SENSITIVE HABITAT INVENTORY AND MAPPING AND AQUATIC HABITAT INDEX

Bessette Creek, Creighton Creek and Duteau Creek

Prepared By:

Ecoscape Environmental Consultants Ltd.

Prepared for:

Secwepemc Fisheries Commission

April 2022

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INFORMATION DISCLAIMER

The results contained in this report are based upon data collected during a single season inventory of each creek over a period of two years. Biological systems respond differently both in space and time. For this reason, the assumptions contained within are based upon field results, previously published material on the subject, and airphoto interpretation. The material in this report attempts to account for some of the variability between years and in space by using safe assumptions and a conservative approach. Data in this assessment was not analyzed statistically and no inferences about statistical significance are made if the word significant is used. Use of or reliance upon biological conclusions made in this report is the responsibility of the party using the information. Neither Ecoscape Environmental Consultants Ltd., nor the authors of this report are liable for accidental mistakes, omissions, or errors made in preparation of this report because best attempts were made to verify the accuracy and completeness of data collected, analyzed, and presented.

This is intended as a "*Living Document*". In so being, it may be continually edited and updated and may evolve and be expanded as needed, and serve a different purpose over time.

EXECUTIVE SUMMARY

A comprehensive inventory and development of an Aquatic Habitat Index (AHI) of three watercourses in the Middle Shuswap River watershed was conducted between 2020 and 2021, within the Shuswap Nation Tribal Council territory, centralized around Lumby, BC. The three creeks inventoried and mapped included:

- Bessette Creek: approximately 29 kms centralized around Lumby, BC;
- Creighton Creek: between the confluence with Bessette Creek, upstream approximately 14 kms; and,
- Duteau Creek: between the confluence with Bessette, upstream approximately 14 kms.

Sensitive Habitat Inventory and Mapping (SHIM) protocols were used to collect baseline information regarding the current condition of the watercourses and associated riparian habitats (Mason and Knight, 2001). An Aquatic Habitat Index (AHI) is generated using the processed field data to determine the relative habitat value of the aquatic habitats. The AHI uses many different criteria, such as biophysical, fisheries values, and anthropogenic characteristics to estimate the habitat value of a stream segment. The Habitat Index classifies this information in a 5-Class system from Very High to Very Low.

Bessette Creek is a major tributary of the Shuswap River and is formed by the joining of Harris Creek, Duteau Creeks, and Creighton Creek near Lumby, BC. Harris Creek flows north and connects with Duteau Creek from the west just south of Lumby, BC. Bessette Creek flows north from Lumby and then easterly until it's confluence with the Shuswap River (Swain, 1991). Bessette Creek is a 5th order stream approximately 35.4 km in total length, with a total watershed area of approximately 794 km^2 (BC MOE, 2022; Shuswap Watershed Project, 2022). Bessette Creek represents the uppermost accessible stream for all anadromous fish in the Shuswap River system. The lower sections of the creek provide essential spawning and rearing habitat for Chinook, Coho, and Rainbow Trout (Minor and Walsh, 2012). The Bridge-Coastal Fish and Wildlife Restoration Program Strategic Plan lists the Coho in Bessette Creek as high risk and the Department of Fisheries and Oceans has deemed them a special conservation concern (Walsh, 2010).

Creighton Creek is a tributary of Bessette Creek entering from the east just south of Lumby BC, and similarly to Bessette and Duteau Creeks provides important spawning habitat for the at-risk Interior Fraser Coho (Swain, 1991; Walsh, 2010). However, spawning is limited by low flows combined with an accumulation of bedload material in the lower sections resulting in stranding or insufficient flows for spawning (Walsh, 2010). Creighton Creek is a 4th order stream approximately 36 km in total length, with a total watershed area of approximately 108 km^2 (BC MOE, 2022; Shuswap Watershed Project, 2022). Creighton

Creek also supports Chinook, Rainbow Trout (resident and Mabel Lake recruits) and other resident species (Walsh, 2010).

Duteau Creek is a tributary to Bessette Creek and originates in the Grizzly Hill area until its confluence with Bessette Creek in Lumby, BC (BC MOE, 1998). Duteau Creek is a 4^{th} order stream approximately 42.6 km in total length, with a watershed area encompassing approximately 224 km^2 (BC MOE, 2022; Kerr Wood Leidal Associates Ltd. and Dobson Engineering Ltd., 2008). Duteau Creek is the primary fish producing tributary of Bessette Creek, providing essential spawning habitat for Rainbow Trout, Coho, and Chinook, when flow is sufficient (Shearing, 2013; Pehl, 2009). Coho and Chinook spawn between Lumby and Whitevale Road, as there is an obstruction (gradient too steep) to anadromous migration at approximately 10.8 km and 25.6 km upstream of its confluence with Harris Creek. The lower section of Duteau Creek are most suitable for rearing (Pehl, 2009).

The three streams support populations of two to three of the seven species of Pacific salmon; Coho *(O. kisutch)*, Chinook *(O. tshawytscha)*, and Sockeye (*O. nerka*) as well as non-anadromous forms (freshwater only), including Rainbow Trout (*O. mykiss*) and Kokanee (*O. nerka*). Non-salmonid fish include Brook trout (*Salvelinus fontinalis*), dace (*Rhinichthys* spp.), Mountain Whitefish (*Prosopium williamsoni*), Northern pikeminnow (*Ptychocheilus oregonensis*) suckers *(Catastomus* spp.*)*, sculpin *(Cottidae* spp.), Redside Shiner (*Richardsonius balteatus*), and mussels (*Anodonta* spp.).

Bessette Creek was divided into 18 segments and a total surveyed area of interest of 28.23 km (Map Set 1); Creighton Creek was divided into 12 segments and a total surveyed area of interest of 14.16 km (Map Set 2); and, Duteau Creek was divided into 13 segments and the total surveyed area of interest included 11.06 km of stream (Map Set 3).

The predominant landuse across all three creeks was agriculture, disturbed, rural residential, natural and urban residential, with primarily riffle/pool hydraulic characters. The Very High and High AHI scores/ranks on these watercourses are limited accounting for no more than 11% to 30% of the surveyed area of interests. These high valued habitats are threatened by a variety of instream and upland activities. The loss of riparian vegetation hay/crop production, livestock, infrastructure, and urban development limit the natural stream cooling mechanisms in turn exacerbating rising stream temperatures caused by increasingly hot and arid climates such as those found in the lower reaches of the Middle Shuswap River. Stream bank destabilization additionally leads to wider and shallower stream sections, consequently increasing temperatures and silting up suitable spawning gravels. Juvenile rearing is affected by local stream temperature variations prompting fish to seek colder groundwater inflows and shade. Many of the natural areas of these watercourses continue to occur throughout the majority of the upper watershed and these high value habitats should be protected as they are critical to maintaining water quality and regulating temperatures throughout the streams.

Impacts of livestock access to the instream habitat of these watercourses was extensive throughout all surveyed areas of interest. Livestock access/crossings amounted to 335 m on Bessette Creek, 443.5 m on Creighton Creek, and 483 m on Duteau Creek. Areas with prevalent livestock access had a tendency to overlap areas with high densities of spawning habitat, such as segment 5 in Duteau Creek and Segment 8 of Creighton Creek where the greatest number of spawning habitat features and livestock access points were recorded. This poses an imminent threat to Coho redds in the fall and eggs through the winter. Furthermore, agricultural areas are also commonly associated with minimal riparian vegetation and lack of structural instream complexity, leaving little rearing habitat for Coho and other key fish species. Priority exclusion fencing sites have been identified for each watercourse; 3 sites on Bessette Creek, 6 sites on Creighton Creek and 8 sites on Duteau Creek. If fencing is installed in these areas, and riparian vegetation restored, impacts to spawning and rearing habitat will be significantly reduced.

The removal of riparian vegetation was extensive throughout the surveyed areas of interest, particularly in the lower reaches of the watercourses in the more modified/disturbed segments. The removal of riparian vegetation was typically associated with agricultural activities, but has resulted in significant bank erosion and fine sediment deposits. Moreover, upland activities can impact floodplains. Several bank restoration features were observed throughout the watercourses, including riparian planting on Duteau Creek in urban areas where it has previously been removed and large woody debris enhancements. Future riparian and channel-bank restoration should use similar bioengineering techniques, which include increasing channel complexity, large woody debris, gravel sources, and more intact stream banks. Benefits of these activities will include bank stabilization and habitat restoration.

Low summer flows have the potential to diminish the availability of suitable spawning habitat for a variety of fish species as waters recede through low floodplains and riverine marshes. This risk is compounded by the high demand for water extraction for agricultural activities during summer low flow periods, which has been found to have significant impacts on the South Thompson Coho population (Interior Fraser Coho Recovery Team, 2006). Considering prolonged periods of significant drought are becoming increasingly more common in the interior of BC with the effects of climate change, the impacts affecting spawning and rearing habitat and migration routes are consequently increasing. Low flows have the added risk of stranding, trapping rearing juveniles in high quality backwater habitats, where survival depends on the availability of food, cover, and cool waters. Furthermore, low summer flows further elevate the risk to fish associated with elevated stream temperatures and increased stress on fish, which can lead to lethal consequences. Fish species such as Coho may be forced to use lower reaches as low flows result in inaccessibility to formerly used higher reaches for spawning.

It is paramount that landuse planning and management of Bessette Creek and key tributaries focus on conservation and restoration of floodplain and riparian ecosystems. In addition, opportunities should be explored to increase the relative abundance of off channel and back water habitats, make natural upper reaches that are currently obstructed accessible, and protect cold water refuge habitats for improved salmon rearing/nursery potential. For example, the man-made dam feature documented in Segment 8 of Creighton Creek, which is suspected to be associated with agricultural activities, is functioning as an obstruction to fish passage to suitable rearing/spawning habitat further upstream. Restoring a functional connection for fish and improving in-water cover may increase the habitat suitability and likelihood of upper reaches being used by juveniles and/or spawning adults.

Further investigation regarding the impacts and potential mitigation of extensive water withdrawal for upland agricultural uses and implications of climate change on increased stream temperatures should be undertaken. Furthermore, exploring the direct impacts to fish and spawning substrates by livestock access should be evaluated. It is recommended that the priority restoration sites provided for each stream be prioritized and implemented as soon as possible to restore and enhance the habitat for not only the Threatened Interior Fraser Coho population, but other essential key fish species that utilize Bessette, Creighton and Duteau Creek.

These watercourses have high productive value for anadromous and resident fish species regardless of individual segment AHI scores. A lower AHI segment score does not imply that particular segment is of low value. Rather, the combination of habitat attribute values in that segment contribute less to fisheries and aquatic production than other segments. However, these lower scoring segments are still important for migration and general living. The review of existing or proposed activities should be measured against these baseline AHI scores as a means of conducting a net change analysis. In doing so, such activities and the potential impacts and modifications they may cause can be evaluated in accordance with the Canadian Policy for the management of fish habitat; where No Net Loss is the guiding principle.

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1.0 INTRODUCTION

In 2020 Ecoscape Environmental Consultants Ltd. (Ecoscape) was contracted by the Secwepemc Fisheries Commission to complete a comprehensive inventory and development of an Aquatic Habitat Index (AHI) of three watercourses in the Middle Shuswap River watershed, which is within the Shuswap Nation Tribal Council territory, centralized around Lumby, BC. The three creeks inventoried and mapped included:

- Bessette Creek: approximately 29 kms centralized around Lumby, BC;
- Creighton Creek: between the confluence with Bessette Creek, upstream approximately 14 kms; and,
- Duteau Creek: between the confluence with Bessette, upstream approximately 14 kms.

The following technical report outlines the project approach and presents and analyzes the results of both the Inventory and AHI phases of the project. This report is intended as a "Living Document". In so being, it may be continually edited and updated and may evolve and expand as needed, and serve a different purpose over time.

Sensitive Habitat Inventory and Mapping (SHIM) protocols were used to collect baseline information regarding the current condition of the watercourses and associated riparian habitats. These inventories provide information on channel character, bank types and condition, substrates, land use, and habitat modifications. This information is combined where possible, with other mapping resources such as previous fisheries inventories, recent orthophotos, and other information.

An Aquatic Habitat Index (AHI) is generated using the processed field data to determine the relative habitat value of the aquatic habitats. The AHI uses many different criteria, such as biophysical, fisheries values, and anthropogenic characteristics to estimate the habitat value of a stream segment. The Habitat Index classifies this information in a 5-Class system from Very High to Very Low.

1.1 Project Background

As resource development and human populations increase in British Columbia, pressures for all resources and services have accelerated. Rapid growth has often overwhelmed the ability of local planners to manage land and preserve sensitive habitats (Mason and Knight, 2001). This has resulted in the loss or degradation of aquatic and riparian habitats that are critical for fish and a diverse wildlife assemblage. More specifically, rapid population growth and development around our large interior lakes, rivers and creeks is one of many factors that is impacting our fish and wildlife resources. This tremendous growth rate has resulted in commercial and residential developments around these waterbodies and watercourses.

This rapid increase in population and development presents a significant challenge to plan and/or manage future growth around our large interior lakes, rivers and creeks. Accordingly, there is an urgent need to develop stronger tools and better methods to conserve, protect and reclaim these habitats.

SHIM is a recognized standards for fish and aquatic habitat mapping in urban and rural watersheds in British Columbia. SHIM attempts to ensure the collection and mapping of reliable, high quality, current, and spatially accurate information about local freshwater habitats, watercourses, and associated riparian communities.

SHIM is designed as a land-planning, computer-generated, interactive GIS tool that identifies sensitive aquatic and terrestrial habitats. It is intended to provide community, stewardship groups, individuals, regional districts, municipalities and First Nations with an effective, low-cost delivery system for information on these local habitats and associated current land uses.

SHIM has numerous applications and can:

- Provide current information not previously available to urban planners, to allow more informed planning decisions and provide inventory information for integration into Official Community Plans. In addition, this information can be used to educate the public as to the natural resource values of these systems and the impacts our activities have on them;
- Assist in the design of stormwater/runoff management plans;
- Monitor for changes in habitat resulting from known disturbance;
- Identify and map potential point sources of pollution;
- Help guide management decisions and priorities with respect to habitat restoration and enhancement projects;
- Assist in determining setbacks and fish/wildlife-sensitive zones;
- Identify sensitive habitats for fish and wildlife along watercourses;
- Provide a means of highlighting areas that may have problems with channel stability or water quality that require more detailed study;
- Provide baseline mapping data for future monitoring activities and development of a shoreline management plan; and
- Map and identify the extent of riparian vegetation available and used by wildlife and fish.

2.0 SHIM METHODOLOGY

Biophysical surveys of the streams used the data collection methods and standards of Sensitive Habitat Inventory and Mapping (SHIM) (Mason and Knight, 2001).

Data on Bessette and Duteau Creek was recorded using a Trimble Geo7x/Data Logger and entered into a digital data dictionary. Whereas data on Creighton Creek was collected using an iPad and an EOS – Arrow 100 Submeter GNSS Receiver and Data Collector working in an ArcGIS Online application. Data collection fields for respective biophysical and anthropogenic attributes are listed in the following sub sections. Data collection methods and processing standards can be reviewed in full at:

http://cmnmaps.ca/cmn/files/methods/SHIM_Methods.html

Entering data into the Trimble Geo 7x on Duteau Creek (Left) using the data dictionary. Entering data from Creighton Creek into the iPad with the use of the GNSS Receiver and Data Collector (Right).

2.1 Centerline Survey

The centerline of the stream channels were mapped along the center of the bankfull (not floodplain) width. The streams were stratified into a series of successive sections (segments), each possessing and being characterized by different attributes or biophysical characteristics (i.e., hydraulic class, channel characteristics, substrates composition, and riparian class, etc.; Table 1). The stream segmentation and associated attributes were the fundamental unit of the centerline survey with point features providing a more quantitative measure of relative disturbance/modification and aquatic habitat quality/complexity (i.e., area abundance of deep pools, spawning substrates, large woody debris, bank erosion, etc.). Furthermore, the right and left bank character and condition within a single stream centerline feature for respective segments is documented (Table 1).

The streams were stratified into a series of successive segments, each possessing and being characterized by different attributes or biophysical characteristics (i.e., hydraulic class, channel characteristics, substrate composition, and riparian class etc.).

