BONAPARTE RIVER

Sensitive Habitat Inventory and Mapping and Aquatic Habitat Index

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Prepared for:
Secwepemc Fisheries Commission

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Prepared For:

SECWEPEMC FISHERIES COMMISSION

On Behalf of:

SHUSWAP NATION TRIBAL COUNCIL (SNTC)

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INFORMATION DISCLAIMER

The results contained in this report are based upon data collected during a single season inventory. 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 is 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 was completed for the Bonaparte River (BRIV) in July and August of 2019 from Bonaparte Lake downstream to the Thompson River confluence. The results of this data were used complete an Aquatic Habitat Index (AHI). This Large River Inventory and Mapping approach (RIM) adapts the data collection methods and standards of Sensitive Habitat Inventory and Mapping (SHIM) (Mason and Knight, 2001) and Foreshore Inventory and Mapping. The resultant AHI uses many different criteria, such as biophysical, fisheries values, and anthropogenic characteristics to estimate the relative habitat value of river reaches and bank segments that were defined during the inventory. The habitat index classifies this information in a 5-class system from Very High to Very Low.

The BRIV flows a distance of approximately 153 km from its headwaters within the Fraser Plateau through Bonaparte Lake, Young Lake and then south towards Highway 97 where it eventually confluences with the Thompson River in Ashcroft. The Thompson River supports a fall run of steelhead trout (*Oncorhynchus mykiss*) with three major tributaries, the Nicola, Deadman, and Bonaparte Rivers identified as spawning and rearing streams. Historically, the BRIV supported a small population of 20 to 50 Steelhead adults annually as a 6.2 m impassible falls, located 2.6 km above the Thompson River confluence, obstructed fish migration. In 1988, a fishway was constructed on the Bonaparte River to allow anadromous and resident salmonids access to the 140 km of stream (Maricle and McGregor, 1990). In total, the BRIV supports populations of five of the seven species of pacific salmon; Sockeye (*O. nerka*), Pink *(Oncorhynchus gorbuscha)*, Coho *(O. kisutch)*, Steelhead (*O. mykiss*) and Chinook *(O. tshawytscha)*, as well as the non-anadromous forms (freshwater only) Kokanee (*O. nerka*) and Rainbow Trout (*O. mykiss*). Other salmonid fish species include the Rocky Mountain Whitefish (*Prosopium williamsoni),* Bull Trout *(Salvelinus confluentus),* and Brook Trout (*Salvelinus fontinalis*). Non-salmonid fish include suckers *(Catastomus* spp*.),* Peamouth Chub *(Mylocheilus caurinus),* Redside Shiner (*Richardsonius balteatus*), Longnose Dace (*Rhinichthys cataractae*), Leopard Dace (*Rhinichthys falcatus),* Northern Pikeminnow (*Ptychocheilus oregonensis)*, Longnose Sucker (*Catostomus catostomus*), Lake Chub (*Couesius plumbeus*), Bridgelip Sucker (*Catostomus columbianus*), and Largescale Sucker (*Catostomus macrocheilus*).

The BRIV was divided into a total of 44 reaches. The left bank (looking downstream) was broken into 91 segments and the right bank was broken into 77 segments.

The BRIV forms a mix of sinuous, irregular and tortuously meandering channel segments through glaciofluvial material and lacustrine sediments from Bonaparte Lake down through the Village of Ashcroft where it confluences with the Thompson River. This results in the predominance of benched riverbanks composed primarily of fine textured substrates (i.e. sand/silt) in reaches upstream of the Thompson River. The hydraulic character of the river is predominantly riffle-pool. Channel complexity and instream habitat quality increases moving further upstream where there is substantial spawning habitat, rearing backwaters, and pools important for cover and general living as well as holding areas for anadromous migrations. Important spawning areas were noted throughout the BRIV, in floodplain gravel fans and on the inside corners of meandering channel bends where gravels are regularly deposited.

About 49.5 km (30%) of the left bank and about 70 km (44%) of the right bank has had medium to high level of impact. About 69% percent of the left bank and 55% of the right bank is natural. The majority of natural streambanks occur upstream of Loon Lake Road. Agricultural land use has altered approximately 41.5 km (26%) of the left bank and about 63 km (40%) of the right bank.

The right bank of the river had a greater cumulative distance where impacts (areas considered to have low, medium or high impacts) to the bank and riparian area was approximately 62% of the total bank distance due to extensive farming, highway disturbance, and land development. Segments with a high level of impact (>40%) combined to over 59 km (37%) of the right bank. Approximately 60 km (38%) of the right bank showed no impact and approximately 82 km (50%) of the left bank showed no impact.

In total, there were 25 water withdrawals (intakes) and 48 bridges. Livestock access was recorded to occur on over 500 m of the riverbank with 63% of it being along the right bank. Bank armouring (rip rap) was recorded on over 1.6 km (0.99%) of the left bank and 1.5 km (0.94%) of the right bank. Retaining walls/bank stabilization were recorded on over 285 m (0.17%) of the left bank and 691 m (0.43%) of the right bank.

Bank instability along much of the river is largely a function of the steep silt banks that have naturally eroded over time through the glaciofluvial and lacustrine material. However, this instability is exacerbated by riparian vegetation removal and encroachment associated with agricultural, urban, and rural development. High to extreme severity bank erosion was documented on approximately 1.2 k m (0.74%) of the left bank and 1.3 km (0.81%) of the right bank

The centerline AHI analysis resulted in close to 40 km (26%) of the river ranked as Very High and just over 70 km (51%) of the river ranked as High. About 25 km (16%) of the river was ranked as Moderate and just over 10 km (7%) ranked as Low. Many of the reaches that scored Very High occur further upstream where land development and agriculture is minimal. These high scoring reaches of the BRIV provide high gradient riffle-pool reaches suitable for Steelhead juvenile rearing and Pink salmon spawning. An increase in channel gradient in many of the reaches both upstream and downstream of Young Lake (Reaches 23, 34, 35, and 37) results in a greater prevalence of higher velocity runs and riffle-pool gravel reaches. The channel complexity is highest in the upper reaches where cottonwood floodplains remain largely undisturbed resulting in deposits of large woody debris and numerous side channels. Reaches such as Reach 32 provide high value riffle-pool habitat and adequate cover for Coho spawning and rearing. Reaches 14 and 15 totaled approximately 10.1 km and were ranked as Low due to low gradient glide hydraulic character, low habitat complexity, and high proportion of fine textured substrates throughout the channel.

Approximately 36% of the left bank of the BRIV is ranked Very High and 14% is ranked low according to Bank AHI scores. Conversely, only about 14% of the Right Bank of the river is ranked Very High, with 25% ranked as low. Moderate AHI segments accounted for 25% and 30% of the left and right banks of the BRIV respectively.

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1.0 INTRODUCTION

In 2019 Ecoscape Environmental Consultants Ltd. (Ecoscape) was contracted by the Secwepemc Fisheries Commission to complete a comprehensive inventory of the Bonaparte River (BRIV) between Bonaparte Lake and the Thompson River and to subsequently develop an Aquatic Habitat Index (AHI). 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 be expanded as needed, and serve a different purpose over time.

Mapping of waterbodies in the Okanagan, Shuswap, Thompson, and Nicola regions is being conducted following the current three step Lake Management process being standardized across British Columbia and described below:

1. Sensitive Habitat Inventory and Mapping (SHIM) and Foreshore Inventory and Mapping (FIM) are protocols used to collect baseline information regarding the current condition of watercourses (SHIM), shorelines (FIM), and associated riparian habitats. These inventories provide information on channel character, shore/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. A protocol was developed specifically for the Shuswap River to map large river habitat and character. This protocol, referred to as River Inventory and Mapping (RIM) was used in the current project to map the BRIV.
2. An Aquatic Habitat Index (AHI) is generated using the processed field data to determine the relative habitat value of the aquatic habitats and shoreline areas. This index follows similar methods that were developed for Okanagan Lake and Windermere Lake and is similar to other assessments used for Wasa, Moyie and Monroe Lakes. The Aquatic Habitat Index uses many different criteria, such as biophysical, fisheries values, and anthropogenic characteristics to estimate the habitat value of a shoreline segment. The Habitat Index classifies this information in a 5-Class system from Very High to Very Low. AHI is used for both FIM and RIM projects.

Shoreline Management Guidelines are prepared to identify the Shoreline Vulnerability or Sensitivity to changes in land use or habitat modification. Shoreline Vulnerability Zones are based upon the AHI described above. The Shoreline Vulnerability uses a risk-based approach to shoreline management, assessing the potential risks of different activities (e.g., construction of docks, groynes, marinas, etc.) in the different shore segments. The Shoreline Management Guidelines document is intended to provide background information to stakeholders, proponents, and governmental agencies when land use changes or activities are proposed that could alter the shoreline thereby affecting fish or wildlife habitat.

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

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

These protocols are designed as land-planning, computer-generated, interactive GIS tools that identify sensitive aquatic and terrestrial habitats. They are intended to provide community, stewardship groups, individuals, regional districts and municipalities with an effective, low-cost delivery system for information on these local habitats and associated current land uses.

SHIM and FIM have 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;
- Provide a catalogue of the current condition of the foreshore to aid with permit and compliance monitoring;
- 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 a baseline inventory of existing shoreline developments/modifications such as docks, retaining walls, groynes, stream mouths, and land use activities;
- 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 RIVER INVENTORY MAPPING

Biophysical surveys of the BRIV used the RIM methodology which adapted the data collection methods and standards of Sensitive Habitat Inventory and Mapping (SHIM) (Mason and Knight, 2001) and Foreshore Inventory and Mapping (FIM). Data was recorded using a Trimble Geo7x/Data Logger and entered into a digital data dictionary. 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 (Left) using the data dictionary developed specifically for RIM (Appendix D). Marking up large format field maps for subsequent incorporation into GIS mapping and integration into the final data deliverables (Right).

2.1 Pre-Field / Start-up

Ecoscape reviewed all pertinent background information useful to the project and incorporated this data, where relevant, into respective watercourse features and their attributes.

Ecoscape obtained aerial imagery for the Bonaparte system from the British Columbia Imagery Web Map Services. Preliminary reach breaks (segments) were identified and right and left bank shoreline segments were determined. In addition, we identified adjacent natural features of interest (i.e., tributaries, side channels, islands, wetlands etc.) that otherwise may not be picked up during standard centerline surveys. Large format field maps were then produced, on which field staff transcribed various field data.

2.2 RIM Adapted SHIM/FIM for Large River Systems

The RIM data collection, data processing, and data deliverables were based on the mapping standards for SHIM (Mason and Knight, 2001), with consideration that the BRIV is a middle sized river. The Data Dictionary (Version 6) is provided in Appendix D. This digital data collection format adapts both SHIM and FIM dictionaries into a common field data collection file, tailored to a spatial biophysical inventory on a mid to large size river system like the BRIV. The intent of this approach is to utilize a specific mapping protocol that can be used for mid to large sized river systems in British Columbia.

2.2.1 Centerline Survey

The centerline of the river channel was mapped along the center of the bankfull (not floodplain) width. While both banks and instream features were digitized using air photo interpretation. Comprehensive data for both the left and right river banks were collected independently of the stream centerline as unique “Right Bank” and “Left Bank” line features (reviewed below in Section 2.2.2).

The river was stratified into a series of successive reaches, 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).

Table 1. Overview of river centerline data fields collected using the Trimble data dictionary.

Reach Length	Linear measure along centerline of channel (m)
Primary Character	Modified; Natural; Other
Channel width	Bankfull 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
Channel Pattern	Straight; Sinuous; Irregular; Irregular meandering; Regular meanders; Tortuous meanders
Bars	Side; Diagonal; Mid-channel; Spanning; Braided
Islands	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
Reach Impact Rating	See Table 2.

A Level of Impact rating was included in the data dictionary and applied to the centerline reach information (Appendix D). This rating system was designed with the intent of providing a more measurable parameter in evaluating river condition and monitoring and evaluating habitat changes on local watercourses and associated riparian and floodplain communities. Individual reach 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 reaches receiving the same impact rating by the total river length being evaluated to obtain a relative value (% of river 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 river grade. This scoring system precedes the Aquatic Habitat Index and, on its own, is a field measure of river/bank condition.

