SOCIETY FOR ECOSYSTEM RESTORATION
IN NORTHERN BRITISH COLUMBIA

Bulkley River and Morice River Watershed Groups Fish Passage Restoration Planning

Prepared for
Habitat Conservation Trust Foundation - CAT21-6-288
BC Fish Passage Remediation Program
Canadian Wildlife Federation

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Acknowledgement

The Bulkley River and Morice River watersheds are within Wet'suwet'en and Gitxsan territory.

Modern civilization has a long journey ahead to acknowledge and address the historic and ongoing impacts of colonialism that have resulted in harm to the ecosystems in Northern British Columbia. That harm naturally extends to the cultures and livelihoods of those that have lived in harmony with the Yintahk/Laxyip (land) for many thousands of years.

The Skeena Fisheries Commission honoured us when they put us in touch with their members in the fall of 2019 and hosted a forum for us to give a presentation about our project in the spring of 2020. Thank you for having the patience to listen to our story which is a story you told us. Thank you Stu Barnes, Ryneld Starr, Allison Oliver, and the rest of the teams.

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Acknowledgement

Our fish passage connection to the watershed began with the trust of Craig Mount, Richard Thompson, Dave Maloney and the rest of the British Columbia Fish Passage Technical Working group through a 2017 project commissioned by the Ministry of Environment and Climate Change Strategy (MoE). Thank you.

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There are many others to which we owe our gratitude and please accept our apologies for leaving people out. It has been a great journey catching up to you all and we are so thankful for everyone willing to help. Please reach out if we did not include you or others yet since the acknowledgment is well deserved.

Fish passage is a wonderful example of how all things are connected and interdependent. The barriers that divide will eventually fall once we understand together where, how and why they stand between.

Dzïn scudïlh'iy misiyh. Hami yaa nee loosim.

Executive Summary

The health and viability of freshwater fish populations can depend on access to tributary and off channel areas which provide refuge during high flows, opportunities for foraging, overwintering habitat, spawning habitat and summer rearing habitat (Bramblett et al. 2002; Swales and Levings 1989; Diebel et al. 2015). Culverts can present barriers to fish migration due to low water depth, increased water velocity, turbulence, a vertical drop at the culvert outlet and/or maintenance issues (Slaney, Zaldokas, and Watershed Restoration Program (B.C.) 1997; Cote et al. 2005). As road crossing structures are commonly upgraded or removed there are numerous opportunities to restore connectivity by ensuring that fish passage considerations are incorporated into repair, replacement, relocation and deactivation designs.

Through this initiative, the Provincial Fish Passage Remediation Program and connectivity restoration planning led by the Canadian Wildlife Federation and funded by the British Columbia Salmon Restoration and Innovation Fund, `bcfishpass` has been designed to prioritize potential fish passage barriers for assessment or remediation. The software is under continual development and has been designed and constructed by Norris (2021d) using of sql and python based shell script libraries to generate a simple model of aquatic habitat connectivity which includes tools to assess the intrinsic value of habitat upstream of potential barrier locations.

Following review of background literature, fisheries information, Provincial Stream Crossing Inventory System (PSCIS) and `bcfishpass` outputs, 70 modelled and PSCIS crossings were reviewed to select sites for follow up with Phase 1 and 2 fish passage assessments in the Morice River watershed. Although planning for field assessments ws still underway at the time of reporting through ongoing modelling, engagement with the Office of Wet'suwet'en, DFO, FLNRORD, BC Ministry of Environment, the Morice Watershed Monitoring Trust and numerous others, 14 crossings were ranked as high priority for future follow up with Phase 1 and/or Phase 2 assessments, 26 crossings ranked as moderate priorities, and 30 crossings ranked as low priorities. Online interactive and georeferenced field maps were produced and a field plan for future on the ground assessments formulated. Some key areas targeted for future fieldwork activity include assessments within the Owen Creek, Lamprey Creek, McBride Lake, Nanika Lake, and Morice Lake watersheds.

During 2020 fieldwork, a total of 31 fish passage assessments were conducted with 13 crossings considered "passable," 3 crossings considered "potential" barriers and 15 crossings considered "barriers" according to threshold values based on culvert embedment, outlet drop, slope, diameter (relative to channel size) and length. "Barrier" and "Potential Barrier" rankings used in this project followed MoE (2011) and reflect an assessment of passability for juvenile salmon or small resident rainbow trout at any flows potentially present throughout the year (Clarkin et al. 2005 ; Bell 1991; Thompson 2013).

Habitat confirmation assessments were conducted at 22 sites in the Bulkley River watershed group and one site in the Morice River watershed group. A total of approximately 18 km of stream was assessed using standardized site assessment procedures (Resources Inventory Committee 2001), fish sampling utilizing electrofishing and/or minnowtrapping was conducted at eight sites, and three sites were mapped using remotely piloted aircraft. All data is included in reporting and whenever possible, workflows have been scripted either in `R`, `SQL` or `Python` to facilitate workflow tracking, collaboration, transparency and continually improving research.

As collaborative decision making was ongoing at the time of reporting, habitat confirmation site prioritization can be considered preliminary. In total, Twelve crossings were rated as high priorities for proceeding to design for replacement, 9 crossings were rated as moderate priorities, and 2 crossings were rated as low priorities.

Recommendations for potential incorporation into collaborative watershed connectivity planning for the Bulkley River and Morice River watershed groups include:

- Continue to develop `bcfishpass`,`bcfishobs`, `fwapg` and other open source data analysis and presentation tools that are scalable and facilitate continual improvement and collaborative adaptation.
- Continue to conduct fish passage and habitat confirmation assessments at road and rail stream crossings at sites in the study areas prioritized through this project and future connectivity analysis/modelling. In the Bulkley River watershed group, particular sites of note where future Phase 1 and Phase 2 assessments are recommended include John Brown Creek, Toboggan Creek, Cesford Creek, Watson Creek and Ailport Creek.
- Continue to acquire funding to procure site plans and replacement designs for structures collaboratively identified as high priorities for restoration. Explore cost benefits and ethics of crossing structure upgrades alongside the cost benefits and ethics of alternative restoration activities and look for opportunities to leverage initiatives together for maximum restoration benefits.
- Refine barrier thresholds for road-stream crossing structures to explore passability metrics specific to life stage and life history types of species of interest.
- Model fish densities (fish/m^2) vs. habitat/water quality characteristics (i.e. gradient, watershed size, channel size, alkalinity, elevation, etc.) using historically gathered electrofishing data to inform crossing prioritization, future data acquisition needs, and the monitoring of subsequent restoration actions.
- Expand the Bulkley River fish passage working group focus area to include the greater Skeena River watershed.
- Build relationships with other working groups (ex. Washington Wildlife Habitat Connectivity Working Group) to share knowledge and biuld capacity related to large scale connectivity remediation.

- Continue to collaborate with potential partners to build relationships, explore perspectives and develop “road maps” for fish passage restoration in different situations (MoT roads, rail lines, permit roads of different usages, FSRs, etc.) – documenting the people involved, discussions and processes that are undertaken, funding options, synergies, measures of success, etc.

1 Introduction

This report is available as pdf and as an online interactive report at https://newgraphenvironment.github.io/fish_passage_bulkley_2020_reporting/. We recommend viewing online as the web-hosted html version contains more features and is more easily navigable.

The health and viability of freshwater fish populations can depend on access to tributary and off channel areas which provide refuge during high flows, opportunities for foraging, overwintering habitat, spawning habitat and summer rearing habitat (Bramblett et al. 2002; Swales and Levings 1989; Diebel et al. 2015). Culverts can present barriers to fish migration due to low water depth, increased water velocity, turbulence, a vertical drop at the culvert outlet and/or maintenance issues (Slaney, Zaldokas, and Watershed Restoration Program (B.C.) 1997; Cote et al. 2005). As road crossing structures are commonly upgraded or removed there are numerous opportunities to restore connectivity by ensuring that fish passage considerations are incorporated into repair, replacement, relocation and deactivation designs.

In April of 2020, the Society for Ecosystem Restoration Northern British Columbia (SERNbc) undertook an initiative to plan and conduct fish passage restoration planning activities in the Bulkley River and Morice River watershed groups which are sub-basins of the Skeena River watershed. The initiative was supported by a grant from the Habitat Conservation Trust Fund that leveraged funds committed in the fall of 2019 from the Provincial Fish Passage Remediation Program and the Canadian Wildlife Federation. New Graph Environment and Hillcrest Geographics were the project team subcontracted to devise the study plan, submit proposals and complete the work which included information gathering, updating/implementation of open source data analysis tools, fish passage assessments and habitat confirmation assessments. Although fish passage restoration planning was conducted for both the Morice River watershed group and the Bulkley River watershed group, on the ground surveys in 2020 focused primarily within Bulkley River tributaries.

In August of 2020, following a province wide prioritization exercise and a series of workshops, the Canadian Wildlife Federation selected the Bulkley River watershed group as a target watershed for connectivity planning efforts supported by a grant from the British Columbia Salmon Restoration and Innovation Fund. Recognizing synergies between the two initiatives, select project activities of both initiatives became a collaboration between SERNbc and CWF with extensive input from numerous organizations and individuals connected to the watersheds.

Spearheaded by the Canadian Wildlife Federation, a Fish Passage Working Group consisting of First Nations, non-profits, stakeholder groups and regulators was established for the Bulkley River watershed group in the fall of 2020. At the time of reporting, collaborative decision making processes regarding connectivity issues were underway through monthly meetings with results forthcoming in a watershed connectivity remediation plan. At the time of reporting, the scope of

connectivity planning explored by the Working Group included the Bulkley River watershed group and not yet the Morice River and other sub-basins of the Skeena River watershed.

Although remediation and replacement of stream crossing structures can have benefits to local fish populations, the costs of remedial works can be significant and the impacts of the work often complex to evaluate and quantify. Additionally, allocation of ecosystem restoration funding towards infrastructure upgrades on transportation right of ways are not always considered ethical under all circumstances from all perspectives. When funds are finite and invested groups are engaged in fund raising, cost benefits and the ethics of crossing replacements should be explored collaboratively alongside the cost benefits and ethics of alternative investment activities including transportation corridor relocation/deactivation, land procurement/covenant, cattle exclusion, riparian restoration, habitat complexing, water conservation, commercial/recreational fishing management, salt water interventions and research.

2 Background

The study area includes the Bulkley River and Morice River watershed groups (Figure 2.1) and is within the traditional territories of the Gitxsan and Wet'suwet'en.

2.1 Wet'suwet'en

Wet'suwet'en hereditary territory covers an area of 22,000km^2 including the Bulkley River and Morice River watersheds and portions of the Nechako River watershed. The Wet'suwet'en people are a matrilineal society organized into the Gilseyhu (Big Frog), Laksilyu (Small Frog), Tsayu (Beaver clan), Gitdumden (Wolf/Bear) and Laksamshu (Fireweed) clans. Within each of the clans there are are a number of kin-based groups known as Yikhs or House groups. The Yikh is a partnership between the people and the territory. Thirteen Yikhs with Hereditary Chiefs manage a total of 38 distinct territories upon which they have jurisdiction. Within a clan, the head Chief is entrusted with the stewardship of the House territory to ensure the Land is managed in a sustainable manner. Inuk Nu'at'en (Wet'suwet'en law) governing the harvesting of fish within their lands are based on values founded on thousands of years of social, subsistence and environmental dynamics. The Yintahk (Land) is the centre of life as well as culture and it's management is intended to provide security for sustaining salmon, wildlife, and natural foods to ensure the health and well-being of the Wet'suwet'en (Office of the Wet'suwet'en 2013; "Office of the Wet'suwet'en" 2021; FLNRORD 2017).

2.2 Gitxsan

The Gitxsan Laxyip (traditional territories) covers an area of 33,000km^2 within the Skeena River and Nass River watersheds. The Laxyip is governed by 60 Simgiigyet (Hereditary Chiefs), within the traditional hereditary system made up of Wilps (House groups). Anaat are fisheries tenures found throughout the Laxyip. Traditional governance within a matrilineal society operates under the principles of Ayookw (Gitxsan law) ("Gitxsan Huwilp Government" 2021).

2.3 Project Location

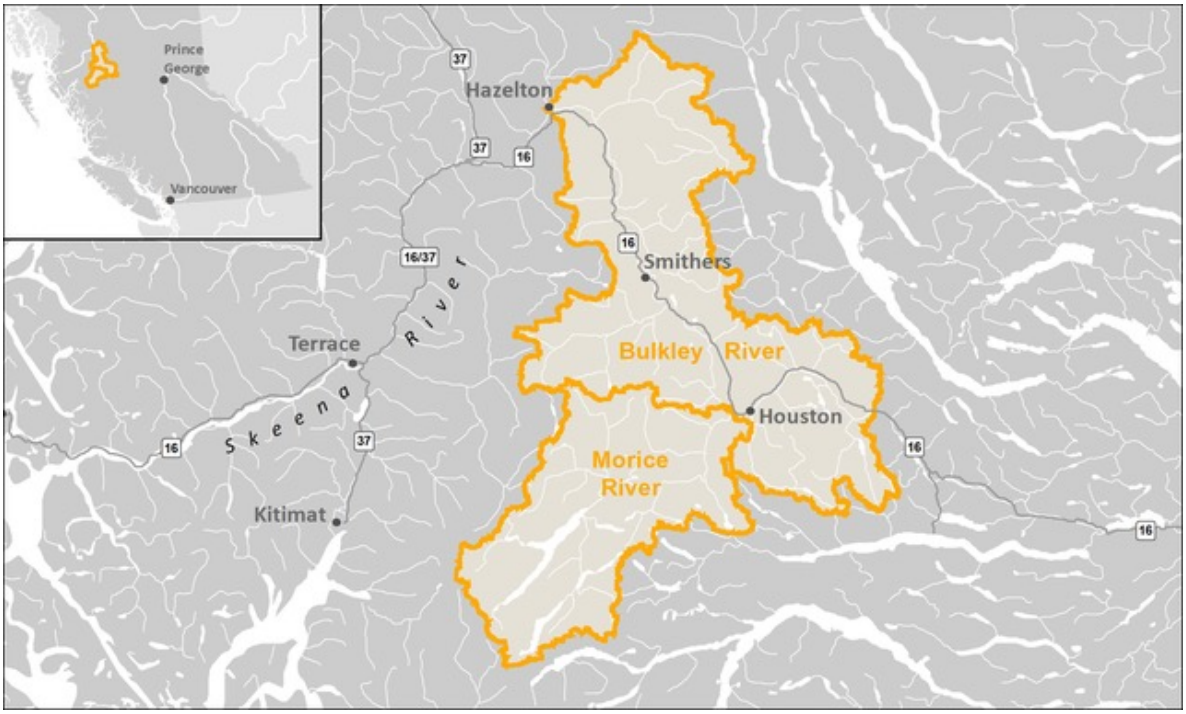

Figure 2.1: Overview map of Study Areas

2.3.1 Bulkley River

The Bukley River is an 8th order stream that drains an area of 7,762 km^2 in a generally northerly direction from Bulkley Lake on the Nechako Plateau to its confluence with the Skeena River at Hazleton. It has a mean annual discharge of 139.1 m^3/s at station 08EE004 located near Quick (~27km south of Telkwa) and 19.6 m^3/s at station 08EE003 located upstream near Houston. Flow patterns at Quick are heavily influenced by inflows from the Morice River (enters just downstream of Houston) resulting in flow patterns typical of high elevation watersheds which receive large amounts of precipitation as snow leading to peak levels of discharge during snowmelt, typically from May to July (Figures 2.2 - 2.3). The hydrograph peaks faster and generally earlier (May - June) for the Bulkley River upstream of Houston where the topography is of lower lower elevation (Figures 2.2 and 2.4).

Changes to the climate systems are causing impacts to natural and human systems on all continents with alterations to hydrological systems caused by changing precipitation or melting snow and ice increasing the frequency and magnitude of extreme events such as floods and droughts (IPCC 2014; ECCC 2016). These changes are resulting in modifications to the quantity and quality of water resources throughout British Columbia and are likely to compound issues

related to drought and flooding in the Bulkley River watershed where numerous water licenses are held with a potential over-allocation of flows identified during low flow periods (ILMB 2007).

The valley bottom has seen extensive settlement over the past hundred years with major population centers including the Village of Hazelton, the Town of Smithers, the Village of Telkwa and the District Municipality of Houston. As a major access corridor to northwestern British Columbia, Highway 16 and the Canadian National Railway are major linear developments that run along the Bulkley River within and adjacent to the floodplain with numerous crossing structures impeding fish access into and potentially out from important fish habitats. Additionally, as the valley bottom contains some of the most productive land in the area, there has been extensive conversion of riparian ecosystems to hayfields and pastures leading to alterations in flow regimes, increases in water temperatures, reduced streambank stability, loss of overstream cover and channelization (ILMB 2007; Wilson and Rabnett 2007).

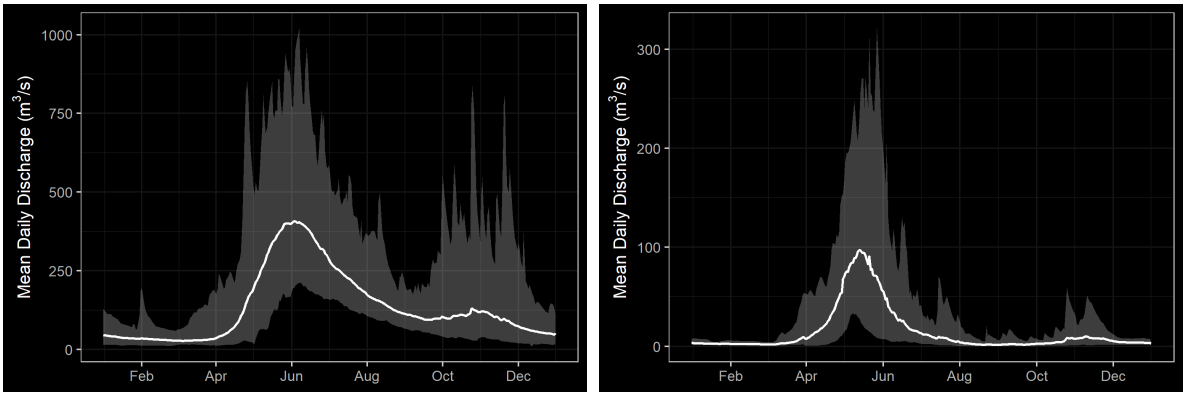

Figure 2.2: Hydrograph for Bulkley River at Quick (Station #08EE004) and near Houston (Station #08EE003).

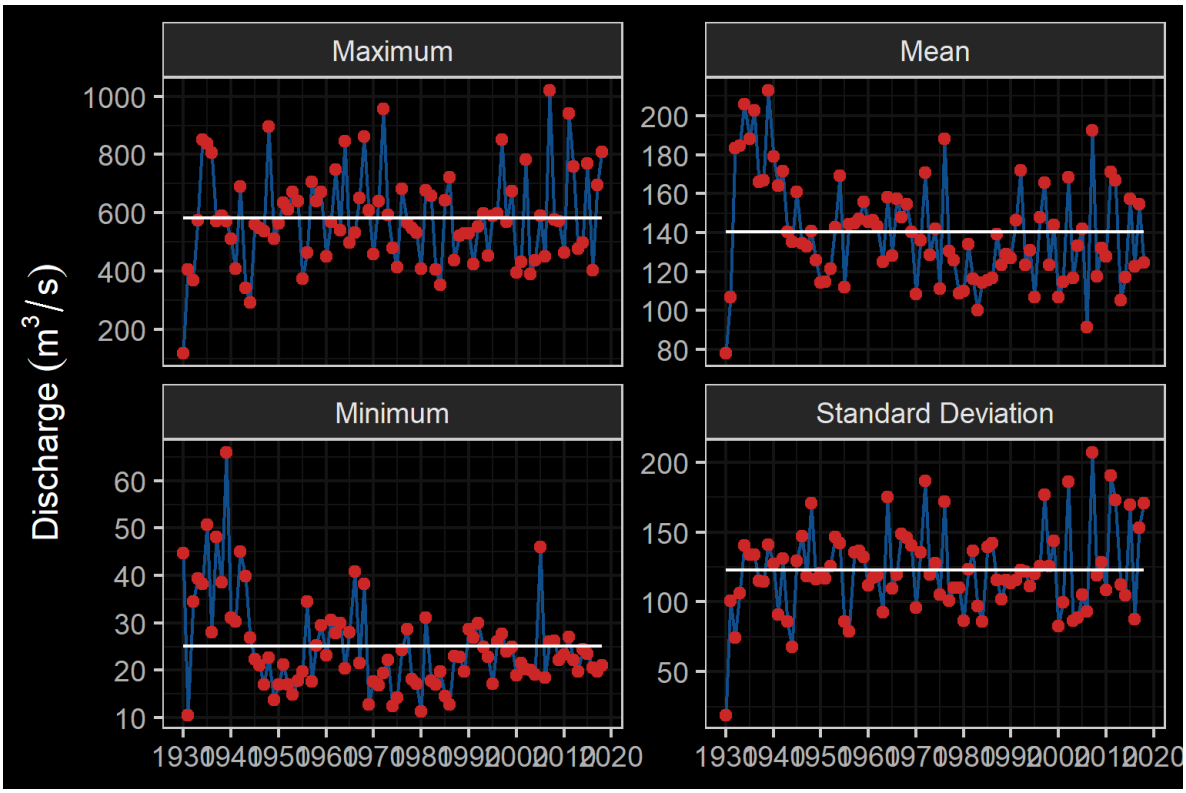

Figure 2.3: Summary of hydrology statistics for Bulkley River at Quick (Station #08EE004 - daily discharge data from 1930 to 2018).

Figure 2.4: Summary of hydrology statistics for Bulkley River near Houston (Station #08EE003 - daily discharge data from 1980 to 2018).

2.3.2 Morice River

The Morice River watershed drains 4,379 km^2 of Coast Mountains and Interior Plateau in a generally south-eastern direction. The Morice River is an 8th order stream that flows approximatley 80km from Morice Lake to the confluence with the upper Bulkley River just north of Houston. Major tributaries include the Nanika River, the Atna River, Gosnell Creek and the Thautil River. There area numerous large lakes situated on the south side of the watershed including Morice Lake, McBride Lake, Stepp Lake, Nanika Lake, Kid Price Lake, Owen Lake and others. There is one active hydrometric station on the mainstem of the Morice River near the outlet of Morice Lake and one historic station that was located at the mouth of the river near Houston that gathered data in 1971 only (Environment and limate Change Canada 2021). An estimate of mean annual discharge for the one year of data available for the Morice near it's confluence with the Bulkley River is 113.3 m^3/s. Mean annual discharge is estimated at 75.2 m^3/s at station 08ED002 located near the outlet of Morice Lake. Flow patterns are typical of high elevation watersheds influenced by coastal weather patterns which receive large amounts of winter precipitation as snow in the winter and large precipitation events in the fall. This leads to peak levels of discharge during snowmelt, typically from May to July with isolated high flows related to rain and rain on snow events common in the fall (Figures 2.5 - 2.6).

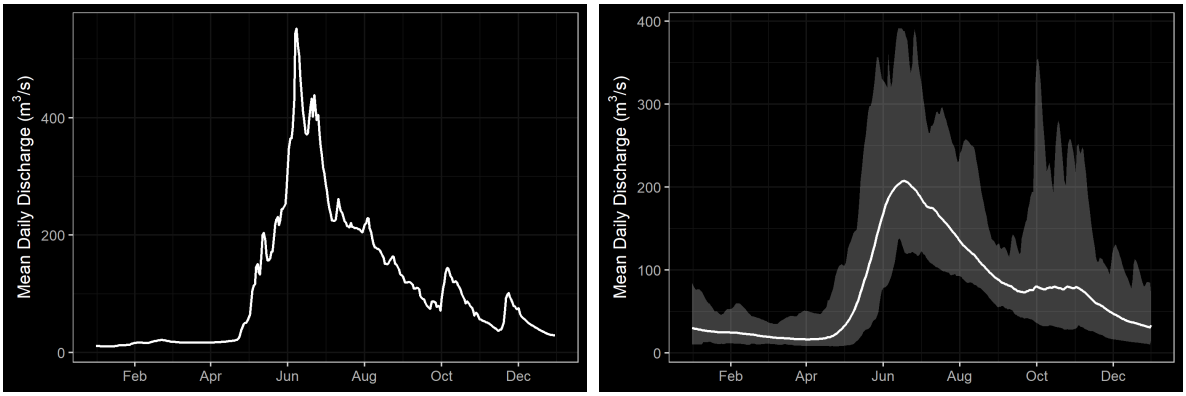

Figure 2.5: Left: Hydrograph for Morice River near Houston (Station #08ED003 - 1971 data only). Right: Hydrograph for Morice River near outlet of Morice Lake (Station #08ED002).

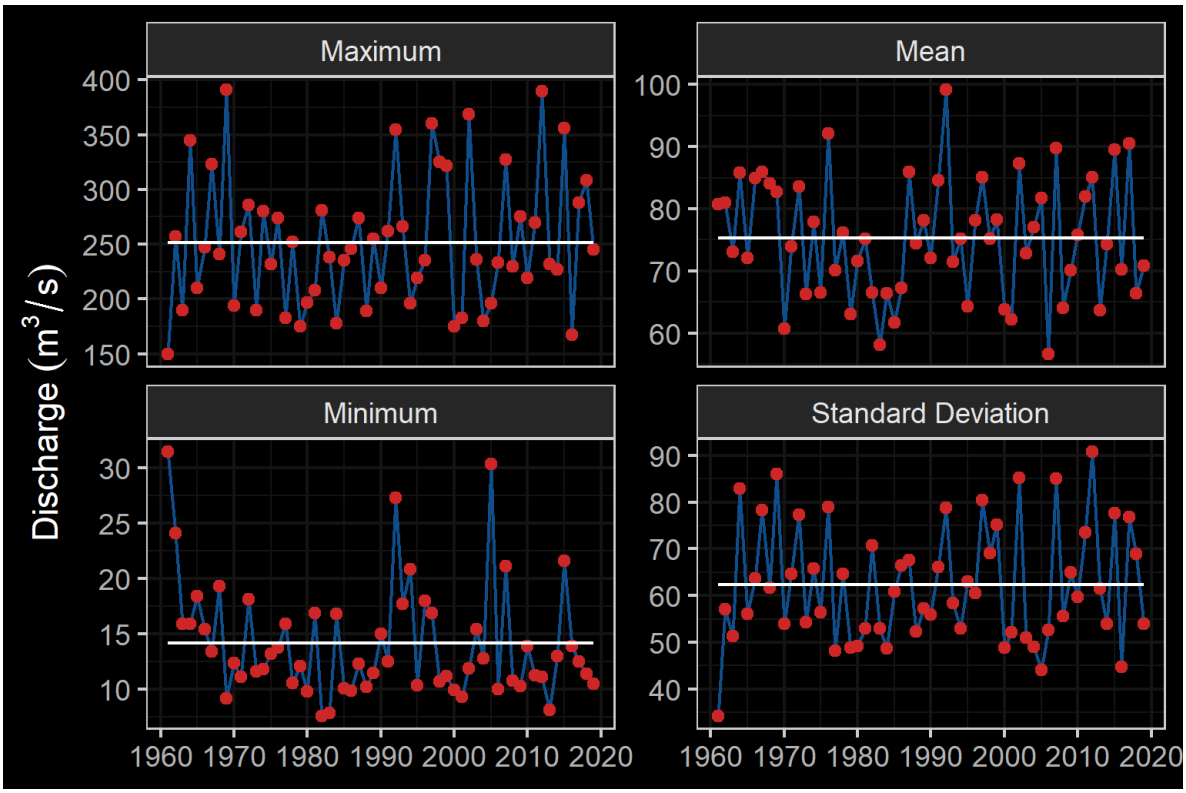

Figure 2.6: Summary of hydrology statistics for Morice River near outlet of Morice Lake (Station #08ED002 - Lat 54.116829 Lon -127.426582). Available daily discharge data from 1961 to 2018.

2.4 Fisheries

In 2004, IBM Business Consulting Services (2006) estimated the value of Skeena Fisheries at an annual average of $110 million dollars. The Bulkley-Morice watershed is an integral part of the salmon production in the Skeena drainage and supports an internationally renown steelhead, chinook and coho sport fishery (Tamblyn 2005).

2.4.1 Bulkley River

Traditionally, the salmon stocks passing through and spawning in Bulkley River were the principal food source for the Gitxsan and Wet'suwet'en people living there (Wilson and Rabnett 2007). Wilson and Rabnett (2007) detail numerous fishing areas located within the lower Bulkley drainage (from the confluence of the Skeena to the confluence with the Telkwa River) and the upper Bulkley drainage which includes the mainstem Bulkley River and tributaries upstream of the Telkwa River confluence. Anadromous lamprey passing through and spawning in the upper Bulkley River were traditionally also an important food source for the Wet'suwet'en (Wilson and Rabnett 2007; pers comm. Mike Ridsdale, Environmental Assessment Coordinator, Office of the Wet'suwet'en).

Approximately 11.3 km downstream of the Bulkley Lake outlet and just upstream of Watson Creek, the upper Bulkley falls is an approximately 4m high narrow rock sill that crosses the Bulkley River, producing a steep cascade section. This obstacle to fish passage is recorded as an almost complete barrier to fish passage for salmon during low water flows. Coho have not been observed beyond the falls since 1972 (Wilson and Rabnett 2007).

Renowned as a world class recreational steelhead and coho fishery, the Bulkley River receives some of the heaviest angling pressure in the province. In response to longstanding angler concerns with respect to overcrowding, quality of experience and conflict amongst anglers, an Angling Management Plan was drafted for the river following the initiation of the Skeena Quality Waters Strategy process in 2006 and an extensive multi-year consultation process. The plan introduces a number of regulatory measures with the intent to provide Canadian resident anglers with quality steelhead fishing opportunities. Regulatory measures introduced with the Angling Management Plan include prohibited angling for non-guided non-resident aliens on Saturdays and Sundays, Sept 1 - Oct 31 within the Bulkley River, angling prohibited for non-guided non-resident aliens on Saturdays and Sundays, all year within the Suskwa River and angling prohibited for non-guided non-resident aliens Sept 1 - Oct 31 in the Telkwa River. The Bukley River is considered Class II waterand there is no fshing permitted upstream of the Morice/Bulkley River Confluence (FLNRO 2013a, 2013b; FLNRORD 2019).

2.4.2 Morice River

Detailed reviews of Morice River watershed fisheries can be found in D. Bustard and Schell (2002), Allen Gottesfeld, Rabnett, and Hall (2002), Schell (2003), A. Gottesfeld and Rabnett (2007), and ILMB (2007) with a comprehensive review of water quality by Oliver (2018). Overall, the Morice

watershed contains high fisheries values as a major producer of chinook, pink, sockeye, coho and steelhead.

2.4.2.1 Fish Species

Fish species recorded in the Bulkley River and Morice River watershed groups are detailed in Table 2.1 (MoE 2020a). Coastal cutthrout trout and bull trout are considered of special concern (blue-listed) provincially. Summaries of some of the Skeena and Bulkley River fish species life history, biology, stock status, and traditional use are documented in Schell (2003), Wilson and Rabnett (2007), Allen Gottesfeld, Rabnett, and Hall (2002) and Office of the Wet'suwet'en (2013). Wilson and Rabnett (2007) discuss chinook, pink, sockeye, coho, steelhead and indigenous freshwater Bulkley River fish stocks within the context of key lower and upper Bulkley River habitats such as the Suskwa River, Station Creek, Harold Price Creek, Telkwa River and Buck Creek. Key areas within the upper Bulkley River watershed with high fishery values, documented in Schell (2003), are the upper Bulkley mainstem, Buck Creek, Dungate Creek, Barren Creek, McQuarrie Creek, Byman Creek, Richfield Creek, Johnny David Creek, Aitken Creek and Emerson Creek.

Some key areas of high fisheries values for chinook, sockeye and coho are noted in D. Bustard and Schell (2002) as McBride Lake, Nanika Lake, and Morice Lake watersheds. A draft gantt chart for select species in the Morice River and Bulkley River watersheds was derived from reviews of the aforementioned references and is included as Figure 2.7. The data is considered in draft form and will be refined over the spring and summer of 2021 with local fisheries technicians and knowledge holders during the collaboratory assessment planning and fieldwork activities planned.

In the 1990's the Morice River watershed, A. Gottesfeld and Rabnett (2007) estimated that chinook comprised 30% of the total Skeena system chinook escapements. It is estimated that Morice River coho comprise approximatley 4% of the Skeena escapement with a declining trend noted since the 1950 in A. Gottesfeld and Rabnett (2007). Coho spawn in major tributaries and small streams ideally at locations where downstream dispersal can result in seeding of prime off channel habitats including warm productive sloughs and side channels. Of all the salmon species, coho rely on small tributaries the most (D. Bustard and Schell 2002). D. Bustard and Schell (2002) report that much of the distribution of coho into non-natal tributaries occurs during high flow periods of May - early July with road culverts blocking migration into these habitats.

Summaries of historical fish observations in the Bulkley River and Morice River watershed groups (n=4033), graphed by remotely sensed average gradient as well as measured or modelled channel width categories for their associated stream segments where calculated with `bcfishpass` and `bcfishobs` and are provided in Figures 2.8 - 2.9.

Table 2.1: Fish species recorded in the Bulkley River and Morice River watershed groups.