Table 1. Overview of river centerline data fields collected using the 2017 SHIM data dictionary.	
Stream Reference Information	Name; Watershed Code; Data; Time; Survey Conditions; Surveyors
Stream Segment Length	Linear measure along centerline of channel (m)
Stream Stage	Dry; Low; Moderate; High; Flood; Other
Primary Character	Modified; Natural; Other
Secondary Character	Beaver Pond; Ephemeral; Flumed; Intermittent; Side Channel; Wetland; Braided; Non-channelized; Other.
Channel width	Bankfull level (m); Wetted level (m)
Gradient	% grade
Salmonid Spawning	Yes/No/Potential; Species
Livestock Access	Yes/No; Comment
Hydraulic Character	Cascade; Cascade-Pool; Falls; Pool; Run; Glide; Riffle; Riffle-Pool; Riffle-Run; Slough; Lake; Wetland; Other
Crown Closure	1-20%; 21-40%; 41-70%, 71-90%, >90%
Bars	None; Side; Diagonal; Mid-channel; Spanning; Braided
Islands	None; Occasional; Split; Frequent – Irregular; Frequent – Regular; Anastomosing
Substrate Composition	% Organic; % Fines; % Gravel; % Cobble; % Boulder; % Bedrock
Embeddedness/Compaction	Degree of embeddedness of coarse substrates in fines (sand/silt)
% Instream Cover	Boulder; Deep Pool; Instream Vegetation; Large Woody Debris; Overstream Vegetation
Segment Impact Rating	See Table 2.
Left and Right Bank Fields	
Riparian Class	Row Crops; Broadleaf; Bryophytes; Coniferous forest; Planted Tree Farm; Disturbed Wetland; Dug out Pond; Exposed Soil; Floodplain; Herbs/Grasses; Highly Impervious; Medium Impervious; Low Impervious; Mixed Forest; Natural Wetland; Rock; Shrubs
Qualifier	Agriculture; Natural; Urban Residential; Rural Residential; Recreation; Disturbed; Unknown
Width and Slope	(m) and % grade, respectively.
Stage	Sparse Bryoidl Grass/Herb; Low Shrub; Tall Shrubs (2-10m); Sapling (>10m); Young Forest; Mature Forest; Old Growth
% Shrubs	<5%; 5-33%; 34-66%; 67-100%
Snags	No; <5; >=5

Veteran Trees	No; <5; >=5
Bank Stability	High; Medium; Low
Bank Material	Concrete; Gabions; Pilings; Stonework; Riprap; Retain Wall/Bank Stability; Sandbags; Wood; Bark Mulch; Asphalt; Dyke; Till; Fines; Gravel; Cobble; Boulder; Bed Rock; Other
Top of Bank	Yes; No
Comments	General comments about each bank.

A Level of Impact rating was included in the data dictionary and applied to the centerline segment information. This rating system was designed with the intent of providing a more measurable parameter in evaluating stream conditions and monitoring and evaluating habitat changes on local watercourses and associated riparian and floodplain communities. Individual segment scores were assigned based on the criteria outlined in Table 2. Weighted scores for respective impact ratings were obtained by dividing the cumulative length of the segments receiving the same impact rating by the total stream length being evaluated to obtain a relative value (% of stream length). This value was then multiplied by the respective Score (0-6) equaling the weighted score. The sum of weighted scores was then divided by the maximum attainable score (6)[1] and transformed into a percentage value or stream grade. This scoring system precedes the Aquatic Habitat Index and, on its own, is a field measure of stream/bank condition.

Table 2. Level of Impact rating criteria included in the SHIM data dictionary.

Stream Bank Impact Criteria[1]	Combined Stream Segment Score
Nil-Nil (*Nil impacts on both banks*)	6
Nil-Low	5
Nil-Mod	4
Nil-High	3
Low-Low	4
Low-Mod	3
Low-High	2
Mod-Mod	2
Mod-High	1
High-High (*Impact on both banks is high*)	0

1. Numeric Bank Impact Scores: Nil=3; Low=2; Mod=1; High=0

[1] A combined weighted score of 6 would be attained if all segments were natural with no discernable human disturbance on either the right or left bank. In other words, the stream is pristine.

2.2 Biophysical Units / Features

The biophysical units / features provide a quantitative measure of relative disturbance/modification and aquatic habitat quality/complexity. Table 3 provides a complete list of biophysical units / features collected using the SHIM Data Dictionary.

Table 3. Overview of biophysical units / features collected using the SHIM Data Dictionary (Mason and Knight, 2001).

Watercourse and Habitat Features	Culvert Attributes	Type-Material; Condition; Barrier; Size; Baffles
	Obstruction Attributes	Type-Material; Barrier; Size; Photo
	Stream Discharge Attributes	Point of Discharge; Type-material; Size
	Erosion Feature	Type of Erosion; severity; exposure; material
	Fish Habitat Attributes	Type of Habitat (Spawning/rearing/cover); Size; Slope; Photo
	Enhancement Areas	Type of Enhancement; Potential or existing enhancement
	Wildlife Observations	Type of Observation; Wildlife species; Photo
	Wildlife Tree Attributes	Type of Tree; Size; Location
	Near Waterbody Attributes	Type of Waterbody (spring/side channel/pond etc.); Size
	Wetland Attributes (Polygon feature)	Wetland Type-Class; Photo
	Photograph Location	Location; Direction.

2.3 Data Processing and Quality Assurance and Control

The Resource Inventory Committee and SHIM Methodology (Mason and Knight, 2001) provide specific requirements for quality assurance and quality control. These standards, such as GPS settings/precision, logging intervals, and data management and deliverables were followed throughout the field inventory stages of the project.

GPS settings and use (when using the Trimble Geo7x) were in accordance with Resource Inventory Committee Standards to ensure the collection of spatially accurate data. The coordinate system used was UTM Zone 11 North, North American Datum 83. Data collection using the EOS system is supported by real-time corrections and provides sub-metric precision.

Field data was differentially corrected using base data provided by UNAVCO, Bellingham, WA, situated at 48°51'22.29941"N 122°29'36.02368"W, and SOPAC, Williams Lake, Institute of Geophysics and Planetary Physics (IGPP), situated at 52°14'12.72718"N, 122°10'04.11708"W.

Processing and mapping was completed using ArcGIS 10.2/ArcGISPro. Processed GPS data (shapefiles) were then converted into geodatabases.

To ensure Quality Assurance and Control the following tasks were followed during completion of this project:

- Field data collected was backed onto the local server and field computer at the end of each field day and synced to ArcGIS Online;
- All field data collected during the field inventories was post processed by the field inventory biologist, Leanne McDonald, B.Sc., R.P.Bio., P.Ag.;
- We reviewed each attribute collected during the field survey as part of a quality control / assurance process. The final database has been provided to the Secwepemc Fisheries Commission and project partners at the completion of the project. Corrections and adjustments to the database will be made as necessary; and,

2.4 Photo Log

SHIM standards require that a detailed photo log accompany and be incorporated into the database. All photos were entered into a log for location and subject reference. In addition, coordinate locations (UTM Zone 11 North, North American datum 83 Canada) where photos were taken was entered into the GPS to enable spatial referencing on the ground for each photo.

3.0 AQUATIC HABITAT INDEX

The Aquatic Habitat Index (AHI) is a categorical scale of relative habitat value and condition that ranks the shoreline of a lake, river channel and bank segments, or in this case, the creek channels, in a range between *Very High* and *Very Low*. AHI was initially developed for Foreshore Inventory Mapping (FIM) to primarily assess the level of shoreline developments in increasingly urbanized areas of the Okanagan Valley. The index was revised for large River Inventory Mapping (RIM). The data collected for the RIM project involved numerous spatial data layers and was substantially more complicated to develop than the AHI developed for lake ecosystems.

The AHI logic was adapted for the Duteau/Creighton/Bessette Creek SHIM. The AHI that was previously revised for RIM projects was revised further given the scale of these creeks compared to larger river systems. AHI for SHIM focused on the instream values and associated riparian character and condition as recorded in the centerline feature class only. As such, the scoring matrix focused on extent and distribution of instream fish habitat features, with particular focus on density of spawning habitat features, large woody debris for shelter and cover, and deep pools and rearing features, as they are both representative of rearing habitat with a secondary assessment of riparian and streambank quality.

The AHI provides a categorical scale of relative habitat value that ranks stream segments in a range between *Very High* and *Low* sensitivity. The following provides a definition for each AHI ranking:

- *Very High* – Segments ranked as *Very High* are considered integral to the maintenance of fish and wildlife species and generally contain important natural riparian and floodplain areas, complex mosaics of habitat units supporting high biodiversity and productivity values, and high value/use salmonid spawning, rearing, and general living habitats. These areas should be considered the highest priority for conservation and protection.
- *High* – Segments ranked as *High* are considered to be very important to the maintenance of fish and wildlife species along and within the river and areas can be ranked as *High* for a variety of reasons. These areas should be considered a priority for maintaining current conditions and a high prioritization for conservation should be given to these areas.
- *Moderate* – Segments ranked as *Moderate* are areas that are common along the river, and have likely experienced some habitat alteration. These areas may contain important habitat areas, such as shore holding areas (deep pools), but these areas are generally considered more appropriate for development. Because areas of high habitat value may be present, caution should be taken when considering changes in land use to avoid unnecessary harm or degradation to existing habitat values.
- *Low* – Segments that are generally highly modified. These areas have been impaired through land development activities. A common symptom along the river is high bank instability and bank erosion exacerbated by the removal/absence of riparian vegetation. Development within these areas should be carried out in a similar fashion as *Moderate* shoreline areas. However, restoration objectives should be set higher in these areas during redevelopment.

Fish habitat features were assigned a relative habitat value for each key fish life history stage/habitat quality categories. The relative productivity value was defined for each habitat unit as the sum of all production scores accrued by each of the fish species during the time they spend any part of their life history in that area (e.g., for spawning, rearing, and feeding) or accrued elsewhere as a result of a strict habitat requirement to use that area of habitat (e.g., for staging, migration, or cover).

Habitat unit: Fish life history and habitat requirement matrices were developed to determine the relative habitat value for each habitat unit. Life history stages considered were:

- Spawning
- Rearing
- General Living/Feeding

Habitat Requirement categories included:

- Substrate composition
- Cover (habitat complexity)

Life history accounts informed the relative values assigned to each habitat unit for each species and life history stage. The sum of species scores for each habitat unit were then transformed to a relative habitat value, which was calculated as the habitat unit score / maximum habitat unit score. The life history and habitat attributes were then weighted based on the relative importance of these components in the index for production. Density of spawning habitat was weighted highest at 4 times that of the density of the other instream features.

4.0 KEY FISH SPECIES

The three streams support populations of two to three of the seven species of Pacific salmon; Coho *(O. kisutch)*, Chinook *(O. tshawytscha)*, and Sockeye (*O. nerka*). Table 4 provides a list of anadromous salmonids, freshwater salmonids, and non-salmonid species documented in each stream.

Table 4. Fish species documented in Bessette Creek, Creighton Creek and Duteau Creek (BC MOE, 2022).

Common Name	Scientific Name	Bessette Creek	Creighton Creek	Duteau Creek
Anadromous Salmonids				
Chinook	*Oncorhynchus tshawytscha*	X	X	X
Coho	*Oncorhynchus kisutch*	X	X	X
Sockeye	*Oncorhynchus nerka*	X		X
Freshwater Salmonids				
Kokanee	*Oncorhynchus nerka*	X	X	
Rainbow Trout	*Oncrohynchus mykiss*	X	X	X
Non-salmonid Species				
Brook Trout	*Salvelinus fontinalis*			X
Dace	Rhinichthys spp.			X
Mountain Whitefish	*Prosopium williamsoni*	X	X	X
Mussels	*Anodonta* spp.	X		X
Northern Pikeminnow	*Ptychocheilus oregonensis*		X	
Redside Shiner	*Richardsonius balteatus*	X		
Sculpin	*Cottidae* spp.	X		X
Sucker	*Catastomus* spp.	X		X

The Interior Fraser population of Coho (*Oncorhynchus kisutch*) was initially assessed by COSEWIC as Endangered in May of 2002 and was later reassessed in 2016 where the status was changed to Threatened. The Lower Thompson, Spring population of Chinook was designated as Endangered by COSEWIC in November 2020 (COSEWIC, 2002; COSEWIC, 2016).

Because of their importance to commercial, recreational and Indigenous fisheries, the following were selected as key species for matrix development (to assign relative habitat scores) in this study, as they occur in all three streams: Chinook, Coho, Kokanee, Rainbow

Trout and Sockeye. Coho was the primary species of focus when it came to evaluating the condition of the streams. Spawning Coho were in the systems during the fall surveys and their documented presence validated sites identified as spawning habitat. In addition, the habitat requisites for Coho spawning and rearing are similar to those for other salmonids, including resident Rainbow Trout.

4.1 Chinook Salmon

In British Columbia Chinook (*Oncorhynchus tshawytscha*) spawn in over 250 rivers and streams (McPhail, 2007). Chinook are the largest of seven species of Pacific salmon and have the widest distribution. They have sustained First Nations for thousands of years, provide important recreational and commercial harvesting opportunities, and were an important part of the colonization of British Columbia.

Within the Shuswap River System and Bessette Creek systems, there are two developmental types of Chinook; 95% are 4_1 ocean-type (sub-yearlings) and the remainder are 4_2 stream-type (yearlings; Shearing, 2013). Ocean type Chinook rear in freshwater for several months and migrate to the ocean in the first fall, whereas stream type Chinook rear in freshwater for one year before migrating to the ocean (DFO, 1997). The stream-type generally spawn in Bessette Creek, and its tributaries (Duteau Creek and Harris Creek; Shearing, 2013). In 2000, the catch per unit effort of Chinook in Bessette Creek was 0.2 and stream walks of Duteau creek documented 31 Chinook adults (Pehl, 2009).

Chinook are a high priority for the Department of Fisheries and Oceans (DFO), who maintain a hatchery to augment the population in the Shuswap River system. They spawn naturally below the Wilsey dam; however, it is believed that historically they accessed areas above the dam. DFO has released adult Chinook above the dam in previous years, which resulted in successful rearing and spawning above the dam (FWCP, 2011). Overall spawning habitat above the dam has been estimated to be 1.5 to 2 times greater than downstream of the dam for both Chinook and Coho (FWCP, 2021).

REPRODUCTION

Ocean-type Chinook return to the Middle Shuswap River system in July with peak spawning occurring between October 2nd and 21st, whereas stream-type juveniles overwinter and out-migrate after their first or second year (Arc Environmental Ltd., 2001; Shearing, 2013). Stream-types typically have large ocean-migrations and return prior to spawning, in the late spring or summer (Shearing, 2013).

Water depths, velocities, and substrates within the lower 15 km of the Middle Shuswap River are not particularly suitable for spawning Chinook (Arc Environmental Ltd., 2001). Significant decline in Middle Shuswap River Chinook escapement was documented in 2012 where only 236 Chinook returned, compared to the 30-year average return of 2,188

Chinook. Bessette’s stream-type Chinook population is considered a conservation priority and was identified as a stock of concern in 2011 (Shearing, 2013).

Chinook females choose the spawning site and appear to prefer sites with subgravel flow (e.g., In the tail-outs of pools immediately above riffles or in upwelling sites; McPhail, 2007). Chinook eggs are the largest of the species of Pacific salmon and require higher rates of flow and oxygen than other species. As with most other species of Pacific salmon, adults will die after spawning.

AGE, GROWTH AND MATURITY

Chinook eggs incubate through the winter period and fry emerge in the early spring. As with the other species discussed, their incubation period varies with water temperatures. Once emerged, the diet of fry includes adult chironomids as well as chironomid larvae and pupae, terrestrial insects taken from the surface, and nymphs of larvae of aquatic insects (McPhail, 2007). Upon emergence, Chinook fry are often moved downstream by flows from areas where they incubated towards Mabel Lake (Arc Environmental Ltd., 2001; Groot and Margolis, 1991). However, some dry will reside in off/side channel habitats for several weeks (Arc Environmental Ltd., 2001). Their habitat range is often keyed to flow velocities rather than habitat types. They range widely in habitat use but generally will occupy boulder areas in faster waters. The majority of Chinook in the Middle Shuswap System will migrate to Mabel Lake within 60-90 days and return to the ocean within 90-150 days post-emergence, returning 4-5 years later to spawn as adults (Arc Environmental Ltd., 2001).

Juvenile rearing is not well understood but both natal streams and lakes are utilized. Densities of spawning Chinook are generally high along the margins of Mabel Lake in June and July, with some fry remaining in the main river for a full year (Arc Environmental Ltd., 2001). Lakes and larger natal streams provide overwintering freshwater habitat for stream type Chinook, which allows fish to attain significant body mass allowing for subsequent salt water adaptation (DFO, 1997). Ocean type Chinook likely realize a greater benefit from the productivity of larger lakes (DFO, 1997).

HABITAT INDEX MATRIX

Chinook adults are heavily dependent on deep pools where they may hold for up to 8 weeks before moving out to spawning grounds. Their spawning areas must have larger diameter clean gravels which will afford adequate percolation of flows and oxygen to meet incubation requirements. They are particularly sensitive to movements of silt or reductions in flow during the incubation period.