Table 2. Level of Impact rating criteria for Bonaparte River Inventory and Mapping**.**

River Bank Impact Criteria[1]	Combined River Reach 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

2.2.2 Left and Right Bank Mapping (adapted SHIM-FIM)

Conventional SHIM methods describe the right and left bank character and condition within a single stream centerline feature for respective reaches. To better map and evaluate the larger scale represented in the BRIV, the SHIM approach was modified (Appendix D), which adapts the FIM field attributes into the data dictionary. Through this approach, left and right bank lines were logged in the field independently of one another (similar to FIM shoreline mapping) and data fields were populated separate from the Centerline. Individual segments were determined as relatively homogenous sections of shoreline based on vegetation structure, physical character, and general land use. Shoreline sections that displayed a consistent pattern or distribution of different biophysical units/features interspersed with anthropogenic units (e.g., clearings and fields) were also considered as a single segment. An example of this would be through rural areas; where remnant natural pockets along the riverbank are interspersed with rural residences and small agricultural clearings. Shoreline segments were determined and assigned independently of river reaches. However, the adjacent river reach was identified in the data for each shoreline segment (e.g., Left Bank Segment 25, River Reach 11).

Large format laminated posters of the River were marked-up to illustrate river and riparian features, attribute lines (e.g., bank armouring) and points (e.g. water withdrawals). These features were then digitized in the office to supplement GPS field

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

data. Table 3 summarizes the data fields that were collected for each bank segment. It is important to note that approximately 40 km of the River between where the BRIV crosses Highway 97, east of Loon Lake Road, and the Thompson River was digitized (bank lines and polygons) in 2018 in preparation for the field components. In 2019, Ecoscape received updated aerial imagery of the Elephant Hill Wildfire area from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (MFLNRORD). As a result, previously digitized bank lines and polygons do not always accurately align within the updated aerial imagery. However, all data collected in the field (i.e. feature points and centerline information) are accurately georeferenced and representative of the existing conditions encountered during the field work conducted in July and August of 2019. Future update considerations for the project may include digitization updates to the bank lines and polygons to ensure they align with the most up to date aerial imagery.

Table 3. Overview of data collected for right and left bank segments during the field inventory.

Segment Number	Reach Number / Segment Length / Representative Photo
Category	**Menu/Data Fields**
Primary Shore Type	Cliff/Bluff; Rocky Shore; Gravel; Sand; Confluence (alluvial fan); Wetland; Other; Flood Low Bench; Flood Mid Bench; Flood High Bench
Shore Modifier	Log Yard; Marina small (6-20); Marina large (20+); Railway; Road; None; Other
Slope (general slope of shore landward)	Bench; Low (0-5%); Moderate (5-20%); Steep (20-60%); Very Steep (60%+)
Land Use (Observed)	Agriculture; Commercial; Conservation; Forestry; Industrial; Institution; Multi Family; Natural Area; Park; Recreation; Rural; Single Family; Urban Park
Level of Impact	None; Low (<10%); Medium (10-40%); High (>40%)
Livestock Access	Yes/No
Relative Condition	%Disturbed; %Natural
% Shore Type Distribution	%Cliff/Bluff; % Rocky; % Gravel; % Sand; % Confluence; % Wetland; % Other; % Flood Low Bench; % Flood Mid Bench; % Flood High Bench
% Landuse Distribution	Agriculture; Commercial; Conservation; Forestry; Industrial; Institution; Multi Family; Natural Area; Park; Recreation; Rural; Single Family; Urban Park
Modifications	% of segment retained/armored by walls and rip rap; % of segment with railway influence; % of segment with a road influence
Bank Stability	High; Medium; Low; Eroding and % Eroding
Bank Material	Clay; Silt; Sand; Gravel; Cobble; Boulder; Bedrock
Comments	Provided with various categories listed above

2.2.3 Feature Mapping

Morphological, habitat, and anthropogenic features were marked with both the GPS and described on field maps and later digitized as points and polygons into the modified BRIV data dictionary. These features, summarized in Table 4, provide a more quantitative measure of relative disturbance/modification, and aquatic habitat quality/complexity (e.g., aerial abundance of spawning substrates/coarse woody debris measure etc.).

Table 4. Overview of watercourse and habitat attributes that were collected using the Data Dictionary developed for this project (Adapted from Module 3, Mason and Knight, 2001). The complete data dictionary can be found in Appendix D.

Main Attribute	Detailed Feature Collected
Modifications	Type (retaining wall/water withdrawal/bridge/dock etc.) material; length; photo
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
Representative Photograph Location	Location; Direction

2.3 Instream Morphology and Habitat Feature Polygonization

We identified and mapped the spatial extents of side channels, backwaters, and associated riverine wetlands and floodplain communities. Relative habitat scores were applied to each type to be used in analysis and habitat index calculations (Section 4.1).

The river channel, extending to the outer limits of the mean annual high water level (to include low bench floodplain areas) was estimated using field inventory data and air photo interpretation. The spatial extents of the channel formed the basis for subsequent stratification of habitat units within (Map Series 1). Habitat units were classified based on complex hydraulic and instream habitat feature classes as one of the following in Table 5.

Table 5. Hydraulic and instream habitat feature classes assigned to Bonaparte River and associated low flood and wetland polygons

BW	Backwater	RN	Run
CO	Confluence	P	Pool
G	Glide	RF	Riffle
GB	Gravel/Sandbar		

2.4 Riparian Polygonization

Broad vegetation communities/habitat types were stratified within a 100-m band along the right and left riverbanks (Map Series 1). Polygons were classified according to Table 6. In addition, site qualifiers (Table 7) were assigned to each polygon to reflect the estimated level of disturbance and habitat quality and condition.

The river channel boundary was established at the estimated mean annual floodplain level to include riparian marshes and low bench floodplain sites. Thus, mid bench floodplain ecosystems (i.e., black cottonwood ecosystems) were included in the 100 m riparian band and not factored into the stream channel analysis (Section 4.2).

Table 6. Broad vegetation communities (Habitat Types) used for classification of stratified polygons occurring along the Bonaparte River (100-m band) from Bonaparte Lake to the Thompson River (adapted from Mackenzie and Moran (2004) and Lloyd et al. (1990).

Map Code	Description	BGC Zone/ Variant/ Phase	Site Series	Association	Site Series Name	Comment
B	Broadleaf Forest	IDFdk3	00	AR	At - Snowberry - Kentucky bluegrass	Upland broadleaf forest ecosystem above the active floodplain predominated by trembling aspen
C	Coniferous Forest	SBPSmk	1	LP	Pl - Pinegrass - Arnica	Upland coniferous forest ecosystems above the active floodplain. Including high bench sites along the Bonaparte River.
			2	LC	Pl - Cladonia - Haircap moss	
			3	FA	Fd - Pinegrass - Aster	
			4	LF	Pl - Pinegrass - Feathermoss	
			5	SM	SxwFd - Step moss	
			6	ST	Sxw - Twinberry	
			7	SH	Sxw - Horsetail - Glow moss	
		IDFdk3	7	SR	SxwFd - Prickly rose - Sedge	
			8	SS	SxwFd - Prickly rose - Sarsaparilla	
			9	SH	Sxw - Horsetail - Glow moss	
		IDFxw	5	DF	Fd - Feathermoss	
			6	SB	Sxw - Water birch	
			7	SR	Sxw - Prickly rose - Coltsfoot	
CF	Cultivated Field					Cultivated fields (i.e., hayfields, row crops, orchards)
CS	Cliff/Scree					
CW	Open Coniferous Woodland	BGxh2	03	PT	Py - Red three-awn	Open ponderosa pine/Interior Douglas-fir woodlands with grassland dominated understory
			04	PW	Py - Bluebunch wheatgrass	
		IDFdk3	01	LP	FdPl - Pinegrass - Feathermoss	
			02	DK	Fd - Juniper - Kinnikinnick	
			03	DJ	Fd - Juniper - Peltigera	
			04	DW	Fd - Bluebunch wheatgrass - Needlegrass	
			05	DM	Fd - Feathermoss - Step moss	
			06	DP	Fd - Pinegrass - Aster	
		IDFxw	01	DJ	Fd - Juniper - Bluebunch wheatgrass	
			02	PW	FdPy - Bluebunch wheatgrass - Pinegrass	
			03	DS	FdPy - Western snowberry - Bluebunch wheatgrass	
			04	DW	FdPy - Bluebunch wheatgrass - Balsamroot	
		PPxh2	01	PF	Py - Bluebunch wheatgrass - Fescue	
			02	DS	FdPy - Bluebunch wheatgrass - Selaginella	
			03	PW	Py - Bluebunch wheatgrass	
			04	PS	Py - Big sage - Bluebunch wheatgrass	
DG	Dry Gully					

Map Code	Description	BGC Zone/ Variant/ Phase	Site Series	Association	Site Series Name	Comment
FL	Low Flood Bench (G=graminoid ; S=Shrub)			Wm01;RG	Water Sedge - Beaked sedge; Reed Canary Grass	Low bench ecosystems occur on sites that are flooded for moderate periods (< 40 days) of the growing season, conditions that limit the canopy to tall shrubs, especially willows and alders. Annual erosion and deposition of sediment generally limit understory and humus development.
				Fl06	Sandbar willow; willow sp.	
FM	Mid Flood Bench	BGxh2	07	CD/Fm01	Cottonwood – snowberry – Rose - Dogwood	Middle bench ecosystems occur on sites briefly flooded (10–25 days) during freshet, allowing tree growth but limiting tree species to only flood-tolerant broadleaf species such as black cottonwood.
		PPxh2	7	CW	Cottonwood - Water birch	
		IDFdk3/IDFxw		CT	Ct - Wood rose - snowberry - Mountain alder floodplain	
FS	Seasonally Flooded					Woodlands and croplands that are intermittently flooded in periods of high flows; found throughout the Bonaparte Valley in agricultural crop fields adjacent to the Bonaparte River.
GB	Gravel/Sand Bar					
GN	Grassland	BGxw2	2	WS	Bluebunch wheatgrass - Selaginella	Natural grassland ecosystems generally not containing shrub or tree strata
		BGxw2	6	FW	Fescue - Bluebunch wheatgrass(Rough fescue)	
		IDFdk3		WJ;WP;WT;WY	Bluebunch wheatgrass - Yarrow	
		IDFxw		SW;WN	Bluebunch wheatgrass	
M	Mixed Forest					Upland Mixed stand Forest. High bench site along the Bonaparte River. Tree canopy mix of trembling aspen, cottonwood, ponderosa pine, interior Douglas-fir, and spruce.
RL	Railway					Railway and associated fillslopes, armouring and other modifiers
RI	River					Tributaries
RZ	Road Surface					Road Surface
RU	Rural					Rural areas containing houses, outbuildings, driveways, and landscaping. A native tree canopy may be present but it is perforated by development and the understory plant associations have been partly removed. In higher disturbed sites the tree canopy is very limited to absence and natural plant associations sparse to absent.
SB	Silt Bluff/ Exposed Bank					Steep, sparsely vegetated silt bank.
SH	Shrub					Persistently disturbed shrub sites that are not included within low flood bench.
SG	Shrub Steppe Gully					
SS	Shrub-steppe	BGxh2	01	SW	Big sagebrush - Bluebunch wheatgrass	Natural grassland/shrub-steppe ecosystems with >15% cover of big sagebrush.
			5	SN	Big sage - Needle-and-thread grass	
		PPxh2	05	SF	Big sage - Bluebunch wheatgrass	
UR	Urban					Urban areas containing higher population densities in single and high density housing, in addition to extensive infrastructure build-up. The native tree canopy is very limited to absence and natural plant associations sparse to absent.
WN	Wetland/Marsh			Wm01	Water sedge	A marsh is a shallowly flooded mineral wetland dominated by emergent grass-like vegetation. A fluctuating water table is typical, with early-season high water tables dropping through the growing season. Exposure of the substrate in late season or during dry years is common.
				Wm02	Beaked Sedge	
				RG	Reed canarygrass	

Table 7. Site qualifiers assigned to each polygon (Table 6) to reflect the estimated level of disturbance and habitat quality and condition.

b	Burned
pb	Partially burned (<50% burned)
d	Ditch
hd	Highly disturbed, fragmented/broken canopy. Analogous to a partly treed rural site. Highly disturbed wetland and fragmented by land use and agricultural practices. The ecological function of this feature is severely impaired by human and associated activities.
md	Moderately disturbed treed riparian area. The habitat community structure may be fragmented or perforated by some land clearing and rural disturbances.
ld	Low disturbance, not recently disturbed. Containing natural tree canopy and understory vegetation associations.
f	Narrow riparian fringe generally less than 5-m wide but occasionally up to 10-m.
n	Natural, undisturbed site

2.5 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 were in accordance with Resource Inventory Committee Standards to ensure the collection of spatially accurate data. The coordinate system used was UTM Zone 10 North, North American Datum 83.