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA	Bulkley	Morice
Catostomus catostomus	Longnose Sucker	LSU	Yellow	–	–	–	Yes	Yes
Catostomus commersonii	White Sucker	WSU	Yellow	–	–	–	Yes	Yes
Catostomus macrocheilus	Largescale Sucker	CSU	Yellow	–	–	–	Yes	Yes
Chrosomus eos	Northern Redbelly Dace	RDC	Yellow	–	–	–	Yes	–
Coregonus clupeaformis	Lake Whitefish	LW	Yellow	–	–	–	Yes	Yes
Cottus aleuticus	Coastrange Sculpin (formerly Aleutian Sculpin)	CAL	Yellow	–	–	–	Yes	Yes
Cottus asper	Prickly Sculpin	CAS	Yellow	–	–	–	Yes	Yes
Couesius plumbeus	Lake Chub	LKC	Yellow	–	DD	–	Yes	Yes
Entosphenus tridentatus	Pacific Lamprey	PL	Yellow	–	–	–	Yes	Yes
Hybognathus hankinsoni	Brassy Minnow	BMC	No Status	–	–	–	Yes	–
Lota lota	Burbot	BB	Yellow	–	–	–	Yes	Yes
Mylocheilus caurinus	Peamouth Chub	PCC	Yellow	–	–	–	Yes	Yes
Oncorhynchus clarkii	Cutthroat Trout	CT	No Status	–	–	–	Yes	Yes
Oncorhynchus clarkii	Cutthroat Trout (Anadromous)	ACT	No Status	–	–	–	Yes	–
Oncorhynchus clarkii clarkii	Coastal Cutthroat Trout	CCT	Blue	–	–	–	Yes	Yes
Oncorhynchus gorbuscha	Pink Salmon	PK	Yellow	–	–	–	Yes	Yes
Oncorhynchus keta	Chum Salmon	CM	Yellow	–	–	–	Yes	Yes
Oncorhynchus kisutch	Coho Salmon	CO	Yellow	–	–	–	Yes	Yes
Oncorhynchus mykiss	Rainbow Trout	RB	Yellow	–	–	–	Yes	Yes
Oncorhynchus mykiss	Steelhead	ST	Yellow	–	–	–	Yes	Yes
Oncorhynchus mykiss	Steelhead (Summer-run)	SST	Yellow	–	–	–	Yes	Yes
Oncorhynchus nerka	Kokanee	KO	Yellow	–	–	–	Yes	Yes
Oncorhynchus nerka	Sockeye Salmon	SK	Yellow	–	–	–	Yes	Yes
Oncorhynchus tshawytscha	Chinook Salmon	CH	Yellow	–	–	–	Yes	Yes
Prosopium coulterii	Pygmy Whitefish	PW	Yellow	–	NAR (Nov 2016)	–	Yes	Yes
Prosopium coulterii pop. 3	Giant Pygmy Whitefish	GPW	Yellow	–	–	–	Yes	–
Prosopium williamsoni	Mountain Whitefish	MW	Yellow	–	–	–	Yes	Yes
Ptychocheilus oregonensis	Northern Pikeminnow	NSC	Yellow	–	–	–	Yes	Yes
Pungitius pungitius	Ninespine Stickleback	NSB	Unknown	–	–	–	Yes	–
Rhinichthys cataractae	Longnose Dace	LNC	Yellow	–	–	–	Yes	Yes
Rhinichthys falcatus	Leopard Dace	LDC	Yellow	–	NAR (May 1990)	–	–	Yes
Richardsonius balteatus	Redside Shiner	RSC	Yellow	–	–	–	Yes	Yes
Salvelinus confluentus pop. 26	Bull Trout	BT	Blue	–	–	–	Yes	Yes
Salvelinus fontinalis	Brook Trout	EB	Exotic	–	–	–	Yes	Yes
Salvelinus malma	Dolly Varden	DV	Yellow	–	–	–	Yes	Yes
Salvelinus namaycush	Lake Trout	LT	Yellow	–	–	–	Yes	Yes
–	Arctic Char	AC	–	–	–	–	–	Yes
–	Cutthroat/Rainbow cross	CRS	–	–	–	–	Yes	–
–	Dace (General)	DC	–	–	–	–	–	Yes
–	Lamprey (General)	L	–	–	–	–	Yes	Yes
–	Minnow (General)	C	–	–	–	–	Yes	Yes

Table 2.1:

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA	Bulkley	Morice
–	Salmon (General)	SA	–	–	–	–	Yes	Yes
–	Sculpin (General)	CC	–	–	–	–	Yes	Yes
–	Sucker (General)	SU	–	–	–	–	Yes	Yes
–	Whitefish (General)	WF	–	–	–	–	Yes	Yes

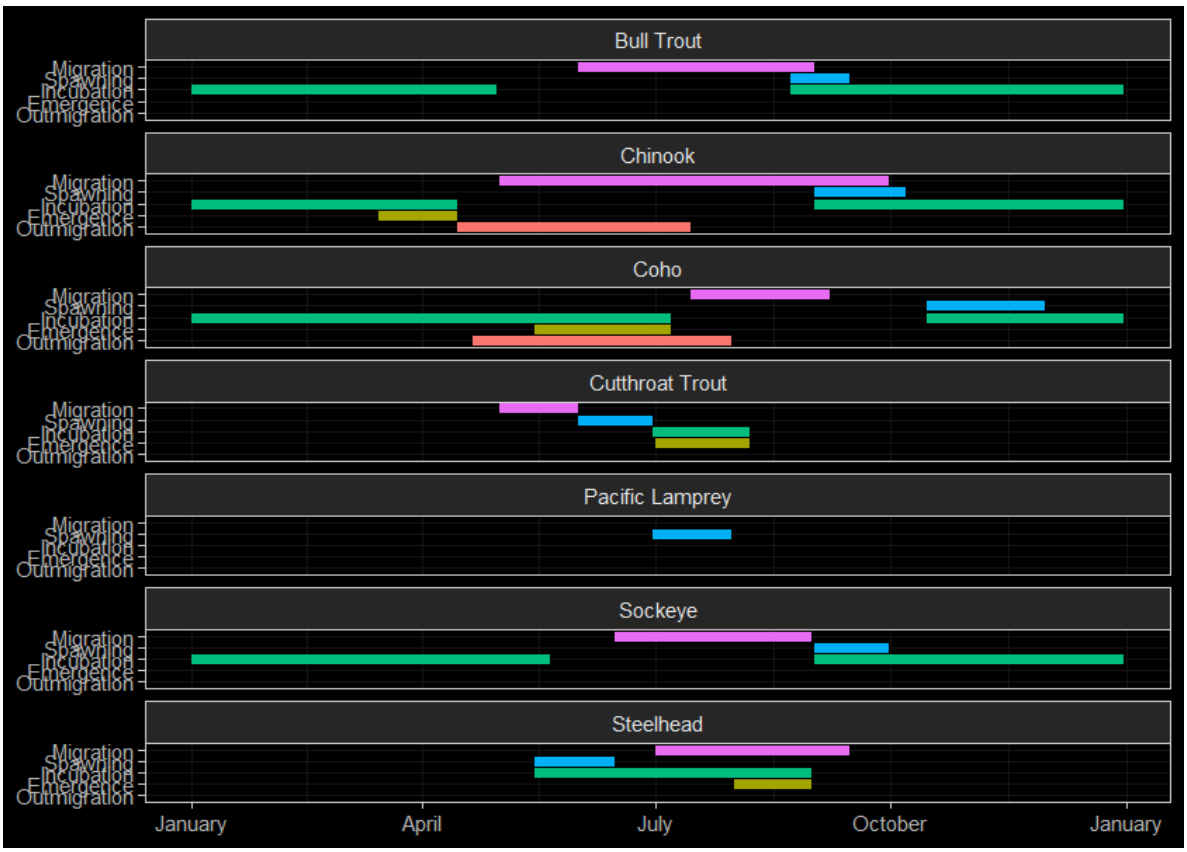

Figure 2.7: Gantt chart for select species in the Morice River and Bulkley River watersheds. To be updated in consultation with local fisheries techicians and knowledge holders.

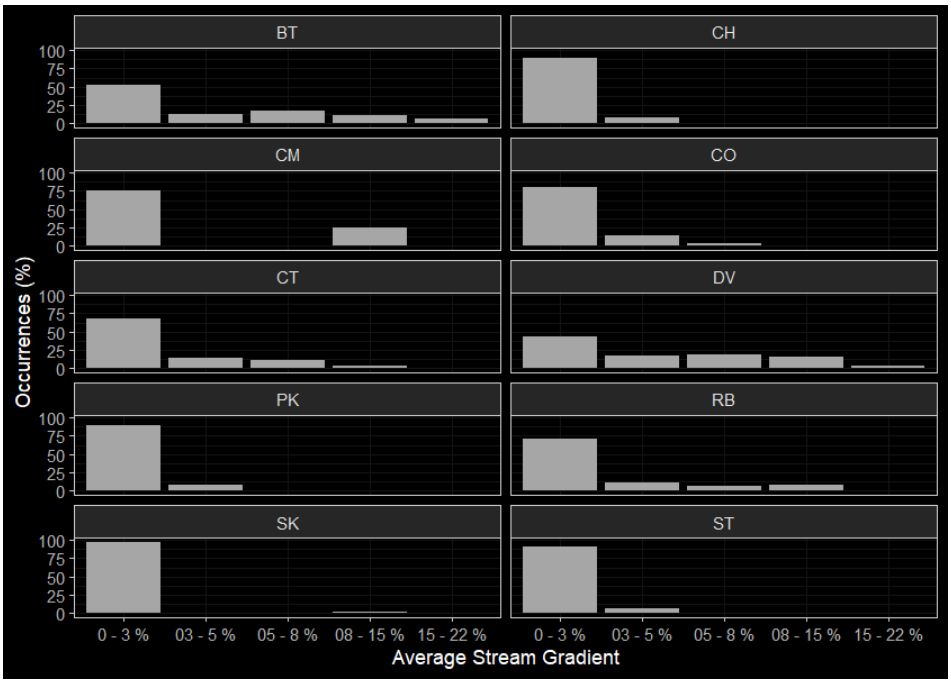

Figure 2.8: Summary of historic salmonid observations vs. stream gradient category for the Bulkley River watershed group.

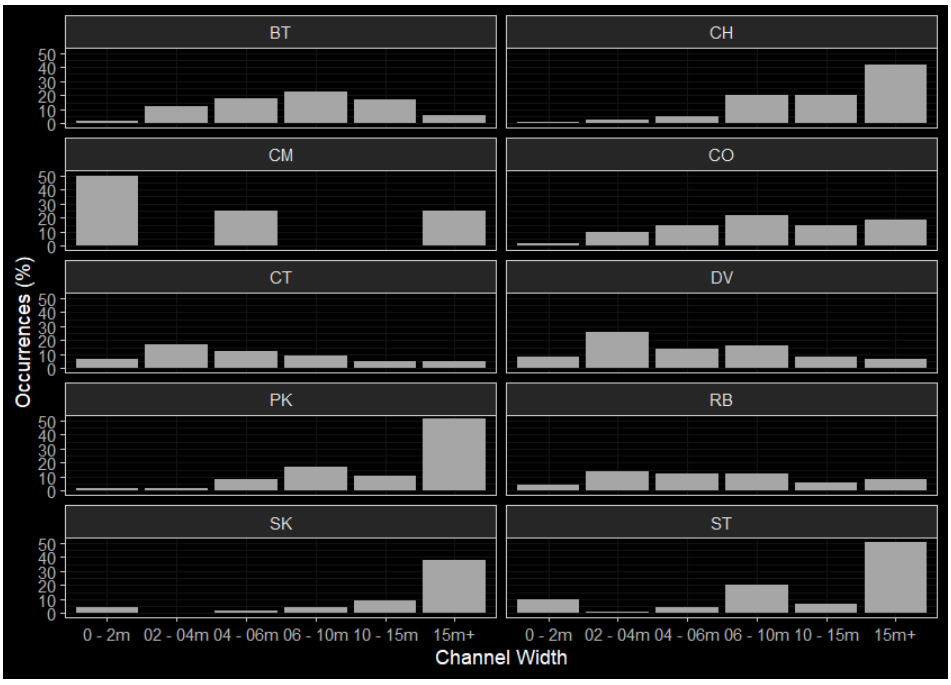

Figure 2.9: Summary of historic salmonid observations vs. channel width category for the Bulkley River watershed group.

2.5 Fish Passage Restoration Planning and Implementation

As a result of high-level direction from the provincial government, a Fish Passage Strategic Approach protocol has been developed for British Columbia to ensure that the greatest opportunities for restoration of fish passage are pursued. A Fish Passage Technical Working Group has been formed to coordinate the protocol and data is continuously amalgamated within the Provincial Steam Crossing Inventory System (PSCIS). The strategic approach protocol involves a four-phase process as described in Fish Passage Technical Working Group (2014) :

- Phase 1: Fish Passage Assessment – Fish stream crossings within watersheds with high fish values are assessed to determine barrier status of structures and document a general assessment of adjacent habitat quality and quantity.
- Phase 2: Habitat Confirmation – Assessments of crossings prioritized for follow up in Phase 1 studies are conducted to confirm quality and quantity of habitat upstream and down as well as to scope for other potential nearby barriers that could affect the practicality of remediation.
- Phase 3: Design – Site plans and designs are drawn for priority crossings where high value fish habitat has been confirmed.
- Phase 4: Remediation – Re-connection of isolated habitats through replacement, rehabilitation or removal of prioritized crossing structure barriers.

2.5.1 Bulkley River

There is a rich history of fish passage restoration planning in the Bulkley River watershed group with not all the work documented in the PSCIS system. A non-exhaustive list of historic fish passage reports for the watershed includes Wilson and Rabnett (2007), McCarthy and Fernando (2015),Smith (2018) Casselman and Stanley (2010) and Irvine (2018).

Review of the PSCIS database indicated that prior to 2020, 1635 assessments for fish passage (Phase 1) at crossing structures within the Bulkley River watershed group have been recorded in the PSCIS database (MoE 2021a). No habitat confirmations are recorded in the PSCIS database (MoE 2021b). Within the Bulkley River watershed group, a number of remediation projects have been completed over the years with backwatering works conducted on Toboggan Creek, Coffin Creek, Moan Creek, Johnny David Creek and potentially others. Three culvert replacements (with open bottom structures) in the watershed group have been tracked in PSCIS and include works on Barren Creek as well as two tributaries to Harold Prince Creek (MoE 2021c). McDowell Creek at Highway 16 was replaced with a horizontally drilled baffled structure in 2017 and a design is currently being drafted for the Highway 16 crossing over Taman Creek (pers. comm. Kathryn Graham, Regional Manager Environmental Services - Ministry of Transportation and Infrastructure).

2.6 Morice river

Within the Morice River watershed group prior to 2020, 21 fish passage assessments (Phase 1) had been recorded in the PSCIS database (MoE 2021a). At the time of reporting, no habitat confirmations had been recorded (MoE 2021b). Two culvert replacements (with open bottom structures) in the watershed group have been tracked in PSCIS in the and include works on a tributary to the Morice River located at km 39.2 of the Morice River FSR and on bridge installation at km 4 of McBride Road on a tributary to McBride Lake (MoE 2021c).

3 Methods

Workflows for the project have been classified into planning, fish passage assessments, habitat confirmation assessments, reporting and mapping. All components leveraged `R`, `SQL` or `Python` programming languages to facilitate workflow tracking, collaboration, transparency and continually improving research. Project workflows utilized local and remote `postgreSQL` databases as well as a "snapshot" of select datasets contained within a local `sqlite` database. A data and script repository to facilitate this reporting is located on Github.

3.1 Planning

To identify priorities for crossing structure rehabilitation, background literature, fisheries information, PSCIS, `Fish Habitat Model` outputs modified from Norris and Mount (2016) and `bcfishpass` (Norris 2021d) outputs were reviewed. The `Fish Habitat Model` was developed by the BC Ministry of Environment to provide estimates of the amount of fish habitat that would potentially be accessible upstream of crossing locations based on the ability of fish to swim upstream against user defined gradient thresholds (Norris and Mount 2016). `bcfishpass` is an updated open-source code repository comprised of tools ported over from the `Fish Habitat Model` along with a number of significant upgrades and new features. Scripts within `bcfishpass` also pull and analyze data using other open-source tools such as `bcdata` (Norris 2021b), `bcfishobs` (Norris 2021c), and `fwapg` (Norris 2021a) which serve numerous functions related to open-data access as well as the analysis of the BC Freshwater Atlas, fish and fish habitat in British Columbia.

3.1.1 Accessible Habitat

The `Fish Habitat Model` calculates the average gradient of BC Freshwater Atlas stream network lines at minimum 100m long intervals starting from the downstream end of the streamline segment and working upstream. The network lines are broken into max gradient categories with new segments created if and when the average slope of the stream line segment exceeds user provided thresholds. For this project, the user provided gradient thresholds used to delineate "potentially accessible habitat" were based on estimated max gradients that salmon (15%) and steelhead (20%) are likely to be capable of ascending. Although not housed within `bcfishpass` at the time of reporting, plans were in place to port over of the latest model version (V2.3.1) of the stream profile analysis tools from `FWAToolsArchive` into `bcfishpass`.

Through this initiative, the Provincial Fish Passage Remediation Program and connectivity restoration planning led by Canadian Wildlife Federation and funded by the British Columbia Salmon Restoration and Innovation Fund, `bcfishpass` has been designed to prioritize potential fish passage barriers for assessment or remediation. The software is under continual development and has been designed and constructed by Norris (2021d) using of sql and python based shell script libraries to generate a simple model of aquatic habitat connectivity. The model identifes natural barriers (ex. steep gradients for extended distances) and hydroelectric dams to classifying the accessibility upstream by fish (Norris 2021d). On potentially accessible streams, scripts identify known barriers (ex. waterfalls >5m high) and additional anthropogenic features which are primarily road/railway stream crossings (i.e. culverts) that are potentially barriers. To prioritize these features

for assessment or remediation, scripts report on how much modelled potentially accessible aquatic habitat the barriers may obstruct. The model can be refined with known fish observations upstream of identified barriers and for each crossing location, the area of lake and wetland habitat upstream, species documented upstream/downstream, an estimate of watershed area (on 2nd order and higher streams), mean annual precipitation weighted to upstream watershed area and channel width can be collated using `bcfishpass`, `fwapg` and `bcfishobs`. This, information, can be used to provides an indication of the potential quantity and quality of habitat potentially gained should fish passage be restored by comparing to user defined thresholds for the aforementioned parameters. A discussion of the methodology to derive channel width is below.

Gradient, channel size and stream discharge are key determinants of channel morphology and subsequently fish distribution. High value rearing, overwintering and spawning habitat preferred by numerous species/life stages of fish are often located within channel types that have relatively low gradients and large channel widths (also quantified by the amount of flow in the stream). Following delineation of “potentially accessible habitat,” the average gradient of each stream segment within habitat classified as below the 15% and 20% thresholds was calculated and summed within species and life stage specific gradient categories. Average gradient of stream line segments can be calculated from elevations contained in the provincial freshwater atlas streamline dataset. To obtain estimates of channel width upstream of crossing locations, Where available, `bcfishpass` was utilized to pull average channel gradients from Fisheries Information Summary System (FISS) site assessment data (MoE 2020c) or PSCIS assessment data (MoE 2021a) and associate with stream segment lines. When both FISS and PSCIS values were associated with a particular stream segment, FISS channel width was used. When multiple FISS sites were associated with a particular stream segment a mean of the average channel widths was taken. To model channel width for 2nd order and above stream segments without associated FISS or PSCIS sites, first `fwapg` was used to estimate the drainage area upstream of the segment. Then, rasters from ClimateBC (Wang et al. 2012) were sampled for each stream segments and a mean annual precipitation weighted by upstream watershed area was calculated. Mean annual precipitation was then combined with the channel widths and BEC zone information (gathered through a spatial query tied to the bottom of the stream segment) into a dataset (n = 22990) for analysis fo the relationship between these variables. The details of this analysis and resulting formula used to estimate channel width on stream segments in the Bukley River and Morice River watersheds is included as a technical appendix at https://github.com/NewGraphEnvironment/fish_passage_bulkley_2020_reporting/raw/master/docs/channel-width-21.pdf.

`bcfishpass` and associated tools have been designed to be flexible in analysis, accepting user defined gradient, channel width and stream discharge categories (MoE 2020c). Although currently in draft form, and subject to development revisions, gradient and channel width thresholds for habitat with the highest intrinsic value for a number of fish species in the Bulkley River and Morice River watersheds groups have been specified and applied to model habitat upstream of stream crossing locations with the highest intrinsic value (Table 3.1). Thresholds were derived based on a literature review with references provided in Table 3.2.

Table 3.1: Stream gradient and channel width thresholds used to model potentially highest value fish habitat.

Variable	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon
Spawning Gradient Max (%)	4	5	4	2
Spawning Width Min (m)	4	2	4	2
Rearing Gradient Max (%)	5.0	5.0	7.4	–

Table 3.2: References for stream gradient and channel width thresholds used to model potentially highest value fish habitat. Preliminary and subject to revisions.

Variable	Chinook Salmon	Coho Salmon	Steelhead	Sockeye Salmon
Spawning Gradient Max (%)	Kirsch et al. 2004, Busch et al. 2011, Cooney and Holzer 2006	Roberge et al. 2002, Sloat et al. 2017	Scheer and Steel 2006, Cooney and Holzer 2006	Lake 1999, Hoopes 1972
Spawning Width Min (m)	Busch et al. 2011, Cooney and Holzer 2006	Sloat et. al 2017	Cooney and Holzer 2006	Woll et al. 2017
Rearing Gradient Max (%)	Woll et al. 2017, Porter et al. 2008	Kirsch et al. 2004, Porter et al. 2008, Rosenfeld et al. 2000	Porter et al. 2008	–

3.1.2 PSCIS and Modelled Stream Crossing Review

To prepare for Phase 1 and 2 assessments in the study area, past fish passage assessment reports for the Bulkley River and Morice River watershed groups were first reviewed to identify crossing structures not yet assessed or previously ranked as priorities for rehabilitation (Casselman and Stanley 2010; Irvine 2018; McCarthy and Fernando 2015; Smith 2018; Wilson and Rabnett 2007). To determine which of those crossings had not yet been assessed with Phase 1 and Phase 2 assessments we cross-referenced these reports with the PSCIS database, available background info and viewed sites within the output of the `Fish Habitat Model` and `bcfishpass`. Outputs for modelled and PSCIS crossings (barriers and potential barriers) that met the following criteria underwent a detailed review to facilitate prioritization for Phase1 - Fish Passage Assessments and Phase 2 - Habitat Confirmations.

- Confirmed fish presence upstream of the structure.
- Stream width documented as > 2.0m in PSCIS.
- Linear lengths of modelled upstream habitat <8% gradient for ≥1km.
- Crossings located on streams classified as 3rd order or higher.
- Crossings located on streams with >5 ha of modeled wetland and/or lake habitat upstream.
- Habitat value rated as “medium” or “high” in PSCIS.

3.2 Fish Passage Assessments

In the field, crossings prioritized for follow-up were first assessed for fish passage following the procedures outlined in “Field Assessment for Determining Fish Passage Status of Closed Bottomed Structures” (MoE 2011). Crossings surveyed included closed bottom structures (CBS), open bottom structures (OBS) and crossings considered “other” (i.e. fords). Photos were taken at surveyed

crossings and when possible included images of the road, crossing inlet, crossing outlet, crossing barrel, channel downstream and channel upstream of the crossing and any other relevant features. The following information was recorded for all surveyed crossings: date of inspection, crossing reference, crew member initials, Universal Transverse Mercator (UTM) coordinates, stream name, road name and kilometer, road tenure information, crossing type, crossing subtype, culvert diameter or span for OBS, culvert length or width for OBS. A more detailed “full assessment” was completed for all closed bottom structures and included the following parameters: presence/absence of continuous culvert embedment (yes/no), average depth of embedment, whether or not the culvert bed resembled the native stream bed, presence of and percentage backwatering, fill depth, outlet drop, outlet pool depth, inlet drop, culvert slope, average downstream channel width, stream slope, presence/absence of beaver activity, presence/absence of fish at time of survey, type of valley fill, and a habitat value rating. Habitat value ratings were based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), fish migration patterns, the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation (Table 3.3). For crossings determined to be potential barriers or barriers based on the data (see Barrier Scoring (page 20)), a culvert fix and recommended diameter/span was proposed.

Table 3.3: Habitat value criteria (Fish Passage Technical Working Group, 2011).

Habitat Value	Fish Habitat Criteria
High	The presence of high value spawning or rearing habitat (e.g., locations with abundance of suitably sized gravels, deep pools, undercut banks, or stable debris) which are critical to the fish population.
Medium	Important migration corridor. Presence of suitable spawning habitat. Habitat with moderate rearing potential for the fish species present.
Low	No suitable spawning habitat, and habitat with low rearing potential (e.g., locations without deep pools, undercut banks, or stable debris, and with little or no suitably sized spawning gravels for the fish species present).

3.2.1 Barrier Scoring

Fish passage potential was determined for each stream crossing identified as a closed bottom structure as per MoE (2011). The combined scores from five criteria: depth and degree to which the structure is embedded, outlet drop, stream width ratio, culvert slope, and culvert length were used to screen whether each culvert was a likely barrier to some fish species and life stages (Table 3.4, Table 3.5. These criteria were developed based on data obtained from various studies and reflect an estimation for the passage of a juvenile salmon or small resident rainbow trout (Clarkin et al. 2005 ; Bell 1991; Thompson 2013).

Table 3.4: Fish Barrier Risk Assessment (MoE 2011).

Risk	LOW	MOD	HIGH
Embedded	>30cm or >20% of diameter and continuous	<30cm or 20% of diameter but continuous	No embedment or discontinuous
Value	0	5	10
Outlet Drop (cm)	<15	15-30	>30
Value	0	5	10
SWR	<1.0	1.0-1.3	>1.3
Value	0	3	6
Slope (%)	<1	1-3	>3
Value	0	5	10
Length (m)	<15	15-30	>30
Value	0	3	6

Table 3.5: Fish Barrier Scoring Results (MoE 2011).

Cumlative Score	Result
0-14	passable
15-19	potential barrier
>20	barrier

3.2.2 Cost Benefit Analysis

A cost benefit analysis was conducted for each crossing determined to be a barrier based on an estimate of cost associated with remediation or replacement of the crossing with a structure that facilitates fish passage and the amount of potential habitat that would be made available by remediating fish passage at the site (habitat gain index).

3.2.2.1 Habitat Gain Index

The habitat gain index is the quantity of modelled habitat upstream of the subject crossing and represents an estimate of habitat gained with remediation of fish passage at the crossing. For this project, a gradient threshold between accessible and non-accessible habitat was set at 20% (for a minimimum length of 100m) intended to represent the maximum gradient of which the strongest swimmers of anadromous species (steelhead) are likely to be able to migrate upstream.

For reporting of Phase 1 - fish passage assessments within the body of this report (Table 3.4), a “total” value of habitat <20% output from `bcfishpass` was used to estimate the amount of habitat upstream of each crossing less than 20% gradient before a falls of height >5m - as recorded in MoE (2020b) or documented in other `bcfishpass` online documentation. To generate areas of habitat upstream, the estimated linear length was multiplied by the downstream channel width measured as part of the fish passage assessment protocol. Although these estimates are not generally conservative, have low accuracy and do not account for upstream stream crossing structures they do allow a rough screening of the best candidates for follow up with more detailed Phase 2 assessments.

For Phase 2 - habitat confirmation sites, conservative estimates of the linear quantity of habitat to be potentially gained by fish passage restoration, mainstem and large tributary streams (>1st order streams) segments upstream of each crossing that were <20%, below natural barriers and downstream of documented culvert barriers were measured by hand with the measure tool within QGIS (QGIS Development Team 2009). To generate estimates of the area of habitat upstream of these sites, the length of habitat was multiplied by the upstream average channel width that was measured in the field.

Potential options to remediate fish passage were selected from MoE (2011) and included:

- Removal (RM) - Complete removal of the structure and deactivation of the road.
- Open Bottom Structure (OBS) - Replacement of the culvert with a bridge or other open bottom structure. For this project we considered bridges as the only viable option for OBS type based on consultation with FLNR road crossing engineering experts. It should be noted however, that box culverts could be considered a viable and economical option as they have been observed as successfully facilitating fish passage on the west coast of the province (Betty Rebellato, Canadian Wildlife Federation - Project Biologist).
- Streambed Simulation (SS) - Replacement of the structure with a streambed simulation design culvert. Often achieved by embedding the culvert by 40% or more. Based on consultation with FLNR engineering experts, we considered crossings on streams with a channel width of <2m and a stream gradient of <8% as candidates for replacement with streambed simulations.
- Additional Substrate Material (EM) - Add additional substrate to the culvert and/or downstream weir to embed culvert and reduce overall velocity/turbulence. This option was

considered only when outlet drop = 0, culvert slope <1.0% and stream width ratio < 1.0.
- Backwater (BW) - Backwatering of the structure to reduce velocity and turbulence. This option was considered only when outlet drop < 0.3m, culvert slope <2.0%, stream width ratio < 1.2 and stream profiling indicates it would be effective..

Cost estimates for structure replacement with bridges and embedded culverts were generated based on the channel width, slope of the culvert, depth of fill, road class and road surface type. Road details were sourced from FLNRORD (2020b) and FLNRORD (2020a) through `bcfishpass`. Interviews with Phil MacDonald, Engineering Specialist FLNR - Kootenay, Steve Page, Area Engineer - FLNR - Northern Engineering Group and Matt Hawkins - MoTi - Design Supervisor for Highway Design and Survey - Nelson were utilized to helped refine estimates.

Base costs for installation of bridges on forest service roads and permit roads with surfaces specified in provincial GIS road layers as rough and loose was estimated at $12500/linear m and assumed that the road could be closed during construction and a minimum bridge span of 10m. For streams with channel widths <2m, embedded culverts were reported as an effective solution with total installation costs estimated at $25k/crossing (pers. comm. Phil MacDonald, Steve Page). For larger streams (>6m), span width increased proportionally to the size of the stream (ex. for an 8m wide stream a 12m wide span was prescribed). For crossings with large amounts of fill (>3m), the replacement bridge span was increased by an additional 3m for each 1m of fill >3m to account for cutslopes to the stream at a 1.5:1 ratio. To account for road type, a multiplier table was also generated to estimate incremental cost increases with costs estimated for structure replacement on paved surfaces, railways and arterial/highways costing up to 20 times more than forest service roads due to expenses associate with design/engineering requirements, traffic control and paving. The cost multiplier table (Table 3.6) should be considered very approximate with refinement recommended for future projects.

Table 3.6: Cost multiplier table based on road class and surface type.

Class	Surface	Class Multiplier	Surface Multiplier	Bridge $K/10m	Streambed Simulation $K
Forest Service Road	Loose	1	1	125	25
Resource	Loose	1	1	125	25
Road Permit	Loose	1	1	125	25
Unclassified	Loose	1	1	125	25
Unclassified	Rough	1	1	125	25
Local	Loose	4	1	500	100
Local	Paved	4	2	1000	200
Highway	Paved	20	2	5000	1000
Rail	Rail	20	2	5000	1000

3.3 Habitat Confirmation Assessments

Following fish passage assessments, habitat confirmations were completed in accordance with procedures outlined in the document “A Checklist for Fish Habitat Confirmation Prior to the Rehabilitation of a Stream Crossing” (Fish Passage Technical Working Group 2011). The main objective of the field surveys was to document upstream habitat quantity and quality and to determine if any other obstructions exist above or below the crossing. Habitat value was assessed based on channel morphology, flow characteristics (perennial, intermittent, ephemeral), the presence/absence of deep pools, un-embedded boulders, substrate, woody debris, undercut banks, aquatic vegetation and overhanging riparian vegetation. Criteria used to rank habitat value was based on guidelines in Fish Passage Technical Working Group (2011) (Table 3.3).

During habitat confirmations, to standardize data collected and facilitate submission of the data to provincial databases, information was collated on “Site Cards”. Habitat characteristics recorded included channel widths, wetted widths, residual pool depths, gradients, bankfull depths, stage, temperature, conductivity, pH, cover by type, substrate and channel morphology (among others). When possible, the crew surveyed downstream of the crossing to the point where fish presence had been previously confirmed and upstream to a minimum distance of 600m. Any potential obstacles to fish passage were inventoried with photos, physical descriptions and locations recorded on site cards. Surveyed routes were recorded with time-signatures on handheld GPS units.

Fish sampling was conducted a subset of sites when biological data was considered to add significant value to the physical habitat assessment information. When possible, electrofishing was utilized within discrete site units both upstream and downstream of the subject crossing with electrofisher settings, water quality parameters (i.e. conductivity, temperature and ph), start location, length of site and wetted widths (average of a minimum of three) recorded. For each fish captured, fork length and species was recorded, with results included within the fish data submission spreadsheet. Fish information and habitat data will be submitted to the province under scientific fish collection permit CB20-611971.

3.4 Reporting

Reporting was generated with `bookdown` (Xie 2016) from `Rmarkdown` (Allaire et al. 2021) with primarily `R` (R Core Team 2020) and `SQL` scripts. In addition to numerous spatial layers sourced through the BC Data Catalogue then stored and queried in a local `postgresql` database data inputs for this project include:

- Populated Fish Data Submission Spreadsheet Template - V 2.0, January 20, 2020
- Populated pscis_assessment_template_v24.xls
- Fish Habitat Model/bcfishpass outputs.
- Custom CSV file detailing Phase 2 site:
    - priority level for proceeding to design for replacement
    - length of survey upstream and downstream
    - a conservative estimate of the linear length of mainstem habitat potentially available upstream of the crossing
    - fish species confirmed as present upstream of the crossing
- GPS tracks from field surveys.
- Photos and photo metadata

3.5 Mapping

Mapping was completed by Hillcrest Geographics. `pdf` maps were generated using `QGIS` with data supplied via a `postgreSQL` database. A QGIS layer file defining and symbolizing all layers required for general fish passage mapping was developed and at the time of reporting was kept under version control within `bcfishpass`.

4 Results and Discussion

4.1 Planning

Following review of background literature, fisheries information, PSCIS and `bcfishpass` outputs, 70 modelled and PSCIS crossings were reviewed to select sites for follow up with Phase 1 and 2 assessments in the Morice River watershed. 14 crossings ranked as high priority for future follow up with Phase 1 and/or Phase 2 assessments, 26 crossings ranked as moderate priorities, and 30 crossings ranked as low priorities. Georeferenced field maps are presented in Attachment 1. Results of the planning review are presented as a zipped Google Earth kml file for overlay on field maps as (Attachment 2). Although planning for field assessments ws still underway at the time of reporting through ongoing modelling, engagement with the Office of Wet'suwet'en, DFO, FLNRORD, BC Ministry of Environment, the Morice Watershed Monitoring Trust and numerous others, some key areas likely targeted for fieldwork include the Owen Creek, Lamprey Creek, McBride Lake, Nanika Lake, and Morice Lake watersheds.

4.2 Phase 1

Field assessments were conducted between August 26 2020 and September 05 2020 by Allan Irvine, R.P.Bio. and Kyle Prince, P.Biol. A total of 30 Phase 1 assessments were conducted with 12 crossings considered "passable," 3 crossings considered "potential" barriers and 11 crossings considered "barriers" according to threshold values based on culvert embedment, outlet drop, slope, diameter (relative to channel size) and length (MoE 2011). Georeferenced field maps are presented in Attachment 1. A summary of crossings assessed, a cost benefit analysis and priority ranking for follow up for Phase 1 sites presented in Table 4.1. Detailed data with photos are presented in Attachment 3.

"Barrier" and "Potential Barrier" rankings used in this project followed MoE (2011) and reflect an assessment of passability for juvenile salmon or small resident rainbow trout at any flows potentially present throughout the year (Clarkin et al. 2005 ; Bell 1991; Thompson 2013). As noted in Bourne et al. (2011), with a detailed review of different criteria in Kemp and O'Hanley (2010), passability of barriers can be quantified in many different ways. Fish physiology (i.e. species, length, swim speeds) can make defining passability complex but with important implications for evaluating connectivity and prioritizing remediation candidates (Bourne et al. 2011; Shaw et al. 2016; Mahlum et al. 2014; Kemp and O'Hanley 2010). Washington Department of Fish & Wildlife (2009) present criteria for assigning passability scores to culverts that have already been assessed as barriers in coarser level assessments. These passability scores provide additional information to feed into decision making processes related to the prioritization of remediation site candidates and have potential for application in British Columbia.

Table 4.1: Upstream habitat estimates and cost benefit analysis for Phase 1 assessments.

PSCIS ID	Stream	Road	Result	Habitat value	Stream Width (m)	Priority	Fix	Cost Est ($K)	Habitat Upstream (km)	Cost Benefit (m / $K)	Cost Benefit (m2 / $K)
3067	Byman Creek	North Road	Barrier	High	9.0	high	OBS	162	3.99	24.6	110.8
58158	McDowell Creek	Highway 16	Barrier	High	2.5	high	OBS	6500	9.90	1.5	1.9
123463	Victor Creek	Tyee Lake Road	Barrier	Medium	1.8	mod	SS-CBS	200	1.80	9.0	8.1
124502	Tributary to Bulkley River	Lawson Road	Barrier	Medium	3.2	mod	OBS	500	8.68	17.4	27.8
197640	Tributary to Buck Creek	Buck Flats FSR	Barrier	High	5.1	high	OBS	–	19.96	–	–
197646	Tributary to Buck Creek	Spur off Parrot FSR	Barrier	Medium	1.4	mod	SS-CBS	25	5.11	204.4	143.1
197647	Tributary to Buck Creek	Carrier FSR	Barrier	Low	1.5	low	SS-CBS	25	1.78	71.2	53.4
197653	Perow Creek	Perow Loop Rd	Barrier	Medium	2.5	mod	OBS	1000	34.23	34.2	42.8
197654	Tributary to Buck Creek	Balsam FSR	Barrier	Medium	1.5	mod	SS-CBS	25	3.34	133.6	100.2
197655	McInnes Creek	Highway 16	Potential	Low	1.0	low	SS-CBS	1000	15.15	15.2	7.6
197656	Tributary to Bulkley River	Highway 16	Potential	Low	5.0	low	OBS	5000	7.16	1.4	3.6
197657	Perow Creek	Highway 16	Potential	High	3.2	mod	OBS	5000	0.19	0.0	0.1
197658	Byman Creek	Highway 16	Barrier	High	11.1	high	OBS	7550	178.46	23.6	131.2
197662	Richfield Creek	Highway 16	Barrier	High	12.5	high	OBS	8250	289.39	35.1	219.2
197663	Johnny David Creek	Highway 16	Barrier	High	6.3	high	OBS	5150	85.39	16.6	52.2
197667	Moan Creek	CN Railway	Barrier	High	3.8	high	OBS	5000	9.68	1.9	3.7
197668	Coffin Creek	CN Railway	Barrier	High	5.3	high	OBS	5000	38.12	7.6	20.2
197669	Riddeck Creek	Private	Barrier	High	2.6	high	OBS	125	0.34	2.7	3.5

4.3 Phase 2

Although not assessed in 2020, Wilson and Rabnett (2007) report that the crossing structure located on Highway 16 and Station Creek (PSCIS 124420, UTM: 9U.586630.6122416) has been the subject of numerous assessments and designs with respect to the rehabilitation of fish passage, and they rated this crossing as the highest priority for rehabilitation in the Bulkley River watershed. Gitxsan Watershed Authority reports that Xsan Xsagiibil was a fishing site located at the mouth of Station Creek (Xsi Gwin Sagiiblax) (Wilson and Rabnett 2007). Identified as a high priority for additional assessments by Rabnett and Williams (2004), SKR Consultants Ltd. (2006) conducted a detailed inspection, offered rehabilitation design options and identified the natural limits of potential fish distribution to support rehabilitation efforts. At the time of this report, fish passage at the crossing had not yet been remediated due to complexities and costs associated with rehabilitation designs (Kathryn Graham, Regional Manager Environmental Services - Ministry of Transportation and Infrastructure pers. comm.).