4.2 Coho Salmon

LIFE HISTORY

Coho Salmon (*Oncorhynchus kisutch*) are an important species and range through hundreds of coastal and interior streams in British Columbia. Interior Fraser River Coho Salmon are genetically unique and can be distinguished from Lower Fraser River Coho. Studies of the genetic structure of Interior Fraser Coho indicate that there are five distinct populations. Three are within the Thompson (North Thompson, South Thompson, and Lower Thompson regions) and two are within the Fraser (the area between the Fraser Canyon and the Thompson-Fraser confluence and the Fraser River and tributaries above the Thompson-Fraser confluence) (Interior Fraser Coho Recovery Team, 2006). Middle Shuswap River Coho, are considered part of the South Thompson sub-population (Shearing, 2013). The average number of mature individuals in the South Thompson sub-population between 2014 and 2016 was an estimated 5,600 (COSEWIC, 2016). Coho in the province is managed federally by Fisheries and Oceans Canada.

Coho populations in British Columbia's Interior face many threats and challenges. So much so that in 2002 the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed them as Endangered. COSEWIC was concerned that if Interior Fraser Coho distribution became too fragmented, genetic exchange within the populations may be insufficient to ensure long-term survival (COSEWIC, 2002). However, in 2016, COSEWIC reassessed them as Threatened. Since the 2002 assessment, there was an observed trend in mature population numbers that indicated the decline previously observed had stopped, but there remained serious threats that could reverse the trend (COSEWIC, 2016).

Between 1985 and 1993, annual returns, which includes catch and spawning escapement, averaged 161,000 without trend. Returns dramatically declined between 1994 and 2012, with an average return of 37,000 with little trend. Escapement was around 60,000 between 1985 and 1989 and dropped dramatically in 1997 to 16,000. In 2001 escapement increased to 39,000 but declined again in 2005 to 15,000. Escapement increased to 41,000 in 2012 but reduced to 21,000 in 2014 (COSEWIC, 2016).

While natural spawning is responsible for producing most of the Coho Salmon escaping to the Interior Fraser River, Coho stocks in the South and Lower Thompson systems are supplemented by hatchery programs on the Nicola and Salmon rivers as well as on Bessette Creek. The majority of the hatchery produced population are released as yearling smolts, as a means to limit freshwater residency by hatchery fish and consequently minimize competition with the wild stock (Interior Fraser Coho Recovery Team, 2006).

Interior Fraser Coho require adequate freshwater and marine habitats to survive and reproduce. These fish spawn in freshwater and the juveniles normally spend one full year in freshwater before migrating to the sea as smolts. The distribution of spawning habitat for Coho is usually clumped within watersheds, often at the heads of riffles in small streams and in side-channels of larger streams. However, Interior Fraser Coho are commonly observed spawning in mainstems of larger rivers during periods of low flow, presumably when tributary and side-channel habitats are less accessible.

The outlook for Interior Fraser Coho is highly uncertain and depends on the magnitude of negative impacts due to fishing, habitat perturbations, and climate related changes in survival. A return to higher survivals, combined with continued low exploitation rates, conservation of existing habitat, and habitat restoration, could produce increases in escapements and subsequently population recovery. However, if survival rates are at low levels, such as those recorded in 2005, spawner numbers will continue to decrease, possibly resulting in the eventual extinction of Interior Fraser Coho. Since there is no predictor of future survival rates, a cautious approach to harvest and habitat management will be required to ensure the long-term viability of Interior Fraser Coho (Interior Fraser Coho Recovery Team, 2006).

REPRODUCTION

The timing of river entry and spawning varies with latitude and distance from the ocean. Middle Shuswap River Coho stocks return at age 3 arrive mid-October with with spawning taking place between October 21st and December 7th (Arc Environmental Ltd., 2001). Spawning Coho are the most secretive of Pacific salmon and most reproduction behavior occurs at night.

Coho have similar tendencies to Rainbow Trout in their selection of rearing habitat (Griffith, 1986). They prefer sites with sub-gravel flow as is found in tail-outs of pools immediately above riffles or upwelling sites. They prefer smaller tributary and headwater streams often not much more than 1 m in width. Eggs incubate over winter and hatch in the spring. Incubation timing is dependent on water temperatures as with all other salmonids in the Thompson system.

Fry emerge from late March through late May and early June (DFO, 1997). Juveniles spend one year in freshwater, rearing initially in their natal streams and subsequently moving downstream to rear and overwinter in rivers and lakes (DFO, 1997). Migration likely occurs between mid-April and early May.

AGE, GROWTH AND MATURITY

In British Columbia, Coho fry usually reach 80-90mm in their first year (McPhail, 2007). Coho fry in interior streams normally spend 1 to 2 years in nursery streams before out-migrating to the Pacific Ocean. They are primarily drift-feeders and take the drifting stages of aquatic insects from the water column or terrestrial insects from the surface. Coho prefer pools and backwater areas. They will aggregate in backwaters, side-channels and quiet embayments along stream margins. They will eventually emigrate to larger rivers and will search out off-channel overwintering areas such as beaver ponds and flooded wetlands (McPhail, 1997).

In winter they will seek cover under woody debris, undercut banks, cobbles and move deeply into root wads.

HABITAT INDEX MATRIX

The Habitat Index Matrices indicate that Coho adults require cascade areas, confluence areas, pools, riffles, runs, cover and access to small streams in upper watersheds. They will hide under cut banks and root wads and will search for suitable gravel in upwelling areas and tail-outs of pools.

Coho juveniles depend heavily on pools, backwaters, instream vegetation areas, low and middle flood benches, marsh areas, side channels, cobble areas and large woody debris. Tributary stream confluences are important as are small, stable streams, which provide rearing habitat. These streams will support Coho through their incubation period and their first year of rearing. Adequate year-round flows and cool temperatures afforded by well-developed riparian zones are important. Some fry will move to the main rivers where they will seek back-waters, flood benches and beaver dams.

Coho in south central B.C. will usually rear for 1 year in freshwater and then begin their migration to the ocean. They will spend 18 months at sea before returning as adults to spawn. As with other Pacific salmon (except for Steelhead and coastal Cutthroat) they die after spawning.

4.3 Kokanee

LIFE HISTORY

Kokanee (*Oncorhynchus nerka*) are considered a keystone species in many large British Columbia lakes. They are most often the major source of forage for other predators such as Burbot, Rainbow Trout, Lake Trout and Bull Trout. Provincially they are third only to Rainbow and Cutthroat Trout in sport fish catch (Ministry of Water, Land and Air Protection, 2003).

Kokanee are a non-migratory form of Sockeye salmon. They have very similar traits to Sockeye with the one major exception that they spend their entire life in freshwater. Traditionally most fishery managers believed that Kokanee were quite abundant, requiring little attention. Today, however, that perception has changed and the prevailing view is that this important species appears to be in trouble in many interior lakes. Reasons for this decline are believed to be habitat related and are focused on spawning habitat deficiencies (Redfish Consulting, 2005).

Kokanee populations was considered stable below Wilsey dam, yet for most of the Shuswap Lake system, are not well understood (FCWP, 2011). There appears to be a critical absence of information on habitat use, angler harvest and escapement numbers over time (Ministry of Forests, Lands and Natural Resource Operations files. 2011).

REPRODUCTION

Kokanee adult spawners normally migrate starting in early October and runs will extend until late October. The spawning peak will usually occur between October 8 and 15 (Ministry of Forests, Lands and Natural Resource Operations files. 2011). Depending on water velocity and female size, gravel diameters utilized range from about 1.0 to 2.5 cm. Water velocities and depths are also variable and range from 0.15 to 0.85 m/s and from 6 to 37 cm, respectively (McPhail, 2007). Like other Pacific Salmon, Kokanee die after spawning. Fecundity ranges from about 200 to about 1500 eggs in Kokanee. Development rate is a function of incubation temperature.

There is a small population (hundreds) that have been documented to spawn in the lower reaches of Bessette Creek; however, historically, this population numbered in the thousands and spawned further upstream towards Lumby, BC (Arc Environmental Ltd., 2001).

Their requirement for lower velocities and shallow conditions can leave them highly vulnerable to a drop in flows through the winter incubation period as these side channels will dry out first causing heavy egg/alevin mortality. In a 1991 study conducted on the Middle Shuswap River it was determined that approximately 50% of the Kokanee eggs deposited in side channels perished due to declining flows caused by B.C. Hydro operations at Wilsey Dam (Jantz, 1992). This study led to a change in operational regimes by B.C. Hydro where flows are now reduced prior to Kokanee spawning and carried for as long as storage supplies last through the incubation period.

Kokanee spawning locations in the Middle Shuswap River have not been conducted annually, and data is generally limited to the Lower Shuswap River where annual spawning numbers have varied considerably since the earliest recorded counts of 1950. Numbers range from a high of 337,000 in 1962 to lows of 3600 in 2002 (Redfish Consulting, 2005). In the 1960’s and 70’s the majority of counts ranged from 50,000 to 100,000. By the 1980’s spawning numbers were on the decline with totals of 5,675 and 16,103 in 1986 and 1987 respectively (Jantz, 1992). A record number for recent years occurred in 2004 when 124,000 were counted (Redfish Consulting, 2005). Low numbers in 2002 are a key indicator, however, that escapements have declined considerably in recent years.

AGE GROWTH AND MATURITY

Upon emergence, Kokanee usually migrate to a nursery lake before starting to feed. This downstream migration occurs at night with peak migration between dusk and midnight (Lorz and Northcote, 1965; Webster, 2007). The fry are negatively photactic (avoid light) and, if the migration takes more than one night, they shelter during the day under rocks and organic debris (McPhail, 2007).

On lake entry the fry of some Kokanee populations immediately move offshore and begin vertical migrations in search of zooplankters, their preferred feed. Other populations, however, remain inshore and forage in the littoral zone for variable amounts of time. These differences in fry behavior probably are related to food availability, temperature and predation risk (McPhail, 2007). Middle Shuswap River Kokanee rear in Mabel Lake and return to spawn as 3-year olds in side channels, or areas with shallow, lower velocity water and small substrates (Arc Environmental Ltd., 2001).

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study accordingly rates Kokanee adult stages as high for spawning gravel requirements but low in requirements for cover and rearing. During the spawning process they show little concern about hiding and cover as they go about the task of building redds and laying and fertilizing eggs. Gravel conditions and flows are very important during the egg to fry incubation stage. The emergent fry may have some limited requirements for cover or habitat complexity as they attempt to swim downstream under cover of darkness as quickly as possible. As McPhail (2007) explains, if the journey takes more than one night they will seek cover of organic debris or boulders along the way then resume their swim after dark.

4.4 Rainbow Trout

LIFE HISTORY

Rainbow Trout (*Oncorhynchus mykiss*) are an important game fish and are considered the number one target for anglers in the British Columbia interior. It is apparent that there are two forms of trout in the system; a resident population that lives its entire life cycle in the river and adjoining tributaries, and an adfluvial form that spends the majority of its life in large lakes but migrates to rivers and streams to spawn or feed (Ministry of Environment files, 2011). There are many similarities between these two groups as far as spawning requirements, early rearing and adult life forms and accordingly these life forms will be grouped in this discussion.

Rainbow Trout in the system, both in lake forms and resident river populations are heavily sought after by anglers and tend to be easily overfished.

REPRODUCTION

Rainbow Trout are spring spawners and migrations into spawning streams are triggered by rising water temps (above 5°C) and rising water levels (McPhail, 2007). Streams are critically important for the nursery phase of Rainbow Trout juvenile rearing. Furthermore, in the Middle Shuswap River system, Rainbow Trout primarily utilize Bessette Creek to spawn and rear for 1 to 2 years (Arc Environmental Ltd., 2001). Maturing adults will migrate into these streams during freshet flows (February through June) and will spawn on the receding flows, generally between February through to the end of May (Arc Environmental Ltd., 2001). Unlike Pacific salmon, Rainbow Trout adults can survive spawning and it has been determined that about 10% will live on to spawn a second time (McPhail, 2007).

Rainbow Trout juveniles rearing in small streams tend to be highly connected with riffles, runs and large woody debris. These areas provide the best habitat for cover and feed consisting of small aquatic insects. They need to select streams that provide suitable habitat to survive summer and winter extremes for up to three years. Low summer flows, caused by agricultural irrigation diversions can have significant impact on smaller streams. Rainbow Trout juveniles can also be displaced by other fish, such as Coho, which tend to compete heavily for prime feeding areas as they have similar diets (Griffith, 1986).

In rivers, Rainbow Trout will normally establish territories in shallow water along stream margins (Slaney and Northcote, 1974). During their adult phase in streams and rivers they occupy riffles, runs, glides and pools and tend to occur in deeper and faster water than juveniles (McPhail, 2007). As they grow, terrestrial insects are added to their diet and so riparian areas along river margins become increasingly important to them (McPhail, 2007).

AGE, GROWTH AND MATURITY

Some Rainbow Trout will live their entire life cycle in small streams or rivers (resident) while others are of an adfluvial nature and will move down to large lakes. In the Middle Shuswap River, Rainbow Trout fry generally rear in side channels and some parr rearing occurring in habitats with suitable velocities and complexity within the mainstem (Arc Environmental Ltd., 2001). Information is limited on downstream migration traits but it is believed that they travel in the freshet and utilize cover habitats along the way to escape their predators (McPhail, 2007). Adfluvial trout can live up to 8 years before maturing with the norm being 5 or 6 (Ministry of Environment files, 2011). Their biggest obstacle in lakes is anglers who target them extensively. Rainbows can tolerate temperatures up to 27°C but anything higher can be lethal (McPhail, 2007). In adfluvial populations, Rainbow Trout rely heavily on Kokanee and Sockeye forage once they move to large lake habits.

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study indicate that Rainbow Trout depend heavily on pools, runs, riffles, boulder areas and cover afforded by riparian vegetation or in-stream woody debris. Log jams associated with pools are also used extensively for feeding and hiding. Tributary stream confluences are important as are small, stable streams that provide rearing habitat for juveniles and resident populations.

4.5 Sockeye Salmon

LIFE HISTORY

Sockeye salmon (*Oncorhynchus nerka*) are the third most abundant of the seven species of Pacific salmon (Groot and Margolis, 1991). In British Columbia Sockeye tend to have similar life history traits as kokanee with a few major exceptions. As with Kokanee, Sockeye fry normally will spend their first year in a fresh water lake, then they will begin the long journey to the Pacific Ocean. This anadromous tendency allows them to become much larger than Kokanee as there is more abundance of feed in the north Pacific than in interior lakes. Sockeye spend from one to four years in the ocean before returning to fresh water to spawn.

REPRODUCTION

Sockeye spawn in the fall, usually when water temperatures drop below 12°C. In the Middle Shuswap River this normally occurs in late September, with peak spawning generally occurring between October 10th and 20th (Arc Environmental Ltd., 2001; McPhail 2007). As with Kokanee, Sockeye will form dense aggregations on spawning grounds. They will normally choose larger spawning substrates than kokanee which tends to cause separation in spawning locations. Like other Pacific salmon, Sockeye will defend their redds until too weak to maintain position and die after spawning.

Even in larger rivers, Sockeye tend to spawn in shallow riffle areas (Groot and Margolis 1991). There are exceptions; however, and it is clear that they have the ability to detect and utilize groundwater upwelling areas. Fecundity varies from about 2,000 to 4,000 eggs related to female size (Groot and Margolis, 1991). Incubation times vary related to water temperatures and in the Shuswap River they tend to emerge from gravels in early spring (April and May) then immediately begin their downward migration to Mabel Lake. Sockeye spend their first-year rearing in freshwater lakes prior to migrating downstream to the Pacific (Arc Environmental Ltd., 2001). Fry need to move downstream quickly to lakes where they begin feeding or they will not survive. They move downstream under cover of darkness to avoid predators.

Sockeye, unlike Kokanee, in the Middle Shuswap River, cycle on a four-year rotation and can vary considerably in numbers from year to year. Dominant cycle years have been documented in 1994 and 1998, with escapements of 31,806 and 15,262, respectively (Arc Environmental Ltd., 2001). Sockeye tend to spawn in areas above nursery lakes or in some cases just below (McPhail, 2007).

AGE, GROWTH AND MATURITY

As with Kokanee, Sockeye fry once emerged from the gravel normally will migrate downstream under cover of darkness to their nursery lake for a period of rearing, usually lasting one year. McPhail (2007) suggests that the migrating fry will look for cover areas in organic debris or boulder substrate if the migration cannot occur in one night. They will then resume their downstream travel once darkness returns.