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.

Data dictionary tools designed for ARC View 3.x were employed to process the data and to export the data into ESRI shapefiles. Subsequent 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.
- All field data collected during the field inventories was post processed by the field inventory biologist, Scott McGill, B.Sc., B.I.T.
- 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.

- We integrated this assessment with additional GIS information provided by other parties.

2.6 Photo Log

SHIM/FIM 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 10 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 BONAPARTE RIVER KEY FISH SPECIES

The BRIV flows a distance of approximately 153 km from its headwaters within the Fraser Plateau through Bonaparte Lake, Young Lake and then south towards Highway 97 where it eventually confluences with the Thompson River in Ashcroft. The Thompson River supports a fall run of steelhead trout (*Oncorhynchus mykiss*) with three major tributaries, the Nicola, Deadman, and Bonaparte Rivers identified as spawning and rearing streams. Historically, the BRIV supported a small population of 20 to 50 adults annually as a 6.2 m impassible falls, located 2.6 km above the Thompson River confluence, obstructed fish migration. In 1988, a fishway was constructed on the Bonaparte River to allow anadromous and resident salmonids access to the 153 km of stream (Maricle and McGregor, 1990). In total, the BRIV supports populations of five of the seven species of pacific salmon; Sockeye (*O. nerka*), Pink *(Oncorhynchus gorbuscha)*, Coho *(O. kisutch)*, Steelhead (*O. mykiss*) and Chinook *(O. tshawytscha)*, as well as the non-anadromous forms (freshwater only) Kokanee (*O. nerka*) and Rainbow Trout (*O. mykiss*). Other salmonid fish species include the Rocky Mountain Whitefish (*Prosopium williamsoni),* Bull Trout *(Salvelinus confluentus),* and Brook Trout (*Salvelinus fontinalis*). Non-salmonid fish include suckers *(Catastomus* spp.*),* Peamouth Chub *(Mylocheilus caurinus),* Redside Shiner (*Richardsonius balteatus*), Longnose Dace (*Rhinichthys cataractae*), Leopard Dace (*Rhinichthys falcatus),* Northern Pikeminnow (*Ptychocheilus oregonensis)*, Longnose Sucker (*Catostomus catostomus*), Lake Chub (*Couesius plumbeus*), Bridgelip Sucker (*Catostomus columbianus*), and Largescale Sucker (*Catostomus macrocheilus*)*.* Because of their importance to commercial, recreational and aboriginal fisheries, the following were selected as key species for matrix development (to assign relative habitat scores) in this study: Kokanee, Sockeye Salmon, Rainbow Trout, Steelhead, Coho Salmon, Chinook Salmon, Pink Salmon, and Bull Trout.

3.1 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. Both species will normally spend their first year of juvenile rearing in a freshwater lake, in this case Nicola Lake, but while Sockeye will out-migrate to the ocean after one year, Kokanee remain for 2 or 3 years in the lake before returning to spawn. In British Columbia, Kokanee typically reach maturity at the end of their third (age 2+) or fourth (age 3+) summer (McPhail 2007). Kokanee management in the system, and in general in B.C., is the responsibility of the provincial Ministry of Forests, Lands and Natural Resource Operations, Fish and Wildlife Branch (formerly B.C. Ministry of Environment).

In 2001, a four year investigation into the status of Kokanee populations in the Thompson-Shuswap watersheds was initiated by the Ministry of Water, Land and Air protection and completed by Redfish Consulting. The results of this study were particularly helpful in the preparation of this species account.

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 in most of the Thompson-Bonaparte system are not well understood. 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

Fisheries personnel use various methods to enumerate these spawning runs including helicopter and drift boat surveys. Frequencies of counts and survey dates have varied considerably over the years which have likely contributed in some part to large variations in annual counts.

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 phototactic (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).

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.

3.2 Sockeye Salmon

LIFE HISTORY

Sockeye Salmon (*Oncorhynchus nerka*) are the third most abundant of 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. Sockeye spend from one to four years in the ocean before returning to fresh water to spawn. Sockeye management in the province is the responsibility of the Federal Department of Fisheries and Oceans. It is noted that although Sockeye occurrences are shown for the BRIV (FIDQ, 2020), only Kokanee occurrences are shown for Young and Bonaparte Lake. Therefore, it is unclear where fry that potentially hatch in the BRIV spend their first year (i.e. rear in freshwater or straight outmigration to the ocean).

REPRODUCTION

Sockeye spawn in the fall, usually when water temperatures drop below 12^{0}C. Historically there have been both early (spawning in early to mid-September) and late Sockeye runs (late October) in the South Thompson River (DFO 1997). 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 (Harris 1986 as discussed in Groot and Margolis 1991). Incubation times vary related to water temperatures. Fry typically emerge from late March to late May with peak emergence occurring in early May (Stewart et al. 1989 and Whelan et al. 1982 in DFO 1997). It is known, however, that these 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. Fry generally rear and overwinter in the lake environment and outmigrate in June and early July. Large numbers of yearlings have been observed in the lower Fraser in September which suggest that Lower Thompson Sockeye smolts enter the Strait of Georgia later than other Fraser stocks (Healy 1980 in DFO 1997).

Sockeye cycle on a four year rotation and can vary considerably in numbers from year to year. 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. J. D. McPhail (2005) 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 nursery lakes and then the remainder of their adult life rearing in the Pacific Ocean.

3.3 Rainbow Trout

LIFE HISTORY

Rainbow Trout *(Oncorhynchus mykiss)* are an important game fish that reside in the BRIV. They 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, Okanagan Region). 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 5^0C.) and rising water levels (Hartman 1966 in McPhail 2007). The BRIV is normally in freshet at this time with high flows and turbid waters. These conditions present a challenge for fisheries managers to monitor their activities and population strengths.

A search of the Ministry of Environment Habitat Wizard reveals that Rainbow Trout have been found in the tributary streams of the BRIV. These streams are critically important for the nursery phase of Rainbow Trout juvenile rearing. Maturing adults will migrate into these streams during freshet flows (April and May) and will spawn on the receding flows following. 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).

It is believed that many of these developing juveniles will eventually move from nursery tributary streams down to the Thompson River. 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. 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 (MOE Okanagan Region Files). Their biggest obstacle in lakes is anglers who target them extensively. Rainbows can tolerate temperatures up to 27^{0}C but anything higher can be lethal (Lee and Rinne 1980 in 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 which provide rearing habitat for juveniles and resident populations. Of the five species of fish discussed in these accounts for the BRIV, Rainbow Trout are likely the most sensitive to habitat changes because they spend so much of their life cycle in these zones.

3.4 Steelhead

LIFE HISTORY

Steelhead (*Oncorhynchus mykiss*) are the anadromous form of Rainbow Trout. There are three distinct Steelhead groups in BC, including North Coast, Vancouver Island and Interior Fraser groups, to which the Thompson population belongs (McPhail 2007). Steelhead enter freshwater in fall and winter and in spring and summer as separate runs. Winter-run Steelhead are almost fully mature when they enter freshwater and spawn shortly thereafter. Summer-run Steelhead are immature when they enter the rivers and spend up to 8 months holding in freshwater before spawning (McPhail 2007). Typically most interior Steelhead are summer run. Run timing is genetically determined and summer and winter runs are distinct races (Ministry of Fisheries, 1999).

The Thompson River and its larger tributaries, namely the Deadman and Nicola River were the second largest Steelhead producers in the Thompson-Nicola System in 1998 (DFO 1998b). Historical Steelhead runs consisted of 10,000 individuals in 1960 (Bos 2006). From 1984 to 2,000, spawning populations ranged from 550 to 3,300 (MoE 2000; LGL Ltd. 2007). During that time, the largest Steelhead producer was the Nicola with 1061 spawners on average, followed by the Deadman River and the Bonaparte River (DFO 1998b).

Steelhead are known to utilize the lower 99.0 km of the BRIV for spawning (96.4 km above the fishway and 2.6 km below the fishway). Telemetry studies conducted in 1989, 1990, and 1991, suggest that steelhead do spawn in the 2.6 km section of BRIV below the fishway, although the telemetry may underestimate the spawning population below the fishway (Morris, 2002).

REPRODUCTION

Timing of river entry is usually a factor of distance to spawning grounds and is affected by seasonal differences in water levels that allow fish to pass barriers that would be present at lower river levels (McPhail 2007). Spawning females typically dig nests in gravel sites with swift water, such as the tail of a pool where it breaks into a riffle (Ministry of Fisheries 1999). Unlike other pacific salmon, not all Steelhead die after spawning, some return to spawn again.

Thompson-Nicola Steelhead populations have been documented as spring and summer-run populations. Alevins remain in gravels for up to three months, after which rearing takes place in tributaries of the Thompson mainstem for 2-3 years (Harding et al 1981 in DFO 1998b). Steelhead smolts then migrate to the Fraser River and to the ocean, returning after 3 years. A very small percentage will return to spawn a second time.

AGE, GROWTH AND MATURITY

Smolting usually occurs in spring and is determined by body size rather than age (McPhail 2007). Egg hatch depends on water temperature with eggs hatching typically four to seven weeks after spawning and fry emergence occurring during summer (Ministry of Fisheries 1999). Migration begins in May and dispersal offshore begins almost immediately after the smolts enter salt water.

HABITAT INDEX MATRIX

The Habitat Index Matrices developed for this study indicate that steelhead depend on gravel sites with adequate flows and associated pools and riffles. Overhead cover (large woody debris and overhanging vegetation) is important in small streams (Flebbe and Dolloff 1995 in McPhail 2007). Deep pools with abundant cover (boulders, ledges and overhanging vegetation) are important holding areas. Currents along the margins of streams are often used by Steelhead fry.

3.5 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). 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).

Over the period of record (1975-2003) the 3-year average escapement for Interior Fraser Coho peaked mid-1980 at over 70,000 fish, and declined to a running average of less than 18,000 individuals in the late 1990's. Similar trends are observed in total abundance (i.e. catch plus escapement), which declined from over 200,000 in the late 1970's and 1980's to less than 30,000 in recent years (Interior Fraser Coho Recovery Team. 2006).

While natural spawning is responsible for producing most of the Coho Salmon escaping to the Interior Fraser River, Coho stocks in the Lower Thompson System are supplemented by the Spius Creek hatchery, which was installed in 1984 to produce Steelhead smolts (DFO 1998b). Hatchery fish outnumber those produced from fish spawning in natural stream areas (DFO 1998a).

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 Salmon 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 1996, 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. Thompson Coho stocks return at age 3 to the lower Fraser between late October and November and spawning occurs from mid-October to December. 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 1m 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 (Sandercock 1991 in 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 (Peterson 1982 in 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, in-stream 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.

3.6 Chinook Salmon

In British Columbia Chinook salmon spawn in over 250 rivers and streams (McPhail 2007). Within the Fraser River system, there are seven genetically recognizable geographic groupings: an upper, middle, and lower Fraser group; a northern, southern and lower Thompson group; and the Birkenhead River population (Beacham et al. in 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.

Chinook stocks exhibit both ocean type and stream type life history patterns. Ocean type Chinook rear in freshwater for several months and migrate to the ocean in the first fall while stream type Chinook rear in freshwater for one year before migrating to the ocean (Fraser et al. 1982 in DFO 1997).

REPRODUCTION

Chinook return to the lower Fraser by mid-July with peak spawning occurring from late August to November.

Chinook females choose the spawning site and appear to prefer sites with subgravel flow (eg. 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 (Groot and Margolis 1991). 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.

Downstream timing appears to be correlated strongly with size (Groot and Margolis 1991). They will eventually move out to the Pacific and return 4-5 years later to spawn as adults.

Juvenile rearing is not well understood but both natal streams and lakes are utilized. 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.

3.7 Pink Salmon

LIFE HISTORY

Pink Salmon are not as adept as other pacific salmon at negotiating barriers and typically spawn closer to the ocean than these other species (McPhail 2007). Pinks mature at two years and southern populations of Pink Salmon (*Oncorhynchus gorbuscha*) typically spawn September to October and return in odd year cycles. A three year life cycle is rare. The short life cycle of the pink species leads to a relatively small body size compared to other salmonids. Pink are abundant salmon species in the Thompson-Nicola system, however they rely mostly on the Thompson mainstem. Less than 2% of total escapements have historically been documented in the Nicola River BRIV, and Deadman River (Williams et al 1994 in DFO 1998a).

