3.0 RESULTS

This section presents recommended EFNs for 18 Okanagan streams developed using the methods described in Section 2.0. Each subsection outlines watershed characteristics relevant to EFN setting and summarizes available literature. Stream-specific data considered in the EFN setting process is described and the recommended EFNs are presented in summary tables and figures. Additional stream-specific information is provided in Appendices B1 to B18, including:

- transect locations, descriptions and photos;
- habitat mapping;
- discharge and water temperature records;
- stream-specific flows and periodicity information;
- detailed weekly Okanagan Tennant, WUW and final recommended EFNs;
- WUW curves;
- critical flow assessments; and
- percentile flow data.

3.1 Coldstream Creek

Coldstream Creek is a tributary of Kalamalka Lake, which then flows into Okanagan Lake through Vernon Creek. Coldstream Creek flows from the east side of the Okanagan Basin to its confluence with Kalamalka Lake in the District of Coldstream just east of Vernon, B.C. The Coldstream Creek watershed is approximately 206 km^2 (Associated 2016). Coldstream Creek flows from its relatively steep headwaters onto the valley floor near the community of Lavington. It traverses the low gradient valley floor for a considerable distance before discharging into Kalamalka Lake. An alluvial aquifer (3266) underlies the valley floor from Lavington to the Kalamalka Lake confluence (Associated 2017). A summary of creek characteristics is provided in Table 3-1 and additional stream-specific data is provided in Appendix B1.

The lower reaches of Coldstream Creek flow through agricultural and urban areas and common impacts such as bank modifications, bank erosion from livestock access, riparian clearing, and water quality problems have been identified (Ecoscape 2010, Larratt Aquatic 2011). Nonetheless, its low gradient, pool-riffle morphology, suitable spawning substrate, and relatively abundant riparian vegetation observed during habitat surveys (Table B1-1, Appendix B1) contribute to its status as one of the most prolific Kokanee spawning streams in the Okanagan (Aqua Resource Management Inc. 2001). The creek is accessible to Kokanee and Rainbow spawners from Kalamalka Lake between the mouth and a barrier posed by an old spillway weir at Coldstream Ranch, approximately 7 km upstream. A further barrier, the culverts below the Highway 6 crossing immediately upstream of Coldstream Ranch, were replaced in 2012 by wider culverts that allow for fish passage. The stream is further known to support resident Rainbow and non-salmonid fish species (Associated 2016).

Study transects in Coldstream Creek were located downstream of the fish barrier at Coldstream Ranch. All four paired riffle and glide transects (eight total) were situated in the section of the creek that contains nearly all Kokanee spawning activity on an annual basis (Figure B1-2, Appendix B1). This section extends between the mouth of the creek to several enhancement weirs installed in Coldstream Park (Webster 2014).

Coldstream Creek (along with Mill Creek) has the highest base flows of any of the study streams and experiences significant groundwater inflows in the valley-bottom reaches (Associated 2019). Past reports have indicated the favorable flow regime to be the greatest asset of fish production in the creek (Wightman & Taylor 1978). One hydrometric station was installed in 2016 to collect hydrometric data for this project. The station is situated at McClounie Road and has collected data since 2016 to the present. Further information on the Coldstream Creek hydrometric station is provided in Appendix B1.

At present, there are 40 points of diversion in the watershed and four pending water licence applications (Associated 2019) and the stream is currently fully recorded for irrigation unless supported by storage (FLNRORD 2016). Greater Vernon Water (GVW) is the main water supplier with developed water storage at King Edward Lake Reservoir. There are no known inter-basin water transfers to or from Coldstream Creek (Associated 2016). Under natural conditions, Coldstream Creek is not 'flow sensitive' during summer and winter with naturalized flows above 20% LTMAD (Table 3-2).

Table 3-1: Coldstream Creek description

Drainage Area	206 km^2
Median Elevation	1040 m
WSC station	08NM142 (Active) – Coldstream above Municipal Intake (1967-present) 08NM124 (Historic) – Coldstream near Lavington (1959-1979) 08NM154 (Historic) – Coldstream at the Mouth (1969-1970) 08NM179 (Historic) – Coldstream above Kalavista Diversion (1970-1982)
ONA station	08NM589 – Coldstream Creek near McClounie Road (2016-2018)
LTMAD	0.748 m^3/s (Associated 2019)
Fish species expected	Rainbow, Kokanee, non-salmonid fish (MOE 1982)
Land use	Agriculture and urban development in lower reaches. Forestry and recreation in upper reaches (Associated 2016)

