose of this document was to provide an initial Environmental Flow Need for the creek, rather than a comprehensive assessment of the habitat losses or gains at different flows

2) **Pools were not sampled as a meta-habitat unit**. Pools are unquestionably vital to the long-term maintenance of healthy fish populations, however, they tend to be less sensitive to flow manipulation. Rather than including pools, which could provide an underestimate of true impacts, additional focus was placed on riffles for food production and fish passage and glides for spawning habitat quality. The reasoning behind this is successful management of the most flow sensitive habitats will ensure the proper functioning of less flow sensitive habitat habitats (Bovee 1974).

3) **This assessment included only 8 transects rather than the recommended 19, or more (Payne et al. 2004).** These limitations add uncertainty to the results which may be treated as a best estimate, however, it this modification was necessary due to limited time and resources to complete the project.

Empirical modelling requires that certain simplifying assumptions be made. In regards to the assumptions made to produce the hydraulic model for Coldstream Creek please refer to the Jowett et al. (2014).

4) **This assessment included one detailed sampling visit and one calibration visit, rather than the two calibration visits recommended by the System for Environmental Flow Analysis (SEFA) software.**

Methodology

Instream Habitat Assessment

Transect selection for detailed sampling

Recognizing that the Coldstream Creek EFN assessment represents a preliminary assessment, the project team selected 4 different sampling locations. Each sampling location provided an opportunity to evaluate a representative riffle and glide, which are defined in Table C1. Pools were not measured in this assessment, please refer to limitations section for justification. Generally speaking the selected sites were selected as they were;

1) Safely accessible under a variety of flows;
2) Representative of available habitat; and
3) Inclusive of habitat types with high or important fish habitat values.

Table C1: Mesohabitat units and descriptions

MesohabitatUnit	Description
Riffle	Elevated areas in the streambed profile, composed of coarser bed elements, shallow depth, higher gradient, higher velocity, turbulent surface, substrate potentially exposed
Pool	Depressions in streambed profile, may contain fine sediments, generally smooth water surface elevation controlled downstream with backwater effects, greater depth, lower velocity
Glide	Typically an area of laminar flow, less downstream control of water surface elevation, low to intermediate gradient, generally uniform shallow depth and higher velocity. May be turbulent if large substrate is present within channel

Bench Marking

Once selected each transect was surveyed. This first step of this process involved the establishment of local bench marks at each of the riffle/glide sampling location. The first benchmark functioned as an elevation control point and was used to calculate the height of the instrument (level), while the second bench mark provided confirmation that the first bench mark has not been disturbed and ensured continuity in the event that the first benchmark is disturbed. Due to the lack of geodetic monuments close to the creek the first benchmarks was given an assumed datum of 100.000m.

Survey Pins

Once a suitable location for a transect location was determined, transects were permanently marked by installing survey pins on the left and right banks of the creek. These pins were installed at or above the elevation of the active channel to ensure that they were accessible under typical high flows. These pins were used as consistent points to secure the measuring tape across the stream during all transect measurements.

Detailed Habitat Transect Assessments

Detailed transect surveys were conducted once at each of the selected transects. To the greatest extent possible the detailed transects were collected during periods where flows were close to the estimated mean annual flows in the system.

General Data Collected

At the beginning of the survey, general information about the site and the sample crew is recorded on the top of the field form. This included comments about the sampling conditions, weather conditions as well as a visual assessment of the flow regime at the time of the sampling. Some examples of flow regimes could include:

Flood: Water surface above the level of the stream banks

High: Water surface at or near the top of the stream banks

Moderate: Some exposed adjacent or mid channel sediment bars evident in the channel

Low: Abundant exposed sediment bars comprising >50% of stream channel

Each transect was sampled during a period of stable discharge where the discharge is known with a good level of confidence (i.e. by measuring a velocity-depth transect at a section that has very homogenous depth and velocity characteristics).

Transect Surveying

Surveying during the detailed transect survey involved setting up the survey level and calculating the instrument height relative to the primary benchmarks. In situations where geodetic reference monuments are not available, the elevation of the primary benchmark was, by convention, arbitrarily set at 100.000 meters. Once the instrument height was established, the elevations of both the left and right bank pins were surveyed and the results recorded on the field form along with the instrument height.

The cross section of the channel profile was carefully surveyed at each transect of the assessment. For consistency the survey crew began the survey by measuring the elevation on the top and at the ground level of the left bank pin. The survey then preceded to take detailed elevation measurements across the channel profile at predetermined distances (offset) from the left bank pin, moving across the section, i.e. travelling downslope on the left bank, across the wetted channel and up the right bank. The final profile measurements were gathered at the top and ground level elevations at the right bank pin. During this survey, the crew made special note of the elevation and transverse location of both the left bank wetted edge (LBWE) and the right bank wetted edge (RBWE) and recorded the information on the field form.

Outside the wetted perimeter, the distance between offsets was selected somewhat arbitrarily; however, it was important to include enough resolution to depict the shape of the bank, as well as, any notable elevation changes that may be associated with channel morphology features (e.g. elevated side channels). Inside the wetted perimeter, a minimum of 20 equally spaced bed elevations were measured; this captured the entire channel width and any notable elevation breaks that are associated with large substrate or natural channel morphology. This number of paired bed elevation, water depth and water velocity measurements was necessary to get an accurate stream discharge measurement, as well as, accurate velocity resolution across the section.

Velocity Measurements

Following the elevation survey, instream velocity measurements were measured in the wetted channel. Flow velocity was measured at the same locations where elevations were collected. In water less than 0.75 meters deep, the average velocity was measured at 60% of the total depth (i.e. 40% of the distance from the stream bed), this was the situation with all measurements made in Coldstream Creek. For this assessment, velocity measurements were recorded using a SonTek Flowtracker 2 in glides, and a Swoffer Current Velocity Meter (model 2100) in riffles.

Substrate Observations

Measurements of substrate size were collected along the same locations as the elevation, depth, and velocity measurements. The dominant substrate (within a 0.5 m^2 patch centered on the vertical) at each location was measured along the B-axis and recorded under the corresponding Substrate Class (Table C2).

Table C2. Substrate class sizes

Substrate Class	Intermediate axis width
Fines	<2 mm
Small Gravels	2 to 16 mm
Large Gravels	16 to 64 mm
Small Cobble	64 to 128 mm
Large Cobble	128 to 256 mm
Boulders	256 to 4,000 mm
Bedrock	>4,000 mm

Water Surface Elevation (WSEL)

The final step of the detailed transect assessment involved surveying the water surface elevation across the channel. Surveyors attempted to survey and record 6 evenly spaced WSEL measurements and record the offset location and elevation on the data sheet.

Repeat Habitat Transect Assessment

Repeat habitat transect assessments were conducted on one occasion subsequent to the detailed transect assessments. These habitat transects were conducted at flows below the estimated Long Term Mean Annual Discharge (LTMAD), while flows were approximately 53% of LTMAD.

The repeat habitat transect assessments involved the collection of general information from the site, re-surveying the bench marks, transect pins and the water surface elevation. In lieu of measuring the discharge at each individual transect, the discharge measurements collected at the hydrometric monitoring location in the relevant reach will be used as the model input. For the Coldstream Creek study, discharge was measured at the glide transect for each riffle-glide pair.

Environmental Flow Needs modelling

The collected data was analyzed using the System for Environmental Flow Analysis (SEFA) software (Aquatic Habitat Analysis Inc. 2012). This software is analogous to PHABSIM in basic function and was designed to implement the Instream Flow Incremental Methodology developed by the Instream Flow Group of the U.S. Fish and wildlife Service. The software links together several sub-models to predict how available instream habitat (and, by inference, capacity for target fish populations) changes with flow. For this analysis, the principle submodels that will be used include a:

- One-dimensional hydraulic analysis module,
- Habitat suitability analysis model, and
- Time series hydrologic analysis model.