The largest Thompson pink escapement was documented in 1981, reaching 1.2 million, which then declined to under 0.3 million in the following years, rising again to 800,000 in 1991. Pink salmon escapements are now estimated for the whole Fraser system, and therefore documentation for upstream tributaries is limited (DFO 1998a).

REPRODUCTION

Spawning typically occurs in September and October. In the Fraser system the spawning run has early and late segments (McPhail 2007). Female Pink Salmon prefer sites with clean coarse gravel and subgravel flow. Sites are typically shallow riffles or channels 20 – 100 cm deep with current. Some streams have both early and late spawning runs (McPhail 2007) and some stocks appear to be adapted to different temperature regimes.

AGE, GROWTH AND MATURITY

Eggs incubate in gravel over winter, hatch in about 1.5 to 3 months and emerge from gravel about 3 to 5 months after hatching. Once they begin swimming, fry quickly migrate downstream (McPhail 2007). Fry migrate to the ocean as soon as they fill their swim bladders (McPhail 2007).

HABITAT INDEX MATRIX

Medium sized gravel areas with sub-gravel flow are the areas that are important to Pink Salmon for spawning. Obstructions to upstream fish passage at Hell's Gate (Fraser River) related to low water levels is a potential limitation to the future productive capacity of Thomson Pink Salmon (DFO 1998a).

3.8 Bull Trout

LIFE HISTORY

Bull Trout (*Salvelinus confluentus*) have a highly variable life history. There are three life history forms in BC: fluvial, adfluvial and resident. The fluvial form spends its entire life in flowing water but often makes extensive migrations within large river systems (McPhail 2007).

REPRODUCTION

Timing of spawning migrations depends on a number of factors such as water temperature, habitat, genetic stock and possibly amount of daylight (MWLAP 2004). They spawn between mid-August and late October (MWLAP 2004) with resident populations tending to migrate shorter distances to spawning grounds. Migratory or adfluvial populations can have a much larger home range and migratory Bull Trout may travel up to or over 250 km (MWLAP 2004). The temperature below which Bull Trout begin spawning activity appears to be 9^0C (MWLAP 2004). Bull Trout spawn in flowing water in habitat similar to other salmonids, often in runs or glides in larger river or in pockets of suitable gravel in smaller streams (McPhail 2007). They show a preference for gravel and cobble sections in smaller, lower order rivers and streams (MWLAP 2004). Size of the redd and size of gravel at the spawning site depends on female size (i.e. larger females spawn in larger gravel).

AGE, GROWTH AND MATURITY

Bull Trout fry tend to stay near the substrate to avoid being swept downstream (Ford et al. 1995 in MWLAP 2004). Juvenile trout feed on aquatic insects. Adfluvial trout are typically piscivorous and tend to grow larger than fluvial populations (MWLAP 2004). Bull Trout reach maturity most often at 5 to 7 years but the range is 3 to 8 years. Juvenile fish (fly to 3+) move from streams to lakes or reservoirs throughout the summer months (McPhail and Murray 1979 in MWLAP 2004).

HABITAT INDEX MATRIX

Mature forest capable of producing large woody debris is typically more important to Bull Trout than younger structural stages. These forests typically trap and store more sediment and provide more nutrients and fish habitat structure than younger forests (MWLAP 2004). Bull Trout are dependent upon cover, usually in the form of deep pools, woody debris jams and undercut banks (MWLAP 2004). Factors that are often associated with Bull Trout distribution and abundance include channel and hydraulic stability, substrate, cover, temperature and the presence of migration corridors (MWLAP 2004). The influence and importance of these factors varies based on life history (resident, adfluvial or anadromous) and life history stage (MWLAP 2004).

4.0 AQUATIC HABITAT INDEX

AHI scores derived for each reach of the river channel and left and right bank segments are analogous to the current productivity, which is defined as the sum of relative habitat values for all subareas occurring within a defined area (i.e., river channel extents of a respective reach) (Minns 1997). The AHI is a categorical scale of relative habitat value that ranks the river channel and bank segments in a range between *Very High* and *Very Low*. Our approach to development of the index incorporated the following components:

1. Utilization of all existing data that occurs in a spatial GIS format to develop the index.
2. Species Accounts (Section 3), developed to inform life history scores for discrete instream habitat units/features for key species of the Bonaparte River.

3. The AHI was developed and calibrated using professional opinion similar to other habitat indices that have been developed for lake systems. Criteria were reviewed for relevancy and weighted appropriately (i.e., representative of the contribution to overall habitat sensitivity), and the index was developed in such a way that new data layers may be added in the future.

The data previously collected for this project involved numerous spatial data layers and is substantially more complicated to develop than an AHI developed for a lake ecosystem. The dynamic nature of riverine ecosystems required that three separate layers of data be collected as part of the inventory phase. One layer of data was attributed to the primary character of the river and habitat features within, one layer was used to describe the right bank, and one layer was used to describe the left bank.

4.1 Instream Polygon Scoring Matrix

Habitat unit classes (Section 3.1) 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 relative habitat unit values are presented in the following matrices (Tables 8-10). A 3-class score was assigned to each matrix cell; where 1 = *low value*, 2 = *moderate value*, and 3 = *High value*. 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 (Table 9) based on the relative importance of these components in the index for production.

Table 8. Fisheries relative habitat values (RHV) and weighted scores for aquatic and riparian habitat features.

Habitat Variable	Code	Rearing		General Living		Cover	
		RHV	Wt. Score	RHV	Wt. Score	RHV	Wt. Score
Backwater	BW	1.00	28.75	0.23	1.31	0.20	3.45
Confluence	CO	0.72	20.76	0.91	5.23	0.83	14.38
Low Flood Bench (graminoid)	FL	0.57	16.25	0.11	0.65	0.08	1.44
Low Flood Bench (shrub-willow)	FL	0.35	10.00	0.11	0.65	0.08	1.44
Mid Flood Bench	FM	0.11	3.19	0.07	0.39	0.05	0.86
Glide	G	0.44	12.78	0.36	2.09	0.27	4.60
Lake	LK	0.44	12.78	0.68	3.92	0.72	12.36
Large Woody Debris	LWD	1.00	28.75	0.91	5.23	0.98	16.96
Mixed Forest	M	0.11	3.19	0.07	0.39	0.07	1.15
Pool	P	1.00	28.75	1.00	5.75	1.00	17.25
Riffle	RF	0.72	20.76	0.82	4.70	0.67	11.50
Riverine Marsh	RM	1.00	28.75	0.16	0.91	0.15	2.59
Run	RN	0.72	20.76	0.80	4.57	0.57	9.78
Side Channel	SC	0.89	25.56	0.84	4.84	0.70	12.08

Table 9. Relative value and weighted scores for mapped instream substrate composition.

Substrate Class	Relative Value	Weighted Score
Organic	0.3	5.175
Fines (silt/sand)	0.2	3.45
Gravel	1	17.25
Cobble	0.75	12.9375
Boulder	0.5	8.625
Bedrock	0.1	1.725

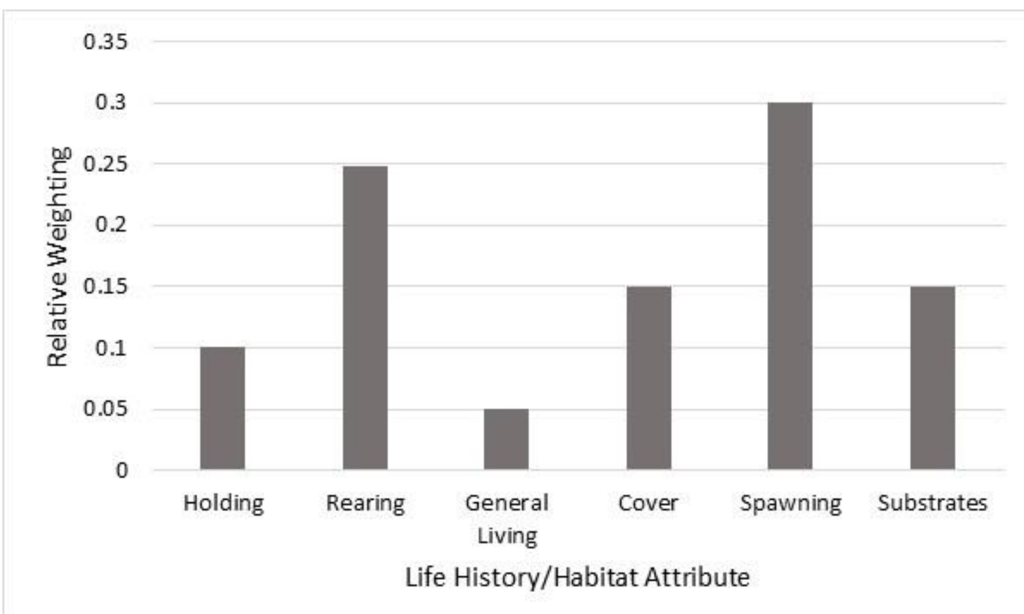

Figure 1. Relative weighting of life history and habitat attributes for instream AHI scores.

4.2 Riparian Polygon Scoring Matrix

Relative habitat values were assigned to riparian polygons (delineated within the 100-m riparian band) based the sum of values of four categories: Wildlife habitat rating; biodiversity rating; nutrient value/leaf and litter fall; and large woody debris recruitment (Table 10). The sum of relative habitat unit scores were then added to the other parameters of the bank AHI system relating to the current level of impact, degree of bank modifications, and current severity of erosion (caused by human activities).

Table 10. Ecological category: riparian habitat unit rating matrix (relative habitat value).

Habitat Type	Code	Qualifier	Wildlife Rating	LWD	Biodiversity Rating	Nutrients
Broadleaf Forest	B	hd	0.40	0.30	0.30	0.40
		b	0.40	0.70	0.30	0.30
		ld	0.70	0.40	0.70	0.80
		n	0.80	1.00	0.80	0.90
Backwater	BW		0.80	0.00	1.00	0.50
		d	0.40	0.70	0.30	0.30
Cliff/Scree/Talus	CS		0.10	0.00	0.20	0.10
			0.70	0.80	0.60	0.60
Coniferous Forest	C	b	0.30	0.60	0.30	0.30
		hd	0.40	0.50	0.30	0.40
		p	0.50	0.50	0.30	0.50
		pb	0.50	0.50	0.30	0.50
		md	0.50	0.60	0.40	0.50
		ld	0.60	0.70	0.50	0.60
		n	0.70	0.80	0.60	0.60
Cultivated Field	CF		0.10	0.00	0.10	0.10
Dry Gulley	DG		0.10	0.00	0.10	0.10
Grassland	GN	hd	0.10	0.00	0.00	0.00
		b	0.10	0.00	0.10	0.10
		pb	0.30	0.00	0.20	0.10
		md	0.50	0.00	0.30	0.10
		ld	0.60	0.00	0.40	0.20
		n	0.60	0.00	0.40	0.20
Low Flood Bench	FL	b	0.50	0.00	0.50	0.30
		hd	0.50	0.00	0.50	0.30
		f	0.60	0.00	0.60	0.30
		md	0.60	0.00	0.60	0.30
		pb	0.60	0.00	0.60	0.30
		ld	0.70	0.00	0.70	0.30
		n	0.90	0.00	0.90	0.40
Low Flood Bench - Graminoid	FLG	b	0.50	0.00	0.50	0.30
		hd	0.50	0.00	0.50	0.30
		md	0.50	0.00	0.50	0.30
		pb	0.50	0.00	0.50	0.30
		f	0.70	0.00	0.70	0.30
		ld	0.70	0.00	0.70	0.30
		n	0.90	0.00	0.90	0.40
Low Flood Bench - Shrub	FLS	b	0.40	0.00	0.30	0.30
		hd	0.40	0.00	0.30	0.30
		f	0.40	0.00	0.50	0.50
		pb	0.50	0.00	0.60	0.30
		md	0.60	0.00	0.60	0.30
		ld	0.70	0.00	0.70	0.30
		n	0.90	0.00	0.90	0.40
Mid Flood Bench	FM	f	0.40	0.40	0.50	0.40
		hd	0.40	0.40	0.50	0.40
		b	0.40	1.00	0.50	0.40
		md	0.60	0.80	0.60	0.70