Okanagan Tennant EFNs for Coldstream Creek were developed in accordance with the methods outlined in Section 2.2. Naturalized flow data was provided by Associated (2019) with an estimated data quality rating of B (data error between 10% and 25%); residual and maximum licensed flow estimates were not available at the time of reporting. Fish periodicity and flow standards described in Table 2-2 to Table 2-6 were used. Weekly Okanagan Tennant EFNs were set to the lower of the naturalized flow or flow standard. Contrary to most other study streams, naturalized flows in Coldstream Creek are much greater than flow standards during the non-freshet period, as were residual flows measured during this project and historically. Therefore, WUW information from the study transects was used to adjust the Okanagan Tennant EFNs upward. The recommended EFNs are intended to maintain current levels of fish production in Coldstream Creek by protecting flow conditions that local populations have become adapted to. A summary of the recommended EFNs is provided in Table 3-3, including the median EFN and the range of weekly EFNs, with weekly details in Figure 3-1, Figure 3-2, and Appendix B1, and flow sensitives in Table 3-2. Critical flows were calculated as described in Section 2.4. Further information regarding EFN and critical flow setting in Coldstream Creek is provided at the end of this section.

Table 3-2: Flow sensitivities in Coldstream Creek

Species & life stage	1-in-2 yr 30-day summer low flow		1-in-2 yr 30-day winter low flow	
	Flow (m³/s)	% LTMAD	Flow (m³/s)	% LTMAD
Rainbow rearing	0.360	48%		
Insect production				
Kokanee spawning				
Rainbow overwintering			0.248	33%
Kokanee egg incubation				

Source: Associated (2019)

Table 3-3: EFN summary table for Coldstream Creek

Species & life stage	Time period	Okanagan Tennant EFN		WUW EFN (m³/s)	Recommended EFN (m³/s)				Critical flow	
		Median (m³/s)	% LTMAD		Median	% LTMAD	Min	Max	Flow (m³/s)	% LTMAD
Rainbow rearing & insect production[a]	April 1 – Oct 31	0.150	20%	0.250	0.250	33%	0.250	0.543	0.075	10%
Rainbow spawning	20-May – 10-Jul	1.06	142%	1.00	0.100	133%	0.704	1.00	0.419	56%
Kokanee spawning	22-Sep – 23-Oct	0.150	20%	0.250	0.250	33%	0.250	0.250	0.164	22%
Rainbow overwintering	Nov 1 – March 31	0.150	20%	n/a	0.250	33%	0.250	0.295	0.075	10%

a while EFNs apply to the entire period, median values are presented for the summer low flow period from Jul 15-Sept 30.