During 2020 field assessments, habitat confirmation assessments were conducted at 22 sites in the Bulkley River watershed group and one site in the Morice River watershed group. A total of

approximately 18 km of stream was assessed, fish sampling utilizing electrofishing and/or minnowtrapping was conducted at eight sites, and three sites were mapped using remotely piloted aircraft. Of note, in 2020, surveys in some larger mid Bulkley River tributaries with high potential low gradient habitat gains (ex. Toboggan Creek and John Brown Creek) were not conducted due to poor survey conditions caused by high water. Additionally, assessment at crossings on some large tributary streams in the upper Bulkley River were not conducted due to finite quantities of field time (ex. Ailport Creek, Cesford Creek and Watson Creek). Georeferenced field maps are presented in Attachment 1.

As collaborative decision making was ongoing at the time of reporting, site prioritization can be considered preliminary. In total, Twelve crossings were rated as high priorities for proceeding to design for replacement, 9 crossings were rated as moderate priorities, and 2 crossings were rated as low priorities. Results are summarized in Tables 4.2 - 4.1 with raw habitat and fish sampling data included in digital format as Attachment 4. A summary of preliminary modelling results illustrating the quantity of chinook, coho and steelhead spawning and rearing habitat potentially available upstream of each crossing as estimated by measured/modelled channel width and upstream accessible stream length are presented in Figure 4.2. Detailed information for each site assessed with Phase 2 assessments (including maps) are presented within site specific appendices to this document.

Table 4.2: Overview of habitat confirmation sites.

PSCIS ID	Stream	Road	UTM (9U)	Fish Species	Habitat Gain (km)	Habitat Value	Priority	Comments
3042	Barren Creek	Barren Creek FSR	654451 6042827	RB	1.7	Medium	moderate	Wilson Falls is located downstream of the crossing, so restoration benefits resident rainbow trout. Beaver influenced habitat upstream.
3054	Johnny David Creek	North road	664881 6052688	RB	7.5	Medium	moderate	Smaller channel upstream with beaver activity throughout areas surveyed. Some potential for a natural barrier downstream.
3139	Trib to McQuarrie Creek	North Road	656657 6048544	RB	7.3	Medium	moderate	4-5 m impassable falls downstream in McQuarrie Creek so remediation benefits resident rainbow trout.
58159	McDowell Creek	Woodmere Nursery Road	627643 6060449	RB, CO	0.8	Medium	high	Electrofishing conducted. Abundant cover available primarily as overhanging vegetation and cobbles. Upstream culvert under Highway 16 has been recently replaced by horizontal drilling. Baffles at upstream crossing.
123445	Tyhee Creek	Highway 16	627238 6061456	see appendices	6.0	Medium	high	Large outlet drop. Tyhee Lake upstream. Beaver dams and agricultural impacts between the highway and the lake.
123446	Tyhee Creek	Tyee Lake Road	627527 6061771	see appendices	5.5	Medium	moderate	Beaver influenced wetland type habitat and private land between road and Tyhee Lake.
123794	Tributary to Blunt Creek	Blunt Creek FSR	616100 6106763	(RB)	0.5	Medium	moderate	Channel was noted as having good complexity with abundant gravels suitably sized for both coho and resident salmonid spawning. 4m high falls at top end of the site.
123795	Tributary to Blunt Creek	Blunt Creek FSR	615760 6106892	SA	1.3	Medium	moderate	Deep glide habitat. Very occasional pockets of gravel suitable for resident and adfluvial salmonid spawning.
124487	Porphyryr Creek	Highway 16	603073 6113363	RB, DV	8.0	High	high	Boulders dominant form of cover with small woody debris, large woody debris, and overhanging vegetation also present. Some pockets of gravel suitable for spawning for resident and anadromous species with minimal pool habitat observed. Difficult survey conditions due to high water.
124500	Helps Creek	Lawson Road	627552 6058697	CT,DV,LNC,LSU,RB, ST, CO, L	9.0	Medium	moderate	Multiple braided channels and ponds within beaver influenced wetland areas.
124501	Moan Creek	Lawson Road	630661 6055713	CO, CH, RB, CT, DV, BT	2.8	High	low	Embedded, baffled and without a significant outlet drop. Recent work completed by LGL and Wet'suwet'en First Nation.
124504	Coffin Creek	Lawson Road	634323 6054587	CO, CSU,CT,DV,LSU,MW,RB,RSC	4.0	High	moderate	Focus area for Environmental Stewardship Initiative. Embedded but non-backwatered. Downstream crossing is more of a pressing issue.
195288	Gibson Creek	Schnider Road	640899 6051559	RB, CT	4.5	Medium	high	Beaver influenced wetland complexes uspstream. Aerial survey conducted.
195290	Gibson Creek	Highway 16	640014 6051697	RB, CT, CO, BT	1.0	Medium	high	Primarily beaver influenced wetland area upstream with narrow and deep channel. Electrofishing and aerial surveys conducted. Coho captured downstream but not upstream.
197360	Riddeck Creek	Morice-Owen FSR	649936 5992406	RB, LSU	1.2	High	high	Cover available in all forms with pools suitable for juvenile RB and CO overwintering. Abundant gravels and small cobbles throughout suitable for CO or RB/ST spawning. Electrofishing and aerial surveys conducted.
197640	Tributary to Buck Creek	Buck Flats Road	654312 6012383	RB	4.2	High	high	Rare pockets of gravel suitable for spawning resident, fluvial and anadromous salmonids. Stream aggraded with side bars common. An estimated 129ha of wetland upstream.
197658	Byman Creek	Highway 16	666847 6044305	CO,CSU,LNC,LSU,RB,RSC,ST	5.0	High	high	High habitat complexity including numerous pools up to 2m deep and frequent glide sections to 1m deep. Extensive areas of gravel suitable for spawning for resident and anadromous species. Shallow depth of water during low flows could block salmon spawners.

Table 4.2:

PSCIS ID	Stream	Road	UTM (9U)	Fish Species	Habitat Gain (km)	Habitat Value	Priority	Comments
197662	Richfield Creek	Highway 16	672405 6044146	CH,CO,LNC,LSU,RB,ST	2.0	High	high	High habitat complexity including pools to 2m deep and glides to 1m deep. Water temperatures significantly cooler than in the upper Bulkley mainstem.
197663	Johnny David Creek	Highway 16	670241 6044772	CO, RB, MW	10.0	High	high	Riffles installed to backwater outlet in 2017. Inlet of culvert damaged. Electrofishing conducted upstream and downstream with coho and rainbow captured.
197664	Barren Creek	Highway 16	660454 6037919	CH,CO,CT,L,RB,SST,ST	6.2	High	moderate	Technically passable but undersized and part of infrastructure causing negative impacts on stream function. Dredging required to keep crossing from directing flows over Highway 16 during high flow events.
197665	Barren Creek	CN Railway	660627 6037843	CH,CO,CT,L,RB,SST,ST	6.4	High	low	Technically passable but undersized. Railway blocks access to a series of historic upper Bulkley River oxbows adjacent to the culvert location. Culvert appears to be potentially failing.
197667	Moan Creek	CN Railway	631092 6055866	CO, CH, RB, CT, DV, BT	3.3	High	high	Pockets of gravels and small cobbles suitable for resident and anadromous salmonid spawning. Undercut banks dominant with small woody debris, large woody debris, and overhanging vegetation also present. Perched culvert with shallow flows within pipe.
197668	Coffin Creek	CN Railway	634336 6054609	CO, CSU,CT,DV,LSU,MW,RB,RSC	4.0	High	high	Focus area for Environmental Stewardship Initiative. Backwater works completed in 2017 but do not appear to be effective. High habitat complexity with occasional patches of gravels suitable for spawning present.

Table 4.3: Summary of Phase 2 fish passage reassessments.

PSCIS ID	Embedded	Outlet Drop (m)	Diameter (m)	SWR	Slope (%)	Length (m)	Final score	Barrier Result
3042	No	0.00	1.00	1.0	1.5	23	21	Barrier
3054	No	0.76	3.00	1.2	2.0	40	34	Barrier
3139	No	1.02	1.20	3.2	2.0	27	34	Barrier
58159	No	0.36	1.00	2.3	3.0	14	36	Barrier
123445	No	0.90	0.90	3.1	3.0	50	42	Barrier
123446	No	0.00	1.85	1.4	1.1	21	24	Barrier
123794	No	0.25	0.90	1.9	5.0	13	31	Barrier
123795	No	0.17	0.90	1.6	1.0	15	29	Barrier
124487	No	2.50	5.00	2.2	4.0	99	42	Barrier
124500	No	0.00	1.50	2.4	1.0	14	21	Barrier
124501	Yes	0.30	1.60	2.8	6.0	25	34	Barrier
124504	Yes	0.20	3.00	1.8	1.0	16	24	Barrier
195288	No	0.30	1.20	2.5	1.0	11	31	Barrier
195290	No	0.66	0.80	3.0	1.5	0	31	Barrier
197360	No	0.24	1.20	1.8	1.0	27	29	Barrier
197640	No	0.40	1.50	3.4	1.5	12	31	Barrier
197658	No	2.00	4.00	2.8	4.0	24	39	Barrier
197662	No	0.20	4.20	3.0	2.0	24	29	Barrier
197663	No	0.00	1.75	3.6	2.0	25	24	Barrier
197664	Yes	0.00	2.50	1.9	2.0	15	14	Passable
197665	Yes	0.00	0.90	3.9	1.0	25	14	Passable
197667	No	0.58	2.50	1.5	4.0	17	39	Barrier
197668	No	0.27	3.00	1.8	2.0	15	29	Barrier

Table 4.4: Cost benefit analysis for Phase 2 assessments.

PSCIS ID	Stream	Road	Result	Habitat value	Stream Width (m)	Fix	Cost Est (in $K)	Habitat Upstream (m)	Cost Benefit (m / $K)	Cost Benefit (m2 / $K)
3042	Barren Creek	Barren Creek FSR	Barrier	Medium	2.3	SS-CBS	25	1700	68.0	156.4
3054	Johnny David Creek	North road	Barrier	Medium	2.6	OBS	388	7500	19.3	50.3
3139	Trib to McQuarrie Creek	North Road	Barrier	Medium	3.3	OBS	162	7300	45.1	148.7
58159	McDowell Creek	Woodmere Nursery Road	Barrier	Medium	2.2	OBS	125	780	6.2	13.7
123445	Tyee Creek	Highway 16	Barrier	Medium	2.1	OBS	12500	6000	0.5	1.0
123446	Tyee Creek	Tyee Lake Road	Barrier	Medium	8.5	OBS	1000	5500	5.5	46.8
123794	Tributary to Blunt Creek	Blunt Creek FSR	Barrier	Medium	1.9	SS-CBS	25	525	21.0	39.9
123795	Tributary to Blunt Creek	Blunt Creek FSR	Barrier	Medium	1.4	OBS	62	1300	21.0	29.4
124487	Porphyryr Creek	Highway 16	Barrier	High	10.7	OBS	15500	8000	0.5	5.5
124500	Helps Creek	Lawson Road	Barrier	Medium	4.8	OBS	500	9000	18.0	86.4
124501	Moan Creek	Lawson Road	Barrier	High	4.8	OBS	500	2800	5.6	26.9
124504	Coffin Creek	Lawson Road	Barrier	High	5.8	OBS	500	4000	8.0	46.4
195288	Gibson Creek	Schnider Road	Barrier	Medium	2.0	OBS	1000	4500	4.5	9.0
195290	Gibson Creek	Highway 16	Barrier	Medium	2.0	OBS	9500	1000	0.1	0.2
197360	Riddeck Creek	Morice-Owen FSR	Barrier	High	3.3	OBS	125	1200	9.6	31.7
197640	Tributary to Buck Creek	Buck Flats Road	Barrier	High	4.4	OBS	500	4200	8.4	37.0
197658	Byman Creek	Highway 16	Barrier	High	12.9	OBS	7550	6000	0.8	10.3
197662	Richfield Creek	Highway 16	Barrier	High	13.2	OBS	8250	2000	0.2	3.2
197663	Johnny David Creek	Highway 16	Barrier	High	6.6	OBS	5150	10000	1.9	12.8
197664	Barren Creek	Highway 16	Passable	High	7.2	–	–	6200	–	–
197665	Barren Creek	CN Railway	Passable	High	–	–	–	6400	–	–
197667	Moan Creek	CN Railway	Barrier	High	4.5	OBS	5000	3300	0.7	3.0
197668	Coffin Creek	CN Railway	Barrier	High	5.3	OBS	5000	4000	0.8	4.2

Table 4.5: Summary of Phase 2 habitat confirmation details.

PSCIS ID	Length surveyed upstream (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
3042	400	2.3	2.2	0.2	3	moderate	moderate
3054	725	2.6	2.1	0.3	5.3	moderate	moderate
3139	625	3.3	2.7	0.4	7.2	abundant	high
58159	440	2.2	1.8	0.4	2	abundant	moderate
123445	540	2.1	1.6	–	0.5	moderate	moderate
123446	100	8.5	7.5	0.8	0.2	abundant	moderate
123794	525	1.9	1.6	0.2	9.6	moderate	moderate
123795	650	1.4	1.3	0.3	7.2	abundant	moderate
124487	540	10.7	9.9	0.3	4.8	moderate	moderate
124500	1100	4.8	4.1	–	0.8	moderate	moderate
124501	520	4.8	3.1	0.4	6.3	moderate	high
124504	415	5.8	3.5	0.4	2.3	moderate	high
195288	180	2	2	–	0	–	moderate
195290	150	2	1.6	0.6	1.3	abundant	moderate
197360	1200	3.3	1.8	0.4	2.7	moderate	high
197640	535	4.4	2.2	0.3	2.5	moderate	moderate
197658	1400	12.9	7.9	0.6	2.1	moderate	high
197662	1200	13.2	9	0.8	2.1	moderate	high
197663	690	6.6	4.4	0.4	3	moderate	high
197664	800	7.2	4.7	3	3	moderate	high
197665	100	–	–	–	–	–	moderate
197667	100	4.5	–	–	–	–	high
197668	40	5.3	–	–	–	–	high

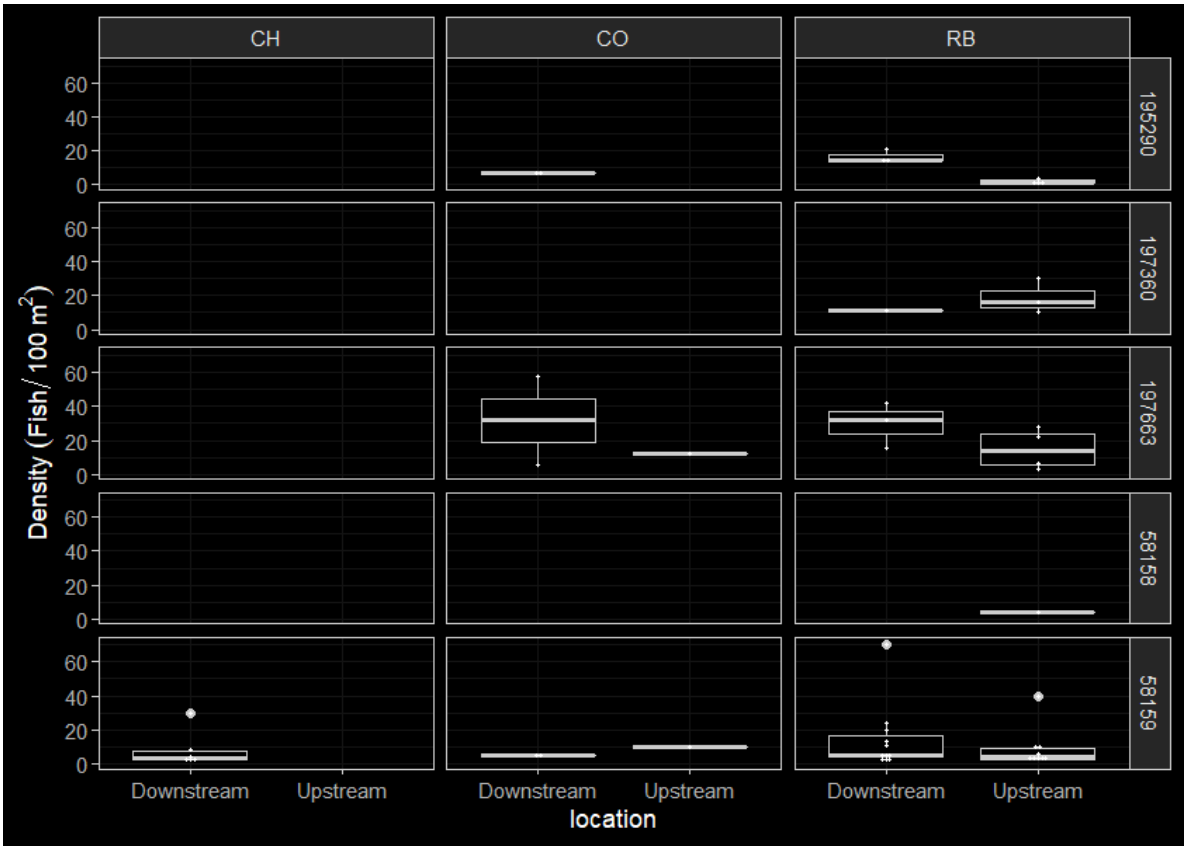

Figure 4.1: Boxplots of densities (fish/100m2) of fish captured by life stage and site for data collected during habitat confirmation assessments.

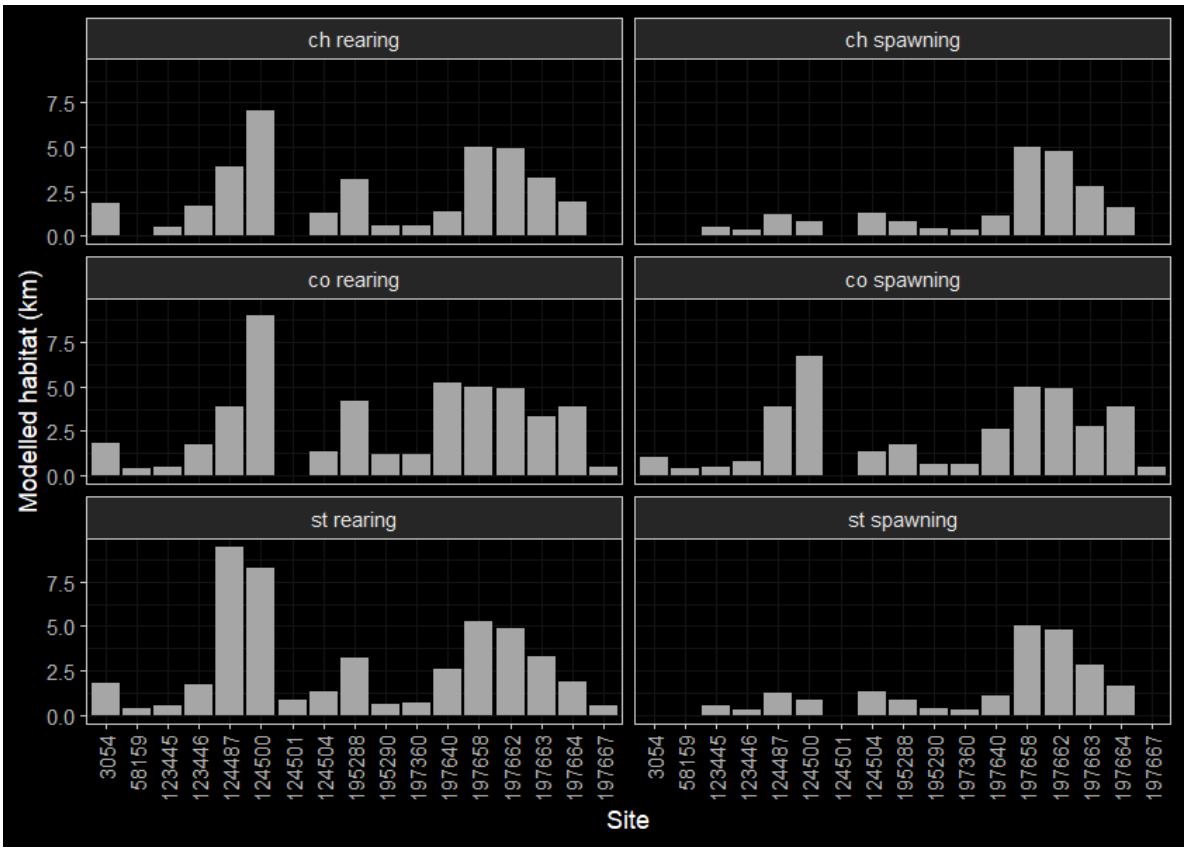

Figure 4.2: Summary of potential habitat upstream of habitat confirmation assessment sites estimated based on modelled channel width and upstream channel length.

5 Recommendations

Recommendations for potential incorporation into collaborative watershed connectivity planning for the Bulkley River and Morice River watershed groups include:

- Continue to develop `bcfishpass`,`bcfishobs`, `fwapg` and other open source data analysis and presentation tools that are scalable and facilitate continual improvement and collaborative adaptation. Tools should continue to be flexible and well documented to allow the future incorporation of alternative fragmentation indicators, habitat gain/value metrics, watershed sensitivity indicators/risk factors and information sharing formats.

- Continue to conduct fish passage and habitat confirmation assessments at road and rail stream crossings at sites in the study areas prioritized through this project and future connectivity analysis/modelling. In the Bulkley River watershed group, particular sites of note where future Phase 1 and Phase 2 assessments are recommended include John Brown Creek, Toboggan Creek, Cesford Creek, Watson Creek and Ailport Creek.

- Continue to acquire funding to procure site plans and replacement designs for structures collaboratively identified as high priorities for restoration. Explore cost benefits and ethics of crossing structure upgrades alongside the cost benefits and ethics of alternative alternative investment activities including transportation corridor relocation/deactivation, land procurement/covenant, cattle exclusion, riparian restoration, habitat complexing, water conservation, commercial/recreational fishing management, salt water interventions and research. Look for opportunities to leverage initiatives together for maximum restoration benefits.

- Refine barrier thresholds for road-stream crossing structures to explore metrics specific to life stage and life history types of species of interest. This will further focus efforts of potential remediation actions based on biological attributes (ex. timing of migration, size/direction of fish migrating, etc.) and could result in the consideration of interim “stop-gap” physical works to alter crossing characteristics that can address key connectivity issues yet be significantly less costly than structure replacements (ex. building up of downstream area with rock riffles to decrease the outlet drop size and/or increasing water depth within pipe with baffles and substrate additions).

- Model fish densities (fish/m^2) vs. habitat/water quality characteristics (i.e. gradient, watershed size, channel size, alkalinity, elevation, etc.) using historically gathered electrofishing data to inform crossing prioritization, future data acquisition needs, and the monitoring of subsequent restoration actions.

- Expand the Bulkley River fish passage working group focus area to include the greater Skeena River watershed. A Skeena level effort will facilitate a more inclusive decision making environment, open up opportunities for collaboration/funding to more governments/organizations/stakeholders and allow consideration of all potential remediation sites that could benefit Skeena fish populations and the livelihoods they support.

- Build relationships with other working groups (ex. Washington Wildlife Habitat Connectivity Working Group) to share knowledge and biuld capacity related to large scale connectivity remediation.

- Continue to collaborate with potential partners to build relationships, explore perspectives and develop “road maps” for fish passage restoration in different situations (MoT roads, rail lines, permit roads of different usages, FSRs, etc.) – documenting the people involved, discussions and processes that are undertaken, funding options, synergies, measures of success, etc. Through this collaboration, such as is occurring with the Bulkley River working group, continue to draft and implement plans for fish passage restoration investments as well as to monitor the impacts of those investments on fish populations.

Appendix - 3139 - Trib to McQuarrie Creek

Site Location

PSCIS crossing 3139 is located on a Trib to McQuarrie Creek at km 31 of North Road. North Road can be accessed from Summit Lake Rd East which meets Highway 16 approximately 11km east of Houston. The culvert is located approximately 490m upstream from the confluence with McQuarrie Creek. North Road is the responsibility of FLNR - Nadina Forest District.

Background

At crossing 3139, Trib to McQuarrie Creek is a third order stream with a watershed area upstream of the crossing of approximately 8.9km^2, containing an estimated 23ha of wetland and 23ha of lake. The elevation of the watershed ranges from a maximum of 1200m to 935m at the crossing. Upstream of North Road, no fish have previously been recorded (MoE 2020a).

Downstream in McQuarrie Creek, longnose sucker, redside shiner, cutthroat trout, coho salmon, rainbow trout, steelhead, and chinook salmon have been recorded as present. Although MoE (2020a) note steelhead in McQuarrie Creek near the confluence with the subject stream (with source reference noted as “personal communications”), NCFDC (1998) recorded a 4-5 m impassable falls (significant overhanging section, lack of plunge pool) in the canyon downstream (UTM 9.662200.6045550). This falls was not recorded in provincial databases at the time of planning and reporting.

Beginning in 2016, the BC Ministry of Forests, Land, Natural Resource Operations and Rural Development (FLNRORD), Land and Water Section established a continuous discharge monitoring station on McQuarrie Creek just upstream of the highway (Westcott 2020). Additionally, three water temperature sensors have been deployed in the watershed. One is located in McQuarrie Creek just above Highway 16, another is in McQuarrie Creek above North Road and one is in McQuarrie Lake (Westcott 2020). Sensors in McQuarrie Creek have been gathering water temperature data at 1hour intervals since 2016 and the sensor in McQuarrie Lake is gathering maximum temperature information from 1m below the surface since July 2018. Data from the two McQuarrie Creek temperature monitoring stations is available through the Skeena Salmon Data Centre (DFO/FLNRO 2019c, 2019b).

The McQuarrie Creek watershed has been selected as a focus watershed for Environmental Stewardship Initiative (ESI) research including critical flow monitoring, benthic invertebrate sampling, water quality monitoring and fisheries assessments (pers. comm Don Morgan, Ministry of Environment and Climate Change Strategy).

PSCIS stream crossing 3139 was ranked as a high priority for follow up in Irvine (2018). It was also selected for follow up with habitat confirmation because McQuarrie Creek was noted as an important rearing area for steelhead by Tredger (1982), because the stream is lake headed (which can stabilize system flows), as steelhead were noted near the confluence, and due to engagement activities with Wet'suwet'en, FLNRO, and Ministry of Environment and Climate Change Strategy representatives that indicated that there could be potential benefits in fish passage remediation/monitoring activities in ESI target watersheds.

Of note, an erronous input into the provincial database for PSCIS crossing 3138 indicated that the oval culvert structure located on McQuarrie Creek just upstream of the confluence with the subject stream was an open bottomed structure and fully passable. The error was discovered during review of PSCIS photos as part of the background review for drafting of this report. NCFDC (1998) noted that this culvert was a barrier to upstream fish passage at low flows, was undersized and was causing fill slope erosion at the road crossing. A map of the watershed is provided in map attachment 093L.114.

Stream Characteristics at Crossing

At the time of the survey, the culvert under North Road was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011). The pipe was 1.2m in diameter with a length of 27m, a culvert slope of 2%, a stream width ratio of 3.2 and an outlet drop of 1.02m (Table 5.1). Water temperature was 11°C, pH was 7.7 and conductivity was 89uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 285m to the confluence with Buck Creek (Figure 5.1). Total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, and undercut banks (Table 5.2). The average channel width was 3.1m, the average wetted width was 2.2m and the average gradient was 3.9%. The dominant substrate was cobbles with boulders subdominant. There were occasional pockets of gravels suitable for resident salmonids. The habitat was rated as high value for resident salmonid rearing.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 3139 for approximately 625m (Figure **??**). Within the area surveyed, total cover amount was rated as abundant with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, undercut banks, and overhanging vegetation (Table 5.2). The average channel width was 3.3m, the average wetted width was 2.7m and the average gradient was 7.2%. The dominant substrate was cobbles with gravels subdominant. Extensive areas of gravels suitable for spawning resident salmonids were present

and fry were observed throughout the surveyed area. Habitat value was rated as high value resident salmonid rearing and spawning.

Structure Remediation and Cost Estimate

Replacement of PSCIS crossing 3139 with a bridge (13m span) is recommended. The cost of the work is estimated at $162,000 for a cost benefit of 45.1 linear m/$1000 and 148.7$m^2$/$1000.

Conclusion

A conservative estimate of mainstem habitat upstream of crossing 3139 is 7.3km to the top end of a 71ha wetland where rainbow trout have been recorded. Habitat in the areas surveyed upstream of the culvert were rated as high value for salmonid rearing and spawning with extensive areas of wetland and lake habitat located upstream. As there is a 4-5 m impassable falls downstream in McQuarrie Creek, remediation of fish passage at the crossing would benefit resident fish species in the watershed and not anadromous fish populations migrating from the Bulkley River mainstem. North Road is the responsibility of the Ministry of Transportation and Infrastructure. Crossing 3139 was ranked as a moderate priority for proceeding to design for replacement.

Table 5.1: Summary of fish passage assessment for PSCIS crossing 3139.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-01	Crossing Sub Type	Round Culvert
PSCIS ID	3139	Diameter (m)	1.2
External ID	–	Length (m)	27
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	656657	Resemble Channel	No
Northing	6048544	Backwatered	No
Stream	Trib to McQuarrie Creek	Percent Backwatered	–
Road	North Road	Fill Depth (m)	4
Road Tenure	MoTi local	Outlet Drop (m)	1.02
Channel Width (m)	3.9	Outlet Pool Depth (m)	0.25
Stream Slope (%)	3.1	Inlet Drop	No
Beaver Activity	No	Slope (%)	2
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	34	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	13
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Inlet plugged with small and large woody debris. Fry and juvenile fish observed upstream.

NO IMAGE AVAILABLE

Table 5.2: Summary of habitat details for PSCIS crossing 3139.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
3139	Downstream	285	3.1	2.2	0.4	3.9	moderate	high
3139	Upstream	625	3.3	2.7	0.4	7.2	abundant	high

Figure 5.1: Left: Habitat downstream of PSCIS crossing 3139. Right: Habitat downstream of crossing 3139.

Figure 5.2: Left: Habitat upstream of PSCIS crossing 3139. Right: Habitat upstream of PSCIS crossing 3139.

Appendix - 58159 - McDowell Creek

Site Location

PSCIS crossing 58159 is located on McDowell Creek on the Woodmere Nursery Road accessed from Highway 16 immediately south of Telkwa, BC. The Woodmere Nursery Road is a private road owned by the Woodmere Nursery. At the time of field surveys it was used to access a newly constructed agricultural facility and by nursery operations to access a waste storage/burn pile area.

Background

McDowell Creek drains McDowell Lake (35ha), Dorsay Lake (4ha) and one other unnamed lake (9ha) flowing from McDowell Lake in a south then west direction for approximately 9km to the confluence with the Bulkley River. At crossing 58159, McDowell Creek is a third order stream with a watershed area upstream of the crossing of approximately 15.9km^2. The elevation of the watershed ranges from a maximum of 1000 to 520m at PSCIS crossing 58159. McDowell Creek is known to contain coho and rainbow trout upstream of the subject culvert (MoE 2020a). There are numerous stream crossing structures located on McDowell Creek upstream of 58159 including crossings on Highway 16, an unnamed road 300m upstream of the highway, Woodmere Road and others.

PSCIS stream crossings 58159 and 58158 were rated as high priorities for follow up by both Irvine (2018) and Smith (2018) due to significant quantities of upstream habitat suitable for salmonid rearing. A map of the watershed is provided in map attachment 093L.118.

Stream Characteristics at Crossing

At the time of the survey, the culvert was un-embedded, non-backwatered and considered a barrier to upstream fish passage. The pipe was 1m in diameter with a pipe length of 14m, a culvert slope of 3%, a stream width ratio of 2.3 and an outlet drop of 0.36m (Table 5.3). Water temperature was 11° C, pH was 8.2 and conductivity was 324uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 135m (Figure 5.4). Overall, total cover amount was rated as abundant with large woody debris dominant. Cover was also present as small woody debris, undercut banks, overhanging vegetation, and instream vegetation (Table 5.5). The average channel width was 2.2m, the average wetted width was 1.7m and the average gradient was 3.8%. The dominant substrate was cobbles with gravels subdominant. Habitat was rated as moderate as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Stream Characteristics Upstream

The stream was surveyed upstream from 58159 for 440m (Figure 5.5). Within the area surveyed, total cover amount was rated as abundant with large woody debris dominant. Cover was also present as small woody debris, undercut banks, overhanging vegetation, and instream vegetation (Table 5.5). The average channel width was 2.2m, the average wetted width was 1.8m and the average gradient was 2%. Habitat value was rated as moderate for salmonid rearing and spawning.

PSCIS culvert 58158 was documented on McDowell Creek, 500m upstream on Highway 16. At the time of the survey the culvert had been newly replaced with a baffled structure embedded with a natural cobble and gravel substrates. Although ranked as a barrier to upstream fish passage using the provincial metric the crossing is likely not a barrier during most flows for adult anadromous salmon and fluvial salmonids migrating upstream from the Bulkley River. The pipe was 2.5m in diameter with a pipe length of 53m, a culvert slope of 5.5%, a stream width ratio of 1 and an outlet drop of 0.36m (Table 5.4).

PSCIS crossing 123544, located on an unnamed road approximately 300m upstream of Highway 16 has been documented as a barrier in the PSCIS system. The culvert is documented as 30m long, with a 1m diameter, a slope of 3.5% and an outlet drop of 0.3m. The culvert is noted as not embedded and not backwatered.

Table 5.6 presents preliminary fish passage modelling data for crossing 58159 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0.4km of potential spawning habitat and 0.4km of potential rearing habitat.

Fish Sampling

To assess potential impacts of the culvert on fisheries values in the stream, electrofishing was conducted upstream and downstream of the crossing. A total of 9 coho were captured downstream with 1 coho captured upstream. Although there is only moderate confidence in their identification, 19 fish captured were identified as chinook. With the exception of one coho, only rainbow trout (19 fish) were captured upstream. Sampling results are summarized in Tables 5.7 - 5.8 and Figure 5.3.

Structure Remediation and Cost Estimate

Structure replacement with a bridge (10m span) is recommended to provide access to the habitat located upstream of PSCIS crossing 58159. The cost of the work is estimated at $125,000 for a cost benefit of 6.2 linear m/$1000 and 13.7$m^2$/$1000.

Conclusion

There is 0.8km of habitat upstream of crossing 58159 to PSCIS crossing 123544 located on an unnamed road approximately 300m upstream of Highway 16. Habitat in this area was rated as moderate value for salmonid rearing/spawning. Woodmere Nursery Road is on private land owned by the Woodmere Nursury. The crossing was ranked as a high priority for proceeding to design for replacement. Although remediation of fish passage at 58159 is considered beneficial, detailed habitat confirmation assessments of upstream culverts (PSCIS 123544) could be pursued to scope for additional potential habitat gains possible within the same system.

Table 5.3: Summary of fish passage assessment for PSCIS crossing 58159.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-03	Crossing Sub Type	Round Culvert
PSCIS ID	58159	Diameter (m)	1
External ID	–	Length (m)	14
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	627643	Resemble Channel	No
Northing	6060449	Backwatered	No
Stream	McDowell Creek	Percent Backwatered	–
Road	Woodmere Nursery Road	Fill Depth (m)	0.75
Road Tenure	MoTi local	Outlet Drop (m)	0.36
Channel Width (m)	2.3	Outlet Pool Depth (m)	0.8
Stream Slope (%)	3.8	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	3
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	36	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Stream flows through the Woodmere Nursury from small culvert on burn pile access road to the Highway. Electrofishing conducted. Abundant cover available primarily as overhanging vegetation and cobbles. Upstream culvert under Highway 16 has been recently replaced by horizontal drilling. Baffles at upstream crossing. Coho fry captured below the Highway crossing.