Habitat Type	Code	Qualifier	Wildlife Rating	LWD	Biodiversity Rating	Nutrients
		ld	0.80	1.00	0.80	0.90
		n	1.00	1.00	1.00	1.00
Mixed Forest	M	md	0.60	0.70	0.60	0.40
		pb	0.60	0.80	0.70	0.40
		ld	0.70	0.80	0.80	0.50
		n	0.90	1.00	1.00	0.60
Open Coniferous Woodland	CW	b	0.40	0.60	0.20	0.20
		c	0.40	0.60	0.20	0.20
		hd	0.40	0.50	0.30	0.40
		md	0.50	0.60	0.40	0.50
		pb	0.50	0.60	0.40	0.50
		ld	0.60	0.70	0.50	0.60
		n	0.70	0.80	0.60	0.70
Railway	RL		0.00	0.00	0.00	0.00
River	RI		0.80	0.00	0.80	0.00
		d	0.30	0.00	0.40	0.00
		hd	0.50	0.00	0.50	0.00
		md	0.60	0.00	0.70	0.00
		ld	0.60	0.00	1.00	0.00
		n	0.60	0.00	1.00	0.00
Road Surface	RZ		0.00	0.00	0.00	0.00
		hd	0.00	0.00	0.00	0.00
Rural	RU	b	0.00	0.00	0.00	0.10
		hd	0.00	0.00	0.00	0.10
		md	0.30	0.20	0.20	0.30
		pa	0.50	0.00	0.50	0.30
		ld	0.40	0.40	0.40	0.40
Seasonally Flooded	SF		0.50	0.00	0.50	0.60
Shrub	SH	hd	0.20	0.00	0.10	0.20
		f	0.30	0.00	0.20	0.30
		md	0.40	0.00	0.30	0.30
		pb	0.40	0.00	0.30	0.30
		n	0.40	0.00	0.50	0.30
		ld	0.50	0.00	0.40	0.50
Shrub Steppe Gully	SG	md	0.30	0.00	0.40	0.10
		ld	0.40	0.00	0.50	0.10
		n	0.50	0.00	0.60	0.10
Silt Bluff/Exposed Bank	SB		0.20	0.00	0.20	0.10
Side Channel	SC		0.50	0.00	0.60	0.30
Shrub-Steppe	SS	f	0.30	0.00	0.30	0.10
		hd	0.40	0.00	0.30	0.10
		md	0.60	0.00	0.50	0.10
		ld	0.70	0.00	0.60	0.10
		n	0.80	0.00	0.70	0.10
Urban	UR		0.00	0.00	0.00	0.10
		pa	0.00	0.00	0.00	0.00
Wetland	WN		1.00	0.00	1.00	0.40
		b	0.60	0.00	0.50	0.10
		hd	0.60	0.00	0.50	0.10
		ld	0.80	0.00	0.80	0.40
		md	0.80	0.00	1.00	0.60
		n	1.00	0.00	1.00	0.40

4.3 AHI Logic, Calibration, and Ranking

As part of the index development for the Bonaparte River RIM, index development and calibration involved multiple iterations - assigning different weights to each of the parameters within the various habitat units, life history and ecological matrices. Following each iteration, the resultant sensitivity outputs were reviewed and scrutinized by fisheries biologists at Ecoscape. Calibration of the index was ultimately finalized using professional judgment.

The AHI provides a categorical scale of relative habitat value that ranks the centerline and shoreline segments in a range between *Very High* and *Very Low* sensitivity. The index is relative, because it only assesses the sensitivity of one shoreline area relative to another within the extents of the river being examined. Thus, index scores and rankings developed for the Lower Shuswap River may not be directly transferable to the Bonaparte River or other river systems without re-calibration. The following provides a definition for each AHI ranking:

- *Very High* – Reaches/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* - Reaches/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* - Reaches/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* – Reaches/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.
- *Very Low* – Segments that are extremely modified and not adjacent to any known important habitat characteristics.

After reviewing the distribution of the data from the iterations, logical breaks in the scores were used to determine the AHI rankings (discussed above). The breaks created reflect the clustering of scores based upon the output of the results, which somewhat mimic a normal distribution (although an analysis of data distribution was not conducted).

4.3.1 Centerline – Instream Zone AHI Logic

The AHI for each channel reach was calculated as the sum of life history scores for each reach. Table 11 presents the categories, relative category weightings, and logic for the Centerline AHI scoring.

The centerline AHI scores for respective reaches (AHI_{reach}) was calculated using the following,

$$AHI_{reach} = \sum\left[\frac{A_h}{A_t} \times W_h\right] + \sum\left[\frac{A_{sp}}{A_t} \times W_{sp}\right] + \sum[P_{sub} \times W_{sub}] + \sum\left[\frac{A_{hold}}{A_t} \times W_{hold}\right] \tag{1}$$

where A represents the area of a described river feature (such as h is habitat, sp is spawning, and $hold$ is holding), P represents a percentage of the area, A_t represents the total area of the river channel contained with the subject reach, and W represents the relative weighting given to the described river feature (Tables 8-11).

Table 11. The parameters and logic for the Centerline of the Bonaparte River

Category	Criteria	Category Weighting	Logic
General Living	Instream Habitat unit and Hydraulic Class polygons	5.75 (5%)	% Area * Category Score
Rearing	Instream Habitat unit and Hydraulic Class polygons	28.5 (25%)	% Area * Category Score
Holding	Mapped deep pool features	11.5 (10%)	% Area * Category Score
Spawning Habitat[1]	Records collected during 2016 field inventory	34.5 (30%)	% total spawning area * Category Score
Substrates	% composition estimated during 2016 field inventory	17.25 (15%)	% Area * Category Score
Cover	Instream Habitat unit and Hydraulic Class polygons	17.25 (15%)	% Area * Category Score

1. For the AHI spawning polygons they were split according to identified reach breaks to allow a reach by reach analysis. To accomplish this, the data was transformed and described as a percentage of the total river area available for individual reaches for mapped anadromous spawning use.

4.3.2 River Bank – Riparian Band AHI Logic

The left and right bank AHI segment scores (AHI_{bank}) were calculated using Equation 2.

$$AHI_{Segment} = \sum[P_{nat} \times W_{nat}] + \sum[P_{retain} \times W_{retain}] + \sum\left[\frac{L_{dock}}{L_t} \times W_{dock}\right] + \sum\left[\frac{L_{erosion}}{L_t} \times W_{erosion}\right] - Modifer$$

(2)

where L is the length of the bank of a described river feature. Modifiers are either railways, roads or other large modifications to the bank or near the bank. Table 12 presents the categories, relative category weightings, and logic for the river bank AHI scoring.

Table 12. The parameters and logic for the banks of the Bonaparte River

Category		Criteria	Maximum Relative Value (Score)	Percent of the Category	Logic
Percent Natural		Percent Natural	5	100	% Natural Value ($\%_{nat}$)* Category Score (P_n)
Wildlife [a]		Wildlife	5	100	% Area * Category Score
Large Woody Debris Recruitment [a]		Large Woody Debris Recruitment	5	100	% Area * Category Score
Biodiversity [a]		Biodiversity	5	100	% Area * Category Score
Leaf and Litterfall [a]		Leaf and Litterfall	5	100	% Area * Category Score
Impairments	Erosion	Low	-0.75	5	% of Segment Length * Score
		Moderate	-1.5	10	% of Segment Length * Score
		High	-4.5	32	% of Segment Length * Score
		Extreme	-7.5	53	% of Segment Length * Score
	Bank Armouring	Retaining wall, rip rap	-2		% of Segment Length * Score
	Modifications	Dock	-0.25		#/km * Score
		Boat Launch	-1		# * Score
	Shore Modifier	Rail	-5		If yes = Score
		Road	-5		If yes = Score
		Other	-2		If yes = Score

a. See Table 11 for rating matrix and relative habitat values

5.0 INVENTORY SUMMARY OF RESULTS

The BRIV flows a distance of approximately 140 km from its headwaters within the Fraser Plateau through Bonaparte Lake, Young Lake and then south towards Highway 97 where it eventually confluences with the Thompson River in Ashcroft.

The BRIV was broken into a total of 44 reaches. The left bank (facing downstream) was divided into 91 segments and the right bank was broken into 77 Segments. The total length of the left and right river banks was 161.5 km and 159.1 km respectively.

5.1 Stream Primary Character

5.1.1 Shore Type Relative Distribution

Low and middle bench active floodplain site associations combined account for about 88% of the left bank and about 92% of the right bank. Low and middle bench site associations occur in the geomorphologically dynamic portion of the floodplain and are maintained by a combination of prolonged flooding and site erosion/sedimentation (Mackenzie and Moran 2004). Low bench ecosystems occur on sites that are flooded for moderate periods (< 40 days) of the growing season, conditions that limit the canopy to tall shrubs, especially willows and alders. Annual erosion and deposition of sediment generally limit understory and humus development (Mackenzie and Moran 2004). Middle bench ecosystems occur on sites briefly flooded (10–25 days) during freshet, allowing tree growth but limiting tree species to only flood-tolerant broadleaf species such as black cottonwood (Mackenzie and Moran 2004).

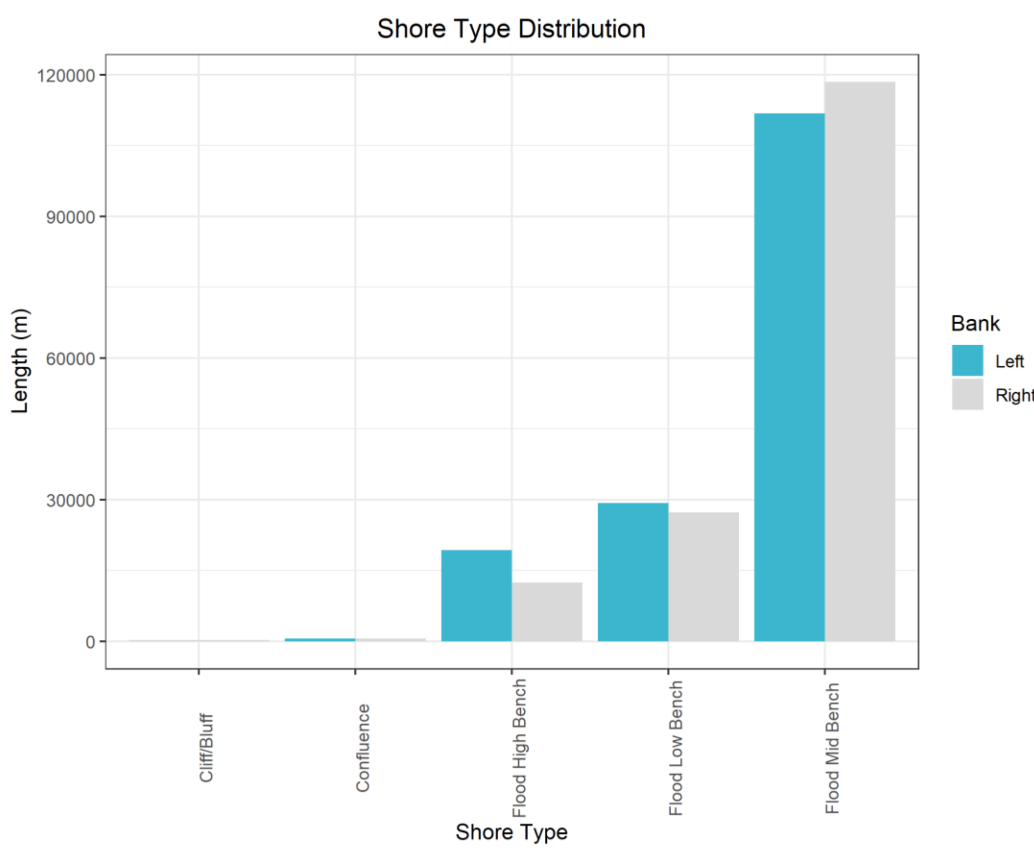

Figure 2. Relative distribution of shore types along the left and right bank of the Bonaparte River.


Low Flood Bench


Mid Flood Bench


Mixed Forest/Flood High Bench


Cultivated Field


Confluence


Riverine Marsh and Backwater

5.1.2 Land Use Relative Distribution

Both the left and right banks of the river are predominantly natural or have not been recently disturbed (Figure 3). Commercial land use encroachment/confinement and disturbance was observed primarily within the Village of Cache Creek and occurs along about 1.5% of the left bank and 0% of the right bank. Agricultural land use occurs along 26% of the left bank and about 40% of the right bank. Rural land use occurs along about 2% of the left bank, and <1% of the right bank. Land use described as single family occurs along about 1.5 % of the left bank and about 4 % of the right bank.