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study tend to be very similar for Sockeye as they are for Kokanee. Spawning gravel attributes score very high for adult spawning and juvenile incubation while rearing and cover attributes score low due to their tendency to spend most of their juvenile stage rearing in Mabel Lake and Shuswap Lakes and then the remainder of their adult life rearing in the Pacific Ocean.

5.0 BESSETTE CREEK INVENTORY SUMMARY OF RESULTS

Bessette Creek is a major tributary of the Shuswap River and is formed by the joining of Harris Creek, Duteau Creeks, and Creighton Creek near Lumby, BC. Harris Creek flows north and connects with Duteau Creek from the west just south of Lumby, BC. Bessette Creek flows north from Lumby and then easterly until it's confluence with the Shuswap River (Swain, 1991). Bessette Creek is a 5th order stream approximately 35.4 km in total length, with a total watershed area of approximately 794 km^2 (BC MOE, 2022; Shuswap Watershed Project, 2022). Bessette Creek represents the uppermost accessible stream for all anadromous fish in the Shuswap River system. The lower sections of the creek provide essential spawning and rearing habitat for Chinook, Coho, and Rainbow Trout (Minor and Walsh, 2012). The Bridge-Coastal Fish and Wildlife Restoration Program Strategic Plan lists the Coho in Bessette Creek as high risk and the Department of Fisheries and Oceans has deemed them a special conservation concern (Walsh, 2010).

Bessette Creek was divided into 18 segments and a total surveyed area of interest of 28.23 km (Map Set 1).

5.1 Land Use Relative Distribution

Utilizing the qualifier data associated with each stream segment, relative land use was determined (Figure 1). The majority of the left bank consisted of *agriculture* (42.5%), followed by *natural* (33.0%). Whereas the right bank was the opposite, with *natural* land use being the predominate qualifier (35.2%) followed by agriculture (31.1%). Disturbed, urban and rural land use qualifiers were less common throughout the surveyed length of the creek. The following photo plates illustrate the land use classes/character described in this inventory.

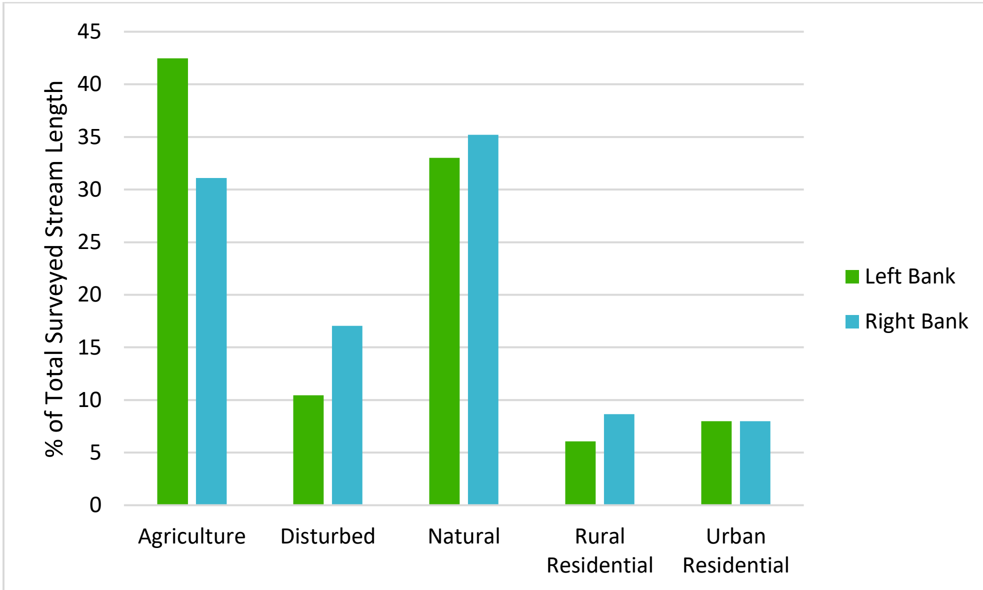

Figure 1. Relative land use distribution along the left and right bank of Bessette Creek.

Agriculture

Disturbed

Natural

Urban Residential

Rural Residential

5.2 Stream Channel and Hydraulic Character

The hydraulic character of Bessette Creek is predominantly riffle-pool on over 19 km (69.1%) of the 28 kms surveyed (Figure 2). To a lesser extent, Bessette Creek also has long stretches of more run morphology, totaling about 6.8 km (23.9%).

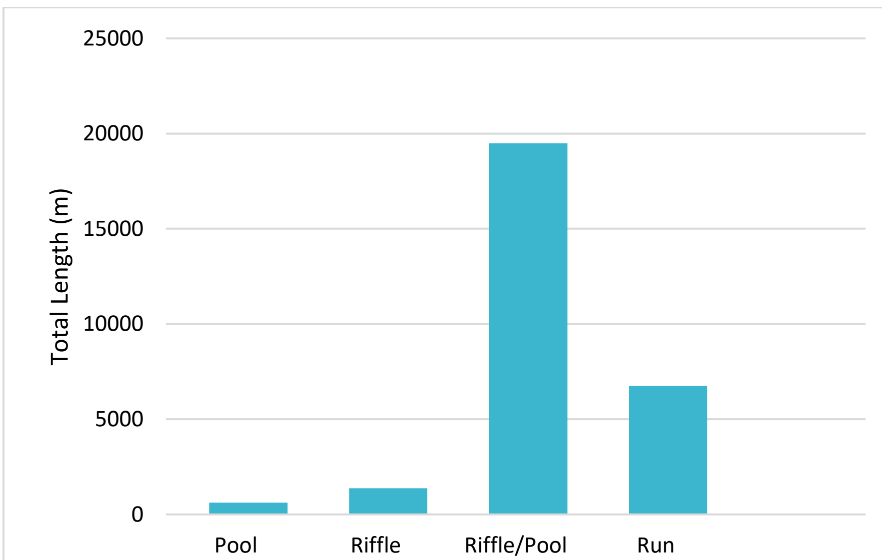

Figure 2. Bessette Creek hydraulic class distribution over the 28 km surveyed area of interest.

5.3 Fish Habitat

Physical habitat in Bessette Creek was found very suitable for Chinook (more so in lower segments) and Coho production. Key rearing areas for Chinook were described by Federenko and Pierce (1982) as flooded pastures, backwaters and sloughs adjacent to spawning areas. Furthermore, Coho prefer pools and backwater areas and will aggregate in backwaters, side-channels and quiet embayments along stream margins. In the winter they will seek cover under woody debris, undercut banks, cobbles and move deeply into root wads.

Deep pools are important for cover and general living as well as holding areas for anadromous migrations. These features amount to about 3.51 ha of the total surveyed instream area of fish habitat features in Bessette Creek, or 66.8% (Figure 3). Large woody debris (LWD) provides important structural cover/complexity for fish, particularly Coho as described above and accounts for 0.77 ha of instream area on Bessette Creek, or 14.8% of the total instream area of fish habitat features. Suitable spawning habitat was recorded for prominent gravel/pebble features through runs, associated with LWD, where any redds were observed and at the outlets of pools. These features areas account for about 0.24 ha or 4.6% of the total instream area of fish habitat features.

The density of spawning habitat across the surveyed area of interest was calculated as both the number of spawning habitat features per segment length (green in Figure 4) as well as the total length of the spawning habitat features per segment length (blue in Figure 4). The greatest density and spatial extent of spawning habitat features per segment length was in segment 11, 15, and 6, with a density of 0.071 m of feature /m of segment, 0.078 m of feature /m of segment, and 0.025 m of feature /m of segment, respectively. The greatest density in terms of number of spawning features per segment length also included segment 15 at 0.011 features/m, as well as segment 16 and segment 12, which ranged between 0.007 features/m and 0.011 features/m (Figure 4). Segments 4, 8, 9, 13, and 18 had no spawning habitat features documented. The recorded spatial extent of spawning is an underestimate of total potential spawning habitat and fish use in Bessette Creek. Over 19 km of the stream is riffle-pool and suitable spawning substrates were documented throughout.

In Bessette Creek, a total of four (4) side channels were documented in segments 4, 17, and 18 and only 1.1% of the instream area was mapped as rearing habitat. Side channels were mapped as singular habitat features. There was a total of 17 tributaries, side channels and/or ditches documented throughout the surveyed creek. These areas are important seasonal habitats that may provide seasonal nursery and rearing habitat for juvenile salmonids.

The data summarized in Table 5 and illustrated in Map Set 1 was also incorporated into the AHI (Section 5.6.1).

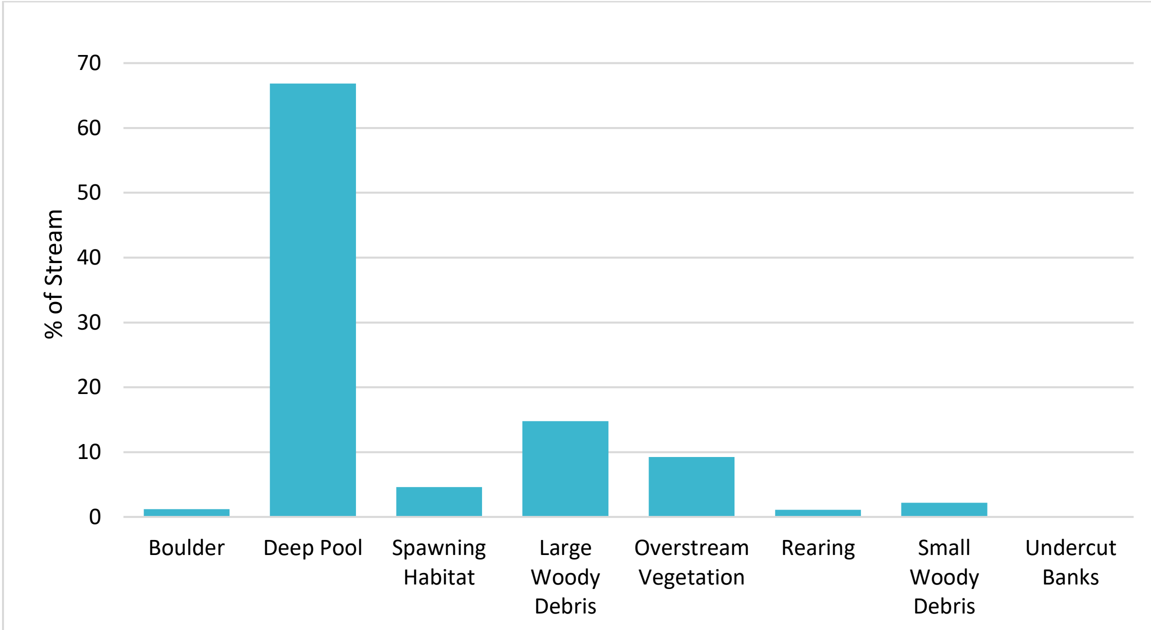

Figure 3. Relative distribution of key habitat elements mapped during the Bessette Creek inventory. Percentage values shown in the illustration represent the estimated spatial coverage of each respective feature over the total instream area of the fish habitat features.

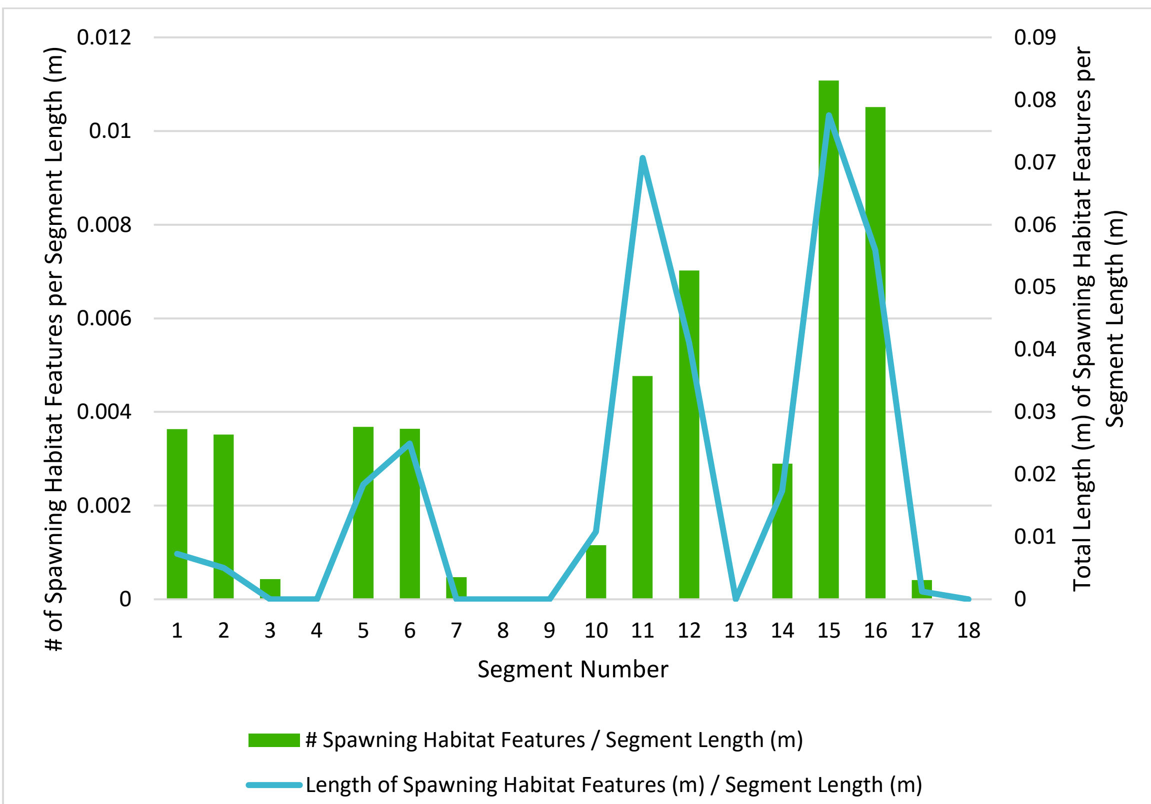

Figure 4. Density of number of spawning habitat features (green) and density in total length of spawning habitat features per total length of each segment on Bessette Creek.

Table 5. Mapped aerial coverage and linear extents of fish habitat in Bessette Creek			
Row Labels	Combined Area (m^2)	Cumulative Length (m)	Relative linear abundance in surveyed area of interest (28,223 m)
Boulder	640	70	0.25%
Deep Pool	35,130	4,579	16.25%
Spawning Habitat	2,423	479	1.70%
Large Woody Debris	7,762	1,098	3.89%
Over Stream Vegetation	4,860	1,990	7.05%
Rearing	592	114	0.40%
Small Woody Debris	1162	461	1.63%
Undercut Bank	24	80	0.28%

Large woody debris.

Spawning habitat.

Backwater (rearing) and associated large woody debris

Tributary (rearing/spawning)

5.4 Modifications

Instream and bank modifications and features were recorded in the field as points and summarized in Table 6. It should be noted that general clearing/removal of riparian vegetation and encroachment by field and urban and rural development was generally recorded as "Other", however, this component is better captured within the percent disturbed field for individual segments.

Bridges were a prevalent feature on the creek, with 19 bridges recorded across the entire 28 kms surveyed. Bank armouring (rip rap) was recorded on close to 2 km of both the left bank and right bank. Livestock access and crossings were another prevalent modification, especially on the right bank with close to 300 m of livestock assess recorded and a total of 13 points of access. General riparian modifications were also over represented on the right bank, with approximately 530 m of modifications recorded compared to 148 m on the left bank. Alternatively, a greater density of garbage/pollution was seen on the left bank, with 170 m compared to 63 m on the right bank.

Table 6. Summary of anthropogenic features and modifications catalogued during the Bessette Creek Inventory.

Feature	Bank	Sum of Length (m)[1]	Count of Modification Type
Bridge	Both	110.5	19
Livestock Access	Both	6	1
	Left	15	3
	Right	291	13
Fences	Both	0[2]	1
	Instream	0[2]	2
Livestock Crossing	Both	23	4
Garbage/Pollution	Left	170	8
	Right	63	9
Other (i.e., general riparian modifications)	Both	10	1
	Instream	0[2]	6
	Left	148	11
	Right	530	18
Retain Wall/Bank Stabilization	Right	20	2
Rip Rap	Both	60	3
	Left	1,961	54
	Right	1,927	49
Road	Both	14	2

	Left	8	4
Water Withdrawal	Instream	0²	1
	Left	0²	9
	Right	0²	2

1. The total surveyed area of interest was 28,223 m.
2. Number of features were recorded but lengths were not always recorded.