In regards to the inputs for this model, the one dimensional hydraulic analysis module was populated with the data collected during the habitat transect assessments. The habitat suitability values, which are pre-established habitat preferences scores based on observed use of different stream depths and velocities by the target fish species, were agreed to by representatives of the Okanagan EFN project team and are presented in Figure C2. Finally, the time series hydrologic data came from the hydrologic measurements collected between 2016 and 2019 at station 08NM589 in Coldstream Creek.

Riffle Analysis

Riffles represent a dynamic and potentially limiting habitat type. Riffles are an important source of Benthic Macro Invertebrate (BMI) productivity for downstream habitat (Rosenfeld & Hudson 1997; Naman et al. 2017). By nature, these relatively shallow and wide features will also be the first to exhibit any negative impacts that might occur due to low flows conditions (Ptolemy & Lewis 2002), which would place BMI productivity in jeopardy. In addition to being a flow sensitive source of instream productivity, riffles exhibit features that may limit fish migration on streams that are not otherwise obstructed. The objective of riffle analysis is to ensure protection to these sensitive and important pieces of aquatic habitat and, by extension, ensure that other less flow sensitive habitat types remain healthy and productive (Bovee 1974).

For this assessment, we evaluate the productive capacity of the riffles by modelling the changes in the wetted width of riffles (Figure C3). This prediction is compared against established BMI habitat suitability curves (Figure C1) to assess how the benthic macroinvertebrate habitat, and by extension stream productivity changed at different flows (Figure C4)

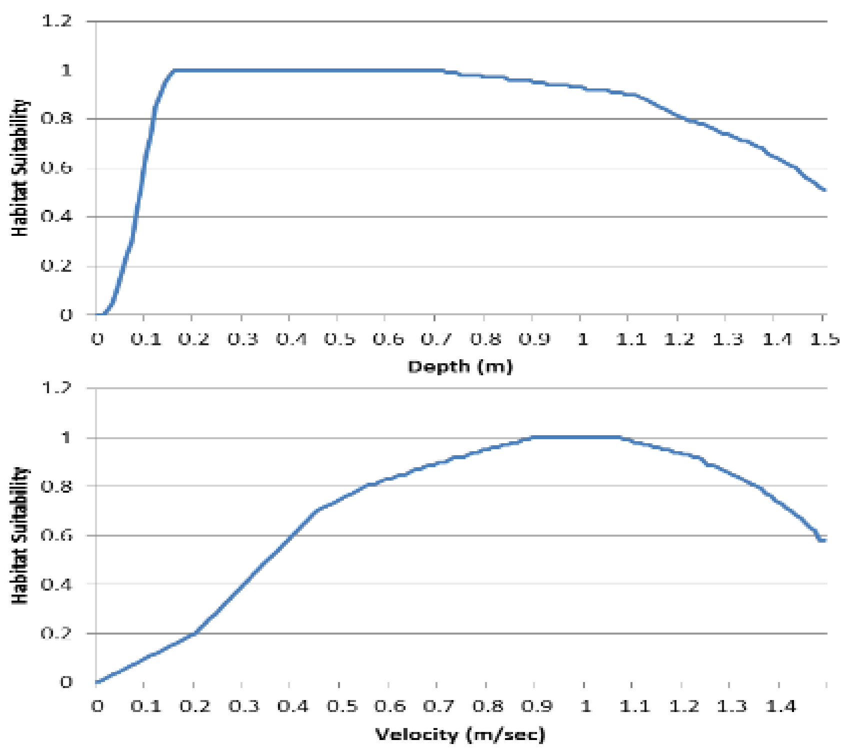

Figure C1. Bentihic Macroinvertebrate Habitat Suitability Curves (Ptolemy 2016)

Fish Passage Assessment

Fish Passage was assessed following the California Department of Fish and Game Critical Riffle Assessment guidance (CDFG 2012). Generally speaking, this involved modelling the depth and velocity changes at varying flows and comparing them against the depth and velocity requirements for fish species by body size as detailed in CDFG (2012) (Depth >0.10m, Velocity<1.25 m/sec). The riffle is considered to be safely passable if greater than 25% of the total width is passable (Figure C5). To provide some context regarding the current (residual) flow conditions that may be expected in Coldstream Creek during the kokanee migration period (August 25 – October 8), a range of discharges representing the 10^{th} to 90^{th} percentile residual and natural flows is presented on the figures (see Figure C5).

Spawning Assessment

Spawning habitat was assessed by modelling how discharge variations affected stream depth and water velocity through glide habitat in Coldstream Creek. These estimates were compared against established Kokanee spawning habitat suitability curves (Figure C2) to produce Weighted Usable Area graphs specific to the glides in Coldstream Creek. Glide habitat was specifically chosen for this assessment because it represents the habitat type most commonly used by spawning kokanee. To provide some context regarding the current (residual) flow conditions that may be expected in Coldstream Creek during the kokanee spawning period (September 1^{st} to October 20^{th}), a range of discharges representing the 10^{th} to 90^{th} percentile residual and natural flows is presented on the figures (see Figure C6).

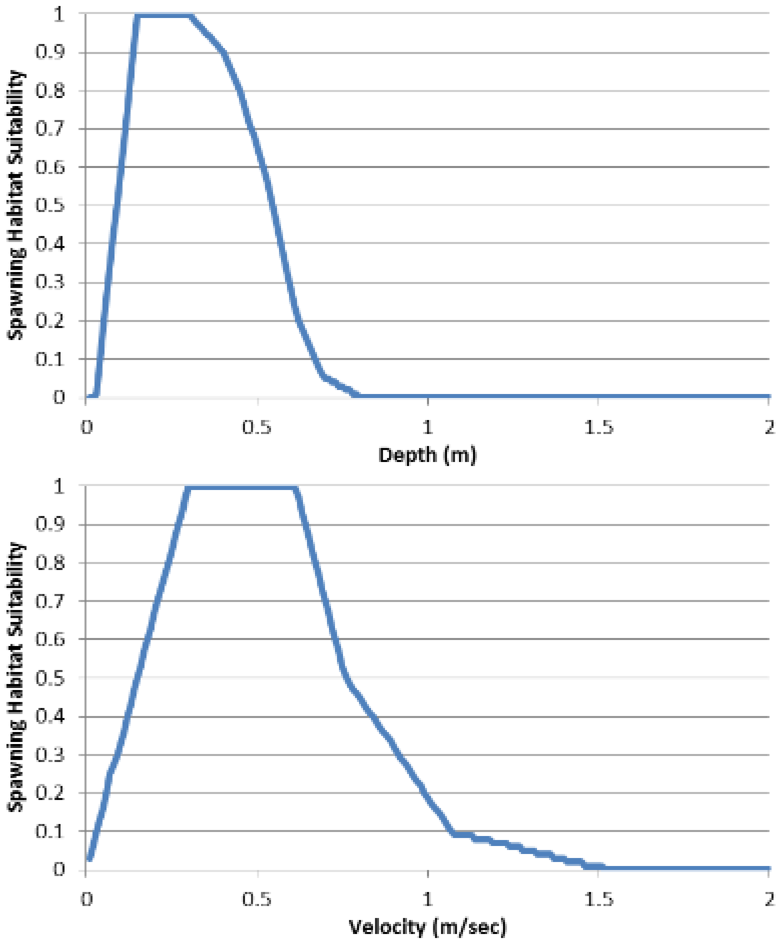

Figure C2. Habitat Suitability Curves for Spawning Kokanee in Coldstream Creek

Results

Instream Flow Assessment

Each of the three monitoring locations were measured on two separate occasions. To the greatest extent possible we attempted to visit the stream at high and low flow volumes (Table C3).