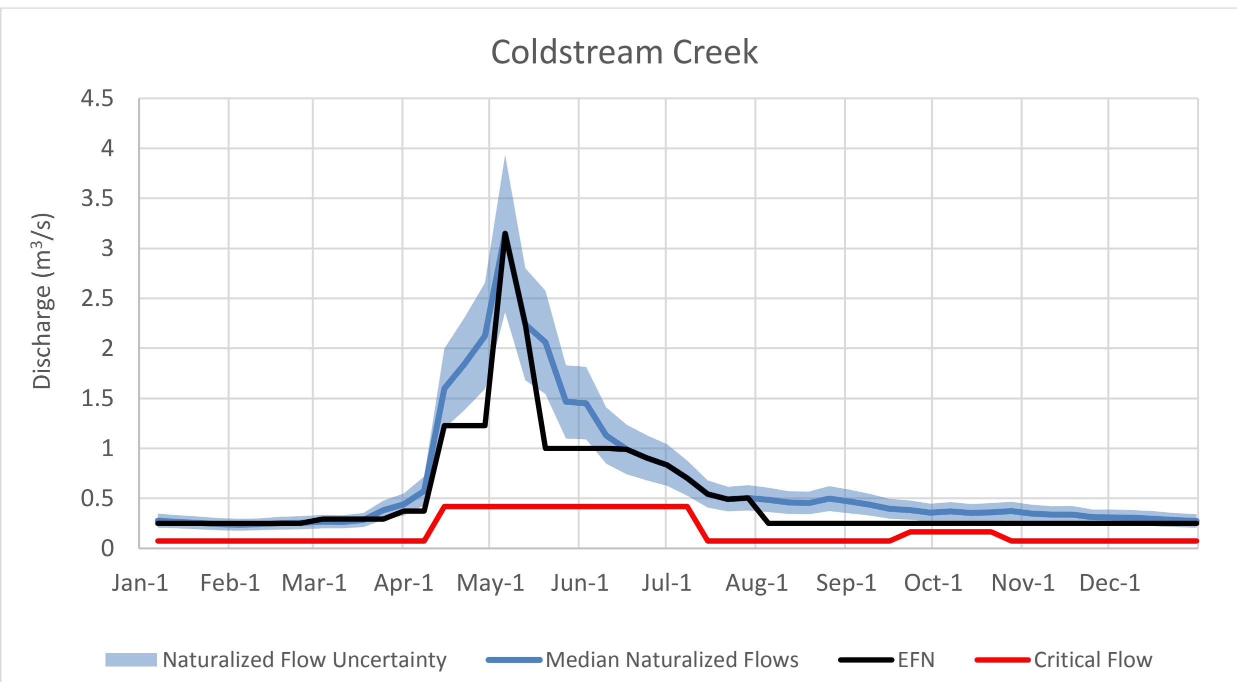

Figure 3-1: Weekly EFNs, critical flow and streamflows in Coldstream Creek

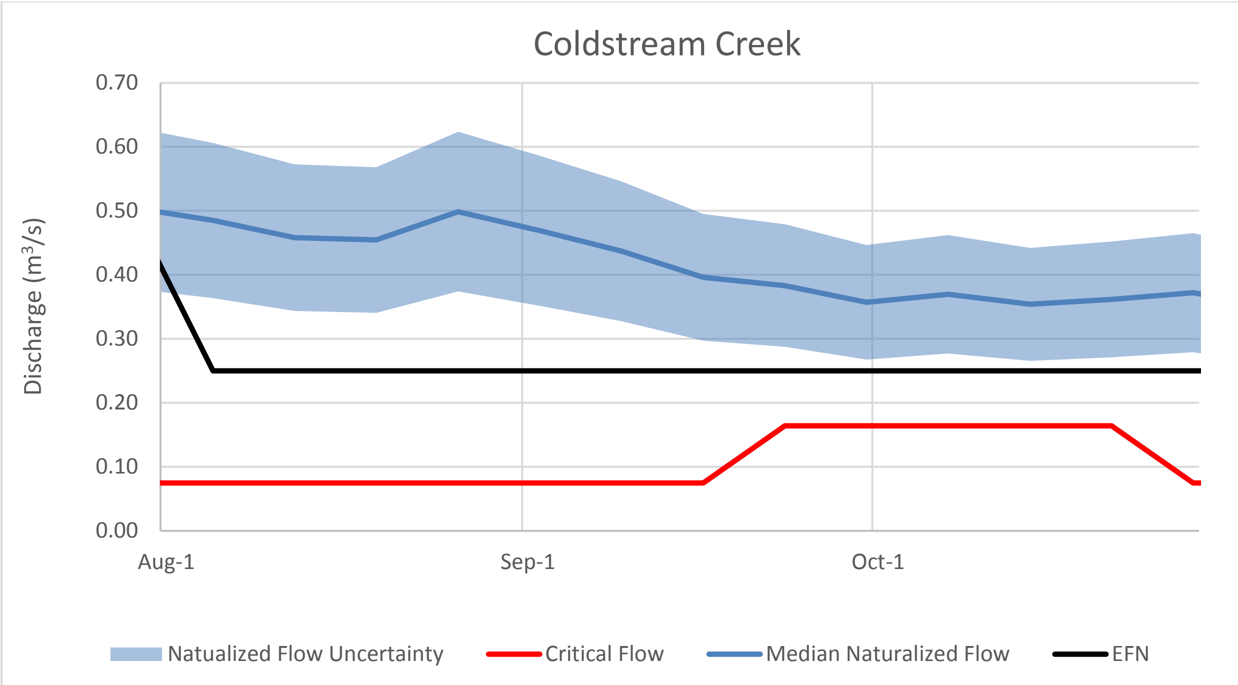

Figure 3-2: Weekly EFNs, critical flow and streamflows during the summer and fall period in Coldstream Creek

Rainbow parr rearing

The recommended EFN for Rainbow Parr Rearing is 0.250 m^3/s (33% LTMAD), which maintains approximately 80% of maximum WUW in glides and 40% in riffles (Figure B1-5, Appendix B1). The recommended EFN is near the lowest late summer flows observed at the ONA hydrometric station between 2016-2018 (Figure B1-3, Appendix B1), indicating that the EFN is generally achieved under current water use conditions even during dry years (2017 and 2018). Photos of habitat conditions in Coldstream Creek at the recommended EFN flows are provided in Plate 3-1.