Bridge

Riparian Modification / Encroachment

Livestock Access

Rip rap

5.5 Bank Stability and Erosion

Erosion on Bessette Creek was extensive, representing just over 20% of the total surveyed area of interest. High severity bank erosion was documented on approximately 2,708 m (9.6%) of the left bank and 3,432 m (12.2%) of the right bank (Table 7). Bank instability appeared to be largely attributed to bank erosion accounting for nearly 75% of the erosion sites, with lack of riparian vegetation and sloughing being the next most common cause of erosion at 9.3% and 9.3%, respectively. All erosion features are shown in Map Set 1 and are included in the data deliverables. The left and right bank experienced the same peaks in erosion at specific segments (Figure 5), the left bank generally experiencing less total length of erosion compared to the right bank, with the exception of segment 6. The majority of the erosion sites on both the left and right bank were recorded in segments 3, 6, 9, 10, 12, 15 and 17 (Figure 5). Bank segments with prominent erosion that are recommended as priority restoration sites are described in Section 5.7.

Table 7. Summary of streambank integrity and erosion along Bessette Creek.

	Sum of erosion length (m)[1]	Percent of surveyed area of interest
Both	**60**	**0.21**
>10 m^2 (high)	50	0.18
5-10 m^2 (medium)	10	0.04
<5 m^2 (low)	-	-
Left	**2,708**	**9.60**
>10 m^2 (high)	1,455	5.16
5-10 m^2 (medium)	83	0.29
<5 m^2 (low)	1,170	4.15
Right	**3,432**	**12.16**
>10 m^2 (high)	2,158	7.65
5-10 m^2 (medium)	221	0.78
<5 m^2 (low)	1,053	3.73
Total	**6,200**	**21.97**

[1.] The total length of the surveyed area of interest was 28,223 m.

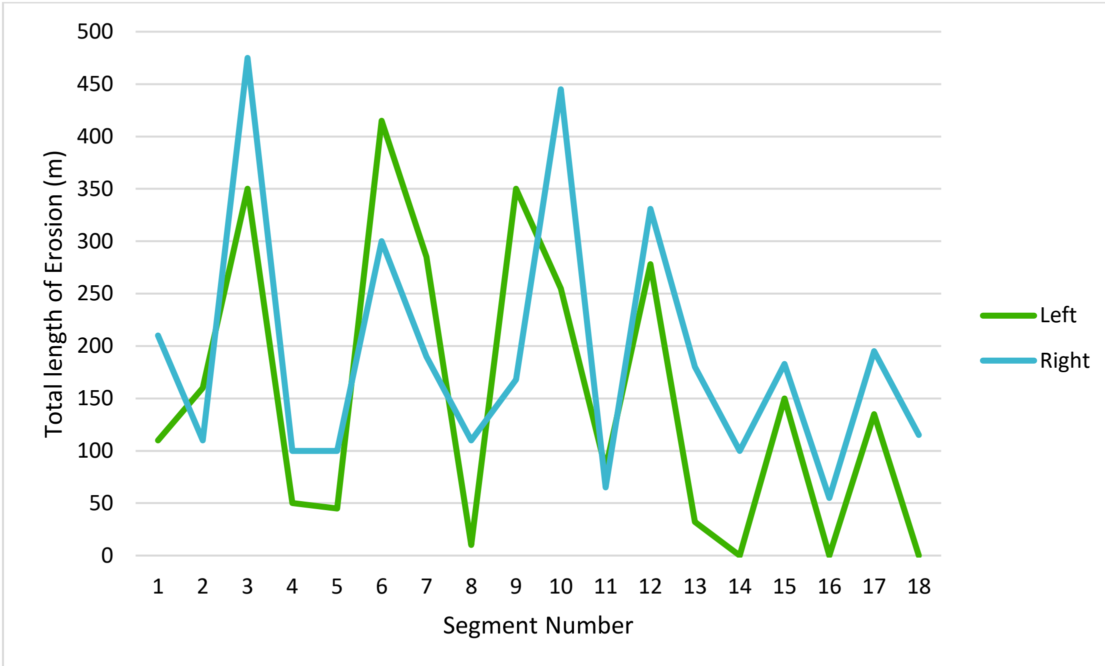

Figure 5. Total length of erosion per bank across 18 segments and 28,223 m surveyed length of Bessette Creek. Instances of erosion occurring on both banks are not included in this figure.

5.6 Bessette Creek Level of Impact and Condition Score

A condition score was assigned to each stream segment. This rating system was designed with the intent of providing a more measurable parameter in evaluating the watercourse condition and monitoring and evaluating habitat changes on local watercourses and associated riparian and floodplain communities.

The sum of weighted scores equaled 2.32 (out of 6), with Bessette Creek receiving a stream grade of 38.7% (Table 8).

Table 8. Level of impact rating / condition score for Bessette Creek.				
Impact Rating	Sum of Length (m)	Condition Value Score[1]	% of Stream	Weighted Score
nil-low	3,357.4	5	11.89	0.59
low-low	6,577.3	4	23.30	0.93
low-mod	2,298.7	3	8.14	0.24
mod-mod	4,592.0	2	16.27	0.32
mod-high	6,406.0	1	22.70	0.22
high-high	4,991.7	0	17.69	0.00
Sum	**28,223.1**	**-**	**-**	**2.32/6.00**
Condition Score				**38.7%**

[1]Condition references the condition of both banks. E.g., high-high translates to high level of impact on both banks over the segment. Numeric Bank Impact Scores: Nil=3;Low=2; Mod=1; High=0

5.6.1 Aquatic Habitat Index

The AHI results summarized below in Table 9 are illustrated in Map Set 1. The majority of Bessette Creek was assessed as having a Moderate AHI rating at 45.2% of the total surveyed area of interest. Very High AHI was limited to segments 15 and 16, which is likely attributed to the high density of spawning habitat (Figure 4). Low AHI was documented in segments 4, 8, 9 and 18, which again can be attributed to the density of spawning habitat, which was 0 in these segments (Figure 4). Each segment AHI scores and resulting ranking is displayed in Figure 6.

Table 9. Relative AHI rank distribution (by length) of Bessette Creek.		
AHI Category	Total Length (m)	Percent of Stream
Very High	3,523.1	12.48%
High	8,086.7	28.65
Moderate	12,765.2	45.23
Low	3,848.0	13.63
	28,223.0	

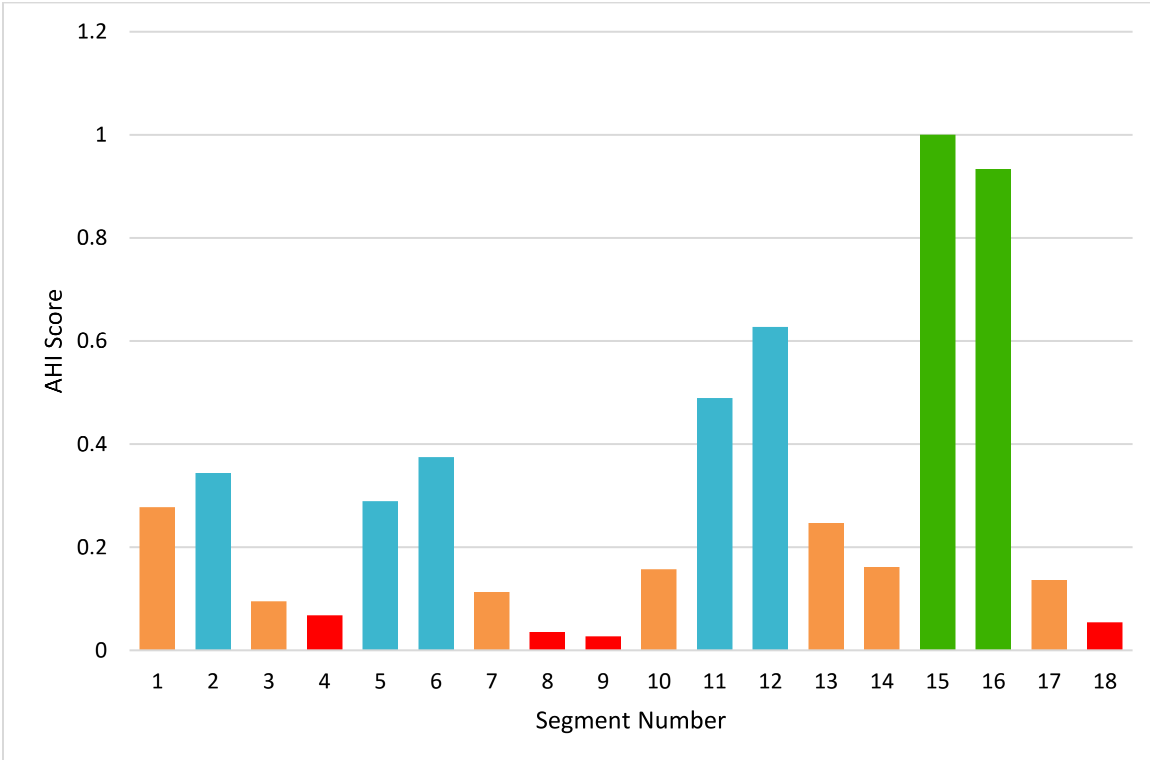

Figure 6. Bessette Creek stream segment AHI scores and AHI rank values (Very High = Green, High = Blue, Moderate = Orange, Low = Red).

5.7 Priority Restoration Sites on Bessette Creek

Areas with extensive high severity erosion and areas with widespread livestock access were identified as Priority Erosion Sites and Priority Fencing Exclusion sites. Of the priority erosion sites identified, this list was refined further to identify Priority Restoration Project Sites. The purpose of identifying these areas is to allow SFC to better identify key areas of concern to conduct restoration activities and/or livestock exclusion fencing installations.

Priority restoration sites are identified in Map Set 1 and are included as a distinct feature class in the GIS data deliverables. A total of 32 priority erosion sites with a total length of 1,238 m and 3 priority livestock exclusion fencing sites with a total length of approximately 340 m were identified. Of these, a total of 13 priority restoration project sites were identified. Nearly half of these sites are within segments 9 and 10. Total length of priority erosion sites and livestock exclusion fencing per bank, per segment is provided in Table 10.

Table 10. Summary of priority erosion sites and livestock exclusion fencing sites by bank and segment on Bessette Creek.

Left Bank				Right Bank		
Segment	**Total Erosion Length (m)**	**Total Livestock Exclusion Fencing Length (m)**		**Segment**	**Total Erosion Length (m)**	**Total Livestock Exclusion Fencing Length (m)**
3	40	-		1	-	100
6	235	-		5	-	200
7	150	-		6	50	
9	90	-		10	135	
10	35	-		13	130	
11	8	-		15	85	
12	120	-		17	40	40
13	20	-		-	-	-
15	80	-		-	-	-
17	20	-		-	-	-

Priority Erosion Site

Priority Exclusion Fencing Site

6.0 CREIGHTON CREEK INVENTORY SUMMARY OF RESULTS

Creighton Creek is a tributary of Bessette Creek entering from the east just south of Lumby BC, and similarly to Bessette and Duteau Creeks provides important spawning habitat for the at-risk Interior Fraser Coho (Swain, 1991; Walsh, 2010). However, spawning is limited by low flows combined with an accumulation of bedload material in the lower sections resulting in stranding or insufficient flows for spawning (Walsh, 2010). Creighton Creek is a 4th order stream approximately 36 km in total length, with a total watershed area of approximately 108 km^2 (BC MOE, 2022; Shuswap Watershed Project, 2022). Creighton Creek also supports Chinook, Rainbow Trout (resident and Mabel Lake recruits) and other resident species (Walsh, 2010).

Creighton Creek was divided into 12 segments and a total surveyed area of interest of 14.16 km (Map Set 2).

6.1 Land Use Relative Distribution

Utilizing the qualifier data associated with each stream segment, relative land use was determined (Figure 7). The majority of the right bank consisted of agriculture (68.2%), followed by rural residential (31.8%). There were no *natural* qualifiers associated with the right bank throughout the entire surveyed area of interest. The left bank was about 25% *natural* and just over 25% rural residential. Agriculture was prevalent on the left bank as well, at 47.6% of the surveyed stream length. The following photo plates illustrate the land use classes/character described in this inventory.

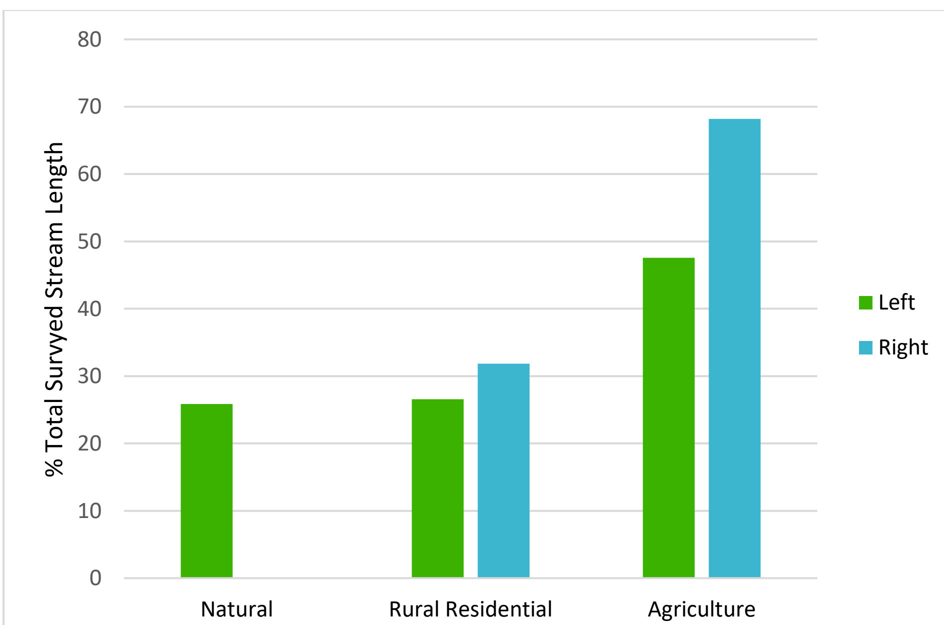

Figure 7. Relative land use distribution along the left and right bank of Creighton Creek.

Agriculture

Rural Residential

Natural

6.2 Stream Channel and Hydraulic Character

The hydraulic character of Creighton Creek is 100% riffle-pool across the total surveyed area of interest. Segment 11 had a small section with cascade/pool morphology, but not for a significant portion of the surveyed stream and was not broken out as a separate segment. Approximately 50% of the surveyed length of stream consisted of a braided secondary hydraulic regime.

6.3 Fish Habitat

Coho adults require cascade areas, confluence areas, pools, riffles, runs, cover and access to small streams in upper watersheds. They will hide under cut banks and root wads and will search for suitable gravel in upwelling areas and tail-outs of pools. A total of 35 Coho adults were observed with an additional 49 salmonids documented in the surveyed area of interest, where the majority of the salmonids observed were sub-adult ages. The adults were often observed at the crest of riffles, or taking shelter in large woody debris clusters or undercut banks. Coho juveniles depend heavily on pools, backwaters, instream vegetation areas, low and middle flood benches, marsh areas, side channels, cobble areas and large woody debris, which is consistent with what was observed in Creighton Creek.

Deep pools account for about 0.30 ha of the total surveyed instream area of fish habitat features in Creighton Creek, or 43.6% (Figure 8), providing ideal rearing and holding habitat. Large woody debris (LWD) is the next most dominant fish habitat feature in the creek and accounts for 0.19 ha of instream area, or 27.9% of the total instream area of fish habitat features. Rearing habitat was likely overestimated in Creighton Creek as most sheltered areas behind large woody debris clusters, undercut banks, backwater areas, side channels and tributaries were mapped as single features, even if rearing was not confirmed. As such, rearing was documented to represent a total instream area of 0.06 ha or 9.6% of the total instream area of fish habitat features. Over stream vegetation provides shade, low over-hanging cover, and nutrients via leaf and litter fall and accounts for approximately 7.4% of the total over-stream area of Creighton Creek.

Suitable spawning habitat areas account for about 0.01 ha or 1.9% of the total instream area of fish habitat features. The 1.9% represented a total of 56 spawning habitat features (i.e., suitable substrates and/or redd observed). (Figure 9). Segment 2 had the greatest number of spawning habitat features and cumulative linear length of spawning habitat features across the total segment length, at 0.023 and 0.054, respectively. Segment 9 starts just beyond the dam (see Section 6.4) that is a suspected barrier to fish passage, which is reflected in the fact no spawning habitat features were recorded beyond segment 8. Segment 6 also had no spawning habitat features mapped. However multiple salmonids, including Coho, were observed in this segment, which could be due to segment 6 initiating after segment 5, which was heavily disturbed by agriculture (see Section 6.4 and Section 6.7). Following segment 2, segment 3 had the next greatest density in total linear length and segment 1 had the next greatest number of features per segment length (Figure 9).