Table C3. Coldstream Creek sampling dates and discharges observed

	Date	Discharge (m^3/s)	Est. % of LTMAD	Modelled Flow Range (%LTMAD)
Detailed Transect Assessment	June 16, 2017	1.270	170	0-100%
Repeat Habitat Transect	August 9, 2017	0.348	47	0-100%

Elevation surveys, measured discharges, and physical site data were used to produce a stage discharge curve for each habitat transect (Appendix A). Overall these curves exhibited good agreement between the observed and predicted water stages.

Riffle Analysis and benthic macro-invertebrate production

Four riffles were initially assessed in Coldstream Creek. The hydraulic relationship for Riffle 1, which is presented in Appendix A, suggests that something was erroneous during sampling. As a result, both the hydraulic relationship and the subsequent habitat predictions were not realistic. For this assessment, they have been removed from the results to avoid confusion.

Wetted widths in Coldstream Creek riffles remained fairly consistent down to approximately 15% of the Long Term Mean Annual Discharge (LTMAD) (Figure C3). Below 15% LTMAD, wetted widths decreased rapidly. At simulated flows below approximately 7% LTMAD, the hydraulic modelling suggests that the wetted channel width of the creek would be less than 50% of the total width available at 100% LTMAD. Loss of wetted width in the riffles of Coldstream Creek could have impacts on physical, chemical and biologic processes of the Creek. Thompson (1972) recommends rearing flows for salmonids should aim to maintain a minimum 60% of the wetted width of riffles covered by flow. This values should be viewed as a critical flow, required to maintain basic riffle functions, rather than a sustainable long-term flow target.

When the wetted riffle wdith predictions detailed in Figure C3 are placed into context with the natural and residual summer flow characteristics presented in Figure C4 it would appear that Coldstream Creek commonly contains water to ensure the riffles remain suitably wetted. At no point during the observations gathered between 2016 and 2018 did the flows decrease to a level below 22% LTMAD.

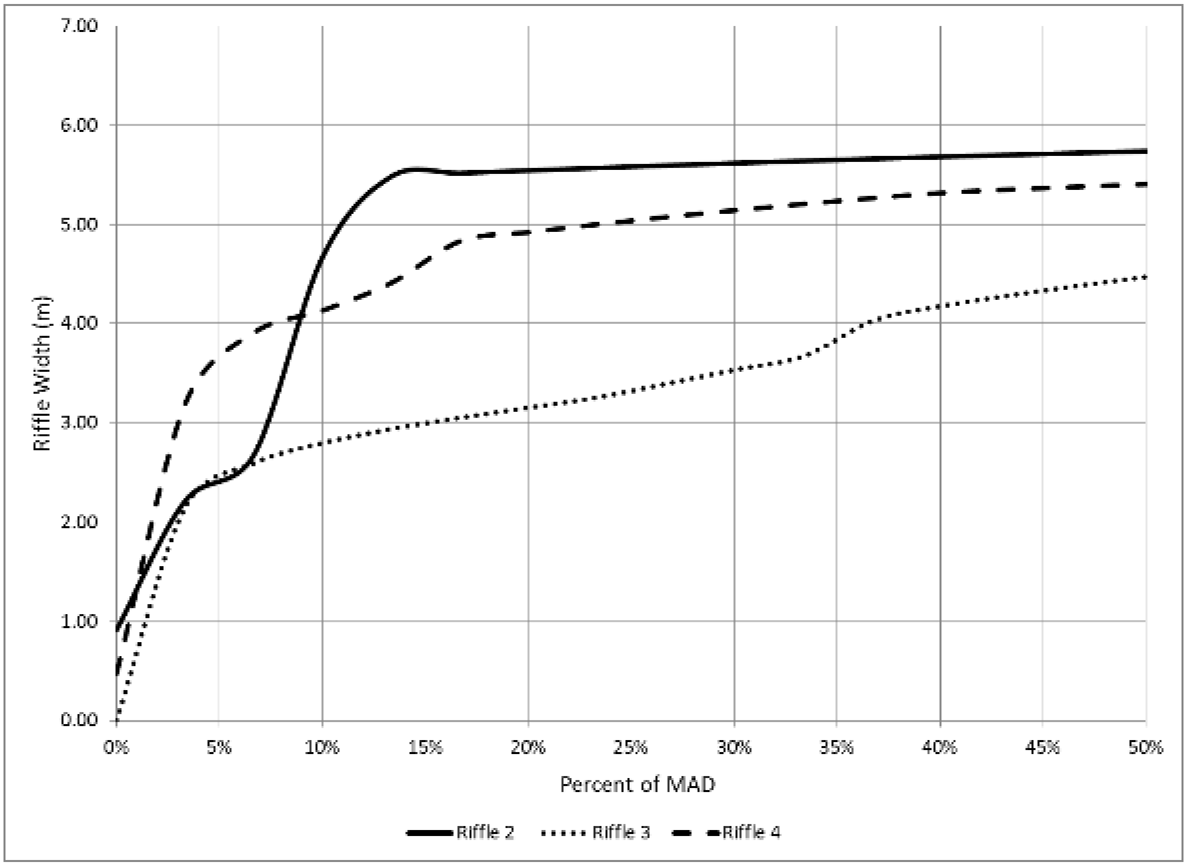

Figure C3. Wetted riffle widths at simulated flows as a function of Long Term Mean Annual Discharge (LTMAD)

Benthic Macro-Invertebrate (BMI) production was assessed in Riffles 2 - 4 using the habitat suitability index curves in Figure C1 (Figure C4). Under natural median conditions during the summer rearing period (April 23 – October 20) the BMI WUW in Coldstream Creek was approximately 3.00 m^2/m. At flow values equal to the natural LTMAD the BMI WUW is slightly higher at approximately 3.30 m^2/m. At the 10^{th} percentile residual flows observed between 2016 and 2018 the BMI WUW value was equal to approximately 1.75 m^2/m, roughly half of what was observed at LTMAD.

When the BMI WUW (Figure C4) is compared to the wetted riffle width graphs presented in Figure C3 it becomes apparent that the BMI production would be significantly impacted at the minimum flows required to maintain 60% of the wetted riffle width. For example at 10% LTMAD the BMI WUW would be equal to roughly 0.50 m^2/m, or approximately 15% of the WUW value available at the natural LTMAD. This is consistent with the rationale that maintenance of 60% of the riffle is required to maintain the basic riffle function for short periods. At 20% of the natural LTMAD the BMI WUW is approximately 1.00 m^2/m, or 30% of the theoretical value available at LTMAD. The residual flows observed between 2016 and 2018 indicate that the BMI WUW is consistently greater than 1.00 m^2/m.