Table 5.4: Summary of fish passage assessment for PSCIS crossing 58158.

Date	2020-09-03	Crossing Sub Type	Round Culvert
PSCIS ID	58158	Diameter (m)	2.5
External ID	–	Length (m)	53
Crew	AI, KP	Embedded	Yes
UTM Zone	9	Depth Embedded (m)	0.5
Easting	628044	Resemble Channel	Yes
Northing	6060527	Backwatered	No
Stream	McDowell Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	4
Road Tenure	MoTi highway	Outlet Drop (m)	0.36
Channel Width (m)	2.5	Outlet Pool Depth (m)	0.45
Stream Slope (%)	3	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	5.5
Habitat Value	High	Valley Fill	Deep Fill
Final score	34	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	13
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: New culvert horizontally drilled under highway in 2017. Structure has baffles made of oured concrete and boulders. Often deep pools up to 50cm before baffles. Baffles seem sarp and have potential to injure fish ascending?

Table 5.5: Summary of habitat details for PSCIS crossing 58159.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
58159	Downstream	135	2.2	1.7	0.2	3.8	abundant	moderate
58159	Upstream	440	2.2	1.8	0.4	2	abundant	moderate

Table 5.6: Summary of fish habitat modelling for PSCIS crossing 58159.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	9.4	0.4	4
Salmon Lake Reservoir (ha)	4.4	0.0	0
Salmon Wetland (ha)	0.0	0.0	–
Steelhead Network (km)	10.3	0.4	4
Steelhead Lake Reservoir (ha)	4.4	0.0	0
Steelhead Wetland (ha)	0.0	0.0	–
CH Spawning (km)	0.0	0.0	–
CH Rearing (km)	0.0	0.0	–
CO Spawning (km)	4.3	0.4	9
CO Rearing (km)	4.3	0.4	9
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.0	0.0	–
ST Rearing (km)	5.0	0.4	8
All Spawning (km)	4.3	0.4	9
All Rearing (km)	5.0	0.4	8
All Spawning and Rearing (km)	5.0	0.4	8

* Model data is preliminary and subject to adjustments.

Table 5.7: Electrofishing sites for PSCIS crossing 58159.

Site	Location	Width (m)	Length (m)	Area (m2)	Effort (s)	Effort (s/m2)
41	Downstream	2.00	5	10	71	7.1
42	Downstream	1.75	33	58	104	1.8
43	Downstream	1.63	47	77	176	2.3
44	Downstream	2.00	50	100	147	1.5
45	Upstream	1.90	23	44	107	2.4
46	Upstream	1.80	31	56	268	4.8
47	Upstream	1.80	26	47	144	3.1
48	Upstream	2.50	4	10	57	5.7

Table 5.8: Fish densities (fish/100m2)

for PSCIS crossing 58159.

Site	Location	Species	Fry	Parr	Juvenile	Adult
41	Downstream	CH	30	0	0	0
42	Downstream	CH	1.7	0	0	0
43	Downstream	CH	3.9	1.3	0	0
44	Downstream	CH	8	3	0	0
43	Downstream	CO	5.2	0	0	0
44	Downstream	CO	5	0	0	0
48	Upstream	CO	0	10	0	0
41	Downstream	RB	70	20	0	0
42	Downstream	RB	24.1	1.7	3.4	0
43	Downstream	RB	10.4	3.9	3.9	1.3
44	Downstream	RB	13	5	0	0
45	Upstream	RB	9.1	2.3	0	0
46	Upstream	RB	0	3.6	5.4	0
47	Upstream	RB	4.3	2.1	2.1	0
48	Upstream	RB	40	0	10	0

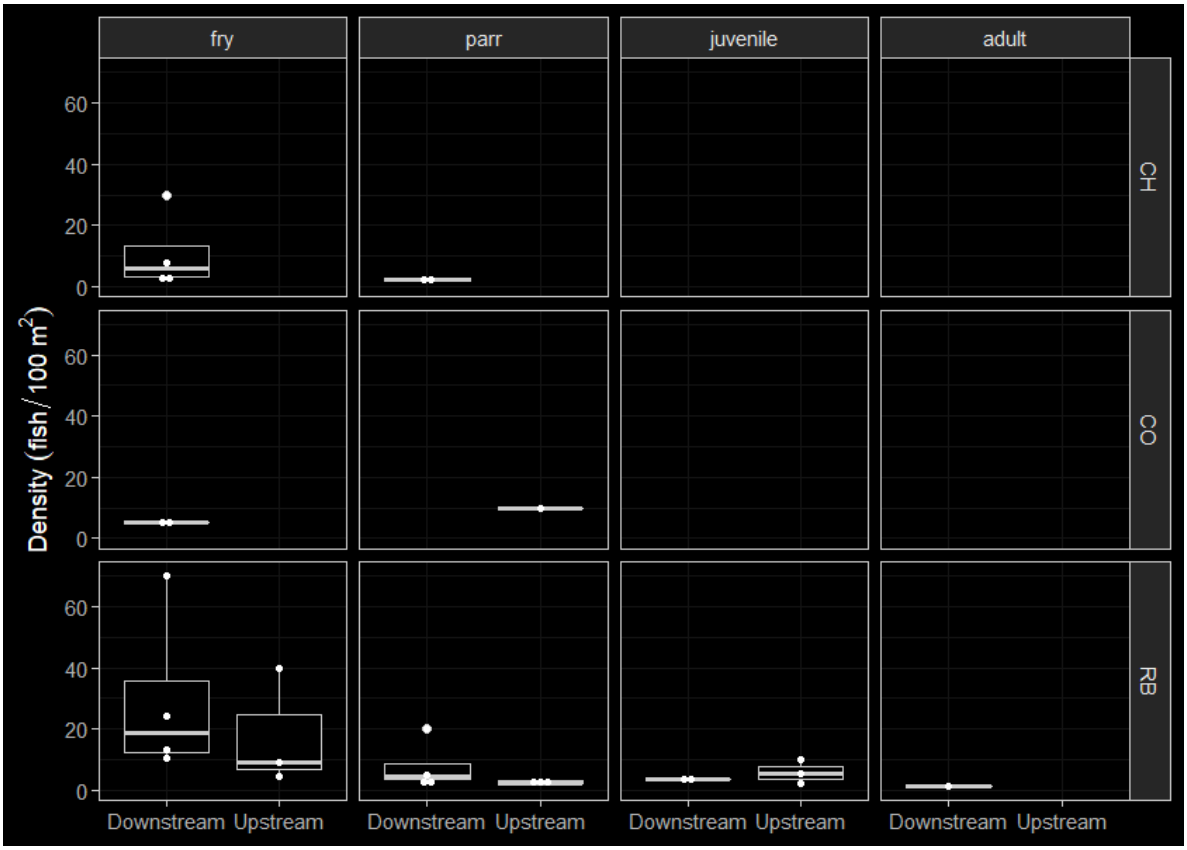

Figure 5.3: Densities of fish captured (fish/100m2) during electrofishing upstream and downstream of PSCIS crossing 58159.

Figure 5.4: Left: Typical habitat downstream of PSCIS crossing 58159. Right: Chinook captured downstream of PSCIS crossing 58159.

Figure 5.5: Left: Typical habitat upstream of PSCIS crossing 58159. Right: Coho captured upstream of PSCIS crossing 58159.

Appendix - 123445 & 123446 - Tyhee Creek

Site Location

PSCIS crossing 123445 is located on Tyhee Creek on Highway 16 approximately 2km south of Telkwa, BC. The highway is located approximately 170m upstream from the confluence with the Bulkley River. PSCIS crossing 123446 is located on Tyee Lake Road approximately 540m upstream of Highway 16. Both crossings are the responsibility of the Ministry of Transportation and Infrastructure.

Background

At crossing 123445, Tyhee Creek is a third order stream with a watershed area upstream of the crossing of approximately 35km^2. The elevation of the watershed ranges from 1000m to 520m at the highway. Numerous fish species have been documented upstream of both crossings including sucker (general), longnose sucker, minnow (general), northern redbelly dace, peamouth chub, northern pikeminnow, redside shiner, burbot, salmon (general), cutthroat trout, pink salmon, chum salmon, coho salmon, rainbow trout, steelhead, sockeye salmon, chinook salmon, giant pygmy whitefish, pygmy whitefish, mountain whitefish, sculpin (general), and prickly sculpin (MoE 2020a).

Tyhee Lake is located approximatley 800m upstream of crossing 123446. Tyhee Lake has a surface area of 3.18km^2, a mean depth of 11.1m, a maximum depth of 22.2m and a mean water retention time estimated at 5 years (Reavie et al. 2000). Reavie et al. (2000) report that Tyhee Lake was a naturally productive system that has experienced moderate eutrophication over time due to adjacent land use. In response to concerns expressed by the Tyhee Lake Protection Society, a management plan was drafted for the lake in 1999 with the objective of slowing down or eliminating eutrophication (Rysavy et al. 1999). Fish passage issues at the highway have also been highlighted by the protection society in the past (Hatlevik 1992). Cutthrout trout have been observed unsuccessfully attempting to ascend into the culvert at the highway (pers comm Mike Ridsdale, Environmental Assessment Coordinator - Office of the Wet'suwet'en). Tyhee Lake has been stocked with rainbow trout since 1955, with stocking events occuring annual since 1990 (BC Ministry of Environment 2021).

There are five tributaries that flow into the lake from the east and north with all systems containing crossings previously inventoried as barriers or potential barriers.

PSCIS stream crossings 123445 and 123446 were rated high priorities for follow up by Wilson and Rabnett (2007) and Irvine (2018) due to significant quantities of lake habitat upstream and historical records of steelhead and salmon upstream. A map of the watershed is provided in mapsheet attachment 093L.118.

Stream Characteristics at Crossings 123445 and 123446

At the time of the survey, crossing 123445 on Highway 16 was un-embedded, non-backwatered and a barrier to upstream fish passage. Downcutting of the downstream area was apparent and due likely to high flow velocities through the pipes during elevated flow events. The pipes were 0.9m in diameter with lengths of 50m, a culvert slope of 3%, a stream width ratio of 3.1 and an outlet drop of 0.9m (Table 5.9). Water temperature was 11°C, pH was 8.1 and conductivity was 418uS/cm.

Crossing 123446 on Tyee Lake Road was un-embedded, 10% backwatered and classified as a barrier to upstream fish passage. The pipe was 1.85m in diameter with a length of 21m, a culvert slope of 1.1%, a stream width ratio of 1.4 and an outlet drop of 0m (Table 5.10).

Stream Characteristics Downstream of 123445

The stream was surveyed downstream from the culvert for 170m to the confluence with the Bulkley River (Figure 5.6). Flows were very low at the time of the survey and the stream channel went subsurface near the Bulkley River floodplain. Overall, total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, boulders, and undercut banks (Table 5.12). The average channel width was 2.8m, the average wetted width was 1.5m and the average gradient was 3%. The dominant substrate was cobbles with boulders subdominant. Some gravels suitable for spawning were observed and unidentified fry/juvenile fish (3 @ 50mm, and 1 @ 90mm) were observed. Habitat value was rated as moderate as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Stream Characteristics Upstream of 123445 and downstream of 123446

The stream was surveyed from 123445 for 540m to 123446(Figure 5.7). Within the area surveyed, total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, undercut banks, and instream vegetation (Table 5.12). The average channel width was 2.1m, the average wetted width was 1.6m and the average gradient was 0.5%. Water within the narrow channel was noted as often stagnant with aquatic vegetation present throughout. Some riparian disturbance by adjacent livestock was also noted. Although, habitat value was considered of low value for rearing and spawning it was rated as moderate overall as it was considered an important migration corridor providing access to the lake.

Stream Characteristics Upstream of 123446

Tyhee Creek was surveyed upstream from 123446 for 100m with the survey discontinued due to difficult survey conditions within the wetland type habitat and the presence of fenced private land

(Figure 5.8). Within the area surveyed, total cover amount was rated as abundant with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, deep pools, and instream vegetation (Table 5.12). The average channel width was 8.5m, the average wetted width was 7.5m and the average gradient was 0.2%. Beaver activity was prevalent in the area surveyed and there was a large agricultural field located on the right bank of the stream. Habitat value was rated as moderate as it was considered an important migration corridor providing access to the lake.

Crossing 123463 is located on Victor Creek and Tyhee Lake Road. Victor Creek flows into the east side of Tyhee Lake approximately 1.7km upstream from the mouth. At the time of the survey, the round culvert appeared to have been recently replaced. The structure was un-embedded, non-backwatered and considered a barrier to upstream fish passage according to the provincial protocol. The pipe was 0.6m in diameter with a length of 18m, a culvert slope of 3%, a stream width ratio of 3.1 and an outlet drop of 0m (Table 5.11).

Table 5.13 presents preliminary fish passage modelling data for crossing 123445 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0.5km of potential spawning habitat and 0.5km of potential rearing habitat. Table 5.14 presents preliminary fish passage modelling data for crossing 123446 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0.8km of potential spawning habitat and 12.3km of potential rearing habitat.

Structure Remediation and Cost Estimate

Structure replacement with bridges for 123445 (25m span) and 123446 (10m span) could be considered to provide access to the habitat located upstream. An estimate of cost for replacement of 123445 is $12,500,000 and $1,000,000 for 123446.

Conclusion

As Tyhee Lake is located upstream of both crossings surveyed with steelhead and mulitple salmon species historically recorded upstream of the highway, the restoration of fish passage at 123445 was rated as a moderate priority for proceeding to design for replacement. Although classified as a barrier to upstream fish passage according to the provincial protocol, crossing 123446 appeared likely passable for resident, fluvial and anadromous adult salmonids migrating to Tyhee Lake if passage to above the highway was facilitated. Crossing 123446 was ranked as a high priority for proceeding to design for replacement. Adjacent land use has been documented as negatively impacting fish habitat values in the watershed and the multiple strategies to quantify and reduce those impacts noted in Rysavy et al. (1999) should be considered alongside restorative works addressing fish passage in the watershed.

Table 5.9: Summary of fish passage assessment for PSCIS crossing 123445.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-29	Crossing Sub Type	Round Culvert
PSCIS ID	123445	Diameter (m)	0.9
External ID	–	Length (m)	50
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	627238	Resemble Channel	No
Northing	6061456	Backwatered	No
Stream	Tyhee Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	8
Road Tenure	MoTi unclassified	Outlet Drop (m)	0.9
Channel Width (m)	2.8	Outlet Pool Depth (m)	0.42
Stream Slope (%)	3	Inlet Drop	No
Beaver Activity	No	Slope (%)	3
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	42	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	25
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Important migration corridor to Tyee Lake. Large outlet drop seems unliklely passabel by any life stage or species.

Table 5.10: Summary of fish passage assessment for PSCIS crossing 123446.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-29	Crossing Sub Type	Round Culvert
PSCIS ID	123446	Diameter (m)	1.85

Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	627527	Resemble Channel	No
Northing	6061771	Backwatered	Yes
Stream	Tyhee Creek	Percent Backwatered	10
Road	Tyee Lake Road	Fill Depth (m)	1.3
Road Tenure	MoTi highway	Outlet Drop (m)	0
Channel Width (m)	2.5	Outlet Pool Depth (m)	0.1
Stream Slope (%)	0.5	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	1.1
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	24	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Important migration corridor to get to Tyee Lake from Bulkley River. Crossing does not appear to be barrier to most life stages/species at most flows.

Table 5.11: Summary of fish passage assessment for PSCIS crossing 123463.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-29	Crossing Sub Type	Round Culvert
PSCIS ID	123463	Diameter (m)	0.6
External ID	–	Length (m)	18
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	627570	Resemble Channel	No
Northing	6064562	Backwatered	Yes
Stream	Victor Creek	Percent Backwatered	30
Road	Tyee Lake Road	Fill Depth (m)	1
Road Tenure	MoTi local	Outlet Drop (m)	0
Channel Width (m)	1.8	Outlet Pool Depth (m)	0.3
Stream Slope (%)	1	Inlet Drop	No
Beaver Activity	No	Slope (%)	3
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	29	Barrier Result	Barrier
Fix type	Replace Structure with Streambed Simulation CBS	Fix Span / Diameter	5
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: No habitat confirmation conducted in 2020. Newly replaced crossing. ID# 8 21 18 01 .

Table 5.12: Summary of habitat details for PSCIS crossings 123445 and 123446.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
123445	Downstream	170	2.8	1.5	–	3	moderate	moderate
123445	Upstream	540	2.1	1.6	–	0.5	moderate	moderate
123446	Upstream	100	8.5	7.5	0.8	0.2	abundant	moderate

Table 5.13: Summary of fish habitat modelling for PSCIS crossing 123445.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	20.6	0.5	2
Salmon Lake Reservoir (ha)	367.3	0.0	0
Salmon Wetland (ha)	9.7	0.0	0
Steelhead Network (km)	20.9	0.5	2
Steelhead Lake Reservoir (ha)	367.3	0.0	0
Steelhead Wetland (ha)	9.7	0.0	0
CH Spawning (km)	0.8	0.5	62
CH Rearing (km)	2.2	0.5	23
CO Spawning (km)	1.3	0.5	38
CO Rearing (km)	2.2	0.5	23
CO Rearing (ha)	–	–	–
SK Spawning (km)	1.3	0.5	38
SK Rearing (km)	10.6	0.0	0
SK Rearing (ha)	367.3	–	–
ST Spawning (km)	0.8	0.5	62
ST Rearing (km)	2.5	0.5	20
All Spawning (km)	1.3	0.5	38
All Rearing (km)	13.0	0.5	4
All Spawning and Rearing (km)	13.0	0.5	4

* Model data is preliminary and subject to adjustments.

Table 5.14: Summary of fish habitat modelling for PSCIS crossing 123446.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	20.2	10.1	50
Salmon Lake Reservoir (ha)	367.3	367.3	100
Salmon Wetland (ha)	9.7	0.0	0
Steelhead Network (km)	20.4	10.1	50
Steelhead Lake Reservoir (ha)	367.3	367.3	100
Steelhead Wetland (ha)	9.7	0.0	0
CH Spawning (km)	0.3	0.3	100
CH Rearing (km)	1.7	1.7	100
CO Spawning (km)	0.8	0.8	100
CO Rearing (km)	1.7	1.7	100
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.8	0.8	100
SK Rearing (km)	10.6	10.6	100
SK Rearing (ha)	367.3	–	–
ST Spawning (km)	0.3	0.3	100
ST Rearing (km)	2.0	1.7	85
All Spawning (km)	0.8	0.8	100
All Rearing (km)	12.6	12.3	98
All Spawning and Rearing (km)	12.6	12.3	98

* Model data is preliminary and subject to adjustments.

Figure 5.6: Left: Typical habitat downstream of PSCIS crossing 123445. Right: Typical habitat downstream of PSCIS crossing 123445.

Figure 5.7: Left: Habitat upstream of PSCIS crossing 123445. Right: Habitat upstream of PSCIS crossing 123445.

Figure 5.8: Left: Habitat upstream of PSCIS crossing 123446. Right: Habitat upstream of PSCIS crossing 123446.

Appendix - 123794 - Tributary to Blunt Creek

Site Location

PSCIS crossing 123794 is located on tributary to Blunt Creek at km 19.3 of the Blunt Creek FSR. The site is accessed via Moricetown Road through Witset approximately 40km north of Smithers. The culvert is located approximately 670m upstream from the confluence with a major tributary to Blunt Creek. Blunt Creek flows east into Harold Price Creek which in turn flows into the Suskwa River. The Suskwa River enters the Bulkley River near Hazleton BC. Blunt Creek FSR is the responsibility of the FLNR - Skeena Stikine District.

Background

At crossing 123794, tributary to Blunt Creek is a second order stream. Watershed area upstream of the crossing is estimated at 0.9km^2 ranging from a maximum elevation of 1260m to 1070m at PSCIS crossing 123794. Upstream of the Blunt Creek FSR, dolly varden have been previously recorded as present (MoE 2020a). MoE (2020a) also indicates that salmon (unidentified species) have been recorded in an adjacent tributary with cutthrout recorded nearby within multiple streams connecting to the greater stream network just downstream of the subject tributary. PSCIS crossing 123785 has been ranked as a barrier and is located on the tributary that the subject stream drains into. It is located approximately 250m north-east on a spur road (R09533) accessed at km 18.3 of the Blunt Creek FSR.

PSCIS stream crossing 123794 was ranked as a high priority for follow up by Irvine (2018) because there was salmon noted nearby, due to the presence of a small lake upstream, and because PSCIS data indicated a larger channel containing habitat rated as high value. Although on a smaller stream, the crossing's location on a forest service road was considered advantageous as these sites are often eligible for funding through forestry supported funds such as the Land Based Investment Fund if restoration of fish passage is warranted. A map of the watershed is provided in map attachment 093M.103.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Blunt Creek FSR was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage acoording to the provincial protocol (MoE 2011). The pipe was 0.9m in diameter with a length of 13m, a culvert slope of 5%, a stream width ratio of 1.9 and an outlet drop of 0.25m (Table 5.15). Water temperature was 9°C, pH was 7.7 and conductivity was 73uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 250m (Figure 5.9). Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody

debris, large woody debris, and overhanging vegetation (Table 5.16). The average channel width was 1.7m, the average wetted width was 1.8m and the average gradient was 5%. The dominant substrate was gravels with cobbles subdominant. Within the area surveyed, the stream had good flow volume and frequent patches of gravel suitable for spawning for coho and resident salmonids. The habitat was rated as moderate value.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 123794 for approximately 525m (Figure 5.10). Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, deep pools, and overhanging vegetation (Table 5.16). The average channel width was 1.9m, the average wetted width was 1.6m and the average gradient was 9.6%. The dominant substrate was gravels with cobbles subdominant. The channel was noted as having good complexity and abundant gravels suitably sized for both coho and resident salmonid spawning. Some small woody debris/large woody debris steps (30-50cm in height) were present intermittently starting approximately 400m above the culvert. A fish (~120mm) was observed 500m upstream of the culvert. A 4m high falls was noted at the top end of the site and represents an impassable barrier to upstream migration. Habitat value was rated as moderate for salmonid spawning and rearing.

Table 5.17 presents preliminary fish passage modelling data for crossing 123794 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0km of potential spawning habitat and 0km of potential rearing habitat.

Structure Remediation and Cost Estimate

Replacement of PSCIS crossing 123794 with a embedded culvert (streambed simulation - 3m span) is recommended in the long term. The cost of the work is estimated at $25,000 for a cost benefit of 21 linear m/$1000 and 39.9$m^2$/$1000.

Conclusion

There is 0.5km of habitat upstream of crossing 123794 with habitat value rated as moderate value for salmonid rearing and spawning. Blunt Creek FSR is the responsibility of FLNR - Skeena Stikine District. The crossing was ranked as a moderate priority for proceeding to design for replacement. Future fish sampling is recommended upstream and downstream of the crossing to scope for anadromous species and evaluate potential impacts of the culvert on fish densities. Although the upstream channel appears to split into three channels just upstream of the crossing, it is also recommended that PSCIS crossing 123785 (located on the spur road R09533 accessed from km 18.3 of the Blunt Creek FSR) be scoped as a habitat confirmation candidate at the same time that other fish passage assessment work is conducted in the area.

Table 5.15: Summary of fish passage assessment for PSCIS crossing 123794.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-24	Crossing Sub Type	Round Culvert
PSCIS ID	123794	Diameter (m)	0.9
External ID	–	Length (m)	13
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	616100	Resemble Channel	No
Northing	6106763	Backwatered	No
Stream	Tributary to Blunt Creek	Percent Backwatered	–
Road	Blunt Creek FSR	Fill Depth (m)	0.75
Road Tenure	FLNR Nadina 9111	Outlet Drop (m)	0.25
Channel Width (m)	1.73	Outlet Pool Depth (m)	0.43
Stream Slope (%)	5	Inlet Drop	No
Beaver Activity	No	Slope (%)	5
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace Structure with Streambed Simulation CBS	Fix Span / Diameter	3
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Smaller stream with good flow. Salmon points noted in adjacent stream. Recommend sampling upstream and downstream and habitat assessment of stream at associated PSCIS crossing 123785.

Table 5.16: Summary of habitat details for PSCIS crossing 123794.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
123794	Downstream	250	1.7	1.8	0.3	5	moderate	moderate
123794	Upstream	525	1.9	1.6	0.2	9.6	moderate	moderate

Table 5.17: Summary of fish habitat modelling for PSCIS crossing 123794.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	0.5	0.5	100
Salmon Lake Reservoir (ha)	–	0.0	–
Salmon Wetland (ha)	–	0.0	–
Steelhead Network (km)	2.1	1.2	57
Steelhead Lake Reservoir (ha)	2.9	0.0	0
Steelhead Wetland (ha)	1.8	0.0	0
CH Spawning (km)	0.0	0.0	–
CH Rearing (km)	0.0	0.0	–
CO Spawning (km)	0.0	0.0	–
CO Rearing (km)	0.0	0.0	–
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.0	0.0	–
ST Rearing (km)	0.0	0.0	–
All Spawning (km)	0.0	0.0	–
All Rearing (km)	0.0	0.0	–
All Spawning and Rearing (km)	0.0	0.0	–

* Model data is preliminary and subject to adjustments.

Figure 5.9: Left: Habitat downstream of PSCIS crossing 123794. Right: Habitat downstream of crossing 123794.

Figure 5.10: Left: Habitat upstream of PSCIS crossing 123794. Right: Cascade upstream of PSCIS crossing 123794.

Appendix - 123795 - Tributary to Blunt Creek

Site Location

PSCIS crossing 123795 is located on tributary to Blunt Creek at km 18.9 of the Blunt Creek FSR. The site is accessed via Moricetown Road through Witset approximately 40km north of Smithers. The culvert is located approximately 670m upstream from the confluence with a major tributary to Blunt Creek. Blunt Creek flows east into Harold Price Creek which in turn flows into the Suskwa River. The Suskwa River enters the Bulkley River near Hazleton BC. Blunt Creek FSR is the responsibility of the FLNR - Skeena Stikine District.

Background

At crossing 123795, the tributary to Blunt Creek is a first order stream. The elevation of the watershed ranges from a maximum of 1260m to 1070m at the crossing. Upstream of the Blunt Creek FSR, salmon (general) have been previously recorded as present (MoE 2020a) with dolly varden recorded as present in the adjacent connected stream. We suspect the salmon noted were likely coho due to the smaller size of the watershed.

PSCIS stream crossing 123795 was ranked as a high priority for follow up by Irvine (2018) because there was salmon noted upstream and because PSCIS data indicated a larger channel containing habitat rated as high value. Although on a generally smaller stream, the crossing's location on a forest service road was considered advantageous for funding eligibility through forestry supported programs such as the Land Based Investment Fund. A map of the watershed is provided in map attachment 093M.103.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Blunt Creek FSR was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage acoording to the provincial protocol (MoE 2011). The pipe was 0.9m in diameter with a length of 15m, a culvert slope of 1%, a stream width ratio of 1.6 and an outlet drop of 0.17m (Table 5.18). Water temperature was 10°C, pH was 7.8 and conductivity was 56uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 200m (Figure 5.11). Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as overhanging vegetation (Table 5.19). The average channel width was 1.4m, the average wetted width was 1.2m and the average gradient was 3.7%. The dominant substrate was gravels with fines subdominant. Within the area surveyed, the stream was noted as having somewhat low complexity, with occasional deep pools and primarily glide habitat. Abundant gravels were noted as present but with only occasional patches unembedded. The habitat was rated as moderate value.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 123795 for approximately 650m to the location of a ford (PSCIS123796).(Figure 5.12). Within the area surveyed, total cover amount was rated as abundant with undercut banks dominant. Cover was also present as small woody debris, large woody debris, deep pools, overhanging vegetation, and instream vegetation (Table 5.19). The average channel width was 1.4m, the average wetted width was 1.3m and the average gradient was 7.2%. The dominant substrate was fines with cobbles subdominant. Deep glide habitat was noted as prevalent in the area surveyed. Gradients leveled out at top end of site, with primarily shrub and wetland riparian area present. Very occasional pockets of gravel suitable for resident and adfluvial salmonid spawning were noted. Habitat value was rated as moderate for salmonid spawning and rearing.

Table 5.20 presents preliminary fish passage modelling data for crossing 123795 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0km of potential spawning habitat and 0km of potential rearing habitat.

Structure Remediation and Cost Estimate

Replacement of PSCIS crossing 123795 with an embedded culvert (streambed simulation - 3m diameter) is recommended in the long term. The cost of the work is estimated at $62,000 for a cost benefit of 21 linear m/$1000 and 29.4$m^2$/$1000.

Conclusion

A conservative estimate of mainstem habitat upstream of crossing 123795 is 1.3km. Habitat in the areas surveyed was rated as moderate value for salmonid rearing and spawning. Blunt Creek FSR is the responsibility of FLNR - Skeena Stikine District. The crossing was ranked as a moderate priority for proceeding to design for replacement. Future fish sampling is recommended upstream and downstream fo the road to clarify salmon species presence and assess densities of fish present.

Table 5.18: Summary of fish passage assessment for PSCIS

crossing 123795.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-24	Crossing Sub Type	Round Culvert
PSCIS ID	123795	Diameter (m)	0.9
External ID	–	Length (m)	15
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	615760	Resemble Channel	No
Northing	6106892	Backwatered	No
Stream	Tributary to Blunt Creek	Percent Backwatered	–
Road	Blunt Creek FSR	Fill Depth (m)	0.75
Road Tenure	FLNR Nadina 7543	Outlet Drop (m)	0.17
Channel Width (m)	1.42	Outlet Pool Depth (m)	0.05
Stream Slope (%)	3.7	Inlet Drop	No
Beaver Activity	No	Slope (%)	1
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	29	Barrier Result	Barrier
Fix type	Replace Structure with Streambed Simulation CBS	Fix Span / Diameter	3

Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.

Comments: Smaller stream with good flow. Salmon point (juvenile) noted upstream. Recommend sampling upstream and downstream and habitat assessment of stream at associated PSCIS crossing 123785.

Table 5.19: Summary of habitat details for PSCIS crossing 123795.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
123795	Downstream	200	1.4	1.2	0.3	3.7	moderate	moderate
123795	Upstream	650	1.4	1.3	0.3	7.2	abundant	moderate

Table 5.20: Summary of fish habitat modelling for PSCIS crossing 123795.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	1.4	1.4	100
Salmon Lake Reservoir (ha)	0.0	0.0	–
Salmon Wetland (ha)	0.3	0.3	100
Steelhead Network (km)	1.4	1.4	100
Steelhead Lake Reservoir (ha)	0.0	0.0	–
Steelhead Wetland (ha)	0.3	0.3	100
CH Spawning (km)	0.0	0.0	–
CH Rearing (km)	0.0	0.0	–
CO Spawning (km)	0.0	0.0	–
CO Rearing (km)	0.0	0.0	–
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.0	0.0	–
ST Rearing (km)	0.0	0.0	–
All Spawning (km)	0.0	0.0	–
All Rearing (km)	0.0	0.0	–
All Spawning and Rearing (km)	0.0	0.0	–

* Model data is preliminary and subject to adjustments.

Figure 5.11: Left: Habitat downstream of PSCIS crossing 123795. Right: Habitat downstream of crossing 123795.

Figure 5.12: Left: Habitat upstream of PSCIS crossing 123795. Right: Cascade upstream of PSCIS crossing 123795.

Appendix - 124487 - Porphyryr Creek

Site Location

PSCIS crossing 124487 is on Porphyryr Creek and Highway 16 approximately 18km south of New Hazelton, BC. The crossing is located approximately 145m upstream from the confluence with the Bulkley River. Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure.

Background

At crossing 124487, Porphyryr Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 43.5km^2. The elevation of the watershed ranges from a maximum of 2300m to 330m at the highway. Upstream, rainbow trout and dolly varden have been recorded (MoE 2020a). A large railway trestle bridge is located over the stream approximately 500m upstream of the highway.

PSCIS stream crossing 124487 was ranked as a high priority for follow up by Irvine (2018) due to the large quantity of habitat modelled upstream and selected for assessment in 2020 following consultation with Alecia Fernando from the Gitksan Watershed Authority. Wilson and Rabnett (2007) assessed the site and reported it as not a priority restoration site due to “the limited amount of high value habitat upstream of Highway 16.” A map of the watershed is provided in map attachment 093M.102.

Stream Characteristics at Crossing

At the time of the survey, the two culverts under Highway 16 were un-embedded, non-backwatered and ranked as a barrier to upstream fish passage (MoE 2011). The culvert is located under an estimated 40m of highway fill. The pipes were 5m in diameter with lengths of 99m, a culvert slope of 4%, a stream width ratio of 2.2 and outlet drops of 2.5m (Table 5.21). Water temperature was 9°C, pH was 7.6 and conductivity was 73uS/cm. Survey conditions were difficult at the time of assessment as stream flows were high due to recent rain events.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 145m to the confluence with the Bulkley River (Figure 5.13). Total cover amount was rated as moderate with boulders dominant. Cover was also present as small woody debris, large woody debris, and overhanging vegetation (Table 5.22). The average channel width was 11.2m, the average wetted width was 10.2m and the average gradient was 2.8%. The dominant substrate was boulders with cobbles subdominant. The cascade-boulder habitat was rated as moderate value as it was considered an important migration corridor with moderate value habitat for salmonid rearing and spawning. During the survey, an approximately 40cm long salomonid was observed attempting to ascend from the outlet pool into the culvert outlet.

Stream Characteristics Upstream

The stream was surveyed upstream from 124487 for 540m (Figure 5.14). Within the area surveyed, total cover amount was rated as moderate with boulders dominant. Cover was also present as small woody debris, large woody debris, and overhanging vegetation (Table 5.22). The average channel width was 10.7m, the average wetted width was 9.9m and the average gradient was 4.8%. The dominant substrate was boulders with cobbles subdominant. There were pockets of gravel suitable for spawning for resident and anadromous species with minimal pool habitat observed. Habitat value was rated as moderate as an important migration corridor with limited spawning habitat and moderate rearing potential for coho, dolly varden, cutthrout rearing and spawning.

Table 5.23 presents preliminary fish passage modelling data for crossing 124487 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 3.9km of potential spawning habitat and 9.5km of potential rearing habitat.

Structure Remediation and Cost Estimate

Structure replacement with a bridge (31m span) is recommended to provide access to the habitat located upstream of PSCIS crossing 124487. The cost of the work is estimated at $15,500,000 for a cost benefit of 0.5 linear m/$1000 and 5.5$m^2$/$1000.

Conclusion

There is an estimated 8km of mainstem habitat upstream of crossing 124487. Habitat in the areas surveyed upstream of the crossing was rated as moderate value for salmonid rearing/spawning. The crossing represents a complete barrier to upstream migration for fish in the Bulkley River watershed regardless of species or life stage. Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure. The crossing was ranked as a high priority for proceeding to design for replacement.

Table 5.21: Summary of fish passage assessment for PSCIS

crossing 124487.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-25	Crossing Sub Type	Round Culvert
PSCIS ID	124487	Diameter (m)	5
External ID	–	Length (m)	99
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	603073	Resemble Channel	No
Northing	6113363	Backwatered	No
Stream	Porphyryr Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	9.99
Road Tenure	FLNR Nadina 7543	Outlet Drop (m)	2.5
Channel Width (m)	11.2	Outlet Pool Depth (m)	4
Stream Slope (%)	2.8	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	4
Habitat Value	High	Valley Fill	Deep Fill
Final score	42	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	31
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Unpassable to all life stages and species. Fill depth is approximately 35m. Salomid (50cm) observed trying to ascend to outlet of main pipe.

Table 5.22: Summary of habitat details for PSCIS crossing 124487.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
124487	Upstream	540	10.7	9.9	0.3	4.8	moderate	moderate
124487	Downstream	145	11.2	10.2	0.5	2.8	moderate	moderate

Table 5.23: Summary of fish habitat modelling for PSCIS crossing 124487.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	15.2	15.2	100
Salmon Lake Reservoir (ha)	–	–	–
Salmon Wetland (ha)	–	–	–
Steelhead Network (km)	16.7	16.7	100
Steelhead Lake Reservoir (ha)	–	–	–
Steelhead Wetland (ha)	–	–	–
CH Spawning (km)	1.2	1.2	100
CH Rearing (km)	3.9	3.9	100
CO Spawning (km)	3.9	3.9	100
CO Rearing (km)	3.9	3.9	100
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	1.2	1.2	100
ST Rearing (km)	9.5	9.5	100
All Spawning (km)	3.9	3.9	100
All Rearing (km)	9.5	9.5	100
All Spawning and Rearing (km)	9.5	9.5	100

* Model data is preliminary and subject to adjustments.