Tributary stream confluences are important as are small, stable streams, which provide rearing habitat. These streams will support Coho through their incubation period and their first year of rearing. Adequate year-round flows and cool temperatures afforded by well-developed riparian zones are important. Side channels and small tributaries were common across the surveyed area of interest of Creighton Creek. Tributaries and side channels were most common in the more natural segments, particularly the last segment (segment 12) where 26% of all of the mapped tributaries and side channels were recorded.

The data summarized in Table 11 and illustrated in Map Set 2 was also incorporated into the AHI (Section 6.6.1).

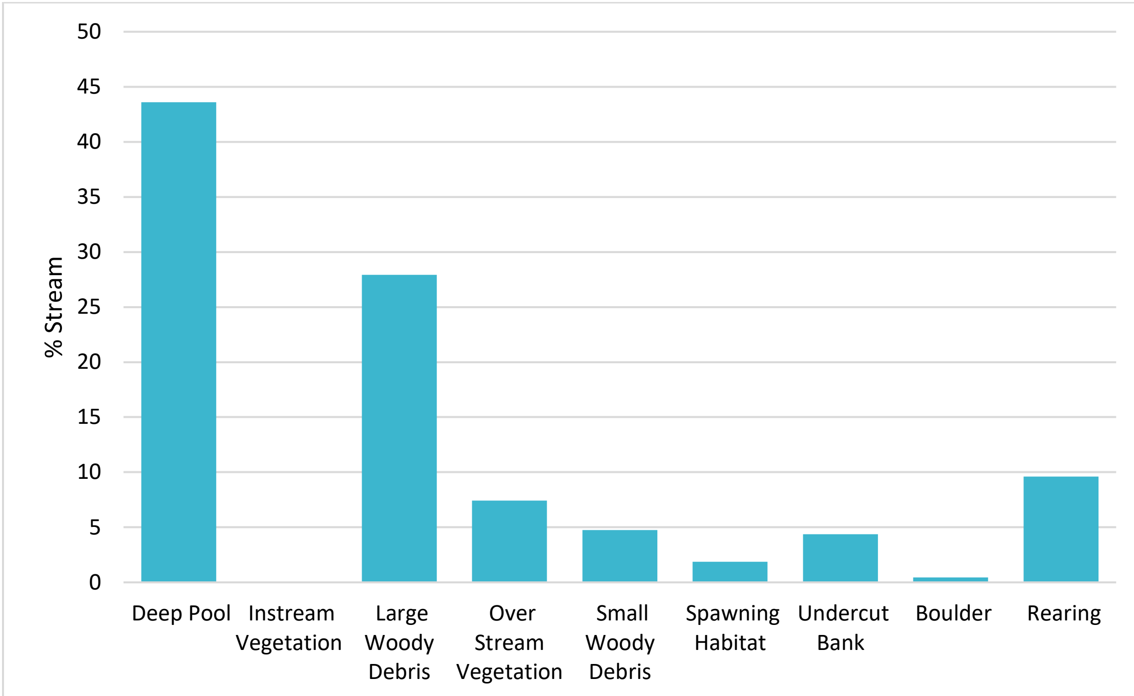

Figure 8. Relative distribution of key habitat elements mapped during the Creighton Creek inventory. Percentage values shown in the illustration represent the estimated spatial coverage of each respective feature over the total instream area of the fish habitat features.

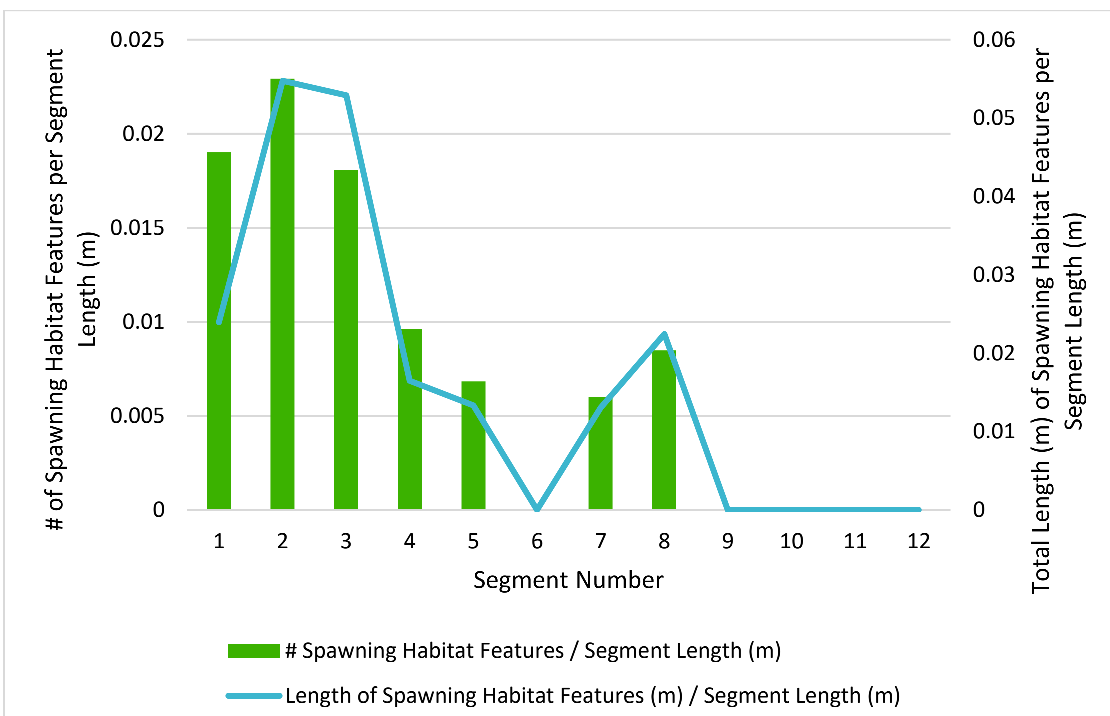

Figure 9. Density of number of spawning habitat features (green) and density in total length of spawning habitat features per total length of each segment on Creighton Creek.

Table 11. Mapped aerial coverage and linear extents of fish habitat in Creighton Creek.			
Row Labels	Combined Area (m^2)	Cumulative Length (m)	Relative linear abundance in surveyed area of interest (14,159 m)
Deep Pool	2,978.3	1,306.9	9.23
Instream Vegetation	2.0	2.0	0.01
Spawning Habitat	128.5	114.5	0.81
Large Woody Debris	1,907.5	877.2	6.20
Over Stream Vegetation	506.4	224.8	1.59
Small Woody Debris	324.8	193.2	1.36
Boulder	31.2	8	0.06
Rearing	656.7	232.3	1.64
Undercut Bank	298.8	670.0	4.73

Large woody debris, over stream vegetation and deep pool

Spawning habitat

Undercut bank

Tributary (rearing/spawning)

6.4 Modifications

Instream and bank modifications and features were recorded in the field as points and summarized in Table 12. It should be noted that general clearing/removal of riparian vegetation and encroachment by field and urban and rural development was not recorded as individual points and instead were captured within the percent disturbed field for individual shore segments.

A notable modification on Creighton Creek was a dam at the end of segment 8. The dam appeared to be man-made with straw and other debris, but likely functioning as an obstruction to fish passage. Livestock access and crossings were prevalent modifications, particularly on the left bank with just over 350 m of livestock access recorded and a total of 5 points of access compared to 27 m on the right bank; however, both banks had a total of 355 m of livestock access and 15 m of instream livestock crossings. Bridges were another prevalent feature on the creek, with 28 bridges recorded across the entire 14 kms surveyed. Bank armouring (rip rap) was recorded more often on the right bank, with 524.1 m recorded compared to 411.5 m on the right bank. This could be a result of the proximity of Creighton Valley Road along the right bank. Retaining wall/bank stabilization features were also overrepresented on the right bank, with 108.5 m recorded compared to 50 m on the left bank. Pump stations, pipe crossings and water withdrawals were not common modifications.

Table 12. Summary of anthropogenic features and modifications catalogued during the Creighton Creek Inventory.

Feature	Bank	Sum of Length (m)[1]	Count of Modification Type
Bridge	Both	105.1	28
Catchbasin	Left	0[2]	2
Dam	Instream	0[2]	1
Livestock Access	Both	355	5
	Left	27	9
	Right	46.5	9
Fences	Both	0[2]	22
	Left	0[2]	3
	Right	0[2]	3
Livestock Crossing	Instream	15	3
Garbage/Pollution	Instream	2.2	2
	Left	22.2	6
	Right	4.2	5
	Both	11	1

Other (i.e., general riparian modifications/encroachments, old bridge abutments)	Left	0[2]	1
	Right	0[2]	5
Retain Wall/Bank Stabilization	Both	1.5	1
	Left	50	1
	Right	108.5	8
Pipe Crossing	Both	0[2]	4
Pump Station	Left	0[2]	2
	Right	0[2]	2
Water Withdrawal	Instream	0[2]	3
	Left	0[2]	6
	Right	0[2]	6
Rip Rap	Both	73	7
	Left	411.5	31
	Right	524.1	37
Road	Both	3	1

1. The total surveyed area of interest was 14,159 m.
2. Number of features were recorded but lengths were not always recorded.

Bridge

Dam

Livestock Access

Rip rap

6.5 Bank Stability and Erosion

Erosion on Creighton Creek was minor, representing close to 7% of the total surveyed area of interest. Little variation in erosion on the right bank compared to the left bank was observed, at 3.79% compared to 3.05%, respectively. High severity bank erosion was documented on approximately 138 m (0.97%) of the left bank and 223 m (1.58%) of the right bank (Table 13). Bank instability appeared to be largely attributed to the lack of riparian vegetation and encroachment associated with agricultural land use and rural and recreational disturbance. Sloughing, bank erosion, and debris flow represented approximately 30% of all erosion features. All erosion features are shown in Map Set 2 and are included in the data deliverables. Erosion was most significant in segment 10, particularly on the right bank (Figure 10). Segments 4 and 6 had high occurrences of erosion on the right bank and segment 5 had significant erosion on the left bank. The lower segments exhibiting such erosion is likely related to the level of agriculture in the area, considering 70% of the erosion features were attributed to lack of riparian vegetation. Bank segments with prominent erosion that are recommended as priority restoration sites are described in Section 6.7.

Table 13. Summary of streambank integrity and erosion along Creighton Creek.

	Sum of erosion length (m)[1]	Percent of surveyed area of interest
Both	**12**	**0.08**
5-10 m^2 (medium)	12	0.08
Left	**430.5**	**3.05**
>10 m^2 (high)	138	0.97
5-10 m^2 (medium)	132	0.93
<5 m^2 (low)	160.5	1.13
Right	**536.5**	**3.79**
>10 m^2 (high)	223	1.58
5-10 m^2 (medium)	163	1.15
<5 m^2 (low)	150.5	1.06
Total	**979**	**6.1**

[1] The total length of the surveyed area of interest was 14,159 m.

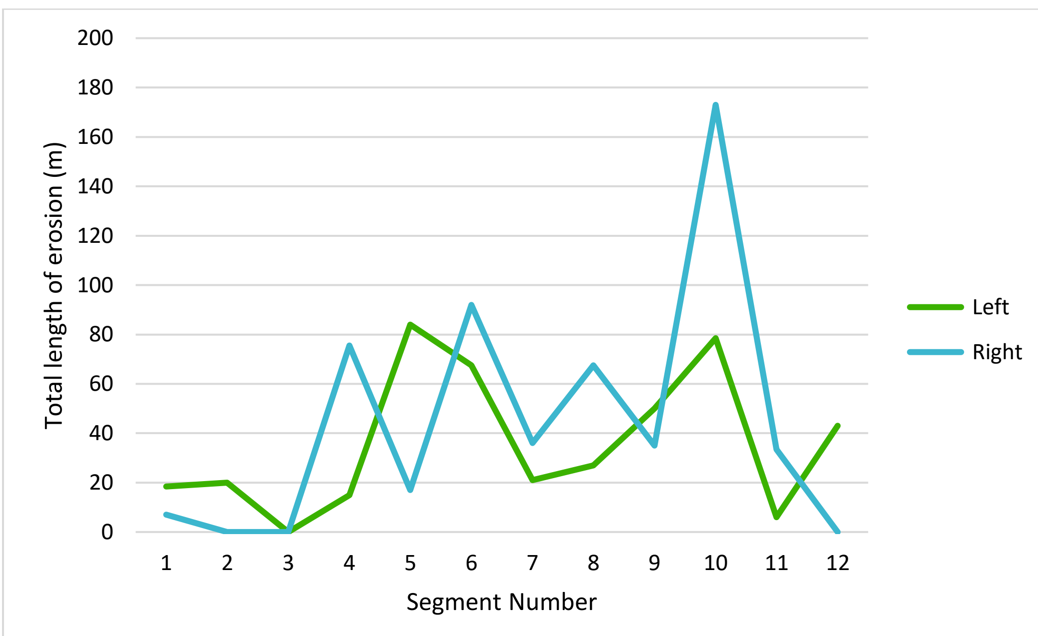

Figure 10. Total length of erosion per bank across 12 segments and 14,159 m surveyed length of Creighton Creek. Instances of erosion occurring on both banks are not included in this figure.

6.6 Creighton Creek Level of Impact and Condition Score

A condition score was assigned to each stream segment. The sum of weighted scores equaled 3.33 (out of 6), with Creighton Creek receiving a stream grade of 55.5% (Table 14).

Table 14. Level of impact rating / condition score for Creighton Creek.

Impact Rating	Sum of Length (m)	Condition Value Score[1]	% of Creek	Weighted Score
nil-low	1,025.7	5	33.68	1.68
low-low	1,576.1	4	11.13	0.45
low-mod	3,481.4	3	24.59	0.74
mod-mod	3,306.8	2	23.35	0.47
high-high	1,025.7	0	7.24	0
Sum				**3.33/6**
				55.5%

[1]Conditionreferences the condition of both banks. E.g., high-high translates to high level of impact on both banks over the segment. Numeric Bank Impact Scores: Nil=3;Low=2; Mod=1; High=0

6.6.1 Aquatic Habitat Index

The AHI results summarized below in Table 15 are illustrated in Map Set 2. The majority of Creighton Creek was assessed as having a Moderate AHI rating at 69.3% of the total surveyed area of interest. Very High AHI was limited to the first three segments, and High AHI applied to segments 4, 5 and 8; these results generally correspond with the density of spawning habitat documented in each segment (Figure 9). There were no segments with an AHI of Low. Each segment AHI scores and resulting ranking is displayed in Figure 11.

Table 15. Relative AHI rank distribution (by length) of Creighton Creek.

AHI Category	Total Length (m)	Percent of Creek
Very High	1,525.6	10.77
High	2,815.1	19.88
Moderate	9,818.1	69.34
	14,158.7	

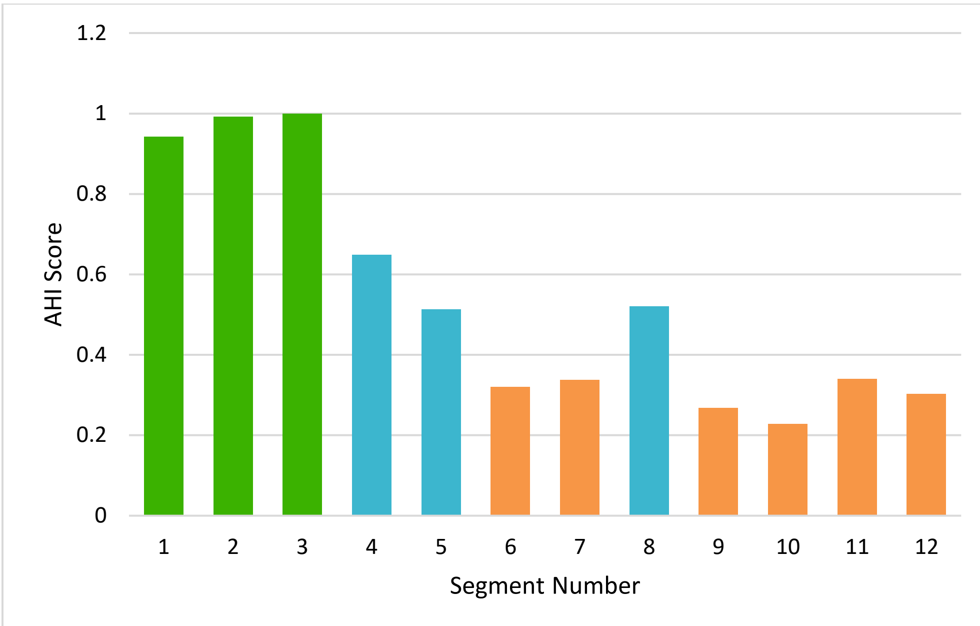

Figure 11. Creighton Creek stream segment AHI scores and AHI rank values (Very High = Green, High = Blue, Moderate = Orange).