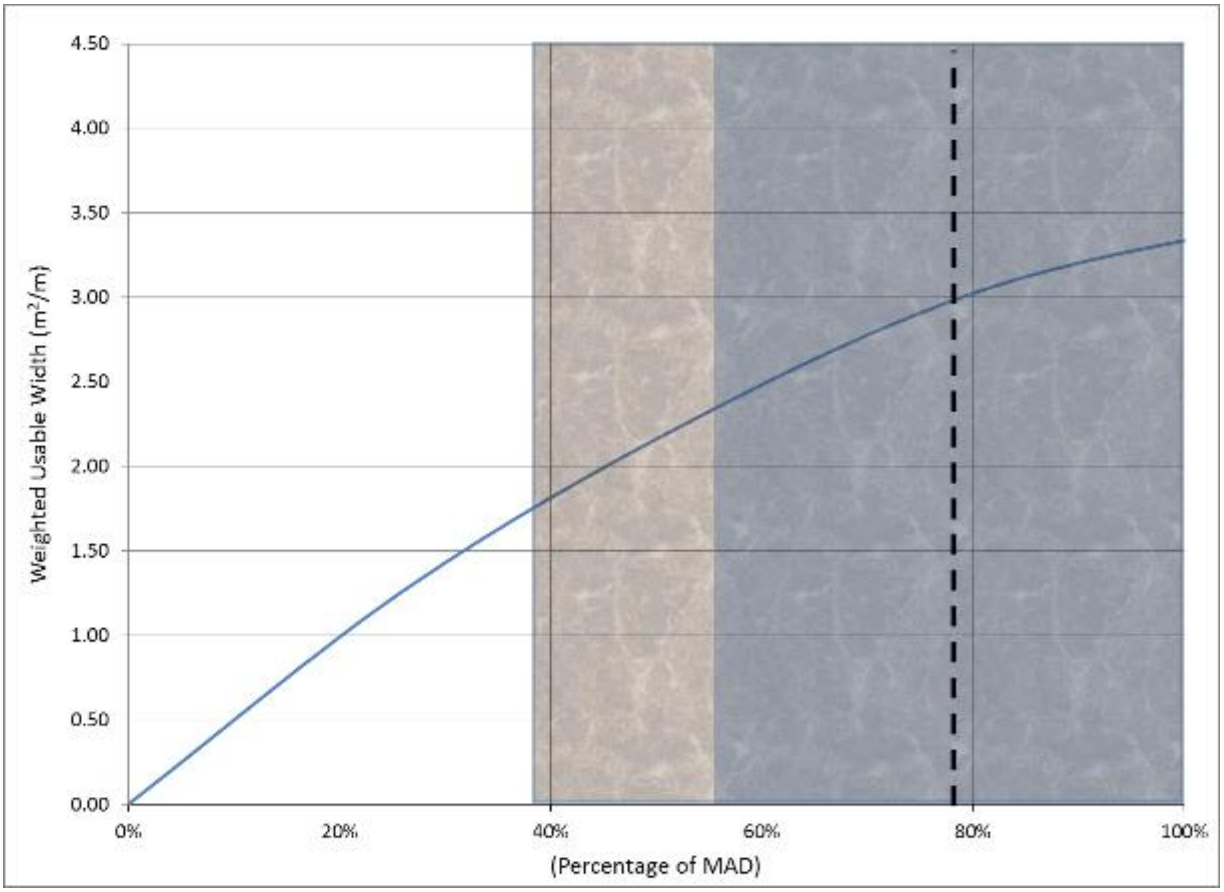

Figure C4. Benthic Macro-Invertebrate habitat suitability In Coldstream Creek as a function of percentage of Long Term Mean Annual Discharge. Grey shaded region indicates the range (10th percentile to 90th percentile) of residual summer rearing flows for the summer rearing period (2016 - 2018). Blue shading is the range in natural flows (10th percentile to 90th percentile) for the summer rearing period. The black dashed line represents the median natural flow during the summer rearing period.

Kokanee migration and spawning

Fish passage was assessed in Riffles 2-4 (Figure C5). The range of residual flows (10th percentile and 90th percentile) observed in Coldstream Creek during the local kokanee migration period was between 31 and 63% of the natural LTMAD. Within this range of flows approximately greater than 25% of the total riffle widths are safely passable to migrating kokanee. The discharge at which less than 25% of the riffle width would be considered safely passable is approximately 30% LTMAD. Between 2016 and 2018 discharges during the migration period exceeded this safe passage threshold 90% of the time.

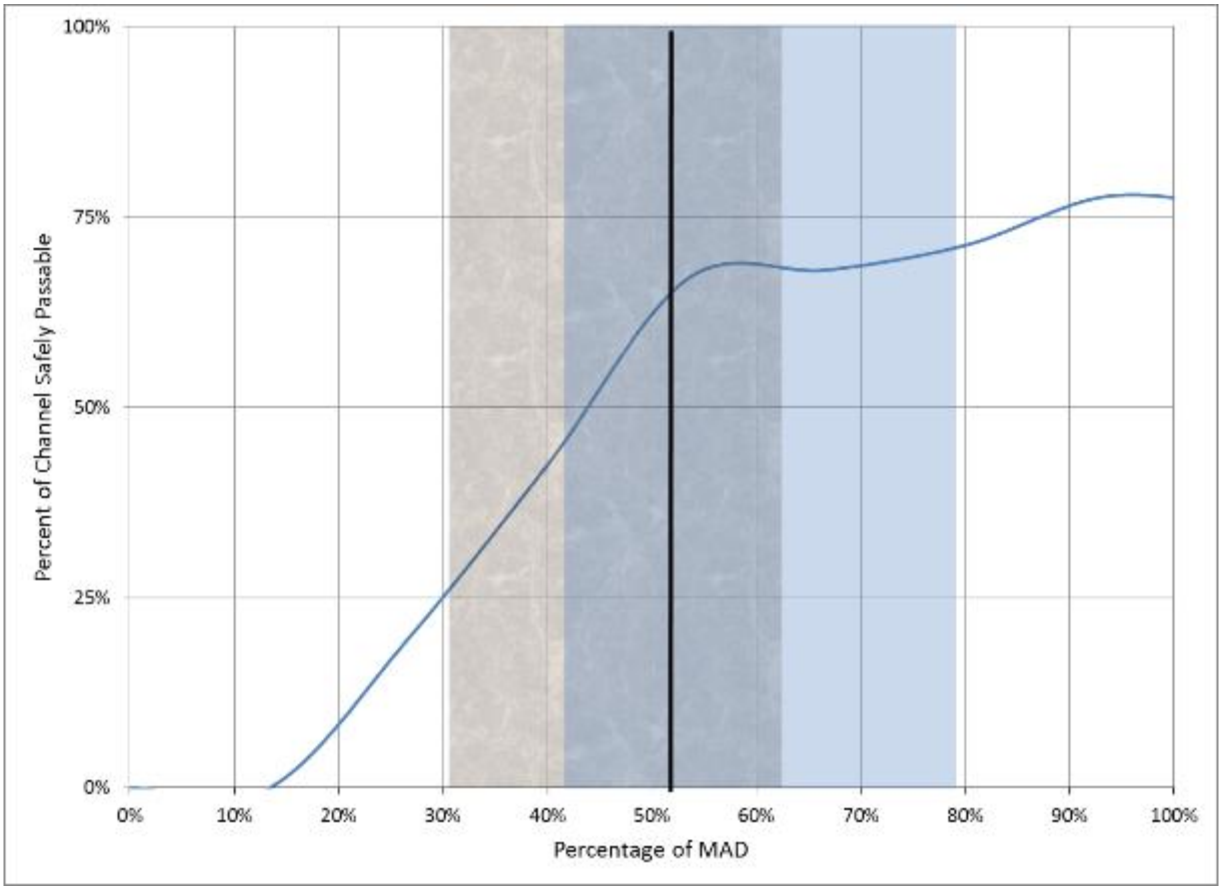

Figure C5. Kokanee migration passage assessment through riffles in Coldstream Creek as a function of percentage of Long Term Mean Annual Discharge (LTMAD). (Passage assessment parameters - Velocity <1.25 m/sec - Depth > 0.10 m). Grey shaded region indicates the range (10th percentile to 90th percentile) of residual flows observed during the Kokanee migration period (2016 - 2018). Blue shading is the range in natural flows (10th percentile to 90th percentile) for the Kokanee migration period. The black solid line represents the median natural flow during the summer rearing period.

Kokanee spawning habitat was assessed in all four glides that were measured in Coldstream Creek. The composite WUW curve appears to reach it's maximum value close to a discharge equal to 70% of LTMAD (Figure C6). The residual flows in the creek during the spawning period (September 22 - October 23) suggest that the habitat suitability for much of the spawning period was close to optimum for the majority of the period. Overall the point of maximum curvature on the kokanee spawning WUW graph suggests that habitat suitability should be expected to decrease rapidly below 20% LTMAD.