Figure 5.13: Left: Outlets of PSCIS crossing 124487. Right: Typical habitat downstream of crossing 124487 below the railway bridge and adjacent to the Bulkley River mainstem.

Figure 5.14: Left: habitat upstream of PSCIS crossing 124487. Right: Habitat upstream of PSCIS crossing 124487.

Appendix - 124500 - Helps Creek

Site Location

PSCIS crossing 124500 is located on Helps Creek on Lawson Road approximately 5km south of Telkwa. The culvert is located approximately 1.7km upstream from the confluence with the Bulkley River. Lawson Road is the responsibility of the Ministry of Transportation and Infrastructure.

Background

At crossing 124500, Helps Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 41.4km^2. The elevation of the watershed ranges from a maximum of 1350m to 530m at PSCIS crossing 124500. Upstream of the Lawson Road, longnose sucker, longnose dace, cutthroat trout, rainbow trout, and dolly varden have been previously recorded as present upstream of the crossing and coho, steelhead, rainbow trout and burbot have been observed below (MoE 2020a). A backwatered and passable rail stream crossing consisting of three round culverts (PSCIS 197666) is located under the railway approximately 1.2km downstream. There is one major tributary to Helps Creek that intersects the mainstem of the creek approximately 1.7km upstream of Lawson Road. There are several stream crossing structures documented on this tributary with the first of which located 4.7km upstream of Lawson Road. The adjacent landowner anecdotally reported a drop in numbers of fry/parr in stream over last 20 years. At the time of the survey a staff gauge was present just upstream of crossing.

PSCIS stream crossing 124500 was ranked as a high priority for follow up by Irvine (2018). The site was assessed by Smith (2018) in 2017 with maintenance to clear the inlet of debris recommended and replacement of the crossing assessed as a low priority. A map of the watershed is provided in map attachment 093L.118.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Lawson Road was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage acoording to the provincial protocol (MoE 2011). The pipe was 1.5m in diameter with a length of 14m, a culvert slope of 1%, a stream width ratio of 2.4 and an outlet drop of 0m (Table 5.24). Water temperature was 10°C, pH was 7.6 and conductivity was 236uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 415m beginning at the culvert location with a short survey conducted adjacent to the downstream railway (Figure 5.15). Total cover amount was rated as abundant with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, undercut banks, deep pools, and instream vegetation (Table 5.26). The average channel width was 3.6m, the average wetted width was 2.3m and the average

gradient was 2.5%. The dominant substrate was gravels with fines subdominant. Within the area surveyed, the channel flowed through an agricultural field with minimal riparian buffer present. The habitat was rated as high value with gravels present suitable for resident, fluvial and anadromous salmonid spawning throughout. At the railway culverts located 1.3km downstream of Lawson Road, the habitat transitioned to wetland type habitat with low velocities likely influenced by beaver (Table 5.25). The landowners of the adjacent property noted that they had seen large numbers of lamprey in the railway culverts in the past and that they suspected negative impacts on the lamprey from dredging by CN Rail.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 124500 for approximately 200m then an adjacent road was walked to access the stream 1100m upstream of the crossing within an area comprised of swamp (Figure 5.16). Within the area immediately upstream of Lawson Road, the stream had multiple braided channels flowing within beaver influenced wetland areas. Within the area surveyed, total cover amount was rated as moderate with small woody debris dominant. Cover was also present as large woody debris, undercut banks, deep pools, overhanging vegetation, and instream vegetation (Table 5.26). The average channel width was 4.8m, the average wetted width was 4.1m and the average gradient was 0.8%. The dominant substrate was fines with gravels subdominant. At top end of the site, the beaver ponds had wetted widths of approximately 12-14m wide and estimated depths of 1m. Habitat value was rated as moderate for salmonid rearing with habitat noted as suitable for coho and cuthrout rearing.

Table 5.27 presents preliminary fish passage modelling data for crossing 124500 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 6.7km of potential spawning habitat and 10.2km of potential rearing habitat.

Structure Remediation and Cost Estimate

Replacement of PSCIS crossing 124500 with a bridge (10m span) is recommended in the long term. The cost of the work is estimated at $500,000 for a cost benefit of 18 linear m/$1000 and 86.4$m^2$/$1000.

Conclusion

A conservative estimate of mainstem and major tributary habitat upstream of crossing 124500 is 9km. Habitat in the areas surveyed was rated as moderate value for salmonid rearing with habitat noted as particulary suitable for coho and cutthrout. Although classified as a “barrier” according to the provincial metric, the crossing is likely passable to adult salmonids during moderate flows. During low flow periods, water depths in the culverts may be an impediment to upstream passage for large adult fish. Lawson Road is the responsibility of the Ministry of Transportation and

Infrastructure. The crossing was ranked as a moderate priority for proceeding to design for replacement.

Table 5.24: Summary of fish passage assessment for PSCIS crossing 124500.

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2020-08-31	Crossing Sub Type	Round Culvert
PSCIS ID	124500	Diameter (m)	1.5
External ID	–	Length (m)	14
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	627552	Resemble Channel	No
Northing	6058697	Backwatered	No
Stream	Helps Creek	Percent Backwatered	–
Road	Lawson Road	Fill Depth (m)	0.8
Road Tenure	MoTi local	Outlet Drop (m)	0
Channel Width (m)	3.6	Outlet Pool Depth (m)	1.3
Stream Slope (%)	2.5	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	1
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	21	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Wetland type habitat upstream with stream channel containing abundant gravels downstream.

Table 5.25: Summary of fish passage assessment for PSCIS crossing 197666.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-29	Crossing Sub Type	Round Culvert
PSCIS ID	197666	Diameter (m)	2
External ID	2020083101	Length (m)	22
Crew	AI, KP	Embedded	Yes
UTM Zone	9	Depth Embedded (m)	0.15
Easting	628108	Resemble Channel	Yes
Northing	6059632	Backwatered	Yes
Stream	Helps Creek	Percent Backwatered	100
Road	CN Railway	Fill Depth (m)	1
Road Tenure	Canadian National	Outlet Drop (m)	0
Channel Width (m)	6	Outlet Pool Depth (m)	0.3
Stream Slope (%)	0	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	0
Habitat Value	High	Valley Fill	Deep Fill
Final score	14	Barrier Result	Passable
Fix type	–	Fix Span / Diameter	–
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Passable and fully backwatered structure. Landowner reports that lamprey (~40cm x 20) at crossing inside of the culvert in the past.

Table 5.26: Summary of habitat details for PSCIS crossing 124500.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
124500	Upstream	1100	4.8	4.1	–	0.8	moderate	moderate
124500	Downstream	415	3.6	2.3	0.7	2.5	abundant	high

Table 5.27: Summary of fish habitat modelling for PSCIS crossing 124500.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	33.5	12.1	36
Salmon Lake Reservoir (ha)	4.2	4.1	98
Salmon Wetland (ha)	113.4	113.4	100
Steelhead Network (km)	36.6	12.5	34
Steelhead Lake Reservoir (ha)	4.2	4.1	98
Steelhead Wetland (ha)	113.4	113.4	100
CH Spawning (km)	0.8	0.8	100
CH Rearing (km)	9.3	7.1	76
CO Spawning (km)	8.8	6.7	76
CO Rearing (km)	11.2	9.0	80
CO Rearing (ha)	66.8	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.8	0.8	100
ST Rearing (km)	12.1	8.3	69
All Spawning (km)	8.8	6.7	76
All Rearing (km)	14.0	10.2	73
All Spawning and Rearing (km)	14.0	10.2	73

* Model data is preliminary and subject to adjustments.

Figure 5.15: Left: Habitat downstream of PSCIS crossing 124500. Right: Habitat downstream of crossing 124500 below the railway culverts.

Figure 5.16: Left: Habitat upstream of PSCIS crossing 124500. Right: Habitat upstream of PSCIS crossing 124500.

Appendix - 195290 & 195288 - Gibson Creek

Site Location

PSCIS crossing 195290 is located on Gibson Creek on Highway 16 approximately 10km south of Telkwa, BC. PSCIS crossing 195288 is also located on Gibson Creek on Schnider Road approximately 1.5km upstream of 195290. Both roads are the responsibility of the Ministry of Transportation and Infrastructure.

Background

Gibson Creek flows through an estimated 39ha of wetland type habitat into Deep Creek approximately 150m downstream of the crossing 195290. From the confluence with Gibson Creek, Deep Creek flows for approximately 1.5km to the Bulkley River. At the crossing location, Gibson Creek is a third order stream with a watershed area upstream of the highway of approximately 17.1km^2. The elevation of the watershed ranges from a maximum of 1300 to 575m at PSCIS crossing 195290. Gibson Creek is known to contain rainbow trout and cutthrout trout upstream of 195290 (MoE 2020a).

PSCIS stream crossings 195290 and 195288 were rated high priorities for follow up by both Irvine (2018) and Smith (2018) due to significant quantities of habitat suitable for salmonid rearing. A map of the watershed is provided in map attachment 093L.113.

Stream Characteristics at Crossing

Surveys were conducted with a remotely piloted aircraft immediately upstream and downstream of both crossings. The resulting images were stitched into orthomosaics and 3-dimensional models (4cm resolution) with models presented here and here. Google earth model kmz files are downloadable here and here.

At the time of the survey, crossing 195290 was un-embedded, non-backwatered and considered a barrier to upstream fish passage. The pipe was 0.8m in diameter with a pipe length of 0m, a culvert slope of 1.5%, a stream width ratio of 3 and an outlet drop of 0.66m (Table 5.28). Crossing 195288 on Schnider Road was also un-embedded, non-backwatered and ranked as a barrier to upstream fish passage. The pipe was 1.2m in diameter with a pipe length of 11m, a culvert slope of 1%, a stream width ratio of 2.5 and an outlet drop of 0.3m (Table 5.29). Water temperature was 13°C, pH was 7 and conductivity was 315uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 150m to the confluence with Deep Creek (Figure 5.22). Overall, total cover amount was rated as abundant with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, undercut banks, and instream vegetation (Table 5.30). The average channel width was 2.4m, the average wetted width was 2m and the average gradient was 1.7%. The dominant substrate was fines with gravels subdominant. Riparian vegetation consisted primarily of a well developed shrub layer and there were occasional pockets of small gravesl present suitable for resident salmonid spawning. Habitat was rated as moderate as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Stream Characteristics Upstream of 195290 and downstream of 195288

The stream was surveyed upstream from 195290 for 150m to where survey conditions because difficult due to the wetland type habitat (Figure 5.23). Immediately upstream of the crossing for approximately 50m, the riparian area is dominated by well developed shrub and mature primarily deciduous forest. Upstream of this location the riparian area transitions to dense shrub and grass with a narrow and deep channel influenced by beaver activity. Within the area surveyed, total cover amount was rated as abundant with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, undercut banks, deep pools, and instream vegetation (Table 5.30). The average channel width was 2m, the average wetted width was 1.6m and the average gradient was 1.3%. Abundant gravels and small cobbles suitable for resident, fluvial, adfluvial and anadromous salmonid spawning were present throughout the area surveyed. Habitat value was rated as moderate for salmonid rearing and spawning.

Stream Characteristics Upstream of 195288

Gibson Creek was surveyed upstream from 195288 for 180m via remotely piloted aerial vehicle as survey conditions were difficult due to the wetland type habitat present. Images acquired from the survey were stitched into an orthomosaic with stream habitat measurements estimated based on interpretation of the orthomosaic. The average channel width was estimated at 2m, the average wetted width was estimated at 2m and the average gradient was estimated at 0%. Habitat value was rated as moderate as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Table 5.31 presents preliminary fish passage modelling data for crossing 195290 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0.6km of potential spawning habitat and 1.2km of potential rearing habitat. Table 5.32 presents preliminary fish passage modelling data for crossing 195288 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or

steelhead habitat upstream of the crossing before potential barriers are 1.7km of potential spawning habitat and 4.2km of potential rearing habitat.

Fish Sampling

To assess potential impacts of the culvert on fisheries values in the stream, electrofishing and minnowtrapping was conducted upstream and downstream of the crossing. A total of 14 fish were captured upstream with 25 fish captured downstream. Species captured downstream included coho, bull trout (or potentially dolly varden) and rainbow trout. Only rainbow trout were captured upstream. Electrofishing results are summarized in Tables 5.33 - Tables 5.34 and Figure 5.17 with minnowtrapping results summarized in Table 5.35.

Structure Remediation and Cost Estimate

Structure replacement with bridges for 195290 (19m span) and 195288 (10m span) are recommended to provide access to the habitat located upstream. An estimate of cost for replacement of 195290 is $9,500,000 resulting in cost benefits of 0.1 linear m/$1000 and 0.2$m^2$/$1000. An estimate of cost for replacement of 195288 is $1,000,000 resulting in cost benefits of 4.5 linear m/$1000 and 9$m^2$/$1000.

Conclusion

There is 1km of habitat upstream of crossing 195290 and downstream of PSCIS barrier culvert 195288. Upstream of 195288 there is another 1km of habitat modelled as <5% and containing wetland areas suitable for coho rearing. Habitat in the areas surveyed was rated as moderate value for salmonid rearing/spawning. Highway 16 and Schnider Road are the responsibility of the Ministry of Transportation and Infrastructure. Although the sample size is small, the presence of coho downstream of the crossing and absense of this species at sites upstream indicates that the crossing may be blocking upstream migration of this species. The large outlet drop at 195290 (0.66m), long pipe length (0m) and high stream width ratio (3) are good indicators that the crossing is likely not passable in an upstream direction by any species or lifestage. The crossings were ranked as high priorities for proceeding to design for replacement.

Table 5.28: Summary of fish passage assessment for PSCIS crossing 195290.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-04	Crossing Sub Type	Round Culvert
PSCIS ID	195290	Diameter (m)	0.8
External ID	–	Length (m)	0
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	640014	Resemble Channel	No
Northing	6051697	Backwatered	No
Stream	Gibson Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	6
Road Tenure	MoTi local	Outlet Drop (m)	0.66
Channel Width (m)	2.4	Outlet Pool Depth (m)	0.7
Stream Slope (%)	1.7	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	1.5
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	19
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Flows into Deep Creek downstream. Electrofished upstream and downstream. Wetland type habitat upstream with CO captured below only. Candidate for backwatering?

Table 5.29: Summary of fish passage assessment for PSCIS crossing 195288.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-04	Crossing Sub Type	Round Culvert
PSCIS ID	195288	Diameter (m)	1.2

Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	640899	Resemble Channel	No
Northing	6051559	Backwatered	No
Stream	Gibson Creek	Percent Backwatered	–
Road	Schnider Road	Fill Depth (m)	1.2
Road Tenure	MoTi highway	Outlet Drop (m)	0.3
Channel Width (m)	3	Outlet Pool Depth (m)	1.5
Stream Slope (%)	2	Inlet Drop	Yes
Beaver Activity	Yes	Slope (%)	1
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Wetland type habitat upstream and downstream. Drone flight conducted upstream to map immediate area upstream.

Table 5.30: Summary of habitat details for PSCIS crossings 195290 and 195288.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
195288	Downstream	250	2.1	1.9	0.7	0.5	abundant	moderate
195288	Upstream	180	2	2	–	0	–	moderate
195290	Downstream	150	2.4	2	0.3	1.7	abundant	moderate
195290	Upstream	150	2	1.6	0.6	1.3	abundant	moderate

Table 5.31: Summary of fish habitat modelling for PSCIS crossing 195290.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	12.6	1.6	13
Salmon Lake Reservoir (ha)	1.9	0.0	0
Salmon Wetland (ha)	39.0	10.1	26
Steelhead Network (km)	13.2	1.6	12
Steelhead Lake Reservoir (ha)	1.9	0.0	0
Steelhead Wetland (ha)	39.0	10.1	26
CH Spawning (km)	1.2	0.4	33
CH Rearing (km)	4.7	0.6	13
CO Spawning (km)	2.3	0.6	26
CO Rearing (km)	6.3	1.2	19
CO Rearing (ha)	23.7	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	1.2	0.4	33
ST Rearing (km)	6.0	0.6	10
All Spawning (km)	2.3	0.6	26
All Rearing (km)	7.7	1.2	16
All Spawning and Rearing (km)	7.7	1.2	16

* Model data is preliminary and subject to adjustments.

Table 5.32: Summary of fish habitat modelling for PSCIS crossing 195288.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	10.9	6.8	62
Salmon Lake Reservoir (ha)	1.9	1.9	100
Salmon Wetland (ha)	29.0	29.0	100
Steelhead Network (km)	11.6	7.2	62
Steelhead Lake Reservoir (ha)	1.9	1.9	100
Steelhead Wetland (ha)	29.0	29.0	100
CH Spawning (km)	0.8	0.8	100
CH Rearing (km)	4.1	3.2	78
CO Spawning (km)	1.7	1.7	100
CO Rearing (km)	5.1	4.2	82
CO Rearing (ha)	18.7	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.8	0.8	100
ST Rearing (km)	5.4	3.2	59

All Spawning (km)	1.7	1.7	100
All Rearing (km)	6.4	4.2	66
All Spawning and Rearing (km)	6.4	4.2	66

* Model data is preliminary and subject to adjustments.

Table 5.33: Electrofishing sites for PSCIS crossing 195290.

Site	Location	Width (m)	Length (m)	Area (m2)	Effort (s)	Effort (s/m2)
51	Downstream	1.8	8	14	42	3.0
50	Upstream	1.6	65	104	152	1.5
52	Upstream	2.8	16	45	71	1.6

Table 5.34: Densities of fish captured (fish/100m2) during electrofishing upstream and downstream of PSCIS crossing 195290.

Site	Location	Species	Fry	Parr	Juvenile
51	Downstream	CO	7.1	7.1	0
51	Downstream	RB	14.3	14.3	21.4
50	Upstream	RB	1	1	3.8
52	Upstream	RB	0	2.2	0

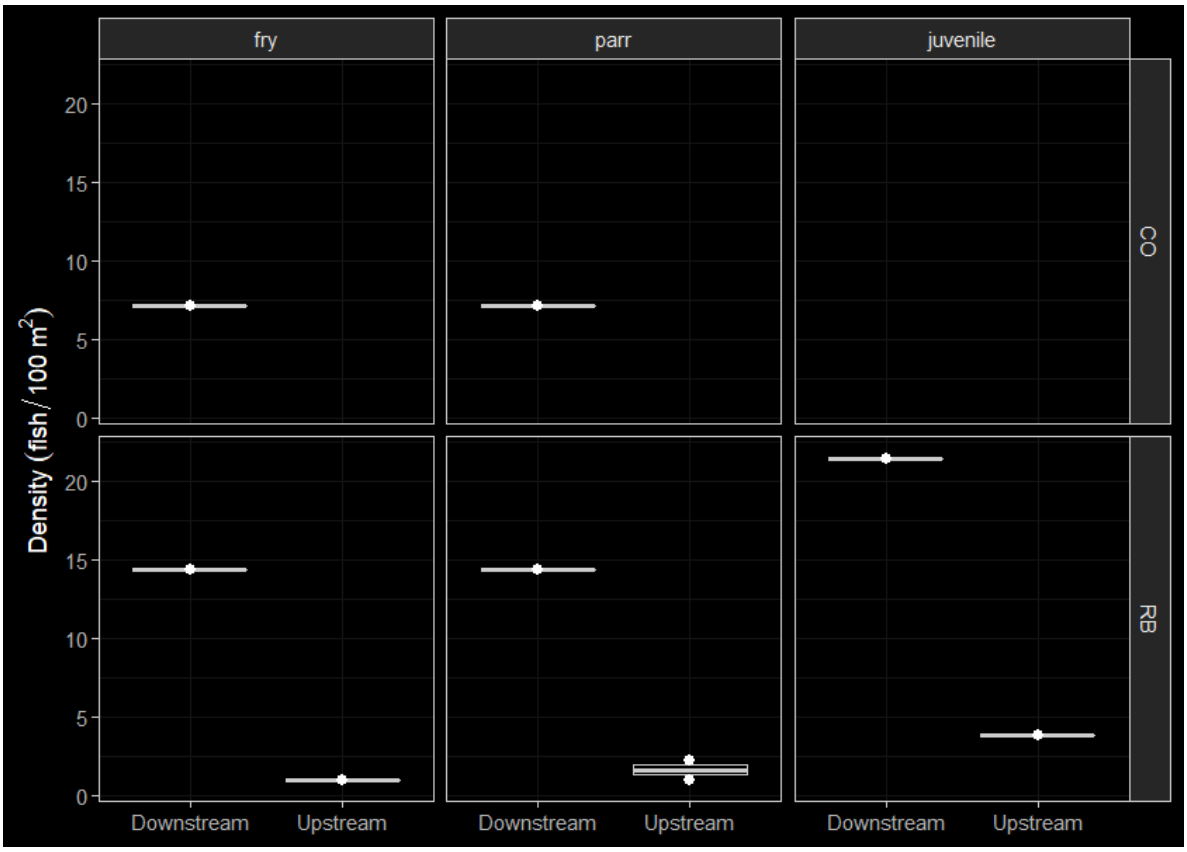

Figure 5.17: Densites of fish (fish/100m2) capture upstream and downstream of PSCIS crossing 195290.

Table 5.35: Fish captured in minnowtraps set overnight upstream and downstream of PSCIS crossing 195290.

Location	Species	fry	parr	adult	juvenile
Downstream	CO	6	1	0	0
Downstream	DV	0	0	1	0
Downstream	RB	1	7	0	0
Upstream	RB	0	1	0	6

Figure 5.18: Left: Typical habitat downstream of PSCIS crossing 195290. Right: Coho captured downstream of PSCIS crossing 195290.

Figure 5.19: Left: Typical habitat upstream of PSCIS crossing 195290. Right: Wetland habitat upstream of PSCIS crossing 195290.

Appendix - 197360 - Riddeck Creek

Site Location

PSCIS crossing 197360 is located on Riddeck Creek at km 47 of the Morice-Owen FSR accessed from Houston, BC. The Morice-Owen FSR is a forest tenure road and the responsibility of the BC Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNR) - Nadina District. The area immediately to the south of the subject crossing is a conservation area manged by the Nature Trust of British Columbia.

Background

Riddeck Creek flows through an extensive area of wetland type habitat into the top end of Owen Lake approximately 1km downstream of the crossing. Owen Lake is drained by Owen Creek emptying into the Morice River approximately 20km to the north. At the crossing location, Riddeck Creek is a 4th order stream with a watershed area upstream of the highway of approximately 29km^2. The elevation of the watershed ranges from a maximum of 1140 to 750m at PSCIS crossing 197360. Riddeck Creek is known to contain longnose sucker and rainbow trout usptream of the subject culvert (MoE 2020a). On the north side of the upper watershed, at an elevation of 1160m, are the 25ha Neuch Lakes. The limit of fish distribution in the Riddeck Creek mainstem is documented by David Bustard and ssociates Ltd. (1999) as a 6m high waterfall located 2.4km upstream of the FSR with the three main tributary systems classified as either non-fish bearing or fish bearing for only short distances (<200m) from the mainstem. Of note, a dam is documented in MoE (2020b) just downstream of Owen Lake and is visible on google earth imagery. FLNRORD team members note that the structure is a beaver dam (pers comm. Lars Reese-Hanson, Aquatic Habitat Specialist, FLNR).

At the time of reporting, as an initiative of the Forest and Range Evaluation Program as well as the Bulkley Valley Research Centre, FLNR and the BC Ministry of Environment and Climate Change Strategy were undertaking a watershed status evaluation of the Owen Creek watershed (D. Pickard et al., n.d.). The evaluation uses remotely sensed and field based surveys to interpret the current functioning condition of the watershed as well as its possible future state as a result of continuing human and natural activities by ranking eight indicators of watershed pressure related to riparian health, fish passage and fine sediment delivery (Darcy Pickard et al. 2014; Porter et al. 2019).

PSCIS stream crossing 197360 was prioritized for follow up with a habitat confirmation through consultation with Lars Reese-Hansen and Don Morgan (Wildlife Habitat Specialist, MoE). They indicated (pers comm.) that following fish passage assessments in 2014 (implemented through watershed status evaluation field surveys throughout the Owen Creek watershed), Riddeck Creek upstream of the crossing contained the highest value habitat potentially blocked by a road-stream crossing barrier. A map of the watershed is provided in map attachment 093L.104.

Stream Characteristics at Crossing

At the time of the survey, the culvert was un-embedded, non-backwatered and considered a barrier to upstream fish passage. The pipe was 1.2m in diameter with a pipe length of 27m, a culvert slope of 1%, a stream width ratio of 1.8 and an outlet drop of 0.24m (Table 5.36). Water temperature was 15°C, pH was 6.8 and conductivity was 140uS/cm.

A survey was conducted with a remotely piloted aircraft immediately upstream and downstream of the crossing. The resulting images were stitched into a 3-dimensional model (4cm resolution) covering an area of approximatley 12ha presented [here](https://www.mapsmadeeasy.com/maps/public_3D/421d3b7404d74cacad6471612260bb41/ and downloadable as a google earth kmz file here.

Figure 5.20: Interactive 3D model of habitat immediately upstream and downstream of PSCIS crossing 197360.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 300m (Figure 5.22). Overall, total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, undercut banks, deep pools, and instream vegetation (Table 5.38). The average channel width was 3.7m, the average wetted width was 3.2m and the average gradient was 1.1%. The dominant substrate was fines with gravels subdominant. A somewhat recent burn was noted within a forested area on left bank of stream. Habitat was rated as moderate as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Stream Characteristics Upstream

The stream was surveyed upstream from 197360 for 1200m (Figure 5.23). Immediately upstream of the crossing for a distance of approximately 150m is a beaver influenced wetland with a beaver dam structure located approximately 40m upstream of the road. Within the area surveyed, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, undercut banks, and overhanging vegetation (Table 5.38). The average channel width was 3.3m, the average wetted width was 1.8m and the average gradient was 2.7%. Abundant gravels and small cobbles suitable for resident, fluvial, adfluvial and anadromous salmonid spawning were present throughout the area surveyed. Habitat value was rated as high for salmonid rearing and spawning.

PSCIS culvert 197669 was documented on Riddeck Creek, 1.2km upstream of the FSR and PSCIS crossing 197360. The culvert was un-embedded, non-backwatered and considered a barrier to upstream fish passage. The pipe was 1.25m in diameter with a pipe length of 6m, a culvert slope of 2%, a stream width ratio of 2.1 and an outlet drop of 0.45m (Table 5.37).

Table 5.39 presents preliminary fish passage modelling data for crossing 197360 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0.6km of potential spawning habitat and 1.4km of potential rearing habitat.

Fish Sampling

To assess potential impacts of the culvert on fisheries values in the stream, electrofishing was conducted upstream and downstream of the crossing. Two sites were sampled upstream and one site was sampled downstream. A total of 14 rainbow trout captured upstream with 2 rainbow trout captured downstream. Raw results are included in digital format as Attachment 2 and summarized in Tables 5.40 - 5.41 and Figure 5.21.

Structure Remediation and Cost Estimate

Structure replacement with a bridge (10m span) is recommended to provide access to the habitat located upstream of PSCIS crossing 197360. In addition to not facilitating high velocities and erosion due resulting from flow constriction, structures with large openings in relation to stream channel size have been demonstrated to reduce the likelyhood of structure blockage due to beaver (Jensen et al. 2001). The cost of the work is estimated at $125,000 for a cost benefit of 9.6 linear m/$1000 and 31.7$m^2$/$1000.

Conclusion

There is 1.2km of habitat upstream of crossing 197360 and downstream of PSCIS barrier culvert 197669. Habitat in this area was rated as high value for salmonid rearing/spawning. Remediation of PSCIS culvert 197669 would facilitate fish passage to an additional 1.5km of habitat upstream of the area surveyed and can also be considered in the future. Densities of rainbow trout fry captured at upstream sites were higher than the density of fish captured downstream however this may have been a result of habitat differences and difficult electrofishing conditions downstream including thick shrub overhead cover and areas deep water. Although only rainbow trout were captured both upstream and downstream the stream contains habitat likely suitable for spawning and rearing for other species including lamprey, burbot, coho salmon and others. In order to delineate pre-road channel locations/conditions and to inform the positioning of a replacement bridge, a pre-road hydrology assessment could be undertaken. Morice-Owen FSR is the responsibility of the Ministry

of Forests, Lands, Natural Resource Operations & Rural Development. The crossing was ranked as a high priority for proceeding to design for replacement.

Table 5.36: Summary of fish passage assessment for PSCIS crossing 197360.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-05	Crossing Sub Type	Round Culvert
PSCIS ID	197360	Diameter (m)	1.2
External ID	–	Length (m)	27
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	649936	Resemble Channel	No
Northing	5992406	Backwatered	No
Stream	Riddeck Creek	Percent Backwatered	–
Road	Morice-Owen FSR	Fill Depth (m)	2.5
Road Tenure	FLNR Nadina 9947	Outlet Drop (m)	0.24
Channel Width (m)	2.2	Outlet Pool Depth (m)	1.6
Stream Slope (%)	1.5	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	1
Habitat Value	High	Valley Fill	Deep Fill
Final score	29	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Wetland type habitat for first 300m upstream then 3m wide channel with cover available in all forms with pools suitable for juvenile RB and CO overwintering. Abundant gravels and small cobbles throught suitable for CO or RB/ST spawning.

Table 5.37: Summary of fish passage assessment for PSCIS crossing 197669.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-05	Crossing Sub Type	Round Culvert

Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	650567	Resemble Channel	No
Northing	5993274	Backwatered	No
Stream	Riddeck Creek	Percent Backwatered	–
Road	Private	Fill Depth (m)	0.3
Road Tenure	unclassified	Outlet Drop (m)	0.45
Channel Width (m)	2.6	Outlet Pool Depth (m)	0.7
Stream Slope (%)	4	Inlet Drop	No
Beaver Activity	No	Slope (%)	2
Habitat Value	High	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Extensive rearing habitat and gravels suitable for spawning. Stream eventually flows into top end of Owen Lake.

Table 5.38: Summary of habitat details for PSCIS crossing 197360.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197360	Downstream	300	3.7	3.2	0.6	1.1	moderate	moderate
197360	Upstream	1200	3.3	1.8	0.4	2.7	moderate	high

Table 5.39: Summary of fish habitat modelling for PSCIS crossing 197360.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	6.6	1.1	17
Salmon Lake Reservoir (ha)	1.3	0.0	0
Salmon Wetland (ha)	84.9	79.9	94
Steelhead Network (km)	6.7	1.1	16
Steelhead Lake Reservoir (ha)	1.3	0.0	0
Steelhead Wetland (ha)	84.9	79.9	94
CH Spawning (km)	0.3	0.3	100
CH Rearing (km)	0.6	0.6	100
CO Spawning (km)	1.5	0.6	40
CO Rearing (km)	2.1	1.2	57
CO Rearing (ha)	79.9	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.3	0.3	100
ST Rearing (km)	2.1	0.7	33
All Spawning (km)	1.5	0.6	40
All Rearing (km)	3.5	1.4	40
All Spawning and Rearing (km)	3.5	1.4	40

* Model data is preliminary and subject to adjustments.

Table 5.40: Electrofishing sites for PSCIS crossing 197360.

Site	Location	Width (m)	Length (m)	Area (m2)	Effort (s)	Effort (s/m2)
57	Downstream	2.0	9	18	94	5.2
55	Upstream	1.9	20	38	48	1.3
56	Upstream	2.0	10	20	33	1.6

Table 5.41: Rainbow trout densities (fish/100m2) for PSCIS crossing 197360.

Site	Location	Species	Fry	Juvenile
57	Downstream	RB	11.1	0
55	Upstream	RB	15.8	0
56	Upstream	RB	30	10

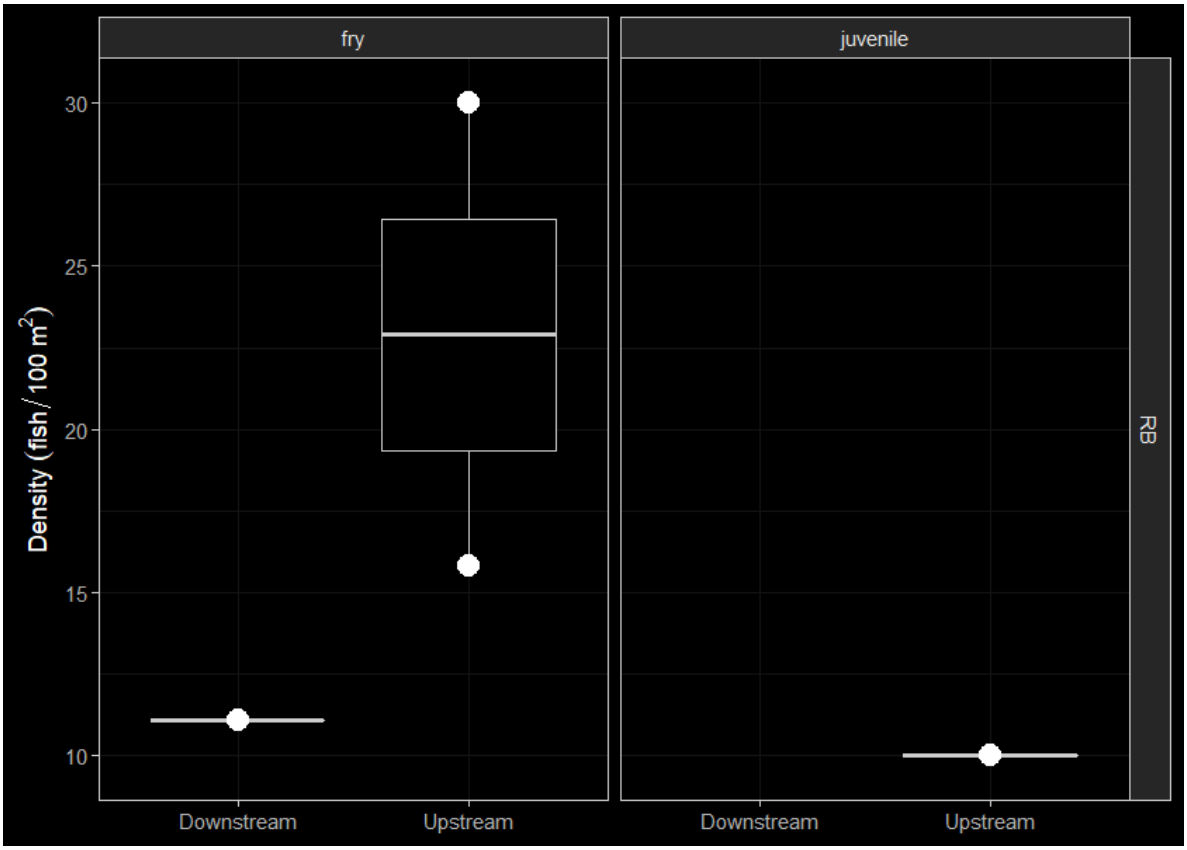

Figure 5.21: Densites of rainbow trout (fish/100m2) capture upstream and downstream of PSCIS crossing 197360.

Figure 5.22: Left: Typical habitat downstream of PSCIS crossing 197360. Right: Aerial view of typical habitat downstream of PSCIS crossing 197360.

Figure 5.23: Left: Typical habitat upstream of PSCIS crossing 197360. Right: Rainbow trout captured upstream of PSCIS crossing 197360.

Appendix - 197640 - Tributary to Buck Creek

Site Location

PSCIS crossing 197640 is located on a tributary to Buck Creek on Buck Flats Road approximately 18km south of Houston and immediately south of the Carrier FSR turn-off. The culvert is located approximately 70m upstream from the confluence with the Bulkley River. Buck Flats Road is the responsibility of the B.C. Ministry of Transportation and Infrastructure.