The recommended critical flow for Rainbow parr rearing is 0.075 m^3/s (10% LTMAD; Table B1-3, Appendix B1). While riffle analysis indicates that 60% of maximum wetted width is maintained at flows of approximately 0.055 m^3/s (7% LTMAD), no measurements were collected below 0.250 m^3/s and there is considerable uncertainty in this estimate. 10% LTMAD is recommended as the critical flow as opposed to the 5% LTMAD routinely applied by FLNRORD, to reflect the naturally high baseflows in Coldstream Creek and consistency with the results of the riffle analysis. Koshinsky (1972) recommended 0.17 - 0.20 m^3/s as a minimum flow for incubation, rearing and fry migration, which is lower than the EFN but higher than the critical flow recommendation.

The recommended EFN is approximately equal to the lowest median weekly flow observed at WSC station 08NM179 (Coldstream Creek above Kalavista Diversion, operational from 1970-1982) for the summer and fall low flow period (mid-July to late September). The recommended EFN also maintains approximately 45% of maximum insect production WUW (Figure B1-6, Appendix B1) and is likely sufficient to maintain the relatively cool water temperatures (daily maximum <16°C) observed at the ONA hydrometric station between 2016 and 2018, which are favorable to Rainbow rearing (Figure B1-4, Appendix B1).

Rainbow spawning

The recommended EFN for Rainbow spawning is 1.00 m^3/s (134% LTMAD, Figure B1-7, Appendix B1), which maintains maximum (~100%) Rainbow spawning WUW while also maximizing Rainbow parr rearing WUW during freshet. The recommended EFN is slightly lower than the median naturalized flows during the spawning period and residual flows are generally above the EFN from late April to mid-June (Appendix B1, Figure B1-3), indicating that the EFN can be met during most years. Photos of habitat conditions in Coldstream Creek at the recommended EFN flows are provided in Plate 3-2.

The recommended critical flow for Rainbow spawning is 0.419 m^3/s (56% LTMAD, Table B1-3, Appendix B1) based on the passage depth criterion (Table 2-7).

Kokanee spawning

Coldstream Creek is one of the primary Kokanee producing streams in the Okanagan Valley and therefore protecting spawning flows in this stream is vital. The recommended EFN for Kokanee spawning is 0.250 m^3/s (33% LTMAD), which maintains near maximum WUW (~90%; Figure B1-8, Appendix B1). Flows observed at the ONA hydrometric 2016-2018 during the Kokanee spawning period were between 0.3 and 0.5 m^3/s (Figure B1-3, Appendix B1) and indicate that the EFN is achievable under current water use conditions even during dry years (2017 and 2018). Median daily flows observed at WSC station 08NM179 (Coldstream Creek above Kalavista Diversion, operational from 1970-1982) during the Kokanee spawning season ranged from 0.27-0.33 m^3/s, which is also above the EFN. Minimum passage depth for Kokanee (0.12 m over $\geq$25% of riffle width) was achieved at all riffle transects at the recommended EFN. Photos of habitat conditions in Coldstream Creek at the recommended EFN flows are provided in Plate 3-1. The recommended EFN is similar to the minimum spawning flow of 0.23 m^3/s suggested by Koshinsky (1972).

The recommended critical flow for Kokanee spawning is 0.164 m^3/s (22% LTMAD; Table B1-3, Appendix B1) based on the passage depth criterion (Table 2-7). Although no measurements were collected below 0.250 m^3/s and there is some uncertainty related to this value, it is well below the summer 1 in 20-year return period 30-day Naturalized Low Flow (Table B1-4, Appendix B1) and is therefore highly likely to be exceeded.

Plate 3-1: Coldstream Creek habitat conditions at flows near the recommended Rainbow parr rearing and Kokanee spawning EFNs (0.250 m^3/s)

Glide 2 at 0.308 m^3/s (41% LTMAD)

Glide 3 at 0.282 m^3/s (38% LTMAD)

Riffle 2 at 0.308 m^3/s (41% LTMAD)

Riffle 3 at 0.282 m^3/s (38% LTMAD)

Plate 3-2: Coldstream Creek habitat conditions at flows near the recommended Rainbow spawning EFN (1.00 m^3/s)

Glide 3 at 0.909 m^3/s (122% LTMAD)

Glide 2 at 1.01 m^3/s (135 % LTMAD)

3.1.1 SEFA analysis trial in Coldstream Creek

During this study, it was identified that the SEFA program may provide utility in modelling habitat information for those streams where WUW field data was lacking. In Coldstream Creek, flows remained high during the study season and low flow WUW data could not be obtained, leading to greater uncertainty in the WUW curve at lower flow rates. Critical riffle analysis required extrapolation beyond the range of observed data, which led to increased uncertainty. SEFA analysis was completed to assess whether the model could provide further information on habitat condition at lower flows. The SEFA model requires fewer field transect measurements than WUW analysis, but incorporates detailed transect elevation surveys and substrate data that are then used to model habitat conditions over the range of flows.