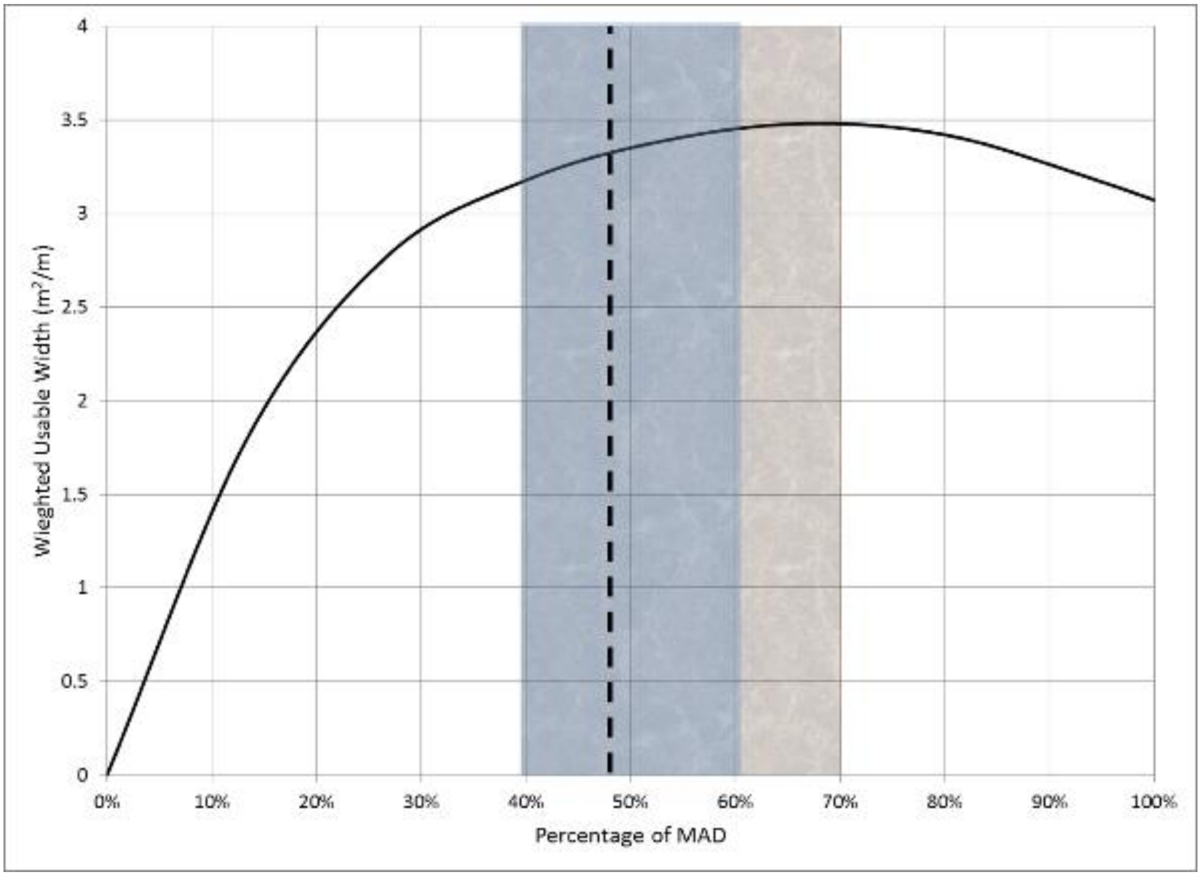

Figure C6. Kokanee spawning habitat suitability In Coldstream Creek as a function of percentage of Long Term Mean Annual Discharge (LTMAD). Grey shaded region indicates the range (10th percentile to 90th percentile) of residual flows during the Kokanee spawning period (2016 - 2018). Blue shading is the range in natural flows (10th percentile to 90th percentile) for the Kokanee spawning period. The black dashed line represents the median natural flow during the summer rearing period.