Background

At crossing 197640, the tributary to Buck Creek is a second order stream, has a watershed area upstream of the crossing of approximately 23.9km^2 that contains an estimated 204ha of wetland. The elevation of the watershed ranges from a maximum of 1460m to 820m at the crossing. Upstream of Buck Flats Road, rainbow trout have been previously recorded as present while downstream chinook, coho and pink salmon are known to spawn downstream in Buck Creek (MoE 2020a; Wilson and Rabnett 2007; NCFDC 1998). Pink salmon have been noted as spawning in the first reach of Buck Creek with coho spawners noted to Reach 3 and chinook spawners to Reach 5 where the subject tributary enters the mainstem (NCFDC 1998). DFO (1991) report that Buck Creek supports a small chinook population ranging from 12-100 spawners.

Three water temperature sensors have been deployed on the Buck Creek mainstem since 2016 (Westcott 2020). The closest water sensor to the subject stream is near the 9km mark of Buck Flats Road. The sensor has been gathering water temperature data at 1hour intervals since 2017 with data available through the Skeena Salmon Data Centre (DFO/FLNRO 2019a).

There are multiple tributaries entering the mainstem of the subject stream upstream of crossing 197640 containing numerous modelled road stream crossings, however, these tributaries are not expected to contain significant quantities of habitat due to the small size and low elevation of their contributing watersheds.

PSCIS stream crossing 197640 was ranked as a high priority for follow up following 2020 Phase 1 - fish passage assessments that targeted all major streams in the Buck Creek watershed. Past assessments information was lacking in PSCIS for this area. Crossing 197640 was noted as located on the stream with the highest value habitat in the watershed potentially blocked to anadromous species by a road-stream crossing structure. A map of the watershed is provided in map attachment 093L.109.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Buck Flats Road was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage according to the provincial protocol (MoE 2011). The pipe was 1.5m in diameter with a length of 12m, a culvert slope of 1.5%, a stream width ratio of 3.4 and an outlet drop of 0.4m (Table 5.42). Water temperature was 10°C, pH was 7.6 and conductivity was 226uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 70m to the confluence with Buck Creek (Figure **??**). Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, and overhanging vegetation (Table 5.44). The average channel width was 4.6m, the average wetted width was 2.5m and the average gradient was 3%. The dominant substrate was gravels with cobbles subdominant. A fish (130mm) was observed in the culvert outlet pool and a substance suspected to be didymo was noted on the substrate. The habitat was rated as moderate value as it was considered an important migration corridor with habitat of moderate rearing potential for fry and juvenile salmonids.

Stream Characteristics Upstream

The stream was surveyed immediately upstream from 197640 for approximately 535m (Figure **??**). Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, boulders, deep pools, and overhanging vegetation (Table 5.44). The average channel width was 4.4m, the average wetted width was 2.2m and the average gradient was 2.5%. The dominant substrate was cobbles with boulders subdominant. Rare pockets of gravel suitable for spawning resident, fluvial and anadromous salmonids were noted. The stream appeared to be aggraded with side bars common. One salmonid (110mm - unidentified species) was observed just upstream of Buck Flats Road. Habitat value was rated as moderate value with moderate rearing potential for fry and juvenile salmonids.

One crossing (PSCIS 197647) was assessed on an upstream tributary crossed by the Carrier FSR (Table 5.43). This tributary that enters the subject stream approximately 3.3km upstream of 197640, was dry at the time of the survey and did not provide any viable fish habitat. Numerous fish inventory sample sites were located downstream of the location of 197647 within the adjacent tributary to the subject stream with no fish observations recorded in two seasons of sampling (MoE 2020c).

Table 5.45 presents preliminary fish passage modelling data for crossing 197640 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total

length of salmon or steelhead habitat upstream of the crossing before potential barriers are 2.6km of potential spawning habitat and 5.2km of potential rearing habitat.

Structure Remediation and Cost Estimate

Replacement of PSCIS crossing 197640 with a bridge (10m span) is recommended. The cost of the work is estimated at $NA for a cost benefit of NA linear m/$1000 and NA$m^2$/$1000.

Conclusion

A conservative estimate of mainstem habitat upstream of crossing 197640 is 4.2km to the top end of a 71ha wetland where rainbow trout have been recorded. Habitat in the areas surveyed upstream of the culvert were rated as moderate value for salmonid rearing with areas of wetland habitat likely suitable for rainbow trout, coho and steelhead rearing. Buck Flats Road is the responsibility of the Ministry of Transportation and Infrastructure. The crossing was ranked as a high priority for proceeding to design for replacement.

Table 5.42: Summary of fish passage assessment for PSCIS crossing 197640.

Location and Stream Data	•	**Crossing Characteristics**	**–**
Date	2020-09-26	Crossing Sub Type	Round Culvert
PSCIS ID	197640	Diameter (m)	1.5
External ID	–	Length (m)	12
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	654312	Resemble Channel	No
Northing	6012383	Backwatered	No
Stream	Tributary to Buck Creek	Percent Backwatered	–
Road	Buck Flats Road	Fill Depth (m)	1
Road Tenure	MoTi local	Outlet Drop (m)	0.4
Channel Width (m)	5.1	Outlet Pool Depth (m)	1.2
Stream Slope (%)	3	Inlet Drop	No
Beaver Activity	No	Slope (%)	1.5
Habitat Value	High	Valley Fill	Deep Fill
Final score	31	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Large tributary on section of tributary connected to salmon bearing Buck Creek. Fish rising in outlet pool (estimated 130mm). Some cattle access points downstream.

NO IMAGE AVAILABLE

NO IMAGE AVAILABLE

Table 5.43: Summary of fish passage assessment for PSCIS crossing 197647.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-26	Crossing Sub Type	Round Culvert
PSCIS ID	197647	Diameter (m)	1

Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	651263.5	Resemble Channel	No
Northing	6012508	Backwatered	No
Stream	Tributary to Buck Creek	Percent Backwatered	–
Road	Carrier FSR	Fill Depth (m)	1.8
Road Tenure	FLNR Nadina 9772	Outlet Drop (m)	0.3
Channel Width (m)	1.5	Outlet Pool Depth (m)	0
Stream Slope (%)	2	Inlet Drop	No
Beaver Activity	No	Slope (%)	1.5
Habitat Value	Low	Valley Fill	Deep Fill
Final score	34	Barrier Result	Barrier
Fix type	Replace Structure with Streambed Simulation CBS	Fix Span / Diameter	3
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Suspect no fish. Multiple fish survey sites located downstream. Dry at time of survey.

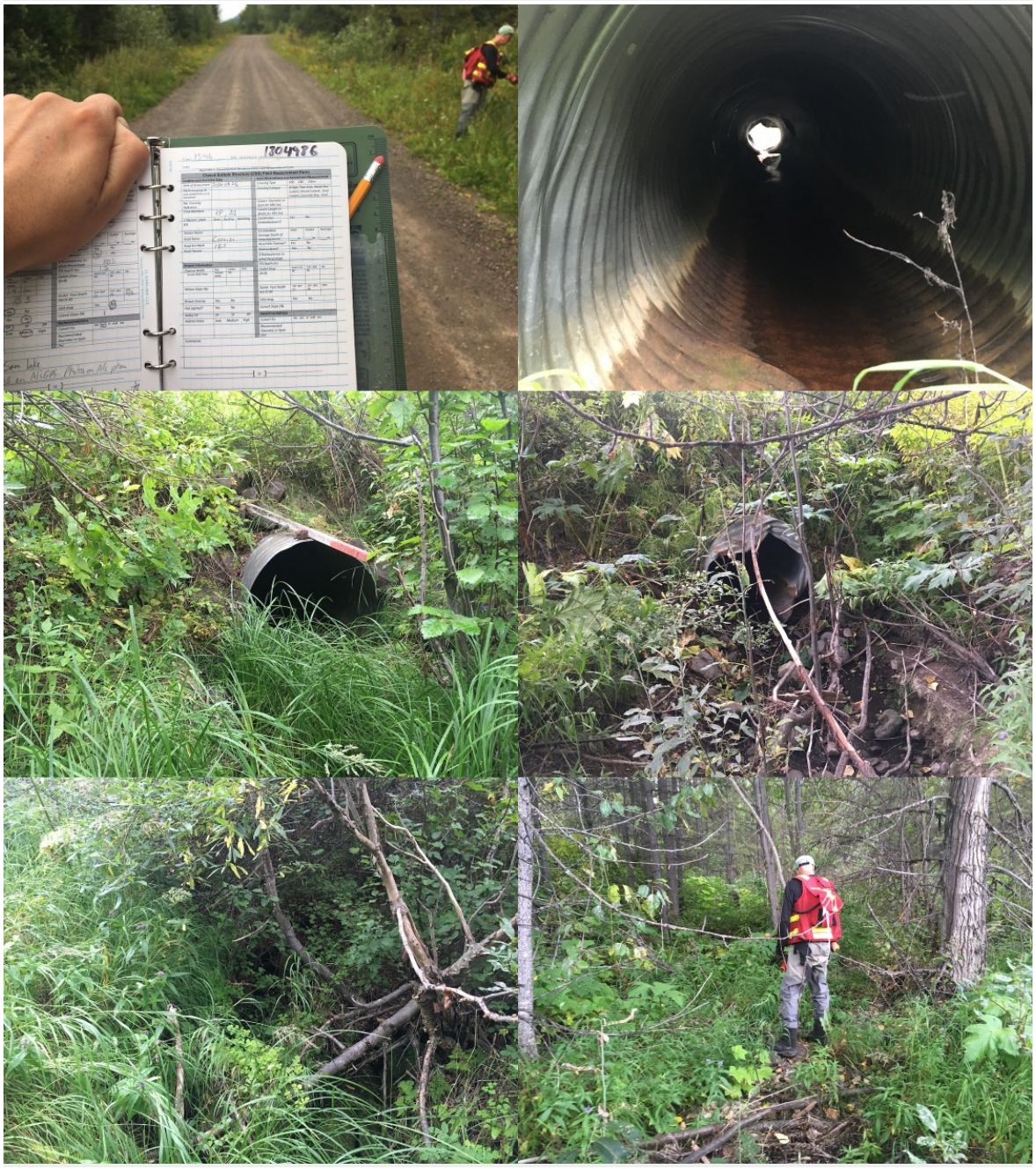

Table 5.44: Summary of habitat details for PSCIS crossing 197640.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197640	Downstream	70	4.6	2.5	–	3	moderate	moderate
197640	Upstream	535	4.4	2.2	0.3	2.5	moderate	moderate

Table 5.45: Summary of fish habitat modelling for PSCIS crossing 197640.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	19.7	8.3	42
Salmon Lake Reservoir (ha)	1.5	0.8	53
Salmon Wetland (ha)	201.4	182.3	91
Steelhead Network (km)	20.0	8.3	42
Steelhead Lake Reservoir (ha)	1.5	0.8	53
Steelhead Wetland (ha)	201.4	182.3	91
CH Spawning (km)	1.1	1.1	100
CH Rearing (km)	1.9	1.4	74
CO Spawning (km)	3.1	2.6	84
CO Rearing (km)	5.7	5.2	91
CO Rearing (ha)	108.0	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	1.1	1.1	100
ST Rearing (km)	3.2	2.6	81
All Spawning (km)	3.1	2.6	84
All Rearing (km)	5.8	5.2	90
All Spawning and Rearing (km)	5.8	5.2	90

* Model data is preliminary and subject to adjustments.

Figure 5.24: Left: Habitat downstream of PSCIS crossing 197640. Right: Habitat downstream of crossing 197640 at the confluence with Buck Creek.

Figure 5.25: Left: Habitat upstream of PSCIS crossing 197640. Right: Habitat upstream of PSCIS crossing 197640.

Appendix - 197658 - Byman Creek

Site Location

PSCIS crossing 197658 is located on Byman Creek on Highway 16 approximately 20km east of Houston, BC with the crossing located approximately 2.5km upstream from the confluence with the Bulkley River. Highway 16 is the responsibility of the B.C. Ministry of Transportation and Infrastructure.

Background

At crossing 197658, Byman Creek is a fifth order stream with a watershed area upstream of the crossing of approximately 89.9km^2. The elevation of the watershed ranges from a maximum of 1240 to 680m at PSCIS crossing 197658. Upstream of the highway, coho, steelhead, rainbow trout, longnose dace, redside shiner, longnose sucker and largescale sucker have been previously recorded as present (MoE 2020a). Chinook, coho and steelhead have been noted as spawning in Byman Creek with chinook documented as present up to the highway culvert only (Allen Gottesfeld, Rabnett, and Hall 2002; DFO 1991). A bridge (PSCIS 197660) is located on the stream under the railway approximately 1.3km downstream. Although there are numerous crossings modelled upstream, a series of three impassable waterfalls are located approximately 6km upstream of the highway (pers. comm. Jonathan Van Barneveld, Forester - FLNR). There are only two modelled crossings (1800233, 1801084) located on a small tributary entering the mainstem below the falls.

In the summer of 1998, the Nadina Community Futures Development Corporation (NCFDC) contracted the British Columbia Conservation Foundation to carry out a detailed Level 1 Fish, Fish Habitat and Riparian Assessment in the first reach of Byman Creek as well as several other large Upper Bulkley River tributary streams and the Upper Bulkley mainstem. The area surveyed extended to 4.2km from the mouth, covering 2.5km of habitat upstream of the culvert (NCFDC 1998). Building on these assessments and detailed fish sampling, NCFDC (1998) developed restoration prescriptions for the lower reaches of the Byman Creek. Prescriptions were developed to address what the authors termed moderately to severely disturbed habitat, which comprised 90% of the area surveyed. Impacts due to land use in the watershed included:

- straightening/diversion of main channel below Highway 16.
- loss of riparian forest and soil compaction in areas used for agriculture, the powerline corridor, transportation corridors and at housing developments within the floodplain.
- loss of the shrub/herb layer and soil compaction from cattle grazing where overstory still present.
- removal of large woody debris which controls lateral channel movement and plant community distribution on the floodplain.
- high water temperatures, poor LWD frequency, extensive channel and slope disturbance and high sediment load, substrate embededdness and low pool frequency/quality.

Overall, NCFDC (1998) report that, in an unimpacted state, the first reach of Byman Creek (including the 2.5km upstream of the culvert) is a critical and productive area for spawning and rearing particularly for coho and steelhead. They also note that the area may be an important area for chinook salmon summer rearing and summer/fall spawning habitat as it contains larger substrate, greater foraging opportunities, greater channel complexity and cooler temperatures than present in the adjacent Bulkley mainstem. The proximity of the reach to the mainstem provides easy access to overwintering habitat, mainstem rearing areas for older juvenile salmonids and options for refuge during high flow events. Detailed prescriptions for restorative measures that address noted impacts are documented in NCFDC (1998).

Overwintering studies using minnowtrapping were conducted downstream of the highway culvert between 2005 and 2009 with coho and rainbow trout/steelhead captured. Results are summarized in Donas and Newman (2006), Donas and Newman (2007), Donas and Newman (2008) and Donas and Newman (2010). During these assessments, fry were observed actively migrating up through the culvert (pers comm Cindy Verbeek, Upper Bulkley Streamkeepers).

PSCIS stream crossing 197658 was ranked as a high priority for follow up by Smith (2018) and was assessed as a barrier to upstream migration during low flows (low water depth) by McCarthy and Fernando (2015). In 2007, Wilson and Rabnett (2007) assessed the site reported that fish passage at 197658 was not hindered by the culverts at that time although they were not using the assessment protocol standardized by the Fish Passage Technical Working Group (MoE 2011). A map of the watershed is provided in map attachment 093L.114.

Stream Characteristics at Crossing

At the time of the survey, the culvert under Highway 16 was un-embedded, non-backwatered and ranked as a barrier to upstream fish passage acoording to the provincial protocol (MoE 2011). The pipe was 4m in diameter with a length of 24m, a culvert slope of 4%, a stream width ratio of 2.8 and an outlet drop of 2m (Table 5.46). Water temperature was 12°C, pH was 7.9 and conductivity was 103uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 300m beginning at the culvert location and then for another 330m beginning downstream of the railway bridge and teminating at the Bulkley River mainstem (Figure 5.26).

In the area immediately below the culvert, total cover amount was rated as trace with large woody debris dominant. Cover was also present as small woody debris (Table 5.47). The average channel width was 11.2m, the average wetted width was 9.8m and the average gradient was 1.2%. The dominant substrate was cobbles with gravels subdominant. Within the area surveyed, the channel flowed through cattle rangeland and appeared to be straightened with low complexity. Cattle

impacts were evident on both banks with extensive grazing of riparian vegetation apparent. There was minimal cover available with no pools, and extensive riffles. The habitat was rated as moderate value as it was considered an important migration corridor and because the larger substrate could provide important salmon fry rearing habitat, particularly in low velocities margins.

Below the railway bridge, the habitat was noted as far more complex than the area immediately below the highway culvert. Total cover amount was rated as abundant with overhanging vegetation dominant. Cover was also present as small woody debris, large woody debris, undercut banks, and deep pools. The average channel width was 8.6m, the average wetted width was 7.5m and the average gradient was 0.8%. The dominant substrate was cobbles with gravels subdominant. There were extensive sections of channel with deep glides (50-70 cm deep at the time of survey) with well developed riparian vegetation creating good structure for all species and life stages of salmonids. An algae layer was noted on the substrate. There were abundant large gravels and small cobbles present suitable for salmon spawning.

Stream Characteristics Upstream

The stream was surveyed upstream from 197658 for 1400m (Figure 5.27). Within the area surveyed, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, undercut banks, and overhanging vegetation (Table 5.47). The average channel width was 12.9m, the average wetted width was 7.9m and the average gradient was 2.1%. The dominant substrate was cobbles with boulders subdominant. Within the area surveyed, riparian areas adjacent to both banks were used as rangeland with several cattle access points on the stream and evidence of understory shrub degradation from cattle grazing. The large stream had high habitat complexity including numerous pools up to 2m deep and frequent glide sections to 1m deep throughout. There were extensive areas of gravel suitable for spawning for resident and anadromous salmonid species. Habitat value was rated as high for resident and anadromous salmonid rearing and spawning.

Table 5.48 presents preliminary fish passage modelling data for crossing 197658 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 5km of potential spawning habitat and 5.3km of potential rearing habitat.

Fish Sampling

Minnowtrapping was conducted with three traps set overnight upstream as well as downstream of the crossing. A total of 5 coho and 6 rainbow trout were captured downstream with 1 coho and 9 rainbow trout captured upstream (Table 5.49 and (Figure 5.28).

Structure Remediation and Cost Estimate

Structure replacement with a bridge (15.1m span) is recommended to provide access to the habitat located upstream of PSCIS crossing 197658. The cost of the work is estimated at $7,550,000 for a cost benefit of 0.8 linear m/$1000 and 10.3$m^2$/$1000.

Conclusion

There is an estimated 6km of mainstem habitat upstream of crossing 197658. Habitat in this area was rated as high value for salmonid rearing/spawning. The crossing may present a barrier not only to potentially all life stages of salmonids at higher flow velocities, but also to adult fish (including chinook and coho spawners) due to shallow water depths in the culvert during low flows. Restoration of riparian forests, cattle exclusion, bank stabilization and habitat complexing could be considered alongside fish passage restoration activities (NCFDC 1998). Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure. The crossing was ranked as a high priority for proceeding to design for replacement.

Table 5.46: Summary of fish passage assessment for PSCIS crossing 197658.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-27	Crossing Sub Type	Oval Culvert
PSCIS ID	197658	Diameter (m)	4
External ID	–	Length (m)	24
Crew	AI, KP	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	666847.2	Resemble Channel	No
Northing	6044305	Backwatered	No
Stream	Byman Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	1.6
Road Tenure	MoTi highway	Outlet Drop (m)	2
Channel Width (m)	11.1	Outlet Pool Depth (m)	3.8
Stream Slope (%)	1.2	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	4
Habitat Value	High	Valley Fill	Deep Fill
Final score	39	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	15.1
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Culvert is likely as passable for most species and life stages at most non-peak and non-lowest flows. Streamkeepers have observed fry moving through culvert in overwintering studies.

Table 5.47: Summary of habitat details for PSCIS crossing 197658.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197658	Upstream	1400	12.9	7.9	0.6	2.1	moderate	high
197658	Downstream	330	8.6	7.5	0.9	0.8	abundant	high
197658	Downstream	300	11.2	9.8	–	1.2	trace	moderate

Table 5.48: Summary of fish habitat modelling for PSCIS crossing 197658.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	5.5	5.5	100
Salmon Lake Reservoir (ha)	–	0.0	–
Salmon Wetland (ha)	–	0.0	–
Steelhead Network (km)	11.4	7.3	64
Steelhead Lake Reservoir (ha)	7.0	0.0	0
Steelhead Wetland (ha)	7.9	0.0	0
CH Spawning (km)	5.0	5.0	100
CH Rearing (km)	5.0	5.0	100
CO Spawning (km)	5.0	5.0	100
CO Rearing (km)	5.0	5.0	100
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	5.0	5.0	100
ST Rearing (km)	5.3	5.3	100
All Spawning (km)	5.0	5.0	100
All Rearing (km)	5.3	5.3	100
All Spawning and Rearing (km)	5.3	5.3	100

* Model data is preliminary and subject to adjustments.

Table 5.49: Fish captured in minnowtraps set overnight upstream and downstream of PSCIS crossing 197658.

Location	Species	fry	parr	juvenile
Downstream	CO	5	0	0
Upstream	CO	1	0	0
Downstream	RB	2	4	0

Upstream RB 1 5 3

Figure 5.26: Left: Typical habitat immediately downstream of PSCIS crossing 197658. Right: Typical habitat downstream of crossing 197658 below the railway bridge and adjacent to the Bulkley River mainstem.

Figure 5.27: Left: habitat upstream of PSCIS crossing 197658. Right: Habitat upstream of PSCIS crossing 197658.

Figure 5.28: Left: Coho captured downstream of PSCIS crossing 197658. Right: Coho captured upstream of PSCIS crossing 197658.

Appendix - 197662 - Richfield Creek

Site Location

PSCIS crossing 197662 is located on Richfield Creek on Highway 16 approximately 30km east of Houston, BC with the highway located approximately 1km upstream from the confluence with the Bulkley River. Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure.

Background

Richfield Creek drains one of the largest tributary watersheds in the upper Bulkley River. At crossing 197662, Richfield Creek is a fifth order stream with a watershed area upstream of the crossing of approximately 161.3km^2. The elevation of the watershed ranges from a maximum of 1660 to 680m at PSCIS crossing 197662. Upstream of the highway, Richfield Creek is known to contain coho, chinook, steelhead, rainbow trout, longnose dace and longnose sucker (MoE 2020a). Steelhead, coho and chinook spawning has been noted in the downstream reaches of the stream with historical escapements ranging from 0-100 spawners in the reach adjacent to the Bulkley River confluence (Allen Gottesfeld, Rabnett, and Hall 2002; Hancock, Leaney-East, and Marshall 1983). Allen Gottesfeld, Rabnett, and Hall (2002) note that in some years during low flow conditions, Richfield is partially dewatered and impassable to fish. A bridge (modelled crossing 1805593) is located under the railway approximately 830m downstream of the crossing which is reported by Wilson and Rabnett (2007) to constrict the channel. Although numerous modelled crossings are located upstream of the highway an impassable waterfall is located approximately 2km upstream of the highway (pers. comm. Jonathan Van Barneveld, Forester - FLNR).

In the summer of 1998, the Nadina Community Futures Development Corporation (NCFDC) contracted the British Columbia Conservation Foundation to carry out a detailed Level 1 Fish, Fish Habitat and Riparian Assessment in the first two reaches of Richfield Creek as well as several other large Upper Bulkley River tributary streams and the Upper Bulkley mainstem. The area surveyed extended to approximately 2km upstream of the culvert where an 18m high waterfall is located (NCFDC 1998). Building on these assessments and detailed fish sampling, NCFDC (1998) developed restoration prescriptions for the lower reaches of the watershed based on the following assessment of impacts associated with landuse in the watershed:

- loss of riparian forest and soil compaction in areas used for agriculture, the powerline corridor, transportation corridors and at housing developments within the floodplain.
- loss of the shrub/herb layer and soil compaction from cattle grazing where overstory still present.
- removal of large woody debris which controls lateral channel movement and plant community distribution on the floodplain.
- loss of connectivity during low flow periods due to a lack of flow and outlet drop at the highway culverts.
- poor LWD function, channelization, high summer water temperatures, extensive eroding banks and associated sediment load, and the consistently high compaction and embeddedness of substrate.

Overall, NCFDC (1998) report that, in an unimpacted state, the first reach of Richfield Creek (including the 2.5km upstream of the culvert) is a critical and productive area for spawning and rearing particularly for coho and steelhead. They also note that the area may be an important area for chinook salmon summer rearing and summer/fall spawning habitat as it contains larger substrate, greater foraging opportunities, greater channel complexity and cooler temperatures than present in the adjacent Bulkley mainstem. The proximity of the reach to the mainstem provides easy access to overwintering habitat, mainstem rearing areas for older juvenile salmonids and options for refuge during high flow events. Detailed prescriptions for restorative measures that address noted impacts (including the construction of riffle structures to backwater the culverts) are documented in NCFDC (1998).

Overwintering studies using minnowtrapping were conducted downstream of the highway culvert between 2006 and 2009 with coho, rainbow trout/steelhead and northern pikeminnow captured. Results are summarized in Donas and Newman (2007), Donas and Newman (2008) and Donas and Newman (2010).

A water temperature monitoring station has been operational on Richfield Creek just upstream of the highway since November 2014. Results in Westcott (2020), indicate that from 2017 - 2019, mean weekly maximum temperatures in Richfield Creek were 3-5°C cooler than temperatures recorded at stations located on the Upper Bulkley River mainstem. Westcott (2020) also reports that a continuous water level and temperature monitoring station is proposed on the stream.

Although in 2007, Wilson and Rabnett (2007) reported that fish passage at 197662 was not hindered by the culverts at that time the site was rated as a priority for follow up following background review and a Phase 1 assessment in 2020 indicating that the crossing was not passable according to provincial metrics and due to the presence of significant quantities of upstream habitat suitable for salmonid rearing and spawning. A map of the watershed is provided in map attachment 093L.115.

Stream Characteristics at Crossing

At the time of the survey, the two culverts under Highway 16 were un-embedded, non-backwatered and considered a barrier to upstream fish passage. The pipes were 4.2m in diameter with lengths of 24m, a culvert slope of 2%, a stream width ratio of 3 and an outlet drop of 0.2m (Table 5.50). Water temperature was 11°C, pH was 7.8 and conductivity was 80uS/cm.

Stream Characteristics Downstream

The stream was surveyed downstream from the culvert for 300m (Figure 5.29). Overall, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small

woody debris, large woody debris, deep pools, and overhanging vegetation (Table 5.51). The average channel width was 12.5m, the average wetted width was 8.8m and the average gradient was 1.5%. The dominant substrate was cobbles with gravels subdominant. There were unembedded gravels and cobbles suitable for spawning present throughout.

Immediately downstream of the culverts for approximately 80m, channel structure was simplified with no pools present and a lack of large woody debris. This is likely the result of armouring of the banks and the high flow velocities out of the crossing structure pipes. Further downstream, the channel flows through a residential area with some deep pools and glides to over 1m deep. Riparian vegetation is comprised of a narrow band of mature cottonwood forest with some areas adjacent to houses lacking trees altogether. There was evidence of large woody debris removal from the channel (chainsaw cut logs in the stream) and some stream corners were armoured with rock, concrete and old vehicles. Although some degradation of habitat was apparent, the area downstream of the crossing was rated as high high value for salmonid rearing and spawning.

Stream Characteristics Upstream

The stream was surveyed upstream from 197662 for 1200m (Figure 5.30). Within the area surveyed, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, undercut banks, and overhanging vegetation (Table 5.51). The average channel width was 13.2m, the average wetted width was 9m and the average gradient was 2.1%. The dominant substrate was gravels with cobbles subdominant. Within the area surveyed, riparian areas adjacent to both banks were used as rangeland with several cattle access points on the stream and evidence of understory shrub degradation from cattle grazing. There was a debris jam (up to 1m high in places) located just upstream of the highway. Overall, the stream had high habitat complexity including numerous pools up to 2m deep and frequent glide sections to 1m deep throughout. There were also extensive areas of gravel suitable for spawning for resident and anadromous species. Robert Hatch Creek enters the main channel approximately 400m upstream of the culvert and adjacent to Richfield Creek was comprised of beaver influenced wetland type habitat. Habitat value in the areas surveyed was rated as high for resident, fluvial and anadromous salmonid rearing and spawning.

Fish Sampling

Minnowtrapping was conducted with three traps set overnight upstream as well as downstream of the crossing. A total of 6 coho and 8 rainbow trout were captured downstream. Only rainbow trout (8 fish) were captured upstream (Table 5.53 and (Figure 5.31).

Table 5.52 presents preliminary fish passage modelling data for crossing 197662 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 4.9km of potential spawning habitat and 4.9km of potential rearing habitat.

Structure Remediation and Cost Estimate

Structure replacement with a bridge (16.5m span) is recommended to provide access to the habitat located upstream of PSCIS crossing 197662. The cost of the work is estimated at $8,250,000 for a cost benefit of 0.2 linear m/$1000 and 3.2$m^2$/$1000.

Conclusion

There is an estimated 2km of mainstem habitat upstream of crossing 197662 before an impassable falls. Habitat in the area surveyed upstream of the crossing was rated as high value for resident, fluvial and anadromous salmonid rearing/spawning. The results of temperature monitoring in Richfield Creek and the Upper Bulkley River mainstem by Westcott (2020) indicate that Rcihfield Creek (and other major tributaries to the upper Bulkley River) may have great importance for providing fish refuge from high temperatures during the hottest and driest months of the year as well as for moderation of temperatures downstream in the Upper Bulkley River. Although the ability of minnowtrapping to detect presence/absence is low when compared to other sampling techniques, the lack of coho salmon captured upstream is consistent with sampling conducted by NCFDC (1998) and adds to the weight of evidence that the culvert is preventing upstream spawner migration.

The crossing at the highway presents a barrier not only to some fry and juvenile salmonids due to the small outlet drop and high flow velocities within the pipes but also to adult salmon migrating upstream to spawn during low flows due to shallow water depths in the pipes. Future electrofishing surveys upstream and downstream of the crossing are recommended to provide presence/absence as well as density data for chinook salmon, coho salmon and other species. Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure and was ranked as a high priority for proceeding to design for replacement. Restoration of riparian forests, cattle exclusion, bank stabilization and habitat complexing as per NCFDC (1998) could be considered alongside fish passage restoration activities and an assessment of the passability of the debris jam just upstream of the crossing is recommended when fish passage restoration works at the highway are initiated.

Table 5.50: Summary of fish passage assessment for PSCIS crossing 197662.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-28	Crossing Sub Type	Round Culvert
PSCIS ID	197662	Diameter (m)	4.2
External ID	–	Length (m)	24
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–

Easting	672404.7	Resemble Channel	No
Northing	6044146	Backwatered	No
Stream	Richfield Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	1
Road Tenure	MoTi highway	Outlet Drop (m)	0.2
Channel Width (m)	12.5	Outlet Pool Depth (m)	1
Stream Slope (%)	1.5	Inlet Drop	No
Beaver Activity	No	Slope (%)	2
Habitat Value	High	Valley Fill	Deep Fill
Final score	29	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	16.5
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Habitat confirmation and minnowtrapping completed.

Table 5.51: Summary of habitat details for PSCIS crossing 197662.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197662	Upstream	1200	13.2	9	0.8	2.1	moderate	high
197662	Downstream	300	12.5	8.8	0.8	1.5	moderate	high

Table 5.52: Summary of fish habitat modelling for PSCIS crossing 197662.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	65.3	5.1	8
Salmon Lake Reservoir (ha)	2.5	0.0	0
Salmon Wetland (ha)	195.2	0.0	0
Steelhead Network (km)	70.9	6.9	10
Steelhead Lake Reservoir (ha)	2.5	0.0	0
Steelhead Wetland (ha)	198.5	0.0	0
CH Spawning (km)	8.9	4.8	54
CH Rearing (km)	12.9	4.9	38
CO Spawning (km)	17.7	4.9	28
CO Rearing (km)	31.1	4.9	16
CO Rearing (ha)	104.4	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	8.9	4.8	54
ST Rearing (km)	14.5	4.9	34
All Spawning (km)	17.7	4.9	28
All Rearing (km)	31.5	4.9	16
All Spawning and Rearing (km)	31.5	4.9	16

* Model data is preliminary and subject to adjustments.

Table 5.53: Fish captured in minnowtraps set overnight upstream and downstream of PSCIS crossing 197662.

Location	Species	fry	parr	juvenile
Downstream	CO	5	1	0
Downstream	RB	2	4	2
Upstream	RB	4	3	1

Figure 5.29: Left: Typical habitat downstream of PSCIS crossing 197662. Right: Typical habitat downstream of PSCIS crossing 197662.

Figure 5.30: Left: Gravel and cobble substrate upstream of PSCIS crossing 197662. Right: Typical habitat upstream of PSCIS crossing 197662.

Figure 5.31: Left: Coho captured downstream of PSCIS crossing 197662. Right: Rainbow trout captured upstream of PSCIS crossing 197662.

Appendix - 197663 & 3054 - Johnny David Creek

Site Location

PSCIS crossing 197663 is located on Johnny David Creek on Highway 16 approximately 25km east of Houston, BC with the highway located approximately 1km upstream from the confluence with the Bulkley River. Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure.

PSCIS crossing 3054 is located on North road at km 42.4 approximately 10km upstream of Highway 16. North road is the responsibility of FLNR - Nadina Forest District.

Background

The Johnny David Creek creek watershed upstream of the highway is approximately 43.5km^2 in area with an estimated 160ha of wetland documented upstream. At the highway, (575m of elevation) Johnny David Creek is a fourth order stream with a maximum watershed elevation of 1300. Fish documented as present downstream of 197663 include coho, chinook, cutthrout, dolly varden, steelhead and rainbow trout (MoE 2020a). Upstream of the crossing, only rainbow trout have been previously documented. One road stream crossing structure is modelled as present approximately 3km upstream of the highway (modelled crossing id 1802089).

The Johnny David Creek creek watershed upstream of 3054 is approximately 13km^2 in area with an estimated 131ha of wetland documented upstream. The stream is third order at this location with rainbow trout documented as present upstream (MoE 2020a).

Wilson and Rabnett (2007) recommended that PSCIS crossing 197663 be a high priority for remedial works to backwater the crossing by establishing a series of pools to step up to the outfall pool. A rehabilitation design was prescribed by Gaboury and Smith (2016). Smith (2018) reported that in 2017, the Wet'suwet'en First Nation - Yinka Dene Economic Development Limited Partnership Inc. and LGL Limited constructed three rock riffles and berms on both banks to backwater the stream and raise the outlet pool water level to above the elevation of the base of the culvert.

PSCIS stream crossing 3054 was rated a moderate priority for follow up by Irvine (2018) as it was rated as having moderate value habitat by Casselman and Stanley (2010) and due to significant quantities of stream and wetland habitat modelled upstream. A map of the watershed is provided in map attachment 093L.115.

Stream Characteristics at Crossings 197663 and 3054

At the time of the survey, the 197663 on Highway 16 was un-embedded, non-backwatered and considered a barrier to upstream fish passage according to the provincial protocol. The pipe was 1.75m in diameter with a length of 25m, a culvert slope of 2%, a stream width ratio of 3.6 and an outlet drop of 0m (Table 5.54). The inlet of the culvert was damaged with the metal folded up by incoming debris. Water temperature was 11°C, pH was 8.1 and conductivity was 186uS/cm.

Crossing 3054 on North road was also un-embedded, non-backwatered and again ranked as a barrier to upstream fish passage. The pipe was 3m in diameter with a length of 40m, a culvert slope of 2%, a stream width ratio of 1.2 and an outlet drop of 0.76m (Table 5.55). Water temperature was 10°C, pH was 7.5 and conductivity was 85uS/cm.

Stream Characteristics Downstream of 197663

The stream was surveyed downstream from the culvert for 300m (Figure 5.33). Overall, total cover amount was rated as moderate with large woody debris dominant. Cover was also present as small woody debris, undercut banks, deep pools, and overhanging vegetation (Table 5.56). The average channel width was 5.3m, the average wetted width was 3.3m and the average gradient was 2.6%. The dominant substrate was cobbles with boulders subdominant. Abundant gravels suitably sized for coho, rainbow and steelhead spawning were present. Habitat was rated as high as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Stream Characteristics Upstream of 197663 and downstream of 3054

The stream was surveyed upstream from 197663 for 690m (Figure 5.34). Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, boulders, deep pools, and overhanging vegetation (Table 5.56). The average channel width was 6.6m, the average wetted width was 4.4m and the average gradient was 3%. Abundant gravels and small cobbles suitable for resident, fluvial, and anadromous salmonid spawning were present throughout the area surveyed. Habitat value was rated as high for salmonid rearing and spawning.