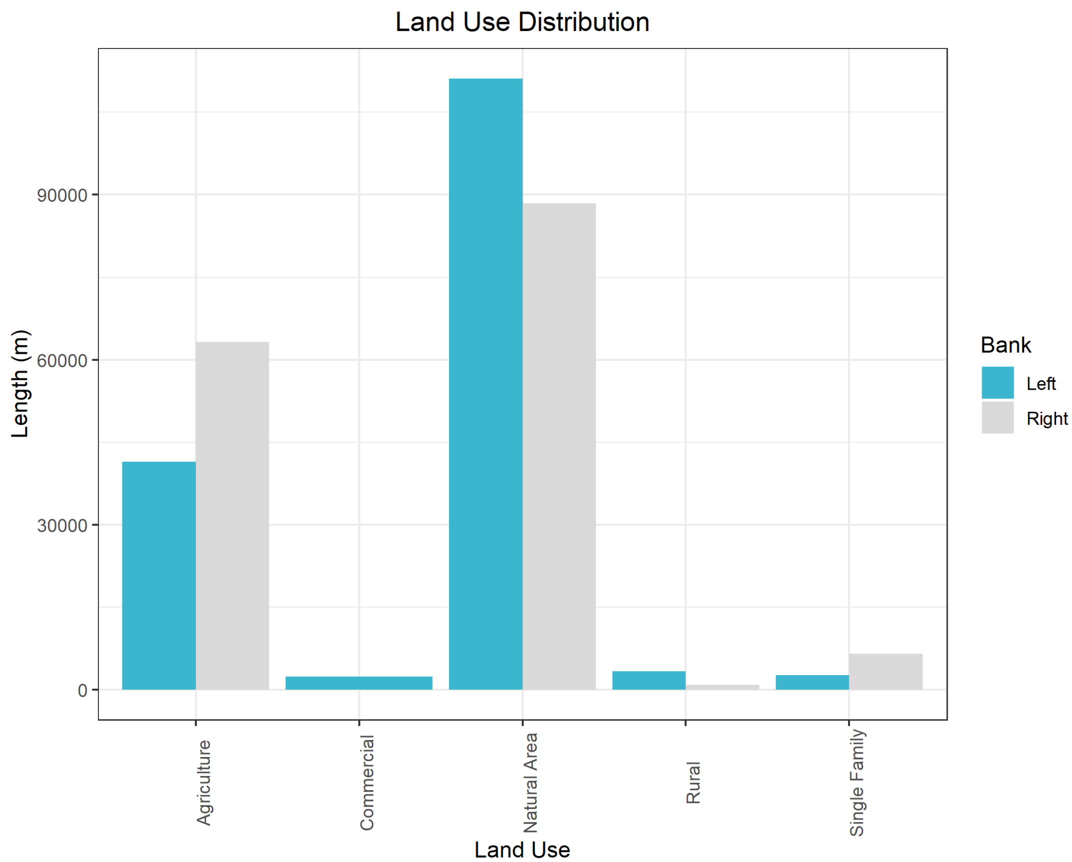

Figure 3. Relative land use distribution of along the left and right bank of the Bonaparte River. The total length of the left (LB) and right riverbanks (RB) was 161.5 km and 159.1 km respectively.


Agriculture


Infrastructure


Natural Area

Silt Bluff

Rock Bluff

Rural

Single Family

Recreational

5.1.3 Riverbank Level of Impact

Anthropogenic impacts to the river occurred in highest density from the areas adjacent to Loon Lake Road (north of Highway 97) southward to Sage and Sand Drive located at the southern end of the Village of Cache Creek. About 49.5 km (30%) of the left bank and about 70 km (44%) of the right bank has had medium to high level of impact. Figure 4 summarizes the distribution of impact rating categories assigned to the left and right banks of the BRIV.

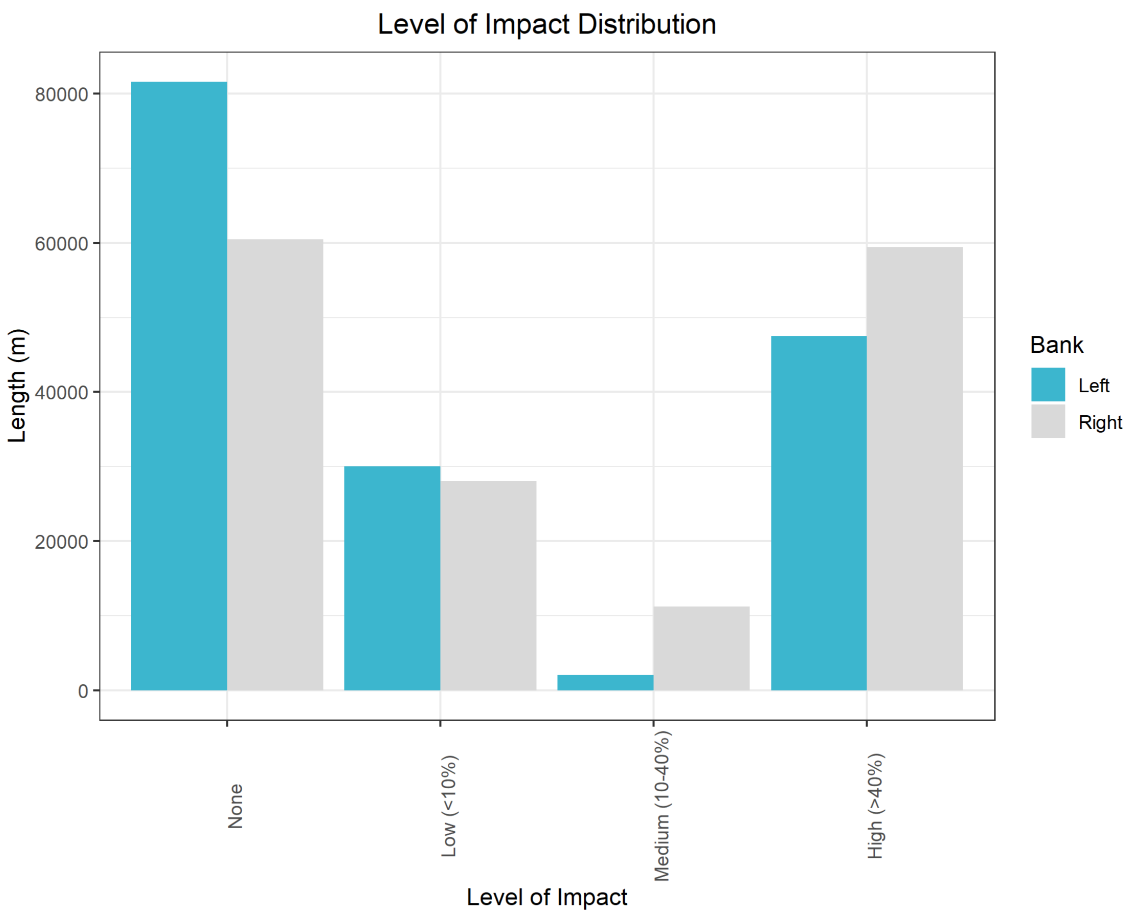

Figure 4. Level of impact category distribution on the left and right bank of the Bonaparte River.

5.2 Stream Channel and Hydraulic Character

The hydraulic character of the BRIV consisted of riffle-pool reaches on over 119 km (78%) of the River (Figure 5). The BRIV also has long expanses of glides and riffles totaling about 10.5 km and 7.5 km respectively. Low gradient glides were especially prevalent in the upper reaches east of the Village of Clinton (Reaches 43, 41, 38, 36, 29). The runs often had associated pools but gradients were too low for more prominent riffle development. Higher gradient riffles and riffle-pool sequences occurred in both the upper reaches (Reaches 37, 35, 34) and lower reaches (4, 3, 2) of the BRIV. Shallow riffle-pool braided gravel sequences occurred in the upper reaches (Reach 32). Persistent coarse substrate riffle-pool sequences began downstream of the Village of Cache Creek as the BRIV flows through a steep canyon towards the Village of Ashcroft and eventually the Thompson River confluence.

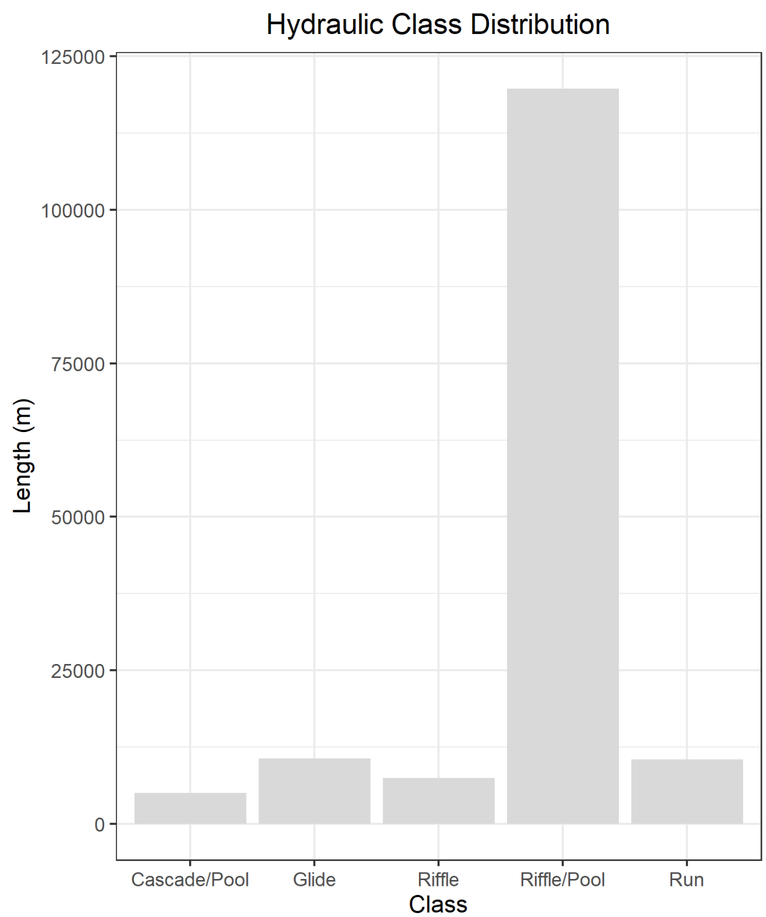

Figure 5. Bonaparte River hydraulic class distribution over the 140 km river centreline length.

5.3 Fish Habitat

Overall there was a marked increase in channel complexity and habitat quality in the upper reaches and through and downstream of the Village of Ashcroft Individual instream habitat features (e.g. deep pool, rearing/nursery, and spawning habitat) were recorded in the GPS and marked on field maps during the field inventory (Figure 6).

Key rearing areas for Chinook were described by Federenko and Pierce (1982) as flooded pastures, backwaters and sloughs adjacent to spawning areas. In terms of potential rearing and nursery habitat, low flood graminoid bench sites, seasonally flooded low bench areas, and riverine wetlands occurring adjacent to the river channel and in backwater areas, cover about 575 ha along the BRIV. These habitats are generally represented as linear bands along the river channel. These sites are flooded for moderate periods (< 40 days) of the growing season, during which time they may provide seasonal nursery and rearing habitat for juvenile salmonids.

Fish habitat in the BRIV was found very suitable for chinook and steelhead production. Chinook and steelhead production in the BRIV watershed below Young Lake is potentially very high (Tredger, 1980). This former assessment of anadromous fish potential in the BRIV was consistent with observations made during this survey. Deep pools, important for cover and general living as well as holding areas for anadromous migrations, amount to about 2.9 ha (0.8%) of the BRIV. Large woody debris (LWD) provides important structural cover/complexity for fish. In excess of 1.6 ha (0.46%) of large woody debris was recorded along the BRIV.