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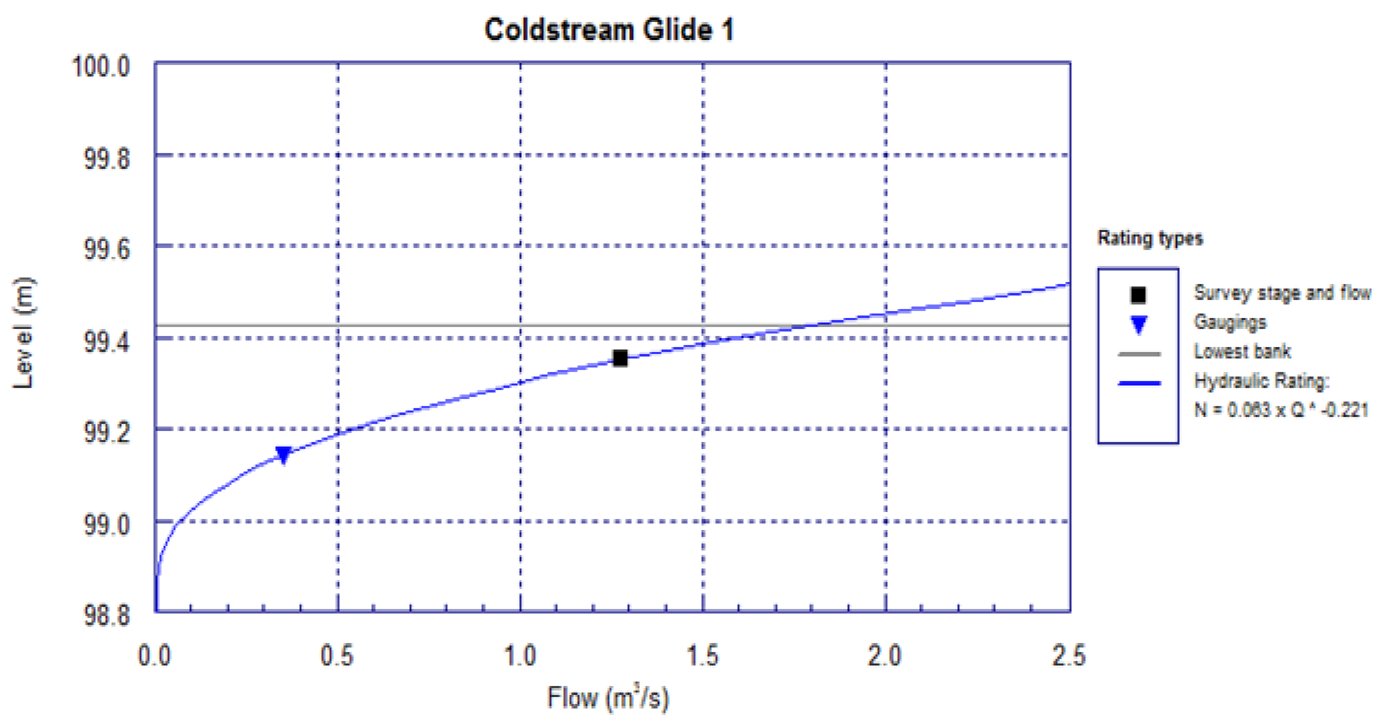
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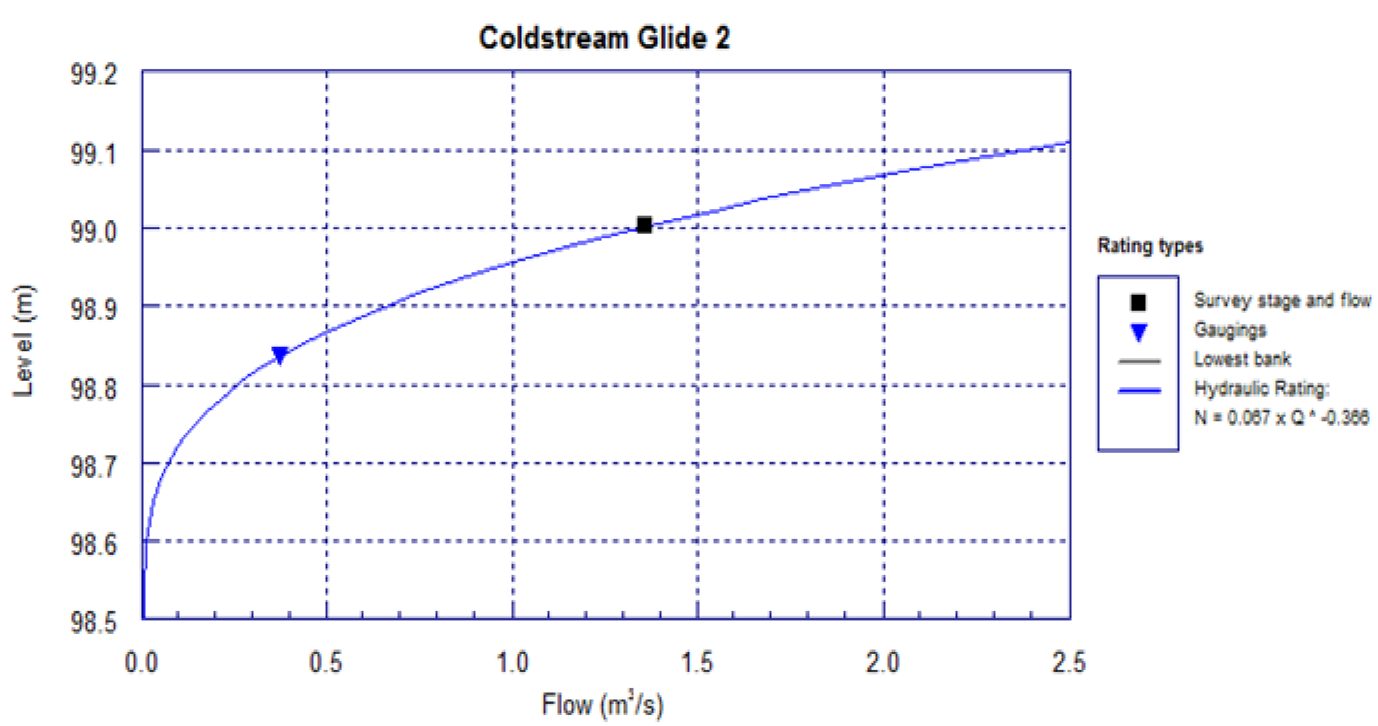
Level (m)
100.0
99.8
99.6
99.4
99.2
99.0
98.8
0.0
0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
N = 0.063 x Q ^ -0.221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Level (m)
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98.8
98.7
98.6
98.5
0.0
0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
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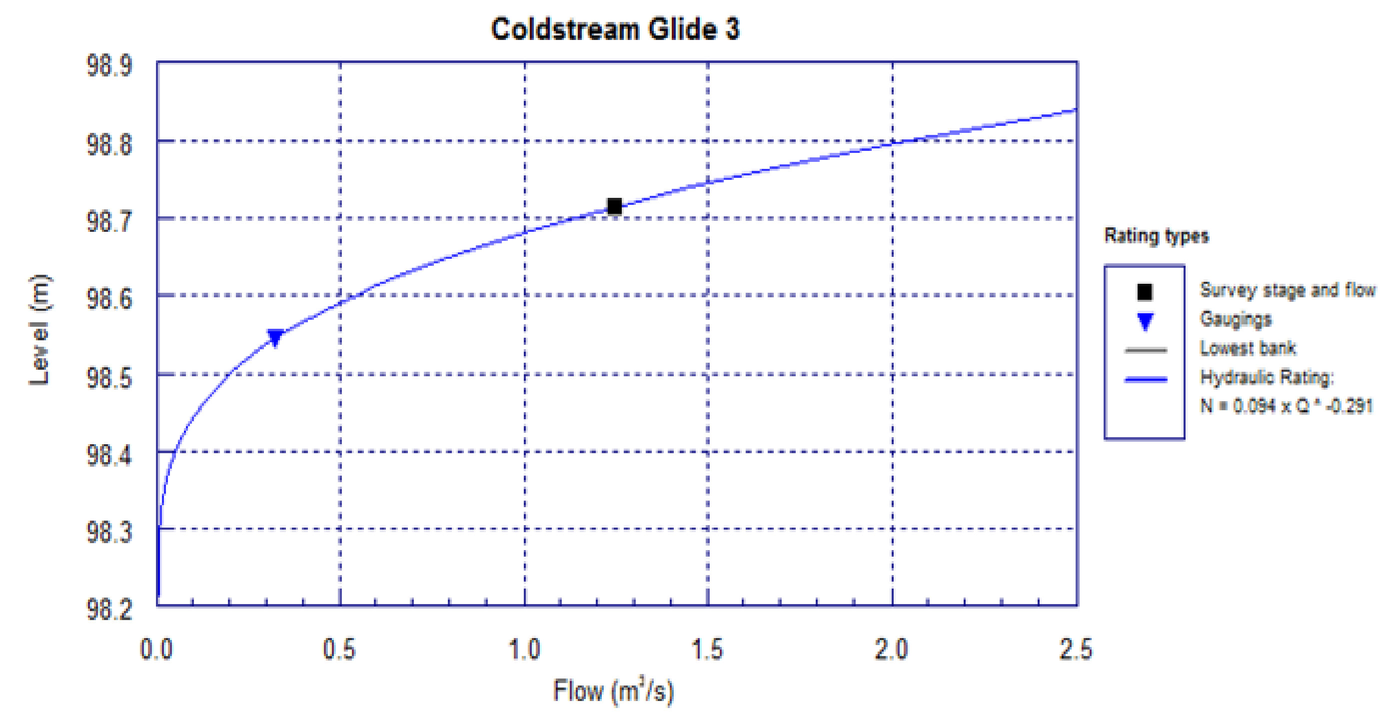
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Level (m)
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98.8
98.7
98.6
98.5
98.4
98.3
98.2
0.0
0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
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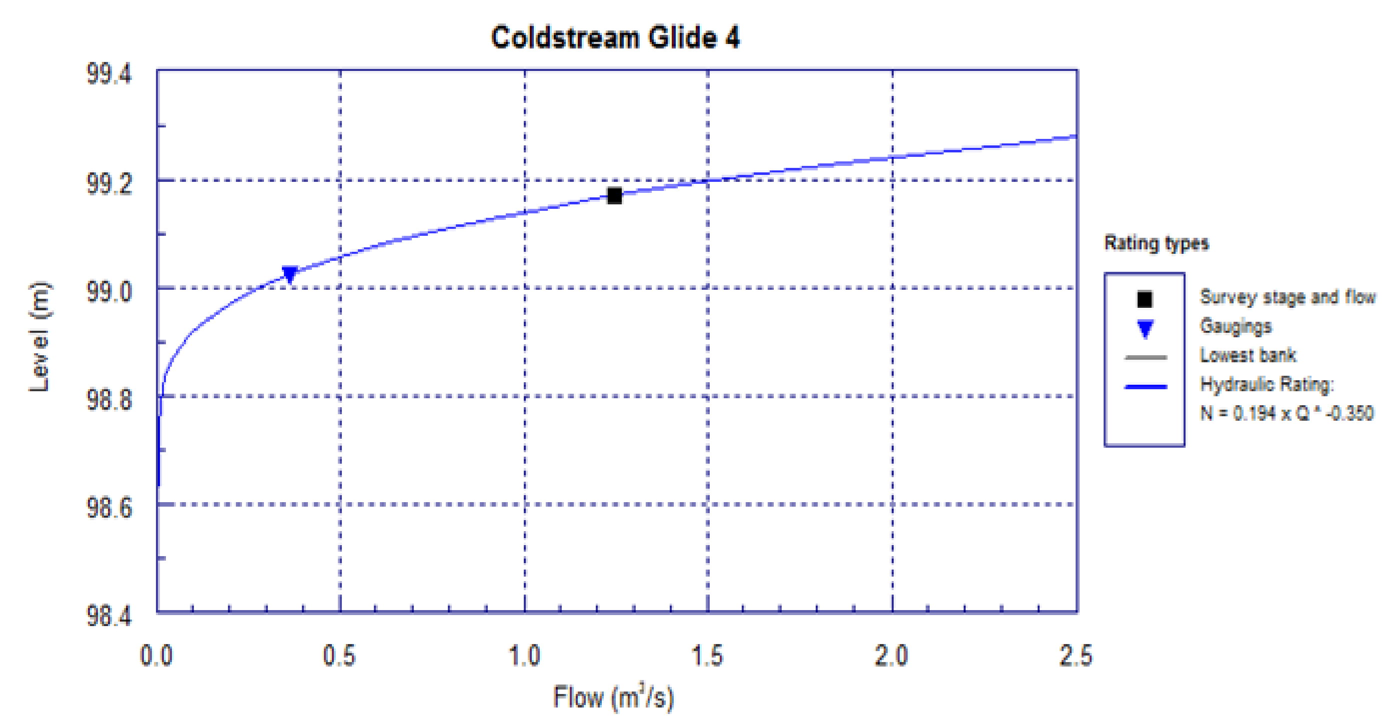
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1.5
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2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
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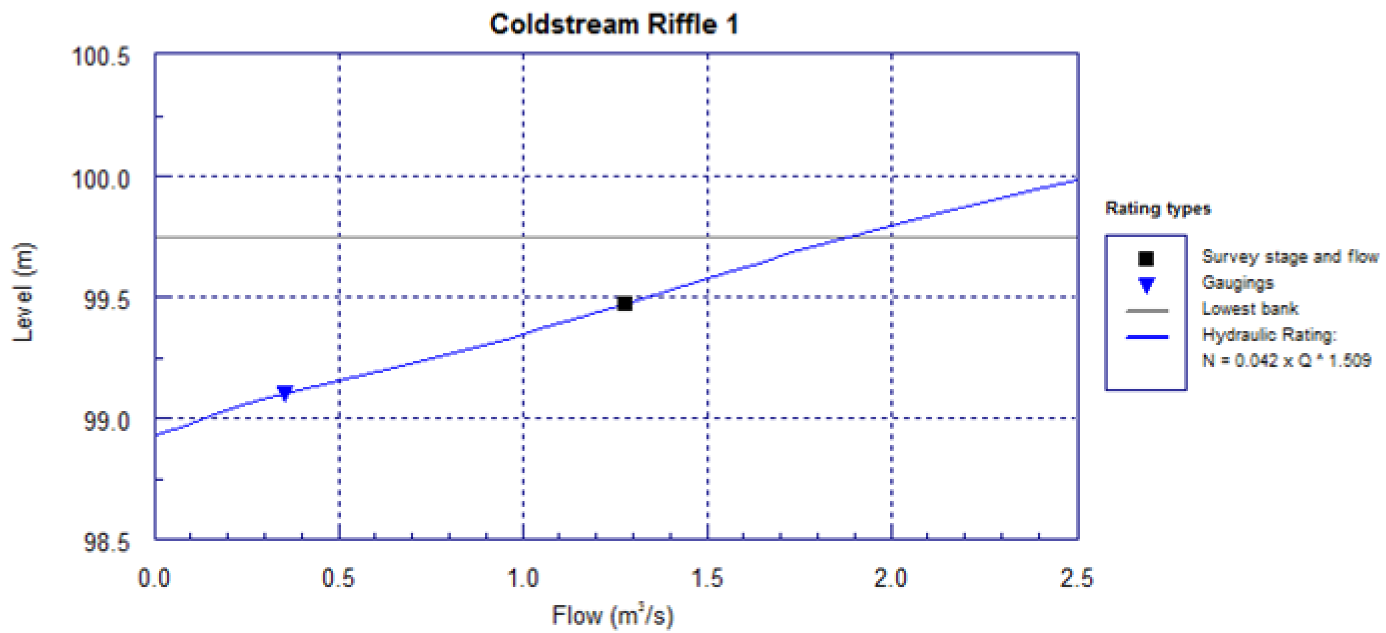