The stream was surveyed downstream from 3054 for 300m (Figure 5.35). Within the area surveyed, total cover amount was rated as abundant with undercut banks dominant. Cover was also present as small woody debris, large woody debris, overhanging vegetation, and instream vegetation (Table 5.56). The average channel width was 3.5m, the average wetted width was 2.3m and the average gradient was 3.3%. Some pockets of gravels suitable for resident and anadromous (if present) salmonids were present throughout the area surveyed. Stream gradients were steepest immediately below the FSR then leveled off with a series of three beaver dams. No deep pools were observed downstream of the beaver influenced areas. Habitat value was rated as moderate as it was

considered an important migration corridor containing suitable spawning habitat with moderate rearing potential for resident adult or fry/juvenile anadromous salmonid rearing and spawning.

Stream Characteristics Upstream of 3054

Johnny David Creek was surveyed upstream from 3054 for 725m until an area of wetland type habitat (Figure 5.36). The stream winds through a canyon section for approximately 300m after the first 100m of beaver influenced wetland located directly upstream of the culvert. Within the area surveyed, total cover amount was rated as moderate with large woody debris dominant. Cover was also present as small woody debris, undercut banks, deep pools, and overhanging vegetation (Table 5.56). The average channel width was 2.6m, the average wetted width was 2.1m and the average gradient was 5.3%. Substrate was noted as colored black from periphyton with pockets of gravel suitable for resident (~20cm) salmonids present. A fish observed (~150mm long) was observed above the culvert approximately 100m. Habitat value was rated as moderate for younger life stages of resident, fluvial and anadromous salmonid rearing and resident adult salmonid spawning.

Table 5.57 presents preliminary fish passage modelling data for crossing 197663 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 2.8km of potential spawning habitat and 3.3km of potential rearing habitat. Table 5.58 presents preliminary fish passage modelling data for crossing 3054 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 1km of potential spawning habitat and 1.8km of potential rearing habitat.

Fish Sampling

To assess potential impacts of the culvert on fisheries values in the stream, electrofishing and minnowtrapping was conducted upstream and downstream of 197663. A total of 30 fish were captured upstream with 60 fish captured downstream (Figure **??**). Species captured downstream included coho and rainbow trout iwth coho, rainbow trout and mountain whitefish captured upstream. Electrofishing results are summarized in Tables 5.59 - 5.60 and Figure 5.32 with minnowtrapping results summarized in Table 5.61.

Structure Remediation and Cost Estimate

Structure replacement with bridges for 197663 (10.3m span) and 3054 (31m span) are recommended to provide access to the habitat located upstream. An estimate of cost for replacement of 197663 is $5,150,000 resulting in cost benefits of 1.9 linear m/$1000 and 12.8$m^2$/$1000. An estimate of cost for replacement of 3054 is $388,000 resulting in cost benefits of 19.3 linear m/$1000 and 50.3$m^2$/$1000.

Conclusion

Although no natural barriers to upstream passage are documented within provincial databases on Johnny David Creek upstream of the highway, large waterfalls have been documented within adjacent streams on both sides (Byman Creek and Richfield Creek pers. comm. Jonathan Van Barneveld, Forester - FLNR) at points approximately 6km upstream from the highway. For this reason, there is potential that there exists a natural barrier to fish passage within Johnny David Creek within this same band of slope. Although, the stream was not surveyed at the location of a modelled road stream crossing approximately 3km upstream of the highway (modelled crossing id 1802089), it is suspected that the crossing is not present as the roads in the area appear old and un-maintained in aerial imagery. Future assessment to scope for a natural barrier at approximately 6km above the highway and to assess the stream at the location of modelled crossing 1802089 is recommended.

There is 10km of mainstem habitat upstream of crossing 197663 to 3054. Habitat in the areas surveyed immediately upstream of 197663 was rated as high value for salmonid rearing/spawning. Although the sample size is small, the electrofishing results indicate that there are higher densities of coho and rainbow trout downstream of the crossing than above which could be an indication of impact by the structure. Although some works have already been conducted to reduce the impact of the crossing on upstream migration of fish, the culvert is damaged and likely presents a barrier to smaller life stages during moderate to high flows (due to flow velocities) and to large adult fish during low flows (due to shallow flow depths). The crossing was ranked as a high priority for proceeding to design for replacement.

Although there is some potential that there may be a natural barrier downstream of North Road, there is 7.5km of mainstem habitat modelled upstream of 3054. Habitat in the areas surveyed immediately upstream of 3054 was rated as moderate value for salmonid rearing/spawning. FLNR - Nadina Forest District is responsible for North road. The crossing was ranked as a moderate priority for proceeding to design for replacement.

Table 5.54: Summary of fish passage assessment for PSCIS crossing 197663.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-28	Crossing Sub Type	Round Culvert
PSCIS ID	197663	Diameter (m)	1.75
External ID	–	Length (m)	25
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	670240.8	Resemble Channel	No

Northing	6044772	Backwatered	No
Stream	Johnny David Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	3
Road Tenure	MoTi highway	Outlet Drop (m)	0
Channel Width (m)	6.3	Outlet Pool Depth (m)	1.35
Stream Slope (%)	5.5	Inlet Drop	Yes
Beaver Activity	No	Slope (%)	2
Habitat Value	High	Valley Fill	Deep Fill
Final score	24	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10.3
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Habitat confirmation and sampling completed.

Table 5.55: Summary of fish passage assessment for PSCIS crossing 3054.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-03	Crossing Sub Type	Round Culvert

External ID	–	Length (m)	40
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	664881	Resemble Channel	No
Northing	6052688	Backwatered	No
Stream	Johnny David Creek	Percent Backwatered	–
Road	North road	Fill Depth (m)	9.99
Road Tenure	MoTi local	Outlet Drop (m)	0.76
Channel Width (m)	3.5	Outlet Pool Depth (m)	0.8
Stream Slope (%)	3.3	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	2
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	34	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	31
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Fill depth approximatley 12m. Fish observed upstream of crossing.

NO IMAGE AVAILABLE

Table 5.56: Summary of habitat details for PSCIS crossings 197663 and 3054.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
3054	Downstream	350	3.5	2.3	0.3	3.3	abundant	moderate
3054	Upstream	725	2.6	2.1	0.3	5.3	moderate	moderate
197663	Upstream	690	6.6	4.4	0.4	3	moderate	high
197663	Downstream	300	5.3	3.3	0.5	2.6	moderate	high

Table 5.57: Summary of fish habitat modelling for PSCIS crossing 197663.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	79.5	4.3	5
Salmon Lake Reservoir (ha)	0.4	0.0	0
Salmon Wetland (ha)	159.8	0.0	0
Steelhead Network (km)	85.4	5.1	6
Steelhead Lake Reservoir (ha)	0.4	0.0	0
Steelhead Wetland (ha)	159.8	0.0	0
CH Spawning (km)	9.8	2.8	29
CH Rearing (km)	23.2	3.3	14
CO Spawning (km)	22.8	2.8	12
CO Rearing (km)	34.4	3.3	10
CO Rearing (ha)	82.5	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	9.8	2.8	29
ST Rearing (km)	23.8	3.3	14
All Spawning (km)	22.8	2.8	12
All Rearing (km)	35.0	3.3	9
All Spawning and Rearing (km)	35.0	3.3	9

* Model data is preliminary and subject to adjustments.

Table 5.58: Summary of fish habitat modelling for PSCIS crossing 3054.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	24.3	2.1	9
Salmon Lake Reservoir (ha)	0.3	0.0	0
Salmon Wetland (ha)	130.8	0.0	0
Steelhead Network (km)	24.3	2.1	9
Steelhead Lake Reservoir (ha)	0.3	0.0	0
Steelhead Wetland (ha)	130.8	0.0	0
CH Spawning (km)	0.0	0.0	–
CH Rearing (km)	3.1	1.8	58
CO Spawning (km)	5.7	1.0	18
CO Rearing (km)	11.9	1.8	15
CO Rearing (ha)	68.7	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.0	0.0	–
ST Rearing (km)	3.2	1.8	56
All Spawning (km)	5.7	1.0	18
All Rearing (km)	12.0	1.8	15
All Spawning and Rearing (km)	12.0	1.8	15

* Model data is preliminary and subject to adjustments.

Table 5.59: Electrofishing sites for PSCIS crossing 197663.

Site	Location	Width (m)	Length (m)	Area (m2)	Effort (s)	Effort (s/m2)
53	Downstream	3.75	5.1	19	199	10.5
54	Upstream	2.50	12.7	32	283	8.8

Table 5.60: Densities of fish (fish/100m2) captured during electrofishing upstream and downstream of PSCIS crossing 197663.

Site	Location	Species	Fry	Parr	Juvenile	Adult
53	Downstream	CO	57.9	5.3	0	0
54	Upstream	CO	0	12.5	0	0
54	Upstream	MW	0	3.1	0	0
53	Downstream	RB	42.1	31.6	15.8	0
54	Upstream	RB	21.9	28.1	6.2	3.1

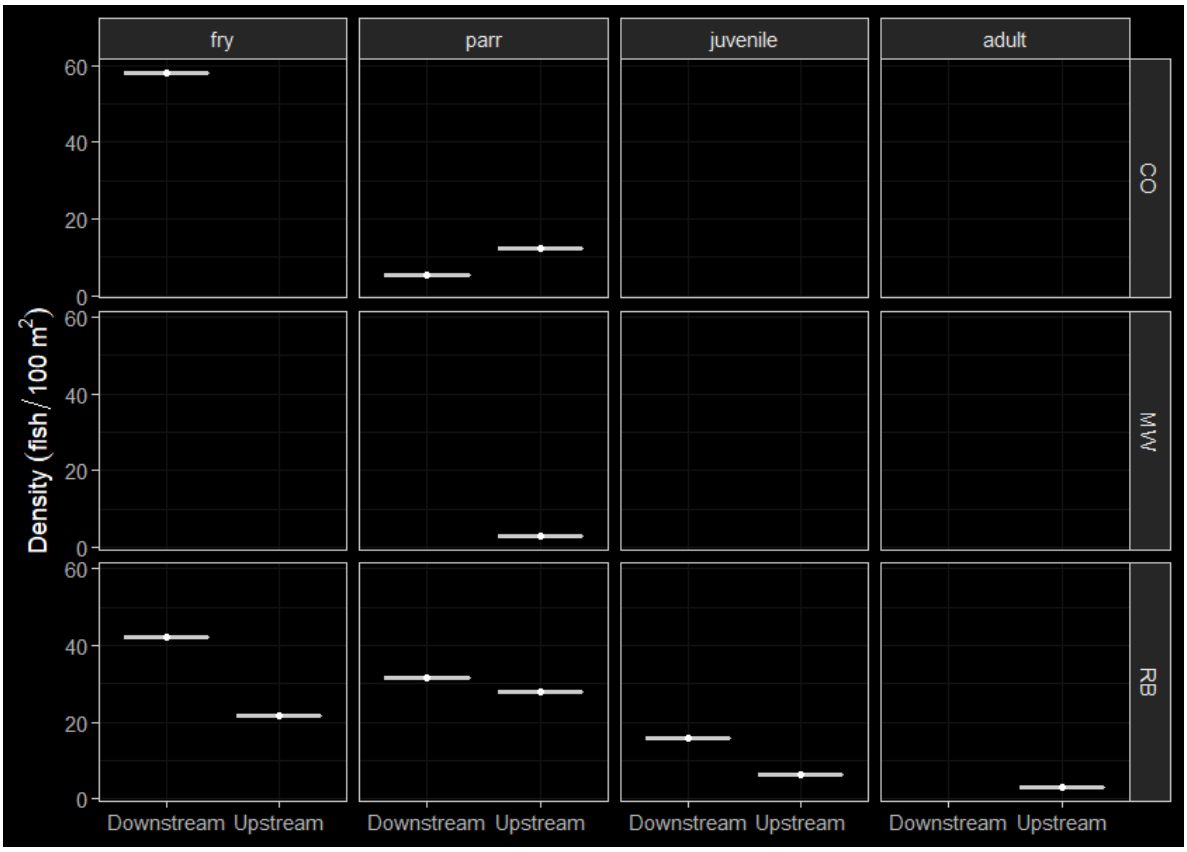

Figure 5.32: Densites of fish (fish/100m2) capture upstream and downstream of PSCIS crossing 197663.

Table 5.61: Fish captured in minnowtraps set overnight upstream and downstream of PSCIS crossing 197663.

Location	Species	fry	juvenile	parr
Downstream	CO	14	1	0
Upstream	CO	0	0	2
Downstream	RB	7	1	8
Upstream	RB	0	0	4

Figure 5.33: Left: Typical habitat downstream of PSCIS crossing 197663. Right: Typical habitat downstream of PSCIS crossing 197663.

Figure 5.34: Left: Habitat upstream of PSCIS crossing 197663. Right: Habitat upstream of PSCIS crossing 197663.

Figure 5.35: Left: Coho captured downstream of PSCIS crossing 197663. Right: Coho captured upstream of PSCIS crossing 197663.

Figure 5.36: Left: Habitat downstream of PSCIS crossing 3054. Right: Habitat upstream of PSCIS crossing 197663.

Appendix - 197665 & 197664 & 3042 - Barren Creek

Site Location

PSCIS crossing 197665 is on Barren Creek under the CN Railway located approximately 25km east of Houston, BC. The structure is located approximately 20m upstream from the confluence with the Bulkley River. CN Railway is the responsibility of CN Rail.

PSCIS crossing 197664 is on Highway 16 with the highway culvert located approximately 120m upstream from the confluence with the Bulkley River and 100m upstream of the railway. Highway 16 is the responsibility of the Ministry of Transportation and Infrastructure.

PSCIS crossing 3042 is located at km 13.5 of Barren Creek FSR and approximately 10km upstream of Barren Creek FSR. Barren Creek FSR is the responsibility of FLNR - Nadina Forest District.

Background

The Barren Creek watershed upstream of the highway is approximately 24.5km^2 in area with an estimated 11ha of wetland and 29ha of lake documented upstream. At the highway, (600m of elevation) Barren Creek is a fourth order stream with a maximum watershed elevation of aproximatley 1300m. Fish documented as present upstream of the highway include cutthroat trout, coho salmon, rainbow trout, steelhead, chinook salmon, and lamprey (general) (MoE 2020a). Although not recorded in MoE (2020b) at the time of reporting, an impassable falls (Wilson Falls) has been documented approximately 6.2km upstream from the highway (pers. comm. Jonathan Van Barneveld, Forester - FLNR). Although there are several unassessed road stream crossing structures and crossings documented in PSCIS as barriers on tributary systems to the Barren Creek mainstem downstream of the falls as well as upstream of Barren Creek FSR, the quantity of habitat in these blocked and potentially blocked stream segments likely very minimal and with low fisheries value due to the small size of the upstream watersheds.

PSCIS crossing 8733, located at km 18.2 of North Road (Michelle Bary FSR) and approximately 1.5km upstream from Highway 16. The culvert was replaced with a bridge by Canadian Forest Products in 2018 (MoE 2021b; Patterson 2010).

The Barren Creek watershed upstream of 3042 is approximately 3.9km^2 in area with an estimated 4ha of wetland and 4ha of lake documented upstream. The stream is fourth order at this location. Although fish have not been previously documented upstream of 3042 in MoE (2020a), FINS Consulting (2014) report rainbow trout fry downstream of the lake at the top end of the watershed.

In the summer of 1998, the Nadina Community Futures Development Corporation (NCFDC) carried out a detailed Level 1 Fish, Fish Habitat and Riparian Assessment in the first and second reaches of Barren Creek as well as several other large Upper Bulkley River tributary streams and the Upper Bulkley mainstem. The area surveyed extended to 4.2km from the mouth covering near 4km of habitat upstream of crossing 197664 (NCFDC 1998). Building on these assessments and detailed fish sampling, NCFDC (1998) developed restoration prescriptions for the lower reaches of the Barren Creek. Prescriptions were developed to address what the authors termed moderately to severely disturbed habitat due to:

- loss of riparian forest and soil compaction in areas used for agriculture, the powerline corridor, transportation corridors and at housing developments within the floodplain.
- loss of the shrub/herb layer and soil compaction from cattle grazing where overstory still present.
- removal of large woody debris which controls lateral channel movement and plant community distribution on the floodplain.

Impacts noted included: * extensive bars, extensive riffles, minimal pool area, eroding banks and sediment wedges. * high water temperatures, the absence of species historically present in the reach, and extreme aggradation.
* access issues related to bank instability, extremes in water levels, as well as undersized and poorly installed culverts.

Overall, NCFDC (1998) report that, in an unimpacted state, the first two reaches of Barren Creek are critical and productive areas for spawning and rearing particularly for coho and steelhead. They also note that the area up to North Road may be utilized for juvenile chinook rearing. Detailed prescriptions for restorative measures that address the noted impacts are documented in NCFDC (1998) and include measures related to slope stabilization, bank stabilization, sediment filtering and cattle exclusion.

Overwintering studies using minnowtrapping were conducted downstream of the highway culvert between 2005 and 2009 with coho and rainbow trout/steelhead captured. Results are summarized in Donas and Newman (2006), Donas and Newman (2007), Donas and Newman (2008) and Donas and Newman (2010).

PSCIS stream crossings 197665 and 197664 were rated as high priorities for habitat confirmation assessments after consultation with the Office of Wet’suwet’en, Fisheries and Oceans Canada representatives and Canadian Wildlife Federation due to concerns related to the aforementioned land-use impacts as well as ongoing dredging taking place upstream and downstream of Highway 16. Crossing 3042 was rated as a high priority for follow up as it was ranked as a high priority in both Irvine (2018) and Casselman and Stanley (2010). A map of the watershed is provided in map attachment 093L.114.

Stream Characteristics at Crossings 197665 and 197664

At the time of the survey, crossing 197665 structures under the CN Railway were fully embedded and considered passable according to the provincial protocol. Each of the two pipes were 0.9m in diameter with lengths of 25m, culvert slopes of 1%, a stream width ratio of 3.9 and outlet drops of 0m (Table 5.62). At the time of the survey, only one of the pipes was passing water and this structure appeared to be potentially failing as the top of the concrete structure was tilted towards the Bulkley River.

Crossing 197664 on Highway 16 was 2.5m in diameter with a length of 15m, a culvert slope of 2%, a stream width ratio of 1.9 and an outlet drop of 0m (Table 5.63). Water temperature was 12°C, pH was 8 and conductivity was 156uS/cm.

Crossing 3042 on Barren Creek FSR was unembedded, not backwatered and considered a barrier to fish passage according to the provincial protocol. The pipe was 1m in diameter with a length of 23m, a culvert slope of 1.5%, a stream width ratio of 1.9 and an outlet drop of 0m (Table 5.64). Water temperature was 10°C and pH was 7.4.

Stream Characteristics Downstream of 197665

Crossing 197665 is located 30m upstream of the Bulkley River and within the active floodplain. The armoured railway bisects a series of three historic oxbows immediately east of culvert, preventing access to potentially valuable rearing and refuge habitat.

Stream Characteristics Upstream of 197665 and downstream of 197664

The stream was surveyed upstream from 197665 for 100m to Highway 16 (Figure 5.37). Within the area surveyed, total cover amount was rated as moderate with overhanging vegetation dominant. Cover was also present as small woody debris (Table 5.65). The average channel width was 4.7m, the average wetted width was 2.7m and the average gradient was 1.8%. Abundant gravels and small cobbles suitable for resident, fluvial, adfluvial and anadromous salmonid spawning were present throughout the area surveyed. Habitat was rated as moderate value with habitat present suitable for resident and anadromous fry/juvenile salmonid rearing and spawning.

Stream Characteristics Upstream of 197664

Barren Creek was surveyed upstream from 197664 for 800m (Figure 5.38). Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, and overhanging vegetation (Table 5.65). The average channel width was 7.2m, the average wetted width was 4.7m and the average gradient

was 3%. An active cut was noted approximately 100m upstream of culvert. It is suspected that this area is constantly depositing gravels into stream. There extensive areas of gravels suitable for CO spawning. Riparian vegetation consisted of a mature cottonwood forest with right bank armouring and riparian removal along the adjacent private road. Habitat was rated as high value for resident and anadromous salmonid rearing and spawning.

Stream Characteristics Downstream of 3042

Barren Creek was surveyed downstream from 3042 for 400m (Figure 5.39). The area surveyed consisted of a series of beaver dams with impounded areas upstream ranging in length from 10 - 100m and dam heights ranging from 0.7 - 1.2m. Total cover amount was rated as moderate with undercut banks dominant. Cover was also present as deep pools, overhanging vegetation, and instream vegetation (Table 5.65). The average channel width was 18m, the average wetted width was 15m and the average gradient was 0.5%. At the bottom end of the site, flooded forest and shrub areas transitioned to a small marsh with emergent aquatic vegetation and extensive areas of open water. Water depths in the marsh were estimated at over 1m. Habitat value was rated as moderate for resident salmonid rearing and overwintering.

Stream Characteristics Upstream of 3042

Barren Creek was surveyed upstream from 3042 for 400m (Figure 5.40). A beaver influenced wetland was located immediately upstream of crossing and extended upstream for more than 200m. Survey data was collected beginning from an area located approximately 900m upstream of crossing and terminating at the beaver dam controlled outlet of a small lake. Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as deep pools, overhanging vegetation, and instream vegetation (Table 5.65). The average channel width was 2.3m, the average wetted width was 2.2m and the average gradient was 3%. The area surveyed varied from cobble/boulder channel flowing freely to primarily glide habitat with depths ranging from 60 - 100 cm in depth. There were occasional pockets of gravels in the channel near the start of the survey with some pools associated with large woody debris throughout. A large beaver pond/lake area was located at the top end of the site. Additional habitat information for areas upstream of the crossing are recorded in the provincial fisheries information summary system (MoE 2020c). Habitat value was rated as moderate for resident salmonid rearing and overwintering.

Table 5.66 presents preliminary fish passage modelling data for crossing 197665 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 303.8km of potential spawning habitat and 605.8km of potential rearing habitat.

Structure Remediation and Cost Estimate

Costs to replace 197665 and 197664 with bridges are estimated at $5,000,000 per crossing. Structure replacement with an embedded culvert is recommended for 3042 (streambed simulation - 3m span) with an estimated cost of $25,000 resulting in cost benefits of 68 linear m/$1000 and 156.4$m^2$/$1000.

Conclusion

Although 197665 and 197664 are technically considered passable, both corridors appear to have been poorly designed. Dredging to keep 197664 from directing flows over Highway 16 during high flow events has been an ongoing source of conflict and the structures are part of a greater land use scenario that negatively affects ecological function and blocks access to a series of historic upper Bulkley River oxbows.

There is 1.7km of mainstem habitat upstream of crossing 3042 including an estimated 4ha of wetland and 4ha of lake. Habitat in the areas surveyed upstream was rated as moderate value for salmonid rearing/spawning. Wilson Falls is located downstream of the crossing, so restoration of passage at Barren Creek FSR could benefit resident rainbow trout only. The crossing was ranked as a low priority for proceeding to design for replacement.

Table 5.62: Summary of fish passage assessment for PSCIS crossing 197665.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-28	Crossing Sub Type	Round Culvert
PSCIS ID	197665	Diameter (m)	0.9
External ID	–	Length (m)	25
Crew	AI, KP	Embedded	Yes
UTM Zone	9	Depth Embedded (m)	0.3
Easting	660627	Resemble Channel	Yes
Northing	6037843	Backwatered	Yes
Stream	Barren Creek	Percent Backwatered	10
Road	CN Railway	Fill Depth (m)	2
Road Tenure	Canadian National	Outlet Drop (m)	0
Channel Width (m)	3.5	Outlet Pool Depth (m)	0.4
Stream Slope (%)	3	Inlet Drop	No
Beaver Activity	No	Slope (%)	1
Habitat Value	High	Valley Fill	Deep Fill
Final score	14	Barrier Result	Passable
Fix type	–	Fix Span / Diameter	–
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Targeted for habitat confirmation due to upstream aggradation and dredging associated impacts on coho

NO IMAGE AVAILABLE

Table 5.63: Summary of fish passage assessment for PSCIS crossing 197664.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-28	Crossing Sub Type	Round Culvert
PSCIS ID	197664	Diameter (m)	2.5
External ID	1801069	Length (m)	15

UTM Zone	9	Depth Embedded (m)	1.9
Easting	660454.3	Resemble Channel	Yes
Northing	6037919	Backwatered	No
Stream	Barren Creek	Percent Backwatered	–
Road	Highway 16	Fill Depth (m)	1
Road Tenure	MoTi highway	Outlet Drop (m)	0
Channel Width (m)	4.7	Outlet Pool Depth (m)	0
Stream Slope (%)	1.8	Inlet Drop	No
Beaver Activity	Yes	Slope (%)	2
Habitat Value	High	Valley Fill	Deep Fill
Final score	14	Barrier Result	Passable
Fix type	–	Fix Span / Diameter	–
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Habitat confirmation completed.

Comments: Targeted for habitat confirmation due to aggradation and dredging associated impacts on coho.

Table 5.64: Summary of fish passage assessment for PSCIS crossing 3042.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-09-01	Crossing Sub Type	Round Culvert
PSCIS ID	3042	Diameter (m)	1
External ID	–	Length (m)	23
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	654451	Resemble Channel	No
Northing	6042827	Backwatered	No
Stream	Barren Creek	Percent Backwatered	–
Road	Barren Creek FSR	Fill Depth (m)	2
Road Tenure	MoTi highway	Outlet Drop (m)	0
Channel Width (m)	1	Outlet Pool Depth (m)	0.5
Stream Slope (%)	0.5	Inlet Drop	Yes
Beaver Activity	Yes	Slope (%)	1.5
Habitat Value	Medium	Valley Fill	Deep Fill
Final score	21	Barrier Result	Barrier
Fix type	Replace Structure with Streambed Simulation CBS	Fix Span / Diameter	3
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Beaver influenced stream with lake upstream.

Table 5.65: Summary of habitat details for PSCIS crossings 197665and 197664.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
3042	Upstream	400	2.3	2.2	0.2	3	moderate	moderate
3042	Downstream	260	18	15	1	0.5	moderate	moderate
197664	Upstream	800	7.2	4.7	3	3	moderate	high
197664	Downstream	240	4.7	2.7	–	1.8	moderate	high
197665	Downstream	20	4.2	1.8	–	2.5	moderate	high

Table 5.66: Summary of fish habitat modelling for PSCIS crossing 197665.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	1164.7	1123.6	96
Salmon Lake Reservoir (ha)	2052.3	2048.7	100
Salmon Wetland (ha)	2821.1	2809.2	100
Steelhead Network (km)	1359.6	1306.3	96
Steelhead Lake Reservoir (ha)	2765.2	2748.1	99
Steelhead Wetland (ha)	3036.8	3025.0	100
CH Spawning (km)	178.6	178.6	100
CH Rearing (km)	309.0	302.9	98
CO Spawning (km)	306.5	303.8	99
CO Rearing (km)	485.2	477.5	98
CO Rearing (ha)	1352.2	1352.2	100
SK Spawning (km)	13.2	13.2	100
SK Rearing (km)	73.0	73.0	100
SK Rearing (ha)	1492.3	1492.3	100
ST Spawning (km)	178.6	178.6	100
ST Rearing (km)	386.5	378.1	98
All Spawning (km)	306.5	303.8	99
All Rearing (km)	615.8	605.8	98
All Spawning and Rearing (km)	615.8	605.8	98

* Model data is preliminary and subject to adjustments.

Figure 5.37: Left: Typical habitat downstream of PSCIS crossing 197664. Right: Typical habitat downstream of PSCIS crossing 197664.

Figure 5.38: Left: Habitat upstream of PSCIS crossing 197664 and location of cutslope. Right: Habitat upstream of PSCIS crossing 197664.

Figure 5.39: Left: Habitat downstream of PSCIS crossing 3042. Right: Habitat downstream of PSCIS crossing 3042.

Figure 5.40: Left: Habitat upstream of PSCIS crossing 3042. Right: Habitat upstream of PSCIS crossing 3042.

Appendix - 197667 & 124501 - Moan Creek

Site Location

PSCIS crossings 197667 and 124501 are located on Moan Creek approximately 5.5km south-east of Telkwa, BC. Crossing 197667 is located on the railway line and crossing 124501 is located on Lawson Road. The crossings are located approximately 475m apart from each other with the railway crossing immediately upstream (15m) from the confluence with the Bulkley River. Crossing 197667 is the responsibility of the Canadian National Railway Company (CN Rail) and Lawson Road is the responsibility of the B.C. Ministry of Transportation and Infrastructure.

Background

The Moan Creek watershed upstream of the railway is approximately 14.9km^2 in area containing an estimated 1ha of lake and 15ha of wetland. The watershed elevation ranges from approximately 1350m to 530m at the railway where Moan Creek is a third order stream. Fish species documented upstream of both crossings include rainbow trout and dolly varden (MoE 2020a). Cutthroat trout have been documented in MoE (2020a) upstream of 197667 and Wilson and Rabnett (2007) report coho salmon and chinook salmon observations within the lower 500m of the stream.

Wilson and Rabnett (2007) recommended that PSCIS crossing 197667 be a high priority for remedial works to backwater the crossing by establishing a series of pools to step up to the outfall pool. In the spring of 2016, Gaboury and Smith (2016) noted that the baffled concrete box culvert (PSCIS 124501) at Lawson Road was likely a significant impediment to upstream fish passage at various discharges due to the height of the outfall drop, steep culvert slope and high water velocities. Rehabilitation designs for both crossings were prescribed by Gaboury and Smith (2016) and in both cases included the installation of downstream backwatering structures. Smith (2018) reported that in 2017, the Wet'suwet'en First Nation constructed three rock riffles and a right-bank berm to backwater the Lawson Road (124501) outlet. For the railway crossing (197667), CN Rail indicated that the design proposed was not feasible for installation, so at the time of reporting, remedial actions had not yet been implemented (pers. comm. Karla Graf, CN Environment, Manager-Environmental Impact). A map of the watershed is provided in map attachment 093L.118.

Stream Characteristics at Crossings 197667 and 124501

At the time of the survey, crossing 197667 on CN Railway was un-embedded, non-backwatered and considered a barrier to upstream fish passage according to the provincial protocol. The pipe was 2.5m in diameter with a length of 17m, a culvert slope of 4%, a stream width ratio of 1.5 and an outlet drop of 0.58m (Table 5.67).

Crossing 124501 on Lawson Road was embedded and non-backwatered and although it was ranked as a barrier to upstream fish passage, we considered it passable for adult salmonids

(resident and anadromous). The concrete box culvert containing baffles was 1.6m in width with a length of 25m, a culvert slope of 6%, a stream width ratio of 2.8 and an outlet drop of 0.3m (Table 5.68). Water temperature was 9°C, pH was 8 and conductivity was 86uS/cm.

Stream Characteristics Downstream of 197667

The Bulkley River is located approximately 30m downstream of the outlet of 197667.

Stream Characteristics Upstream of 197667 and downstream of 124501

The stream was surveyed upstream from 197667 for 450m to 124501 (Figure 5.41). Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, and overhanging vegetation (Table 5.69). The average channel width was 4.5m, the average wetted width was 2.8m and the average gradient was 4.5%. There were pockets of gravels and small cobbles suitable for resident and anadromous salmonid spawning present throughout the area surveyed. Habitat was rated as high value for salmonid rearing and spawning.

Stream Characteristics Upstream of 124501

Moan Creek was surveyed upstream from 124501 for 520m (Figure 5.42). Within the area surveyed, total cover amount was rated as moderate with deep pools dominant. Cover was also present as small woody debris, large woody debris, boulders, undercut banks, and overhanging vegetation (Table 5.69). The average channel width was 4.8m, the average wetted width was 3.1m and the average gradient was 6.3%. There were multiple debris jams present upstream from 350m above Larson Road with heights ranging from 0.4 - 1m high. Habitat was noted as complexwith abundant gravels suitable for resident, fluvial and anadromous salmonid spawning. Habitat was rated as high value.

Table 5.70 presents preliminary fish passage modelling data for crossing 197667 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0.5km of potential spawning habitat and 0.5km of potential rearing habitat. Table 5.71 presents preliminary fish passage modelling data for crossing 124501 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0km of potential spawning habitat and 0.8km of potential rearing habitat.

Fish Sampling

Minnowtrapping was conducted upstream and downstream of 197667 with traps set in the best available habitat and left overnight. One rainbow trout was captured upstream and 4 rainbow trout were captured downstream (Table 5.72).

Structure Remediation and Cost Estimate

A cost estimate for replacing 197667 with a bridge (10m span) is $5,000,000, resulting in cost benefits of 0.7 linear m/$1000 and 3$m^2$/$1000. Although 124501 on Lawson Road was considered passable for most species/life stages during most flows, an estimate of cost for replacement (10m span) is $500,000 resulting in cost benefits of 5.6 linear m/$1000 and 26.9$m^2$/$1000.

Conclusion

There is 3.3km of habitat upstream of crossing 197667 and below 124501. Upstream of Lawson Road there is an additional 2.8km of habitat modelled. Habitat in the areas surveyed upstream of 197667 and 124501 was rated as high value for salmonid rearing with some habitat also suitable for spawning in both areas. Crossing 197667 on the railway was ranked as a high priority for proceeding to design for replacement. Although not quantified with current assessment protocols, the low depth of water in 197667 during moderate to low flows (such as those observed during the 2020 survey) could prevent upstream migration (particularly for larger fish such as coho and chinook salmon). Although classified as a “barrier” according to provincial metrics, crossing 124501 is embedded, baffled and without a significant outlet drop. As such, we suspect that provided conditions at the site do not change substantially from those observed during surveys, the crossing will remain passable to adult salmonids migrating upstream during most flows. The crossing was assessed as a low priority for proceeding to design for replacement.

Table 5.67: Summary of fish passage assessment for PSCIS crossing 197667.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-31	Crossing Sub Type	Round Culvert
PSCIS ID	197667	Diameter (m)	2.5
External ID	–	Length (m)	17
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	631092	Resemble Channel	No
Northing	6055866	Backwatered	No
Stream	Moan Creek	Percent Backwatered	–
Road	CN Railway	Fill Depth (m)	0.8

Road Tenure	Canadian National	Outlet Drop (m)	0.58
Channel Width (m)	3.8	Outlet Pool Depth (m)	0.57
Stream Slope (%)	4.5	Inlet Drop	No
Beaver Activity	No	Slope (%)	4
Habitat Value	High	Valley Fill	Deep Fill
Final score	39	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Comments: Approximately 17m from the outlet to the Bulkley River.			
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Table 5.68: Summary of fish passage assessment for PSCIS crossing 124501.

Location and Stream Data	•	Crossing Characteristics	–
Date	2020-08-31	Crossing Sub Type	Round Culvert
PSCIS ID	124501	Diameter (m)	1.6
External ID	–	Length (m)	25
Crew	KP, AI	Embedded	Yes
UTM Zone	9	Depth Embedded (m)	0.15
Easting	630661	Resemble Channel	Yes
Northing	6055713	Backwatered	No
Stream	Moan Creek	Percent Backwatered	–
Road	Lawson Road	Fill Depth (m)	1
Road Tenure	MoTi resource	Outlet Drop (m)	0.3
Channel Width (m)	4.5	Outlet Pool Depth (m)	0.7
Stream Slope (%)	4.5	Inlet Drop	No
Beaver Activity	No	Slope (%)	6
Habitat Value	High	Valley Fill	Deep Fill
Final score	34	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Fully embedded and baffled culvert. Likely passable for all salmonid adults.