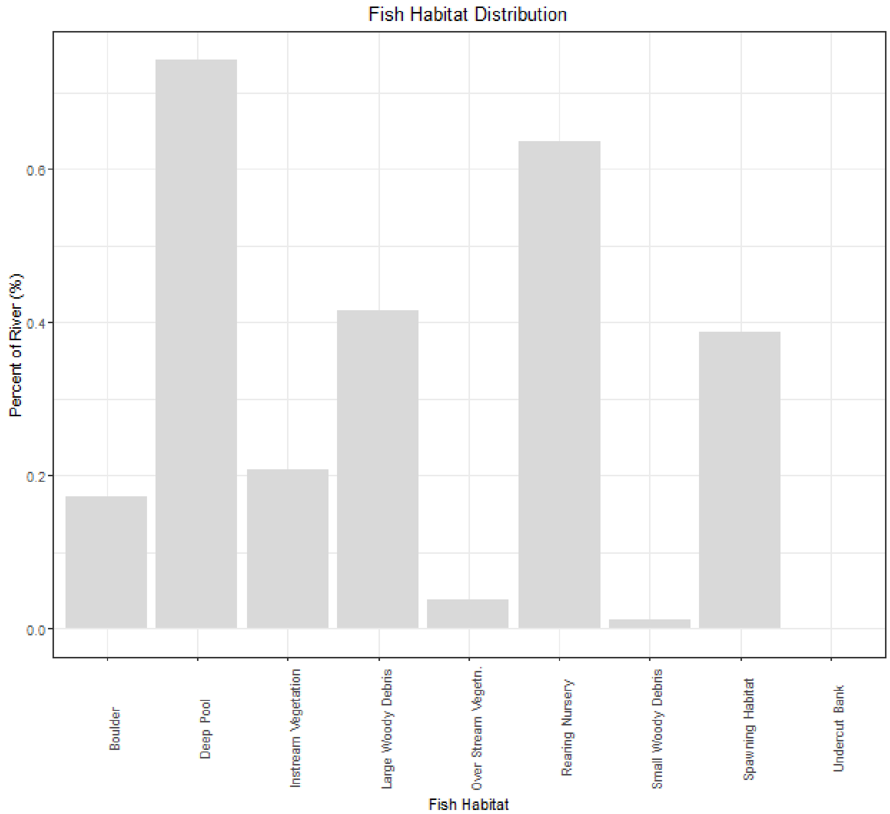

Figure 6. Relative distribution of key habitat elements mapped during the Bonaparte River inventory. Percentage values shown in the illustration represent the estimated spatial coverage of respective features over the total instream area (~hectares).

As shown in Table 13, deep pool habitat was measured to occupy about 0.8% of the river, followed by rearing and large woody debris habitat, with 0.7% and 0.46% respectively. The data summarized in Table 13 and illustrated on Map Set 2 was also incorporated into the AHI (Section 6.1).

Table 13. Mapped aerial coverage of fish habitat in the Bonaparte River.

Spawning Feature	Area (m^2)	Percent of Bonaparte Channel [1]	Relative abundance of total measured instream habitat/cover
Boulder	6851	0.19%	7%
Deep Pool	29443	0.81%	28%
Instream	20	0.00%	0%
Instream Vegetation	8274	0.23%	8%
Large Woody Debris	16527.5	0.46%	16%
Over Stream Vegetn.	1494	0.04%	1%
Rearing/Nursery	25220	0.70%	24%
Small Woody Debris	506	0.01%	0%
Spawning Habitat	15371	0.42%	15%
Undercut Bank	40	0.00%	0%

Total River Channel= 3627419 m^2

Side channel

Large woody debris and associated spawning habitat

Juvenile rearing habitat (backwaters and riverine marsh)

Holding area/deep pool

5.4 Modifications

Instream and bank modifications and features were recorded in the field as points and summarized in Table 14. 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 total of 25 water withdrawals (intakes) were recorded throughout the BRIV. Livestock access was recorded to occur on over 500 m of the riverbank with 63% of it being along the right bank. Bank armouring (rip rap) was recorded on over 1.6 km (0.99%) of the left bank and 1.5 km (0.94%) of the right bank. Retaining walls/bank stabilization were recorded on over 285 m (0.17%) of the left bank and 691 m (0.43%) of the right bank.

Table 14. Summary of anthropogenic features and modifications catalogued during the Bonaparte River Inventory.

Feature	Bank	Sum of Length (m)[1]	Count of Modification Type
Bridge	Both	281	48
Livestock Access	Left	192	29
	Right	329	30
Livestock Crossing	Both	2	1
General riparian modifications	Both	0	1
	Instream	8	2
	Left	390	13
	Right	754	22
Pipe Crossing	Both	38	9
Rec Access	Both	8	1
	Right	7	1
Retain Wall/Bank Stabilization	Left	285	19
	Right	691	21
Rip Rap	Both	24	3
	Left	1616	50
	Right	1507	51
Water Withdrawal	Left	0[2]	12
	Right	0[2]	13

1. The total lengths of the left (LB) and right river banks (RB) were 161.5 km and 159.1 km, respectively.
2. Number of water withdrawals were recorded but lengths were not recorded.

Bridge

Water Withdrawal
Improperly screened intakes result in impingement or entrainment of fish.

Livestock Access

Rip rap and Bank Stabilization

Discharge

5.5 Bank Stability and Erosion

High to extreme severity bank erosion was documented on approximately 1.2 k m (0.74%) of the left bank and 1.3 km (0.81%) of the right bank (Table 15). Bank instability appeared to be largely attributed to the lack of riparian vegetation and encroachment associated with agricultural land use, rural, and residential sites. All erosion features are shown in Map Set 2 and are included in the data deliverables. Bank segments with prominent erosion are listed in Table 15.

Table 15. Summary of riverbank integrity and erosion along the Bonaparte River.

	Sum of erosion length (m)[1]	Percent of respective riverbank
Left	**6512**	**4.02%**
High	1250	0.74%
Moderate	3376	2.04%
Low	1886	1.36%
Right	**5978**	**3.7%**
Extreme	40	0.02%
High	1310	0.81%
Moderate	3077	1.88%
Low	1551	0.94%
Total	**12708**	

The total length of the left and right riverbanks was 161.5 km and 159.1 km respectively.

High Severity Erosion

Extreme Severity Erosion

Table 16. Summary of prominent left bank and right bank erosion by segment.

Left Bank			Right Bank		
Segment	Extreme Erosion (m)	High Erosion (m)	Segment	Extreme Erosion (m)	High Erosion (m)
6		51	3		27
10		66	11		135
11		77	13		141
17		40	14		87
18		19	15		119
21		119	16		89
23		47	17		84
24		111	18		89
25		175	20		63
26		60	21		42
27		166	25		43
32		288	30		36
33		138	42		32
62		48	50		22
64		117	55	59	364
72		21	63		126
			70		30

5.6 Bonaparte River Condition Score

A condition score was assigned to each river reach. 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 5.63 (out of 6), with the Bonaparte River receiving a stream grade of 94% (Table 17).

Table 17. Level of impact rating / condition score for the Bonaparte River.

Impact Rating	Sum of Length (m)	Condition Value Score	% of River	Weighted Score
high_high	0	0	0%	0.00
mod_high	0	1	0%	0.00
mod_mod	7928	2	5%	0.10
low_mod	0	3	0%	0.00
nil_high	0	3	0%	0.00
low_low	0	4	0%	0.00
nil_mod	0	4	0%	0.00
nil_low	22762	5	14%	0.74
nil_nil	122564	6	79%	4.79
Sum	153254			5.63
Condition Score				**94%**

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

6.0 AQUATIC HABITAT INDEX RESULTS

The AHI results summarized below are illustrated in Map Series 2 and the raw AHI analysis scores are included in Appendices A – C with centerline and bank segment information. Section 6.1 summarizes the AHI scores and resultant rankings (i.e., *Very Low – Very High*) for the 44 reaches of the BRIV, represented in the maps and data analysis as the *centerline*. Section 6.2 summarizes the AHI scores and resultant rankings for the respective left and right bank segments.

6.1 The River

The centerline AHI analysis resulted in about 2% of the river being ranked as Very High and 51% of the river ranked as High (Table 18). The centerline/reach AHI rankings are illustrated in Figure 7. Figure 8 represents a scaled profile of reach/AHI scores moving upstream (left to right) from Nicola Lake to the Thompson confluence.

Table 18. Relative AHI rank distribution (by length) of the Bonaparte River.

AHI Category	Total Length (m)	Percent of River
Very High	39849	26
High	78221	51
Moderate	25041	16
Low	10143	6

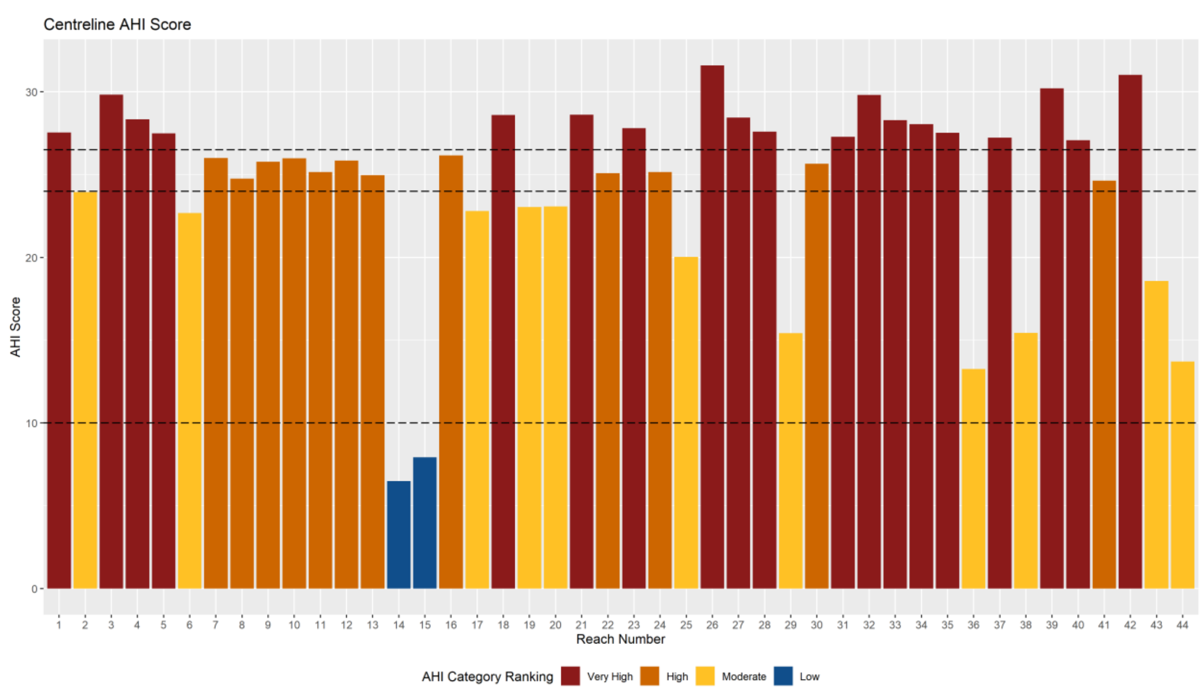

Figure 7. Centerline/reach AHI scores and AHI Rank values (Low/Moderate/High/Very High

6.2 The Banks

Approximately 36% of the left bank of the BRIV is ranked Very High and 14% is ranked low according to Bank AHI scores (Table 19). Conversely, about 14% of the Right Bank of the river is ranked Very High, with 25% ranked as low. The higher relative abundance of Very High segment scores along the left bank is largely due to more natural character to this bank in reaches adjacent to the Loon Lake Road and other isolated areas along Highway 97 where development is restricted to the right bank. The right bank of the river is largely affected by agricultural land uses. Figures 8 and 9 illustrate respective segment scores on the left and right banks.

Table 19. Relative AHI rank distribution (by length) of the left and right banks (looking downstream) of the Bonaparte River.