6.7 Priority Restoration Sites on Creighton Creek

A total of 11 priority erosion sites with a total length of 224 m and 6 priority livestock exclusion fencing sites with a total length of approximately 788 m were identified. Of these, a total of 7 priority restoration project sites were identified. One of the 7 priority restoration sites is the dam situated at the upstream limit of Segment 8 that should be removed to restore upstream fish passage and habitat gained. All of the priority exclusion fencing sites are isolated to segments 3, 4, 5, and 7, with priority erosion sites limited to segments 9 and 10 on the left bank and segment 4 and 7 through 10 on the right bank. Total length of priority erosion sites and livestock exclusion fencing per bank, per segment is provided in Table 16, illustrated in Map Set 2 and the GIS data deliverables.

Table 16. Summary of priority erosion sites and livestock exclusion fencing sites by bank and segment on Creighton Creek.

Left Bank			Right Bank		
Segment	**Total Erosion Length (m)**	**Total Livestock Exclusion Fencing Length (m)**	**Segment**	**Total Erosion Length (m)**	**Total Livestock Exclusion Fencing Length (m)**
3	-	*300	3	-	*100
4	-	*50	4	60	*50
5	-	*125	5	-	*125
7	-	-	7	15	-
8	-	147.5	8	7	*87.5
9	25	-	9	15	-
10	34	-	10	68	-

* Where priority fencing was documented on 'both' banks, the total length was split evenly between left and right banks

Priority Erosion Site

Priority Exclusion Fencing Site

Priority Restoration Site (i.e., dam obstructing fish passage)

7.0 DUTEAU CREEK INVENTORY SUMMARY OF RESULTS

Duteau Creek is a tributary to Bessette Creek and originates in the Grizzly Hill area until its confluence with Bessette Creek in Lumby, BC (BC MOE, 1998). Duteau Creek is a 4th order stream approximately 42.6 km in total length, with a watershed area encompassing approximately 224 km^2 (BC MOE, 2022; Kerr Wood Leidal Associates Ltd. and Dobson Engineering Ltd., 2008). Duteau Creek is the primary fish producing tributary of Bessette Creek, providing essential spawning habitat for Rainbow Trout, Coho, and Chinook, when flow is sufficient (Shearing, 2013; Pehl, 2009). Coho and Chinook spawn between Lumby and Whitevale Road, as there is an obstruction (gradient too steep) to anadromous migration at approximately 10.8 km and 25.6 km upstream of its confluence with Harris Creek. The lower section of Duteau Creek are most suitable for rearing (Pehl, 2009).

Duteau Creek was divided into 13 segments and the total surveyed area of interest included 11.06 km of streamline (Map Set 3).

7.1 Land Use Relative Distribution

Utilizing the qualifier data associated with each stream segment, relative land use was determined (Figure 12). The majority of the right and left banks were considered disturbed, at 45.9% and 32.0% of the total surveyed area of interest, respectively. The left bank also had higher occurrences of rural and urban residential, at 26.6% and 17.5% respectively compared to 14.1% and 7.1% on the right bank. Agriculture was the next most likely qualifier on the right bank to disturbed, at 19.1%. The following photo plates illustrate the land use classes/character described in this inventory.

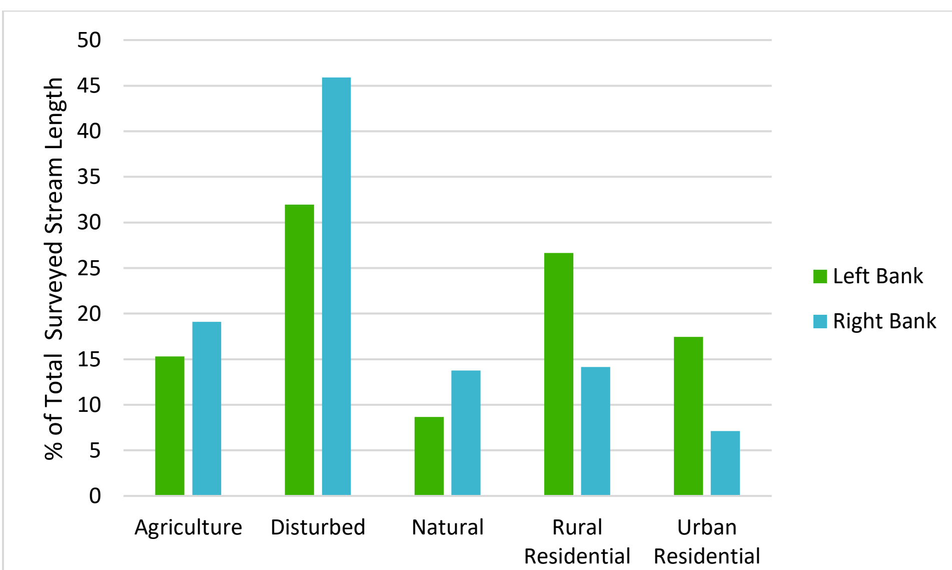

Figure 12. Relative land use distribution along the left and right bank of Duteau Creek.

Agriculture

Disturbed

Natural

Urban Residential

Rural Residential

7.2 Stream Channel and Hydraulic Character

The hydraulic character of Duteau Creek is dominantly riffle-pool on over 6 km (60.2%) of surveyed area of interest (Figure 13). However, run morphology is also common at 34.6% of the total surveyed length.

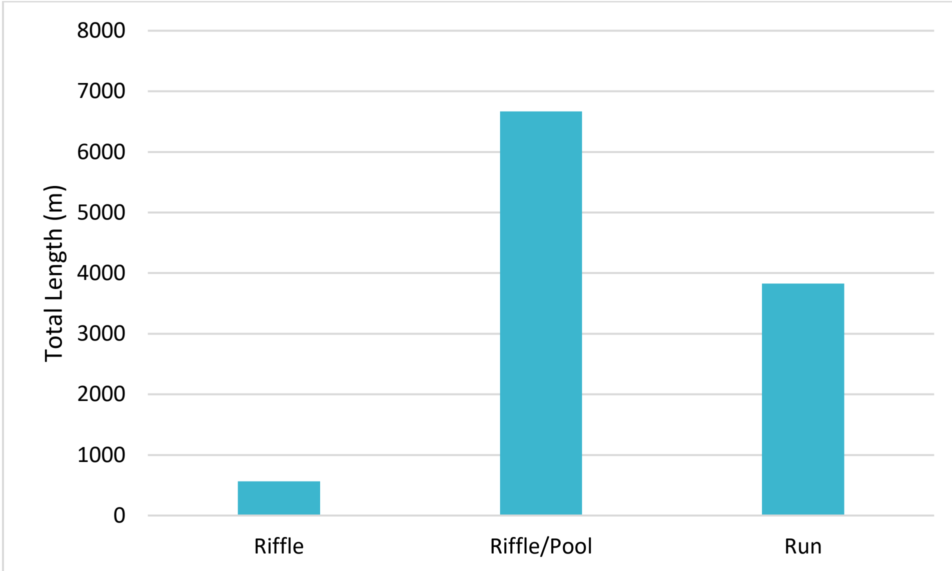

Figure 13. Duteau Creek hydraulic class distribution over the 11 km surveyed area of interest.

7.3 Fish Habitat

In the absence of low flow considerations, physical habitat in Duteau Creek was found very suitable for Chinook, Rainbow Trout and Coho production. Deep pools account for about 0.64 ha of Duteau Creek, or 52.2% of the total instream area of fish habitat features (Figure 14). Large woody debris (LWD) accounts for 0.20 ha of instream area, or 16.2% of the total instream area of fish habitat features. Over stream vegetation provides nutrients via leaf and litter fall and accounts for approximately 13.9% of the total over stream area of Duteau Creek. Suitable spawning habitat areas account for about 0.11 ha or 9.3% of the total instream area of fish habitat features. The 9.3% represented a total of 180 spawning habitat features and a total linear length of 453 m (i.e., suitable substrates and/or redd observed; Figure 15). Segment 5 had the greatest density of spawning habitat, documented at 35 individual features, or 0.036 spawning habitat features per linear meter of stream or 0.10 m per segment length. Segment 8 and segment 11 had the next greatest densities of spawning habitat, at 0.023 features/segment length or 0.058 linear length/segment length and 0.020 features/m or 0.050 linear length/segment length, respectively. There were no spawning habitat features documented in segment 13 and only one feature was documented in segment 9.

In Duteau Creek, tributaries and side channels were most common in segments 6 and 11, with 60% of the total waterbody features observed throughout the surveyed area of interest occurring in these segments. Although rearing habitat was not collected as a single feature on Duteau Creek, suitable rearing habitat was observed in the sheltered areas behind large woody debris clusters, undercut banks and the side channel/tributary features.

The data summarized in Table 17 and illustrated in Map Set 3 was also incorporated into the AHI (Section 7.6.1).

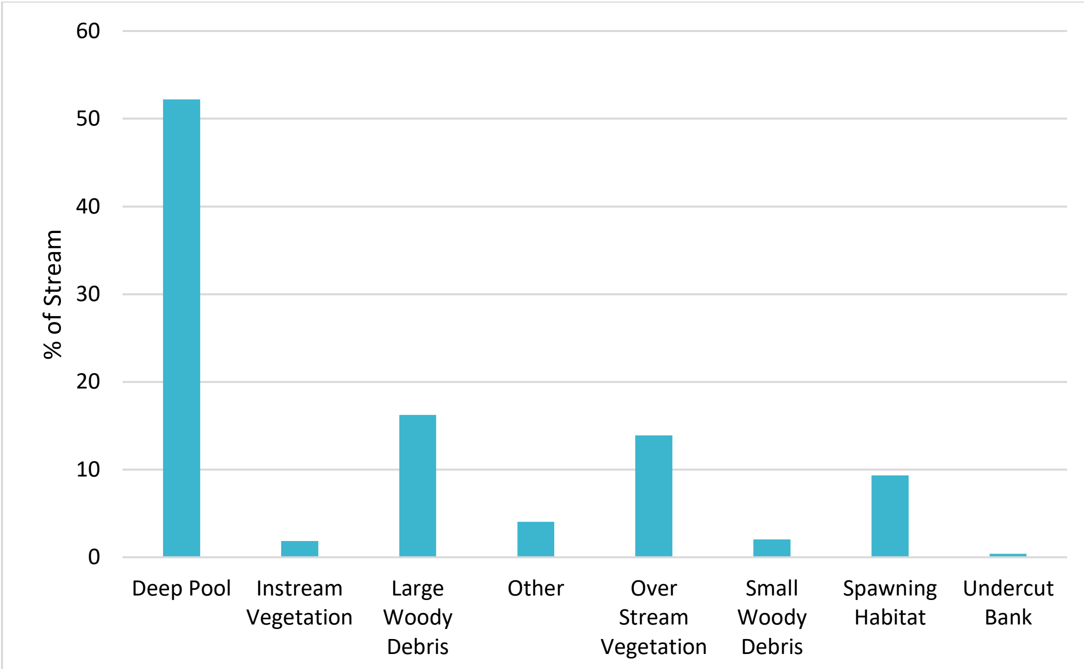

Figure 14. Relative distribution of key habitat elements mapped during the Duteau Creek inventory. Percentage values shown in the illustration represent the estimated spatial coverage of each respective feature over the total instream area (% total instream area of fish habitat features).

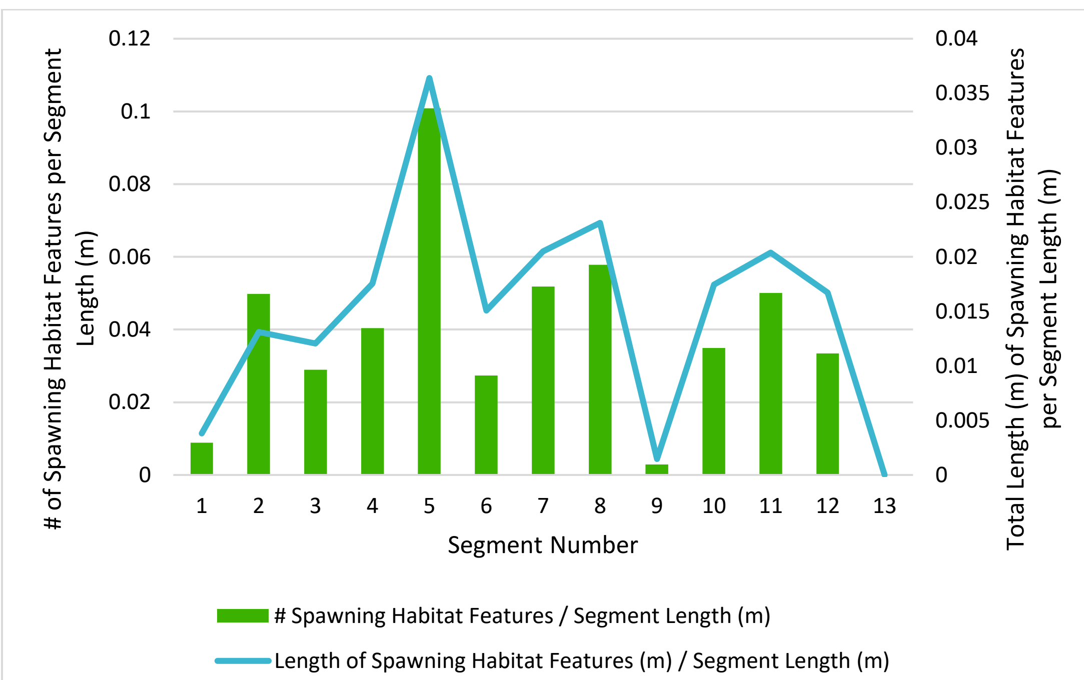

Figure 15. Density of number of spawning habitat features (green) and density in total length of spawning habitat features per total length of each segment on Duteau Creek.

Table 17. Mapped aerial coverage and linear extents of fish habitat in Duteau Creek.			
Row Labels	Combined Area (m^2)	Cumulative Length (m)	Relative linear abundance in surveyed area of interest (11,060 m)
Deep Pool	6,375.4	1,314	11.88%
Instream Vegetation	227.5	46	0.42%
Spawning Habitat	1,140.5	453	4.10%
Large Woody Debris	1,984.3	394.5	3.57%
Over Stream Vegetation	1,696.5	406	3.67%
Small Woody Debris	247.3	54.5	0.49%
Undercut Bank	47.8	105	0.95%

Large woody debris.

Spawning habitat.

Backwater (rearing)

Tributary (rearing/spawning)

7.4 Modifications

Instream and bank modifications and features were recorded in the field as points and summarized in Table 18. Similarly to Bessette Creek, general clearing/removal of riparian vegetation and encroachment by field and urban and rural development was generally recorded as “Other”, however, this component is better captured within the percent disturbed field for individual segments.

Bridges were a prevalent feature on the creek, with 21 bridges recorded across the entire 11 kms surveyed. Bank armouring (rip rap) was recorded more often on the left bank, with a little over 500 m recorded compared to 263 m on the right bank. This could be a result of two roads being documented on the left bank. No water withdrawals (intakes) were documented along Duteau Creek. Livestock access and crossings were another prevalent modification, particularly on the right bank with close to 140 m of livestock assess recorded and a total of 6 points of access compared to 3 m on the left bank; however, both banks had a total of 305 m of livestock access and 39 m of livestock crossings. Retaining wall/bank stabilization features were also overrepresented on the right bank, with 263 m recorded compared to 97 m on the left bank. General riparian modifications were most prevalent on the left bank with approximately 175 m of modifications recorded compared to 35 m on the right bank. One dam feature and four pipe crossings were observed.

Table 18. Summary of anthropogenic features and modifications catalogued during the Duteau Creek Inventory.

Feature	Bank	Sum of Length (m)[1]	Count of Modification Type
Bridge	Both	102.7	21
Channelization	Both	15	1
Dam	Instream	1	1
Livestock Access	Both	305	4
	Left	3	1
	Right	136	6
Fences	Both	0[2]	1
	Instream	1	1
	Left	3	1
	Right	12	1
Livestock Crossing	Both	39	3
Garbage/Pollution	Left	5	1
	Right	7	1
	Both	15	1
	Left	175	8

Other (i.e., general riparian modifications, old bridge abutments)	Right	35	5
Retain Wall/Bank Stabilization	Both	10	2
	Left	97	7
	Right	263	11
Pipe Crossing	Both	0[2]	4
Rip Rap	Both	10	2
	Left	503	21
	Right	263	21
Road	Left	75	2

1. The total surveyed area of interest was 11,060 m.
2. Number of features were recorded but lengths were not always recorded.