Coldstream Riffle 1
Level (m)
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100.0
99.5
99.0
98.5
0.0
0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
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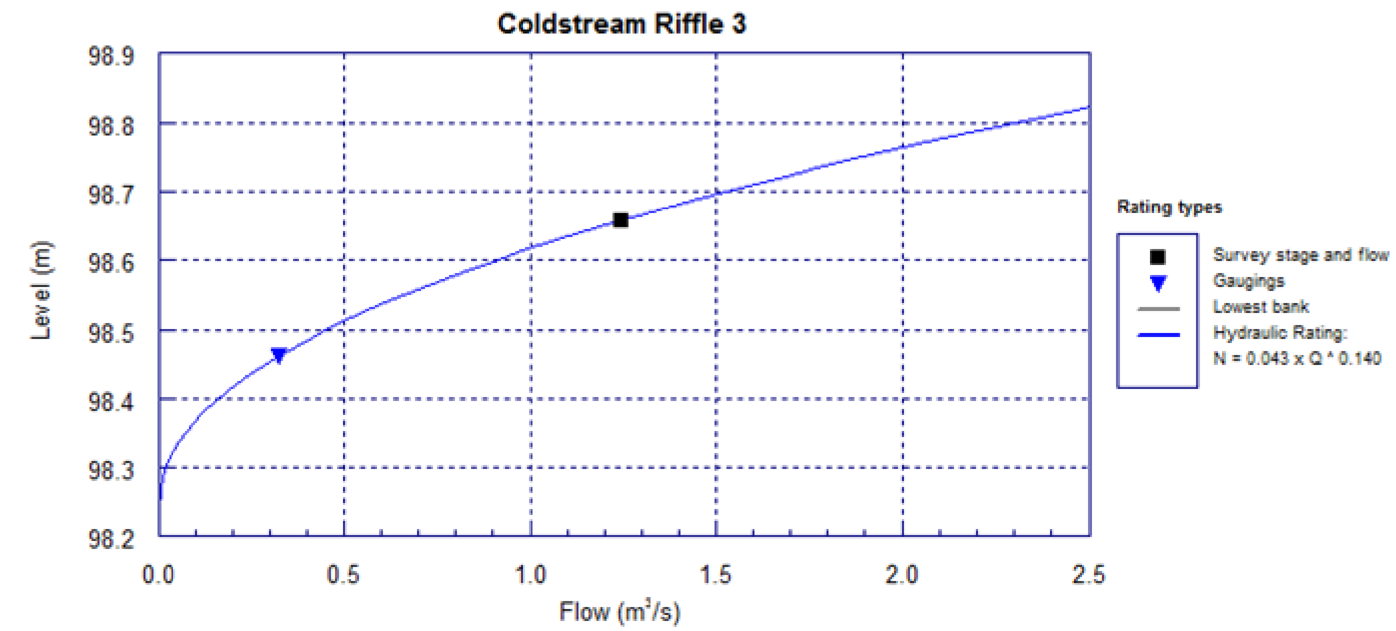
Coldstream Riffle 3
Level (m)
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98.8
98.7
98.6
98.5
98.4
98.3
98.2
0.0
0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
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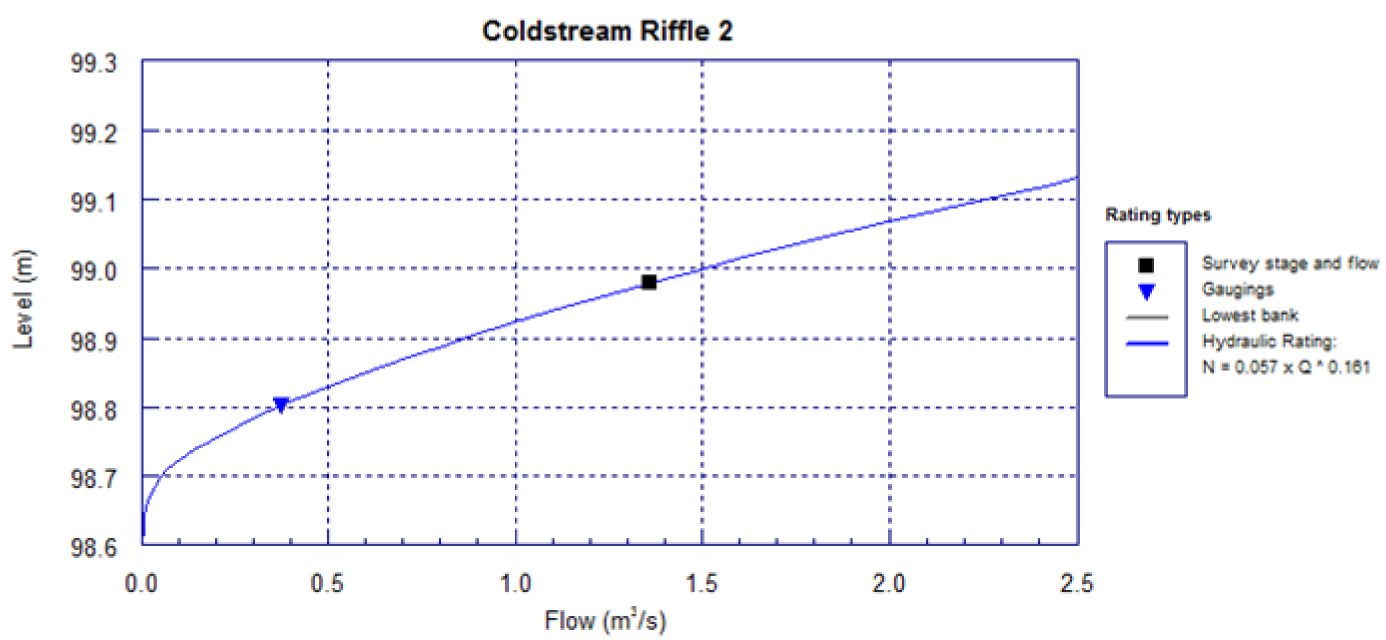
Coldstream Riffle 2
Level (m)
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99.1
99.0
98.9
98.8
98.7
98.6
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0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
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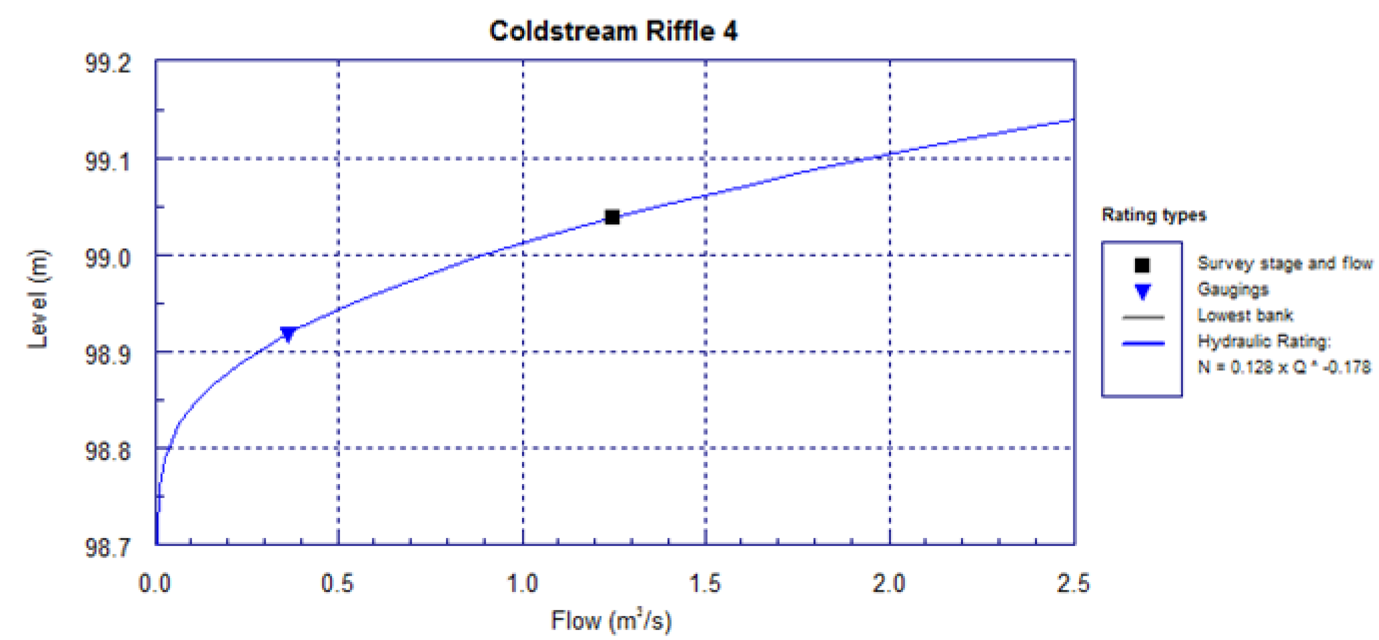
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99.0
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98.8
98.7
0.0
0.5
1.0
1.5
2.0
2.5
Flow (m³/s)
Rating types
Survey stage and flow
Gaugings
Lowest bank
Hydraulic Rating:
N = 0.128 x Q ^ -0.178