The WUW analysis in Coldstream Creek was based on 11 field measurements of depth and velocity at eight transects as described in Section 2.3.2. The SEFA analysis used the station, velocity, and depth data from two of the WUW field measurements (high and moderate flows) as well as detailed cross-sectional elevation surveys and substrate data from each transect. Ideally, a third flow measurement at low flows would be incorporated but was unavailable for reasons mentioned above. The modelling parameters differed slightly between SEFA and WUW: for Rainbow parr rearing EFNs, SEFA only utilized information on invertebrate production from riffles whereas WUW analysis also used parr rearing HSIs applied to riffles and glides. Critical flow analysis used the same parameters between the two modelling approaches (passage depth for Kokanee and riffle width for parr rearing). A description and full results of the SEFA analysis completed for Coldstream Creek is presented in Appendix C.

SEFA produced similar, though not identical, information on the habitat-flow relationships as the WUW analysis. Kokanee spawning WUW peaked at higher flows and declined slightly more rapidly than the curve produced by the WUW analysis; however, differences in the lower flow range were very small. The SEFA model showed maximum habitat suitability at 0.52 m^3/s (70% LTMAD) with a rapid decrease below 0.15 m^3/s (20% LTMAD). The WUW curve peaked at slightly lower flows of approximately 0.37 m^3/s (Figure B1-8, Appendix B1). The recommended EFN from the WUW analysis was 0.250 m^3/s (33% LTMAD) and this value would also be supported by the SEFA analysis. For critical flows, the SEFA model recommended that 0.22 m^3/s (30% LTMAD) should be the minimum flow to maintain at least 25% riffle width deep enough for passage. In contrast, the critical riffle analysis recommended a critical flow of 0.164 m^3/s (22% LTMAD) though uncertainty was high for lack of low flow measurements. Overall, EFN recommendations would be similar in this case though critical flow recommendations based on SEFA would be higher.

Similarly, for Rainbow parr rearing, SEFA predicted a slightly more rapid decline in insect production with dropping flows though EFN recommendations would likely be similar. SEFA predicted that wetted riffle widths drop off considerably below 0.11 m^3/s (15% LTMAD) and decline to approximately 50% of bankfull wetted width at 0.052 m^3/s (7% LTMAD); this is quite similar to the results of the critical riffle analysis (Table B1-2, Appendix B1) which indicated that 60% of bankfull wetted width is maintained at 0.055 m^3/s. As a result, critical flow recommendations would be similar between the two models.

The SEFA model is a promising program for EFN investigations but like all models, the relevance of the outputs relies heavily on the selection of the data inputs. It is possible that model results at low flows would have been more informative if low flow field surveys had been obtained. With the data inputs listed above, the SEFA model provided similar though not identical information to support EFN and critical flows setting. Application of the SEFA model is most useful where field surveys can be obtained over the full range of flows (low, moderate, and high) but resource constraints prevent the number of field visits typically required for full WUW analysis (8-10).

Using SEFA to extrapolate beyond the measured range to fill in gaps in field data is less certain. Running the SEFA analysis for a dataset with a complete range of WUW observations and excluding the low flow observation; then comparing SEFA-modelled habitat suitability at low flows and critical passage flows to those derived from WUW and critical riffle analyses would provide further information on SEFA's suitability for this purpose. However, extrapolation beyond the range of measured data generally introduces a high degree of uncertainty.

Several advantages and disadvantages of the SEFA model compared to WUW analysis are listed below:

Advantages:

- Less fieldwork – streams only need to be visited 3 times per season (high, medium and low flows). This simplifies field planning and reduces the frequency of visits.
- Gathering more data (substrate, surveying, gradient) on the transect allows for more options in future analysis, such as analyses in programs like HEC-RAS, which could be used for stream engineering projects. WUW data is somewhat limited to EFN analysis with few options for other uses.

Disadvantages:

- More intensive fieldwork – the requirement for detailed transect surveys and substrate measurements adds significant time and some additional expertise required during field visits. This limits the number of transects that can be surveyed in one day.
- Manning's Roughness values have a large influence on modeled flow velocities, particularly at low flows which are often most critical to EFN setting. Manning's Roughness values cannot be adjusted within the SEFA model. In SEFA trials completed for several EFN streams, SEFA-modeled velocities were very different from measured velocities. This results in differing habitat suitability estimates between SEFA and WUW analysis. Further comparison between modeled and measured velocities are advised before applying the SEFA model for EFN setting.