Bridge

Riparian Modification / Encroachment

Livestock Access

Rip rap

7.5 Bank Stability and Erosion

Erosion on Duteau Creek was minor, representing just over 5% of the total surveyed stream length. High severity bank erosion was documented on approximately 85 m (0.77%) of the left bank and 155 m (1.40%) of the right bank (Table 19). Bank instability appeared to be largely attributed to the lack of riparian vegetation and encroachment associated with agricultural land use and rural and recreational disturbance. Erosion was more commonly associated with the right bank at 3.38% compared to 1.97% on the left bank. Other features, however, were natural such as cut banks and silt bluffs. All erosion features are shown in Map Set 3 and are included in the data deliverables. The majority of the erosion sites on both the left and right bank were recorded in segments 2 and 8 (Figure 16). Bank segments with prominent erosion that are recommended as priority restoration sites are described in Section 7.7.

Table 19. Summary of streambank integrity and erosion along Duteau Creek.

	Sum of erosion length (m)[1]	Percent of surveyed area of interest
Left	**217.5**	**1.97**
>10 m^2 (high)	85	0.77
5-10 m^2 (medium)	77.5	0.70
<5 m^2 (low)	55	0.50
Right	**374**	**3.38**
>10 m^2 (high)	155	1.40
5-10 m^2 (medium)	140	1.27
<5 m^2 (low)	79	0.71
Total	**591.5**	**5.35**

[1.] The total length of the surveyed area of interest was 11,060 m.

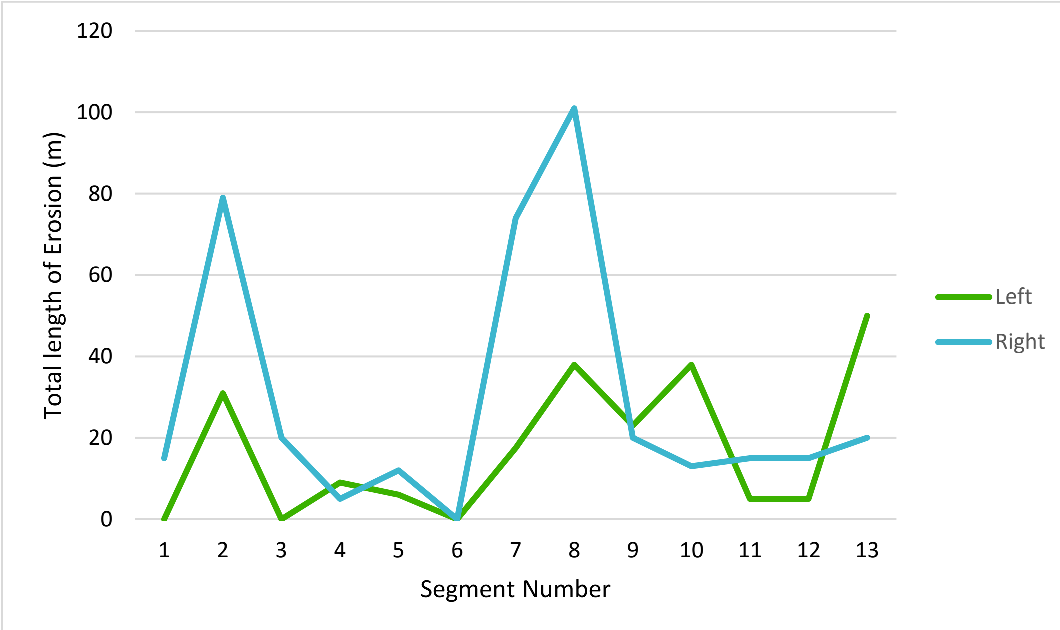

Figure 16. Total length of erosion per bank across 13 segments and 11,060 m surveyed length of Duteau Creek.

7.6 Duteau Creek Level of Impact and Condition Score

A condition score was assigned to each stream segment. The sum of weighted scores equaled 2.00 (out of 6), with Duteau Creek receiving a stream grade of 33.3% (Table 20).

Table 20. Level of impact rating / condition score for Duteau Creek.

Impact Rating	Sum of Length (m)	Condition Value Score[1]	% of Creek	Weighted Score
nil-low	957.4	5	8.66	0.43
low-low	829.7	4	7.50	0.30
low-mod	1,027.0	3	9.29	0.28
mod-mod	5,195.3	2	46.97	0.94
mod-high	573.0	1	5.18	0.05
high-high	2,477.9	0	22.40	0
Sum	**11,060.3**			**2.00**
Condition Score				**33.3%**

[1]Condition references the condition of both banks. E.g., high-high translates to high level of impact on both banks over the segment. Numeric Bank Impact Scores: Nil=3;Low=2; Mod=1; High=0

7.6.1 Aquatic Habitat Index

The AHI results summarized below in Table 21 are illustrated in Map Set 3 and corresponding GIS data. The surveyed length of Duteau Creek was evenly divided into Moderate, High, and Very High AHI categories. There is no real trend in distribution of Very, High and Moderate AHI, but it generally corresponds with Figure 15 where segments 5, 8 and 11 had Very High AHI and high densities of spawning habitat. There were no segments with an AHI of Low. Each segment AHI scores and resulting ranking is displayed in Figure 17. Although segments 9 and 13 have notably lower AHI scores, they were still ranked as Moderate. Segment 13 was generally natural and the segment would have extended further upstream; however, it was cut short as to not extend beyond the area of interest. Consequently, the reason the score is so low can be attributed to insufficient inventory information. Segment 9 was largely impounded by beaver dam/ponding and as such, had a lower density of spawning habitat features, while still providing good holding cover. Considering the inherent dynamic nature of Duteau Creek, it is likely the dam/ponding will not persist and the segment could provide suitable riffle-pool hydrology that would be conducive of spawning in the near future.

Table 21. Relative AHI rank distribution (by length) of Duteau Creek.

AHI Category	Total Length (m)	Percent of Creek
Very High	3,762.8	34.02
High	3,287.2	29.72
Moderate	4,010.4	36.26
	11,060.3	

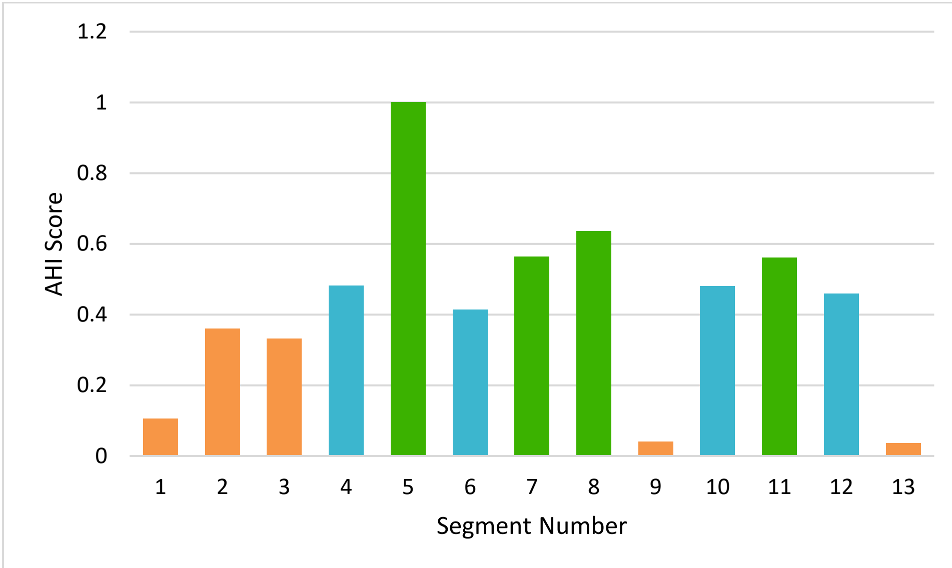

Figure 17. Duteau Creek stream segment AHI scores and AHI rank values (Very High = Green, High = Blue, Moderate = Orange).

7.7 Priority Restoration Sites on Duteau Creek

A total of 6 priority erosion sites with a total length of 100 m and 8 priority livestock exclusion fencing sites with a total length of approximately 432 m were identified. Of these, a total of 3 priority restoration project sites were identified (Map Set 3 and GIS data set). All of the priority exclusion fencing sites are isolated to segments 5 and 6, with priority erosion sites limited to segments 1, 2, 3, 8 and 9. Total length of priority erosion sites and livestock exclusion fencing per bank, per segment is provided in Table 22.

Table 22. Summary of priority erosion sites and livestock exclusion fencing sites by bank and segment on Duteau Creek.

Left Bank				Right Bank		
Segment	Total Erosion Length (m)	Total Livestock Exclusion Fencing Length (m)		Segment	Total Erosion Length (m)	Total Livestock Exclusion Fencing Length (m)
5	-	63*		1	15	-
6	-	100*		2	15	-
8	15	-		3	20	-
		-		5	-	75*
		-		6	-	195*
		-		8	15	-
		-		9	20	-

* Where priority fencing was documented on 'both' banks, the total length was split evenly between left and right banks

Priority Erosion Site

Priority Exclusion Fencing Site

8.0 SUMMARY

The preceding report has summarized the detailed Sensitive Habitat Inventory and Mapping (SHIM) and Aquatic Habitat Index (AHI) data collected on Bessette Creek, Creighton Creek and Duteau Creek, which are situated within the Middle Shuswap River watershed centralized around Lumby, BC. This report is intended as a "Living Document". In so being, it may be continually edited and updated and may evolve and expand as needed, and serve a different purpose over time.

SHIM protocols were used to collect baseline information regarding the current condition of the watercourses and associated riparian habitats. These inventories provide information on channel character, bank types and condition, substrates, land use, and habitat modifications. This information is combined where possible, with other mapping resources such as previous fisheries inventories, recent orthophotos, and other information.

AHI is generated using the processed field data to determine the relative habitat value of the aquatic habitats as well as impairments along the watercourse. The AHI uses many different criteria, such as biophysical, fisheries values, and anthropogenic characteristics to estimate the habitat value of a stream segment. The Habitat Index classifies this information in a 5-Class system from Very High to Very Low.

The Very High and High AHI scores/ranks on these watercourses are limited accounting for no more than 11% to 30% of the surveyed area of interests. These high valued habitats are threatened by a variety of instream and upland activities. The loss of riparian vegetation hay/crop production, livestock, infrastructure, and urban development limit the natural stream cooling mechanisms in turn exacerbating rising stream temperatures caused by increasingly hot and arid climates such as those found in the lower reaches of the Middle Shuswap River. Stream bank destabilization additionally leads to wider and shallower stream sections, consequently increasing temperatures and silting up suitable spawning gravels. Juvenile rearing is affected by local stream temperature variations prompting fish to seek colder groundwater inflows and shade. Many of the natural areas of these watercourses continue to occur throughout the majority of the upper watershed and these high value habitats should be protected as they are critical to maintaining water quality and regulating temperatures throughout the streams.

Agricultural practices result in high nutrient loading, which can lead to increased biological oxygen demand and subsequent habitat impairments (e.g., algae blooms and substrate fouling) impacting sensitive benthic macroinvertebrates, and resident and anadromous fish. Plants and bacteria in the riparian zone remove excess nutrients through assimilation processes, however a lack of channel complexity can confine nutrients. Transient hydrological zones such as pools, eddies, channel margins and backwaters effectively remove excess nutrient loading (Johnson, 2016). Agricultural side channels and runoff locations provide insight into point-source nutrient loading, where systems may benefit from floodplain reconnection or runoff diversion.

Not only does agricultural activities increase nutrient loading, impacts of livestock access to the instream habitat of these watercourses was extensive throughout all surveyed areas of interest. Livestock access/crossings amounted to 335 m on Bessette Creek, 443.5 m on Creighton Creek, and 483 m on Duteau Creek. Areas with prevalent livestock access had a tendency to overlap areas with high densities of spawning habitat, such as segment 5 in Duteau Creek and Segment 8 of Creighton Creek where the greatest number of spawning habitat features and livestock access points were recorded. This poses an imminent threat to Coho redds in the fall and eggs through the winter. Furthermore, agricultural areas are also commonly associated with minimal riparian vegetation and lack of structural instream complexity, leaving little rearing habitat for Coho and other key fish species. Priority exclusion fencing sites have been identified for each watercourse; 3 sites on Bessette Creek, 6 sites on Creighton Creek and 8 sites on Duteau Creek. If fencing is installed in these areas, and riparian vegetation restored, impacts to spawning and rearing habitat will be significantly reduced.

The removal of riparian vegetation was extensive throughout the surveyed areas of interest, particularly in the lower reaches of the watercourses in the more modified/disturbed segments. The removal of riparian vegetation was typically associated with agricultural activities, but has resulted in significant bank erosion and fine sediment deposits. Moreover, upland activities can impact floodplains. Several bank restoration features were observed throughout the watercourses, including riparian planting on Duteau Creek in urban areas where it has previously been removed and large woody debris enhancements. Future riparian and channel-bank restoration should use similar bioengineering techniques, which include increasing channel complexity, large woody debris, gravel sources, and more intact stream banks. Benefits of these activities will include bank stabilization and habitat restoration.

Riparian Plantings on Duteau Creek

Large woody debris revetment and bank stabilization on Bessette Creek

Low summer flows have the potential to diminish the availability of suitable spawning habitat for a variety of fish species as waters recede through low floodplains and riverine marshes. This risk is compounded by the high demand for water extraction for agricultural activities during summer low flow periods, which has been found to have significant impacts on the South Thompson Coho population (Interior Fraser Coho Recovery Team, 2006). Considering prolonged periods of significant drought are becoming increasingly more common in the interior of BC with the effects of climate change, the impacts affecting spawning and rearing habitat and migration routes are consequently increasing. Low flows have the added risk of stranding, trapping rearing juveniles in high quality backwater habitats, where survival depends on the availability of food, cover, and cool waters. Furthermore, low summer flows further elevate the risk to fish associated with elevated stream temperatures and increased stress on fish, which can lead to lethal consequences. Fish species such as Coho may be forced to use lower reaches as low flows result in inaccessibility to formerly used higher reaches for spawning. An increase in the abundance of cover in lower reaches would lead to the creation of suitable Coho habitat. It has been recommended by the Fish and Wildlife Compensation Program (FWCP) that strategies to improve fish production in the Middle Shuswap River during low flows be explored. Recommendations included assessing opportunities for watering areas with groundwater, with a focus on over-wintering and rearing habitats for Coho and further assess habitat constraints during critical low flow periods, which would be inclusive of potential effects of water temperature for key fish species (FCWP, 2021).

It is paramount that landuse planning and management of Bessette Creek and key tributaries focus on conservation and restoration of floodplain and riparian ecosystems. In addition, opportunities should be explored to increase the relative abundance of off channel and back water habitats, make natural upper reaches that are currently obstructed accessible, and protect cold water refuge habitats for improved salmon rearing/nursery potential. For example, the man-made dam feature documented in Segment 8 of Creighton Creek, which is suspected to be associated with agricultural activities, is functioning as an obstruction to fish passage to suitable rearing/spawning habitat further upstream. Restoring a functional connection for fish and improving in-water cover may increase the habitat suitability and likelihood of upper reaches being used by juveniles and/or spawning adults.

Further investigation regarding the impacts and potential mitigation of extensive water withdrawal for upland agricultural uses and implications of climate change on increased stream temperatures should be undertaken. Furthermore, exploring the direct impacts to fish and spawning substrates by livestock access should be evaluated. It is recommended that the priority restoration sites provided for each stream be prioritized and implemented as soon as possible to restore and enhance the habitat for not only the Threatened Interior Fraser Coho population, but other essential key fish species that utilize Bessette, Creighton and Duteau Creek.

These watercourses have high productive value for anadromous and resident fish species regardless of individual segment AHI scores. A lower AHI segment score does not imply that particular segment is of low value. Rather, the combination of habitat attribute values in that segment contribute less to fisheries and aquatic production than other segments. However, these lower scoring segments are still important for migration and general living. The review of existing or proposed activities should be measured against these baseline AHI scores as a means of conducting a net change analysis. In doing so, such activities and the potential impacts and modifications they may cause can be evaluated in accordance with the Canadian Policy for the management of fish habitat; where No Net Loss is the guiding principle.

9.0 CLOSURE

This Document has been prepared for the exclusive use of the Secwepemc Fisheries Commission and project partners. It has been prepared based upon information collected during the comprehensive field inventory and other related documentation.

Questions or comments in reference to this report, and the data presented should be forwarded to the undersigned.

Respectfully Submitted,

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MAP SET 1

BESSETTE CREEK

MAP SET 2

CREIGHTON CREEK

MAP SET 3

DUTEAU CREEK

APPENDIX A

BESSETTE CREEK CENTERLINE DATA

APPENDIX B

CREIGHTON CREEK CENTERLINE DATA

APPENDIX C
DUTEAU CREEK CENTERLINE DATA