Appendix B

Fish Periodicity Table **Coldstream Creek**

Dominant period		Timing		Duration (days)	Reference
Species	**Life stage**	**Start date**	**End date**		
Rainbow trout	Adult migration	15-Apr	10-Jul	entire	Wightman (1975)
	Spawning	20-May	10-Jul		Roberge et al. 2002; Wightman (1975)
	Incubation	1-Jun	15-Jul	entire	Ptolemy pers. comm. 2017; CNAT 2018; Becker & Neitzel 1983
	Rearing	23-Apr	20-Oct	entire	Ptolemy pers. comm. 2017
	Juvenile migration	1-May	15-Jul	15	Ptolemy pers. comm. 2017; CNAT 2018 (15 days mean for 75% emergence at freshet flows)
	Overwintering	20-Oct	22-Apr	entire	Ptolemy pers. comm. 2017
Kokanee	Adult migration	25-Aug	8-Oct	entire	Webster 2015
	Spawning * Coldstream specific	22-Sep	23-Oct	entire	Webster 2008 to 2016
	Incubation	1-Sep	31-Mar	entire	Webster 2015
	Juvenile migration	1-Apr	31-May	15	McGrath et al. 2012; McGrath et al. 2014; Webster 2015; 15 days mean for 75% emergence at freshet flows (CNAT 2018)
Ecological Flows	Wetland, side channel linkage, flushing and channel maintenance flow	1-Apr	30-Jun	15	Jones et al 2015, Leopold et al. 1964; Richter & Richter 2000; Scott et al. 1996; Amlin & Rood 2001; Mahoney & Rood 1998
	Ramp up flows	all year		x	typical spring freshet, based on fish timeing of fry emergence; duration depends on the magnitude of the peak
	Ramp down flows	all year		x	typical spring freshet; duration depends on the magnitude of the peak