Segment/AHI Ratings		Sum of Segment Length (m)	Percent of Bank
Left	Very High	57933	36%
	High	40583	25%
	Moderate	40425	25%
	Low	22614	14%
Right	Very High	22882	14%
	High	48523	31%
	Moderate	47808	30%
	Low	39941	25%

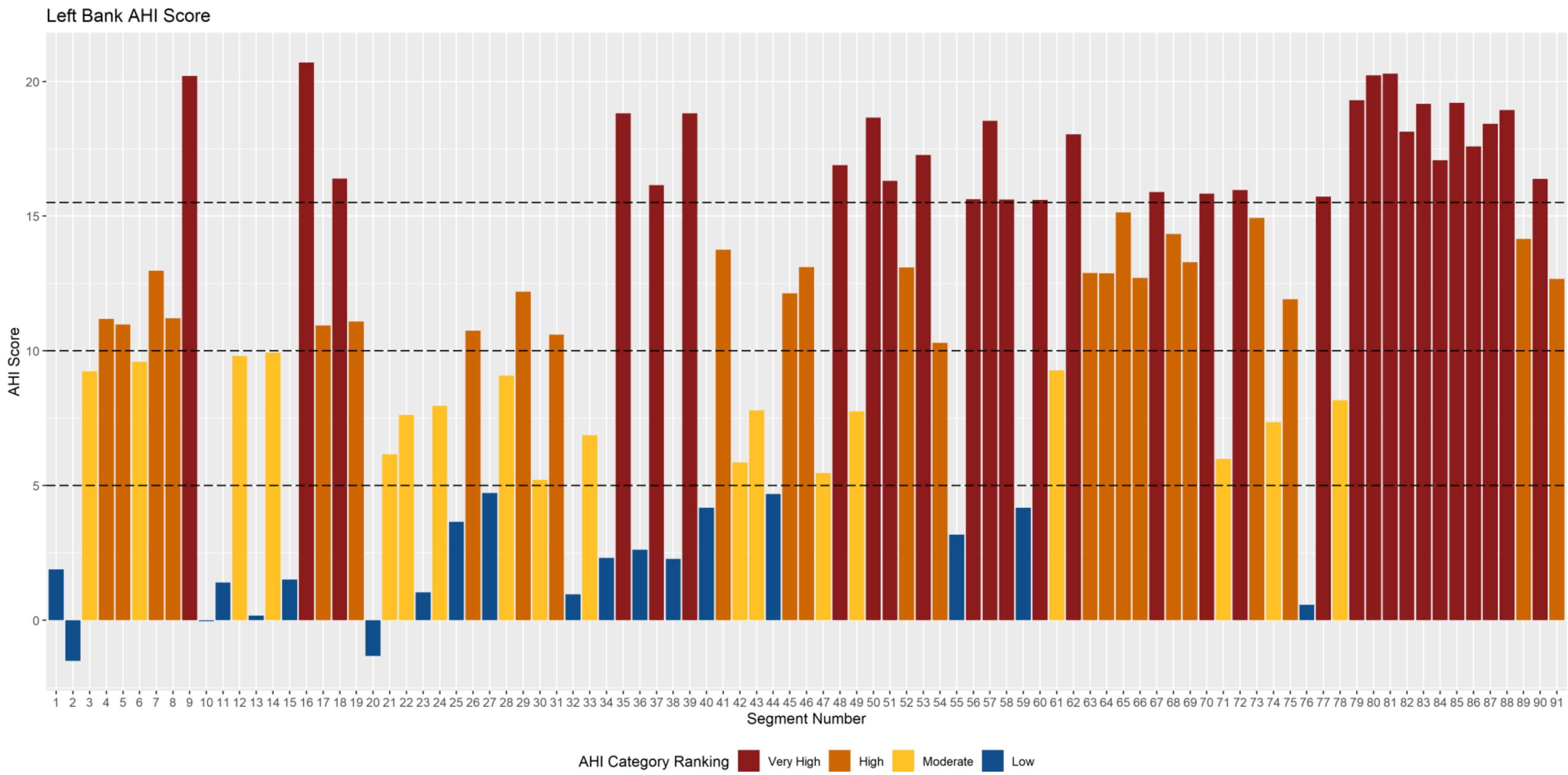

Figure 8. Left bank segment AHI scores.

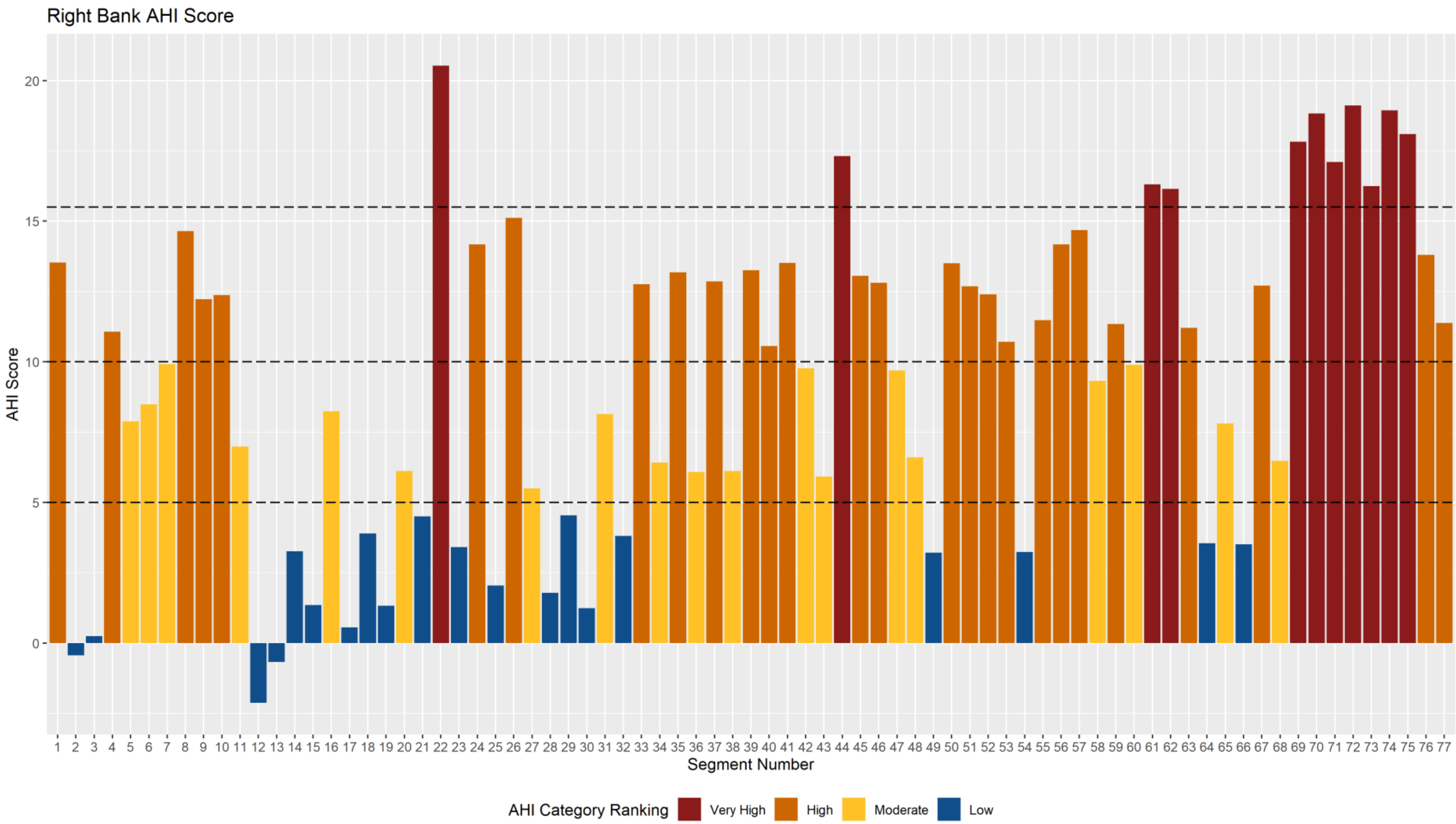

Figure 9. Right bank segment AHI scores.

7.0 DISCUSSION

Flood ecosystems are intensively used by many wildlife species. These are lush habitats with structural elements often not found in adjacent uplands. In addition, the low flood sites may provide critical rearing habitat for juvenile salmonids during seasonal inundation periods. The *High* and *Very High* AHI scores/ranks supports this ecological statement; where the mosaic of riparian habitats and complex instream habitat subunits and diverse fish life history utilization combine to represent the highest centerline and bank AHI scores throughout the BRIV.

The areal extent of flood associated ecosystems remains constant in a stream reach over time, given no fundamental change in water regime or sediment load, but their location in the floodplain changes in response to stream channel changes (Mackenzie and Moran 2004). Flood ecosystems are maintained by a combination of annual flooding, erosion, channel movement, and deposition, which modify the site conditions on the floodplain regularly. Middle bench ecosystems will succeed low benches as sites accumulate sediments and become raised above the stream. With human influence, continued isolation of middle or low bench ecosystems from the regular flooding, through sediment accumulation or stream channel changes, hastens the natural succession and can lead to the formation of seral ecosystems that progress towards modified high bench ecosystems (Mackenzie and Moran 2004).

The *High* and *Very High* AHI scores/ranks on the BRIV are threatened by a variety of instream and upland activities. Intensive 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.

Approximately 521 m of open livestock access was recorded along the BRIV and several additional kilometers of livestock grazing within close proximity to the BRIV was observed. Riparian vegetation is highly affected by grazing livestock, either through successional changes or through the elimination of the necessary riparian fringe, leading to a reduction of shade, cover, and terrestrial food supply and bank stability (Armour 1977). Fencing off livestock areas provides additional management of upland agricultural land that will protect and restore the riparian fringe, benefitting the system as a whole.

The loss of riparian vegetation from logging, crop production, infrastructure and urban sprawl limit the natural river cooling mechanisms in turn exacerbating rising river temperatures caused by increasingly hot and arid climates such as those found in the lower reaches of the BRIV. Stream bank destabilization additionally leads to wider and shallower stream sections, consequently increasing temperatures. Juvenile rearing is affected by local river temperature variations prompting fish to seek colder groundwater inflows and shade. River tributary confluences generally supply cold water influxes to the BRIV mainstem. Tredger (1980) indicated that the BRIV above Clinton Creek represents a basically pristine watershed. Since that time, increased logging, wildfires, and rural development is likely to have further altered these upper reaches. However, many natural areas 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 BRIV.

Twenty six water intakes were catalogued on the BRIV below Bonaparte Lake, many of which were unscreened. Water withdrawals can directly impact fish as fry can become trapped and lost in withdrawal canals. Initiative should be taken to ensure water withdrawals are properly screened to prevent small-bodied fish and fry entrainment. The Department of Fisheries and Oceans (DFO) *Freshwater Intake End-of-Pipe Fish Screen Guidelines* can be used to determine appropriate screen sizes. To avoid excessively low flows, it is imperative that constructive regulations (Environmental Flow Needs) are set to limit excessive water withdrawal from the BRIV during drought periods.

In addition to direct effects on fish, extensive water withdrawals have exacerbated low river flows triggered by climate variability. 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. Low flows have the added effect of trapping rearing juveniles in high quality backwater habitats, where survival depends on the availability of food and cover. Fish species such as Coho may be forced to use lower reaches as low flows result in inaccessibility to formerly used higher reaches. An increase in the abundance of cover in lower reaches would lead to the creation of suitable Coho habitat. Additional investigation should be initiated to determine the significance of backwater habitat to fish in the BRIV.

Recognizing the above, it is paramount that landuse planning and management of the BRIV 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 and protect cold water refuge habitats for improved salmon rearing/nursery potential. Currently rearing habitats were recorded to account for about 0.70% of instream habitats with side channels accounting for about 1.6% of instream habitats. Relic ox bow channels that have been isolated from the river provide an opportunity to realize an increase in backwater habitat.

Hard armouring of gravel banks can reduce the supply of gravel through natural stream channel migration processes and the removal of riparian vegetation hastens bank erosion and fine sediment deposits. Moreover, upland activities can impact floodplains. Several bank restoration features were observed throughout the lower reaches of the BRIV. 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.


Large woody debris revetment and bank stabilization on the BRIV

The BRIV is a high value anadromous and resident system regardless of individual reach AHI scores. A low AHI reach score does not imply that particular reach is of low value. Rather the combination of habitat attribute values in that reach contribute less to fisheries and aquatic production than other reaches. Reaches 14 and 15 had Low centerline AHI scores. The Low ranking is a result of more limited habitat complexity (i.e., being a slow glide with fine-textured substrates), absence of salmonid spawning habitat, generally limited in instream cover, and increased fine sediments and turbidity as a result of livestock access, loss of riparian vegetation and channel bank erosion. However, these lower reaches are still important and more sensitive for both spawning migration and fry outmigration.

The *Very High* and *High* river bank areas and those adjacent to *High* and *Very High* ranked reaches are considered the most important areas and mechanisms to protect these key habitat features need to be developed. This analysis highlights the importance of conserving important natural areas that remain and prioritizing habitat improvements where feasible.

Conservation of existing riparian conditions is paramount to prevent a reduction in Bank AHI scores for respective segments. The scores and corresponding rankings established in this analysis should form the baseline when reviewing current and proposed activities along the River. The review of existing or proposed activities should be measured against these baseline AHI scores using the metrics and relative habitat value scores for riparian band habitat units of the Bank AHI (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.

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. In light of the extensive impacts of excessive water withdrawal and to provide continuity and consistency in this assessment, it is recommended that further cataloguing and indexing of large tributary reaches be undertaken to document additional important fish habitat and potential impairments in the Bonaparte system.

8.0 CLOSURE

This Document has been prepared for the exclusive use of the Secwepemc Fisheries Commission. 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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