Table 5.69: Summary of habitat details for PSCIS crossings 197667and 124501.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
124501	Upstream	520	4.8	3.1	0.4	6.3	moderate	high
124501	Downstream	450	4.5	2.8	0.4	4.5	moderate	high
197667	Upstream	100	4.5	–	–	–	–	high

Table 5.70: Summary of fish habitat modelling for PSCIS crossing 197667.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	8.0	0.5	6
Salmon Lake Reservoir (ha)	–	0.0	–
Salmon Wetland (ha)	–	0.0	–
Steelhead Network (km)	9.7	0.5	5
Steelhead Lake Reservoir (ha)	–	0.0	–
Steelhead Wetland (ha)	–	0.0	–
CH Spawning (km)	0.0	0.0	–
CH Rearing (km)	0.0	0.0	–
CO Spawning (km)	0.5	0.5	100
CO Rearing (km)	0.5	0.5	100
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.0	0.0	–
ST Rearing (km)	1.2	0.5	42
All Spawning (km)	0.5	0.5	100
All Rearing (km)	1.2	0.5	42
All Spawning and Rearing (km)	1.2	0.5	42

* Model data is preliminary and subject to adjustments.

Table 5.71: Summary of fish habitat modelling for PSCIS crossing 124501.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	7.5	2.8	37
Salmon Lake Reservoir (ha)	–	0.0	–
Salmon Wetland (ha)	–	0.0	–
Steelhead Network (km)	9.2	2.8	30
Steelhead Lake Reservoir (ha)	–	0.0	–
Steelhead Wetland (ha)	–	0.0	–
CH Spawning (km)	0.0	0.0	–
CH Rearing (km)	0.0	0.0	–
CO Spawning (km)	0.0	0.0	–
CO Rearing (km)	0.0	0.0	–
CO Rearing (ha)	–	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	0.0	0.0	–
ST Rearing (km)	0.8	0.8	100

All Spawning (km)	0.0	0.0	–
All Rearing (km)	0.8	0.8	100
All Spawning and Rearing (km)	0.8	0.8	100

* Model data is preliminary and subject to adjustments.

Table 5.72: Fish captured in minnowtraps set overnight upstream and downstream of PSCIS crossing 197667.

Location	Species	parr
Downstream	RB	4
Upstream	RB	1

Figure 5.41: Left: Typical habitat upstream of PSCIS crossing 197667. Right: Typical habitat upstream of PSCIS crossing 197667.

Figure 5.42: Left: Habitat upstream of PSCIS crossing 124501. Right: Habitat upstream of PSCIS crossing 124501.

Appendix - 197668 & 124504 - Coffin Creek

Site Location

PSCIS crossings 197668 and 124504 are located on Coffin Creek approximately 9km south-east of Telkwa, BC. Crossing 197668 is located on the railway line and crossing 124504 is located on Lawson Road. The crossings are located approximately 30m apart from each other with the railway crossing 300m upstream from the confluence with the Bulkley River. Crossing 197668 is the responsibility of the Canadian National Railway Company (CN Rail) and Lawson Road is the responsibility of the B.C. Ministry of Transportation and Infrastructure.

Background

The Coffin Creek watershed upstream of the railway is approximately 45.2km^2 in area containing an estimated 74ha of lake and 139ha of wetland. The watershed elevation ranges from approximately 1400m to 530m at the railway where Coffin Creek is a fifth order stream. Numerous fish species have been documented upstream of both crossings including coho salmon, longnose sucker, largescale sucker, redside shiner, cutthroat trout, rainbow trout, mountain whitefish, and dolly varden (MoE 2020a; Wilson and Rabnett 2007).

Coffin Lake is a shallow lake (max depth 2m) located approximately 4.5km upstream of Lawson Road. In the late 1980s, Ducks Unlimited raised water levels in Coffin Lake and a downstream wetland area by installing a 63m long X 2.3m high earthen dam incorporating a variable crest weir capable of a 1.0m drawdown. Additionally excavated level ditching (1800m) within the sedge willow meadow was planned.The intent of the works was to provide a more secure and stable water regime, improve water/cover interspersion and provide territorial, loafing and nesting sites for waterfowl (Hatlevik 1985; Simpson 1986; MoE 2020b). Feedback on the preliminary development proposal by a regulatory fisheries technician noted that an ideal dam structure would be one providing options to either allow fish passage or comprise a complete barrier. Documentation detailing specifics of the final design of the dam and potential fishway was not obtained with a search of available literature.

There is one unnassessed modelled crossing located on the mainstem of Coffin Creek (modelled crossing 1802798) approximately 1.3km upstream from Lawson Road and approximately 800m downstream of the hydro transmission line. Review of aerial imagery indicates that this crossing is likely a ford. There are two fords documented in PSCIS on the mainstem of Coffin Creek. The first is located on the hydro power transmission line approximately 2km upstream of the lake inlet and the second (PSCIS 195972) is located approximately 2km upstream of the inlet of Coffin Lake. There is a 10m high falls recorded adjacent to PSCIS 195972 likely representing the upstream fish distribution limit in the mainstem. There are several fords located on tributary streams approximately 2km upstream of the Coffin Lake inlet and several other culverts further upstream previously assessed as barriers.

Wilson and Rabnett (2007) recommended that PSCIS crossing 197668 be a high priority for remedial works to backwater the crossing by establishing a series of pools to step up to the outfall pool. However, they also noted that velocities within the culvert averaged 2.5m/s which they indicated were excessive for maintaining backwater structures. A rehabilitation design was prescribed by Gaboury and Smith (2016) in the spring of 2016 and completed by CN Rail in the fall of 2016 by constructing two rock weirs downstream of the outlet. Smith (2018) reported that in 2017, the lowermost riffle required repairs using larger sized rocks. Wilson and Rabnett (2007)

The Coffin Creek watershed has been selected as a focus area for Environmental Stewardship Initiative (ESI) sampling research critical flow monitoring, benthic invertebrate sampling and fisheries assessments (pers. comm Don Morgan, Ministry of Environment and Climate Change Strategy).

PSCIS stream crossings 197668 was rated as a high priority for follow up due to the large amount of low gradient stream/wetland/lake habitat upstream, information communicated in Wilson and Rabnett (2007) and Smith (2018) related to the need for the work and the potential failures of 2017 remedial works, and because engagement activities with Wet'suwet'en, FLNRO and Ministry of Environment and Climate Change Strategy representatives indicated that there could be potential efficiencies by overlapping fish passage assessment/remediation/monitoring in ESI watersheds. A map of the watershed is provided in map attachment 093L.118.

Stream Characteristics at Crossings 197668 and 124504

At the time of the survey, the 197668 on CN Railway was un-embedded, non-backwatered and considered a barrier to upstream fish passage according to the provincial protocol. The pipe was 3m in diameter with a length of 15m, a culvert slope of 2%, a stream width ratio of 1.8 and an outlet drop of 0.27m (Table 5.73). Water temperature was 13°C, pH was 7.9 and conductivity was 92uS/cm.

Crossing 124504 on Lawson Road was embedded but non-backwatered and ranked as a barrier to upstream fish passage. The pipe was 3m in diameter with a length of 16m, a culvert slope of 1%, a stream width ratio of 1.8 and an outlet drop of 0.2m (Table 5.74).

Stream Characteristics Downstream of 197668

The stream was surveyed downstream from the culvert for 300m (Figure 5.43). Overall, total cover amount was rated as moderate with large woody debris dominant. Cover was also present as small woody debris, undercut banks, deep pools, and overhanging vegetation (Table 5.75). The average

channel width was 5.3m, the average wetted width was 3.7m and the average gradient was 2%. The dominant substrate was cobbles with gravels subdominant. Abundant gravels suitably sized for coho, rainbow and steelhead spawning were present. Habitat was rated as high as it was considered an important migration corridor with moderate value habitat for fry/juvenile salmonid rearing.

Stream Characteristics Upstream of 124504

Coffin Creek was surveyed upstream from 124504 for 415m and again upstream approximately 2.2km at a powerline ford crossing (Figure 5.44). Within the area surveyed, total cover amount was rated as moderate with undercut banks dominant. Cover was also present as small woody debris, large woody debris, boulders, deep pools, and overhanging vegetation (Table 5.75). The average channel width was 5.8m, the average wetted width was 3.5m and the average gradient was 2.3%. The stream in the areas surveyed was noted as having high complexity with occasional patches of gravels suitable for spawning present. Habitat value was rated as high for younger life stages of resident and anadromous salmonid rearing and resident adult salmonid spawning.

Table 5.76 presents preliminary fish passage modelling data for crossing 197668 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 0km of potential spawning habitat and 0km of potential rearing habitat. Table 5.77 presents preliminary fish passage modelling data for crossing 124504 with spawning and rearing habitat estimated for chinook, coho, sockeye and steelhead. Modelled estimates of the total length of salmon or steelhead habitat upstream of the crossing before potential barriers are 1.3km of potential spawning habitat and 1.3km of potential rearing habitat.

Fish Sampling

Minnowtrapping was conducted upstream and downstream of 197668. A total of 14 fish were captured upstream with 14 fish captured downstream (Figure **??**). Species captured upstream included coho and rainbow trout with coho, sucker and rainbow trout captured downstream. Results are summarized in Table 5.78.

Structure Remediation and Cost Estimate

Replacement with bridges for 197668 (10m span) and 124504 (10m span) are recommended to provide unimpeded access to the habitat located upstream. An estimate of cost for replacement of 197668 is $5,000,000 resulting in cost benefits of 0.8 linear m/$1000 and 4.2$m^2$/$1000. An estimate of cost for replacement of 124504 is $500,000 resulting in cost benefits of 8 linear m/$1000 and 46.4$m^2$/$1000.

Conclusion

There is 4km of habitat upstream of crossings 197668 and 124504 to the earthen dam constructed by Ducks Unlimited in the late 1980s. Habitat in the areas surveyed upstream of 197668 and 124504 was rated as high value for salmonid rearing/spawning. Although some works have already been conducted to reduce the impact of crossing 197668 on upstream fish migration, the works do not appear to be functioning as intended and replacement of the crossing with a bridge will increase passability for all life stages and species. The crossing was ranked as a high priority for proceeding to design for replacement. Although classified as a “barrier” according to provincial metrics, crossing 124504 is partially embedded and we suspect that it is passable to most juvenile and adult salmonids during most flows. Although the crossing should be replaced with an open bottomed structure in the long term, the crossing was assessed as a moderate priority for proceeding to design.

Table 5.73: Summary of fish passage assessment for PSCIS crossing 197668.

Location and Stream Data	•	**Crossing Characteristics**	–
Date	2020-08-31	Crossing Sub Type	Round Culvert
PSCIS ID	197668	Diameter (m)	3
External ID	–	Length (m)	15
Crew	KP, AI	Embedded	No
UTM Zone	9	Depth Embedded (m)	–
Easting	634336	Resemble Channel	No
Northing	6054609	Backwatered	No
Stream	Coffin Creek	Percent Backwatered	–
Road	CN Railway	Fill Depth (m)	0.8
Road Tenure	Canadian National	Outlet Drop (m)	0.27
Channel Width (m)	5.3	Outlet Pool Depth (m)	0.47
Stream Slope (%)	2	Inlet Drop	No
Beaver Activity	No	Slope (%)	2
Habitat Value	High	Valley Fill	Deep Fill
Final score	29	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: CN crossing has had Newbury riffles constructed to decrease the size of the outlet drop but drop still present. Abundant gravels suitable for spawning chinook and coho present. Some deep pools available for fry/parr overwintering.

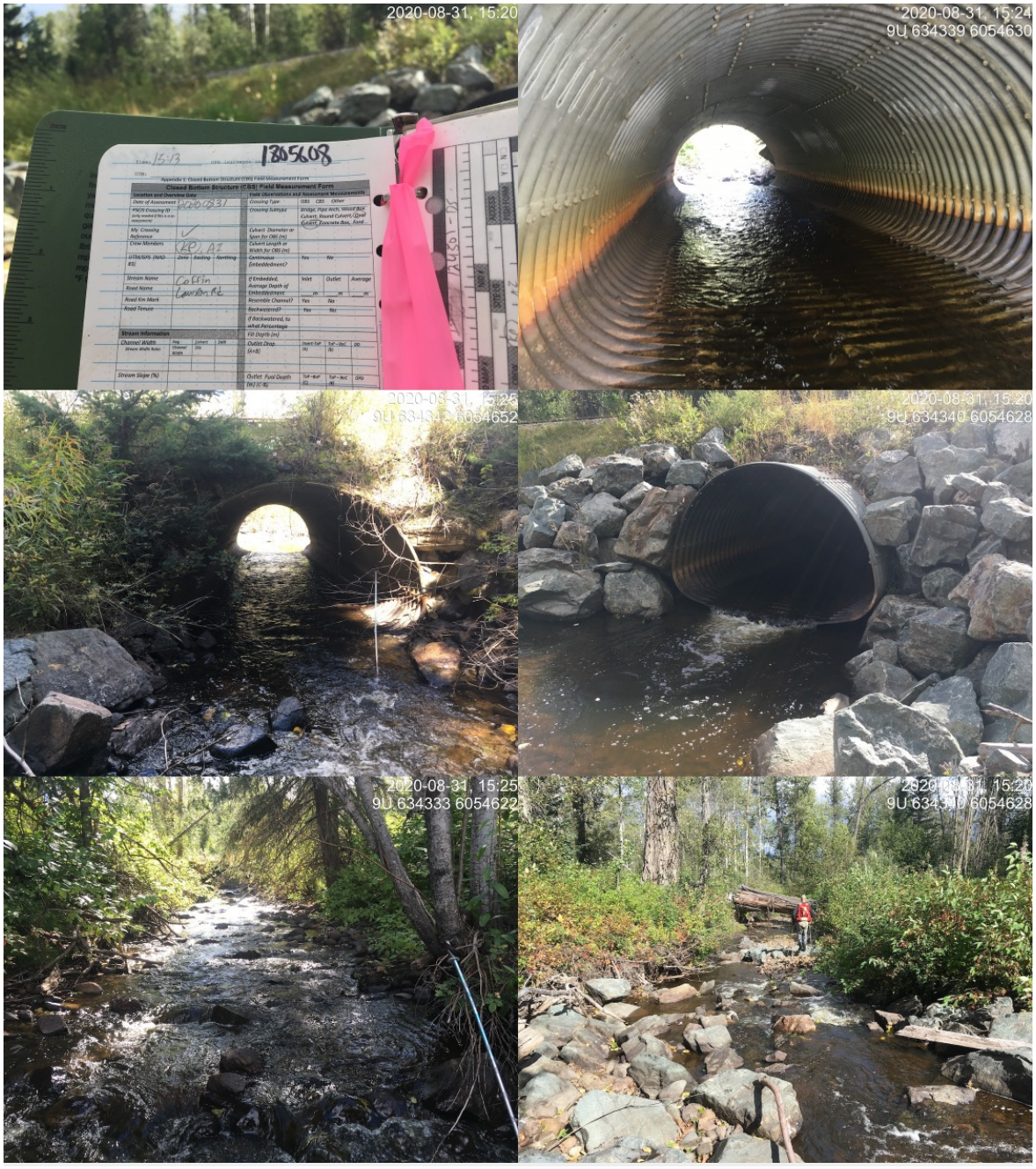

Table 5.74: Summary of fish passage assessment for PSCIS crossing 124504.

Date	2020-08-31	Crossing Sub Type	Round Culvert
PSCIS ID	124504	Diameter (m)	3
External ID	–	Length (m)	16
Crew	KP, AI	Embedded	Yes
UTM Zone	9	Depth Embedded (m)	0.15
Easting	634323	Resemble Channel	Yes
Northing	6054587	Backwatered	No
Stream	Coffin Creek	Percent Backwatered	–
Road	Lawson Road	Fill Depth (m)	0.5
Road Tenure	MoTi resource	Outlet Drop (m)	0.2
Channel Width (m)	5.3	Outlet Pool Depth (m)	0.1
Stream Slope (%)	2	Inlet Drop	No
Beaver Activity	No	Slope (%)	1
Habitat Value	High	Valley Fill	Deep Fill
Final score	24	Barrier Result	Barrier
Fix type	Replace with New Open Bottom Structure	Fix Span / Diameter	10
Photos: From top left clockwise: Road/Site Card, Barrel, Outlet, Downstream, Upstream, Inlet.			

Comments: Partially embedded with several large boulders (30 - 50cm) in culvert. No outlet drop at the time of survey but there may be at lowest flow levels.

Table 5.75: Summary of habitat details for PSCIS crossings 197668and 124504.

Site	Location	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
124504	Upstream	415	5.8	3.5	0.4	2.3	moderate	high
197668	Downstream	300	5.3	3.7	0.4	2	moderate	high
197668	Upstream	40	5.3	–	–	–	–	high

Table 5.76: Summary of fish habitat modelling for PSCIS crossing 197668.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	32.1	0	0
Salmon Lake Reservoir (ha)	73.4	0	0
Salmon Wetland (ha)	121.5	0	0
Steelhead Network (km)	37.2	0	0
Steelhead Lake Reservoir (ha)	73.4	0	0
Steelhead Wetland (ha)	121.5	0	0
CH Spawning (km)	5.7	0	0
CH Rearing (km)	10.5	0	0
CO Spawning (km)	8.2	0	0
CO Rearing (km)	14.5	0	0
CO Rearing (ha)	89.1	–	–
SK Spawning (km)	0.0	0	–
SK Rearing (km)	0.0	0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	5.7	0	0
ST Rearing (km)	13.7	0	0
All Spawning (km)	8.2	0	0
All Rearing (km)	17.6	0	0
All Spawning and Rearing (km)	17.6	0	0

* Model data is preliminary and subject to adjustments.

Table 5.77: Summary of fish habitat modelling for PSCIS crossing 124504.

Habitat	Potential	Remediation Gain	Remediation Gain (%)
Salmon Network (km)	32.1	1.3	4
Salmon Lake Reservoir (ha)	73.4	0.0	0
Salmon Wetland (ha)	121.5	0.0	0
Steelhead Network (km)	37.1	1.3	4
Steelhead Lake Reservoir (ha)	73.4	0.0	0
Steelhead Wetland (ha)	121.5	0.0	0
CH Spawning (km)	5.7	1.3	23
CH Rearing (km)	10.5	1.3	12
CO Spawning (km)	8.1	1.3	16
CO Rearing (km)	14.5	1.3	9
CO Rearing (ha)	89.1	–	–
SK Spawning (km)	0.0	0.0	–
SK Rearing (km)	0.0	0.0	–
SK Rearing (ha)	–	–	–
ST Spawning (km)	5.7	1.3	23
ST Rearing (km)	13.6	1.3	10

All Spawning (km)	8.1	1.3	16
All Rearing (km)	17.6	1.3	7
All Spawning and Rearing (km)	17.6	1.3	7

* Model data is preliminary and subject to adjustments.

Table 5.78: Fish captured in minnowtraps set overnight upstream and downstream of PSCIS crossing 197668.

Location	Species	fry	parr	juvenile
Downstream	CO	4	1	0
Upstream	CO	1	2	0
Downstream	RB	4	1	3
Upstream	RB	3	8	0
Downstream	SU	0	1	0

Figure 5.43: Left: Typical habitat downstream of PSCIS crossing 197668. Right: Coffin Creek downstream of PSCIS crossing 197668 at confluence with the Bulkley River.

Figure 5.44: Left: Habitat upstream of PSCIS crossing 124504. Right: Habitat 2.1km upstream of PSCIS crossing 124504.

Figure 5.45: Left: Coho captured downstream of PSCIS crossing 197668. Right: Coho captured upstream of PSCIS crossing 124504.

References

Allaire, JJ, Yihui Xie, Jonathan McPherson, Javier Luraschi, Kevin Ushey, Aron Atkins, Hadley Wickham, Joe Cheng, Winston Chang, and Richard Iannone. 2021. *Rmarkdown: Dynamic Documents for r*. https://CRAN.R-project.org/package=rmarkdown.

BC Ministry of Environment. 2021. “Fish Inventories Data Queries.” 2021. http://a100.gov.bc.ca/pub/fidq/viewWatershedDictionary.do.

Bell, M. C. 1991. “Fisheries Handbook of Engineering Requirements and Biological Criteria.”https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Bell_1991_Fisheries_handbook_of_engineering_requirements_and.pdf.

Bourne, Christina, Dan Kehler, Yolanda Wiersma, and David Cote. 2011. “Barriers to Fish Passage and Barriers to Fish Passage Assessments: The Impact of Assessment Methods and Assumptions on Barrier Identification and Quantification of Watershed Connectivity.”*Aquatic Ecology* 45: 389–403. https://doi.org/10.1007/s10452-011-9362-z.

Bramblett, Robert, Mason Bryant, Brenda Wright, and Robert White. 2002. “Seasonal Use of Small Tributary and Main-Stem Habitats by Juvenile Steelhead, Coho Salmon, and Dolly Varden in a Southeastern Alaska Drainage Basin.”*Transactions of the American Fisheries Society* 131: 498–506. https://doi.org/10.1577/1548-8659(2002)131<0498:SUOSTA>2.0.CO;2.

Busch, D.Shallin, Mindi Sheer, Kelly Burnett, Paul McElhany, and Tom Cooney. 2013. “Landscape-Level Model to Predict Spawning Habitat For Lower Columbia River Fall Chinook Salmon (*Oncorhynchus Tshawytscha*): Intrinsic Potential Model for Spawning Fall Chinook Salmon.”*River Research and Applications* 29 (3): 297–312. https://doi.org/10.1002/rra.1597.

Bustard, David, and ssociates Ltd. 1999. “Stream Inventory Owen Creek Watershed 1998.”http://a100.gov.bc.ca/pub/acat/documents/r3189/finalreport_1123266138656_9957d84b557b40fe84fbab26f1511fa6.pdf.

Bustard, D, and C Schell. 2002. “Conserving Morice Watershed Fish Populations and Their Habitat.”Community Futures Development Corporation of Nadina. https://waves-vagues.dfo-mpo.gc.ca/Library/315091.pdf.

Casselman, J, and D Stanley. 2010. “Bulkley/Fulton Watershed Fish Passage Culvert Assessment Program.” 2010. http://a100.gov.bc.ca/appsdata/acat/documents/r24143/8094011_Final_Report_Part_1328571584158_0bd68c842ee1398fde7c7fe754a7643122e5cb4e7c79ddd8436406d529bd7151.pdf.

Clarkin, K, A Connor, M Furniss, B Gubernick, M Love, K Moynan, and S WilsonMusser. 2005. “National Inventory and Assessment Procedure For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings.”United States Department of Agriculture, Forest Service, National Technology and Development Program. https://www.fs.fed.us/biology/nsaec/fishxing/publications/PDFs/NIAP.pdf.

Cooney, Thomas, and Damon Holzer. 2006. “Appendix C: Interior Columbia Basin Stream Type Chinook Salmon and Steelhead Populations: Habitat Intrinsic Potential Analysis,” 21.

Cote, David, P Frampton, M Langdon, and R Collier. 2005. *Fish Passage and Stream Habitat Restoration in Terra Nova National Park Highway Culverts*.

DFO. 1991. “Fish Habitat Inventory and Information Program.” Stream Summary Catalogue. Subdistrict 4d Smithers, Volume 2. Vanvouver, B.C.: Department of Fisheries and Oceans (DFO). https://data.skeenasalmon.info/dataset/3d44aae6-5785-42d5-8c13-5e1fddb567a7/resource/d5cbda12-d373-4cd8-85c0-5d831eeea1a5/download/fish_habitat_inventory_info_program_stream_summary_catalogue.pdf.

DFO/FLNRO. 2019a. “Water Temperature Data: Buck Creek Above Bridge 1 - Skeena Salmon Data Catalogue.” 2019. https://data.skeenasalmon.info/dataset/water-temperature-monitoring-data-buck

-creek-above-bridge.
———. 2019b. “Water Temperature Data: McQuarrie Creek above Hwy 16 - Skeena Salmon Data Catalogue.” 2019. https://data.skeenasalmon.info/no/dataset/water-temperature-monitoring-data-lower-mcquarrie-creek.
———. 2019c. “Water Temperature Data: McQuarrie Creek Above North Rd - Skeena Salmon Data Catalogue.” 2019. https://data.skeenasalmon.info/ca/dataset/water-temperature-monitoring-data-mcquarrie-creek-at-north-rd.
Diebel, M. W., M. Fedora, S. Cogswell, and J. R. O’Hanley. 2015. “Effects of Road Crossings on Habitat Connectivity for Stream-Resident Fish: STREAM-RESIDENT FISH HABITAT CONNECTIVITY.”*River Research and Applications* 31 (10): 1251–61. https://doi.org/10.1002/rra.2822.
Donas, Brenda, and Natalie Newman. 2006. “Bulkley River Watershed Overwintering Study 2005 - 2006.”https://data.skeenasalmon.info/dataset/514a5b48-aa8b-41b7-9d08-99666d91c8ad/resource/e293d7b4-fe2d-4b4c-a1b4-e277d94df889/download/upper-bulkley-overwintering-study-donas-newman-2005-06.pdf.
———. 2007. “Bulkley River Watershed Overwintering Study 2006 - 2007.”https://data.skeenasalmon.info/dataset/514a5b48-aa8b-41b7-9d08-99666d91c8ad/resource/b02f4709-9a53-4382-a3da-1c25e11b8c8f/download/bulkley_river_watershed_overwintering_study_2006-2007.pdf.
———. 2008. “Bulkley River Watershed Overwintering Study 2007 - 2008.” 2008. https://data.skeenasalmon.info/dataset/514a5b48-aa8b-41b7-9d08-99666d91c8ad/resource/ef022862-69c8-4a0f-a2c6-78a89a719327/download/upper-bulkley-overwintering-study-donas-newman-2007-08.pdf.
———. 2010. “Bulkley River Watershed Overwintering Study 2009 - 2010.”https://data.skeenasalmon.info/dataset/514a5b48-aa8b-41b7-9d08-99666d91c8ad/resource/c2efd020-15b8-465c-ac4b-b6c902a0f350/download/upper-bulkley-overwintering-donas-newman-2009-10.pdf.
ECCC. 2016. *Climate Data and Scenarios for Canada: Synthesis of Recent Observation and Modelling Results*. Environment and Climate Change Canada (ECCC). http://proxy.library.carleton.ca/loginurl=https://www.deslibris.ca/ID/10066004.
Environment, and limate Change Canada. 2021. “National Water Data Archive: HYDAT.” Service description. Environment and Climate Change Canada (ECCC). 2021. https://www.canada.ca/en/environment-climate-change/services/water-overview/quantity/monitoring/survey/data-products-services/national-archive-hydat.html.
FINS Consulting. 2014. “2014 Stream Assessment for Select Areas and Road Crossings Within Nadina Forest District.” 2014. https://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=51782.
Fish Passage Technical Working Group. 2011. “A Checklist for Fish Habitat Confirmation Prior to the Rehabilitation Fo a Stream Crossing.”https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/checklist-for-fish-habitat-confirmation-201112.pdf.
———. 2014. “Fish Passage Strategic Approach: Protocl for Prioritizing Sites for Fish Passage Remediation.”https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/fish-passage/strategic20approach20july202014.pdf.
FLNRO. 2013a. “Bulkley River Angling Management Plan.”Ministry of Forests, Lands and Natural Resource Operations (FLNRO). http://www.env.gov.bc.ca/fw/fish/guide/docs/amp/skeena-amp-bulkley-river.pdf.
———. 2013b. “Overview of Angling Management Plans for the Skeena Watershed.”Ministry of Forests, Lands, Natural Resource Operations (FLNRO). http://www.env.gov.bc.ca/skeena/fish/AMPs/Context_AMP.pdf.

FLNRORD. 2017. “Natural Resource Stewardship Monitoring and Assessment Report for the Wetâ€™suwetâ€™en Hereditary Territory.”https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/integrated-monitoring/nrsmonitoringandassessmentreport-wetsuweten.pdf.
———. 2019. “Freshwater Fishing Regulations Synopsis.”Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD). https://www2.gov.bc.ca/assets/gov/sports-recreation-arts-and-culture/outdoor-recreation/fishing-and-hunting/freshwater-fishing/region_6_skeena.pdf.
———. 2020a. “Digital Road Atlas (DRA) - Master Partially-Attributed Roads - Data Catalogue.” 2020. https://catalogue.data.gov.bc.ca/dataset/digital-road-atlas-dra-master-partially-attributed-roads.
———. 2020b. “Forest Tenure Road Section Lines - Data Catalogue.” 2020. https://catalogue.data.gov.bc.ca/dataset/forest-tenure-road-section-lines.
Gaboury, M. N., and J. J. Smith. 2016. “Development Of Aquatic Restoration Designs And On-Farm Cattle Management Improvements Within the Wet’suwet’en First Nation Territory.”Prepared by: Wet’â€™suwet”en First Nation.
“Gitxsan Huwilp Government.” 2021. 2021. http://gitxsan.ca/.
Gottesfeld, Allen, Ken Rabnett, and Peter Hall. 2002. “Conserving Skeena Fish Populations and Their Habitat - Skeena Stage I Watershed-Based Fish Sustainability Plan.”Skeena Fisheries Commission. https://www.psf.ca/sites/default/files/Skeena%20WFSP%2012%20%28low%20res%29.pdf.
Gottesfeld, A, and K Rabnett. 2007. “Skeena Fish Populations and Their Habitat.”Skeena Fisheries Commission.
Hancock, M. J., A. J. Leaney-East, and D. E. Marshall. 1983. “Catalogue of Salmon Streams and Spawning Escapements of Statistical Area 4 (Upper Skeena River).” 394. Canadian Data Report of Fisheries & Aquatic Sciences. Vancouver, B.C.: Department of Fisheries and Oceans Enhancement Services Branch. https://www.psf.ca/sites/default/files/15029.pdf.
Hatlevik, S. P. 1985. “A Reconnaissance Survey of Coffin Lake.”https://a100.gov.bc.ca/pub/acat/documents/r54856/AReconnaissanceSurveyofCoffinLake,1985,00999Bulk_1540249774271_0248447820.pdf.
———. 1992. “Letter of Communications with the Tyhee Lake Protection Society.”
IBM Business Consulting Services. 2006. “Valuation of the Wild Salmon Economy of the Skeena River Watershed.”https://www.psf.ca/sites/default/files/IBM_skeena_report_061.pdf.
ILMB. 2007. “Morice Land and Resource Management Plan.”Ministry of Agriculture and Lands - Integrated Land Management Bureau (ILMB). https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/land-water-use/crown-land/land-use-plans-and-objectives/skeena-region/morice-lrmp/morice_lrmp_july2007.pdf.
IPCC, ed. 2014. *Climate Change 2014: Synthesis Report*. Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC). Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [[Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].
Irvine, A. 2018. “Analysis and Priority Identification Of Existing Fish Passage Data: Bulkley River Watershed,” 114. http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=56648.
Jensen, Paul G., Paul D. Curtis, Mark E. Lehnert, and David L. Hamelin. 2001. “Habitat and Structural Factors Influencing Beaver Interference with Highway Culverts.”*Wildlife Society Bulletin* 29 (2): 654–64. http://www.jstor.org/stable/3784192.
Kemp, P. S., and J. R. O’Hanley. 2010. “Procedures for Evaluating and Prioritising the Removal of Fish Passage Barriers: A Synthesis: EVALUATION OF FISH PASSAGE BARRIERS.”*Fisheries*

Management and Ecology, no–. https://doi.org/10.1111/j.1365-2400.2010.00751.x.
Kirsch, J M, Joseph D Buckwalter, and Daniel J Reed. 2014. “Fish Inventory and Anadromous Cataloging in the Susitna River, Matanuska River, and Knik River Basins, 2003 and 2011.” 149.
Mahlum, Shad, David Cote, Yolanda Wiersma, Dan Kehler, and K. Clarke. 2014. “Evaluating the Barrier Assessment Technique Derived from FishXing Software and the Upstream Movement of Brook Trout Through Road Culverts.”*Transactions of the American Fisheries Society* 143. https://doi.org/10.1080/00028487.2013.825641.
McCarthy, M, and A Fernando. 2015. “2015 Inventory of High Priority Culverted Fish Passage Barriers in the Lower/Middle Skeena, Bulkley, Morice, and Babine River Watersheds.”
MoE. 2011. “Field Assessment for Determining Fish Passage Status of Closed Bottom Structures.”BC Ministry of Environment (MoE). https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/field-assessment-for-determining-fish-passage-status-of-cbs.pdf.
———. 2020a. “Known BC Fish Observations and BC Fish Distributions.” Ministry of Environment and Climate Change Strategy - Knowledge Management. 2020. https://catalogue.data.gov.bc.ca/dataset/known-bc-fish-observations-and-bc-fish-distributions.
———. 2020b. “Provincial Obstacles to Fish Passage - Data Catalogue.” 2020. https://catalogue.data.gov.bc.ca/dataset/provincial-obstacles-to-fish-passage.
———. 2020c. “Stream Inventory Sample Sites.” Ministry of Environment and Climate Change Strategy - Knowledge Management. 2020. https://catalogue.data.gov.bc.ca/dataset/stream-inventory-sample-sites.
———. 2021a. “PSCIS Assessments - Data Catalogue.” Ministry of Environment and Climate Change Strategy - Knowledge Management (MoE). 2021. https://catalogue.data.gov.bc.ca/dataset/pscis-assessments.
———. 2021b. “PSCIS Habitat Confirmations - Data Catalogue.” Ministry of Environment and Climate Change Strategy - Knowledge Management (MoE). 2021. https://catalogue.data.gov.bc.ca/dataset/pscis-habitat-confirmations.
———. 2021c. “PSCIS Remediation - Data Catalogue.” Ministry of Environment and Climate Change Strategy - Knowledge Management (MoE). 2021. https://catalogue.data.gov.bc.ca/dataset/pscis-remediation.
NCFDC. 1998. “Mid-Bulkley Detailed Fish Habitat/Riparian/Channel Assessment for Watershed Restoration.”Nadina Community Futures Development Corporation (NCFDC). http://a100.gov.bc.ca/appsdata/acat/documents/r8931/Mid-BulkleyDetailedFishHabitatRiparian.ChannelAss_1169052197910_e76ab8bf05ee4953b589da961b220f69.pdf.
Norris, Simon. 2021a. *Smnorris/Fwapg*. https://github.com/smnorris/fwapg.
———. 2021b. *Smnorris/Bcdata*. https://github.com/smnorris/bcdata.
———. 2021c. *Smnorris/Bcfishobs*. https://github.com/smnorris/bcfishobs.
———. 2021d. *Smnorris/Bcfishpass*. https://github.com/smnorris/bcfishpass.
Norris, Simon, and Craig Mount. 2016. “Fish Passage GIS Analysis Version 2.2 â€“ Methodology and Output Data Specifications.”https://data.skeenasalmon.info/dataset/bc-fish-passage-program.
Office of the Wet’suwet’en. 2013. “Wet’suwet’en Title and Rights Regarding Canada Department of Fisheries & Oceans And Pacific Trails Pipeline.”http://www.wetsuweten.com/files/PTP_FHCP_Response_to_DFO-25Nov13-Final.pdf.
“Office of the Wet’suwet’en.” 2021. 2021. http://www.wetsuweten.com/.
Oliver, Allison. 2018. “Analysis of Water Quality Monitoring in the Morice Water Management Area.”http://moricetrust.ca/reports/MWMT%20Water%20Quality%20Analysis.pdf.
Patterson, W. 2010. “Project Completion Abstract Barren Creek, S3 Km. 18.2 Michelle Bay FSR Fish Passage Project.”Allnorth Consultatns Limited. https://a100.gov.bc.ca/pub/acat/documents

/r26164/8102001Abstract_1332460013357_c88dd9f39c24d687b5b3a78f6dd8b0f6a3bd22c19460794ce61663225200de49.pdf.
Pickard, Darcy, Marc Porter, Lars ReeseHansen, Richard Thompson, Derek Tripp, Brian Carson, Peter Tschaplinski, Troy Larden, and Simon Casley. 2014. “Fish Values: Watershed Status Evaluation Protocol. Version 1.0.”
Pickard, D, M Porter, L Reese-Hansen, R Thompson, D Tripp, D Morgan, B Carson, and N Tamburello. n.d. “DRAFT - Owen: Watershed Status Evaluation.”
Porter, Marc, Simon Casley, Darcy Pickard, Emily Snead, Russell Smith, and Katherine Wieckowski. 2019. “Watershed Status Evaluation Protocol (WSEP): Tier 1 Watershed-Level Fish Values Monitoring Version 3.4.”
Porter, Marc, Darcy Pickard, Katherine Wieckowski, and Katy Bryan. 2008. “Developing Fish Habitat Models for Broad-Scale Forest Planning in the Southern Interior of B.C.”ESSA Technologies Ltd. and B.C. Ministry of the Environment (MOE) for B.C. Forest Science Program. https://www.for.gov.bc.ca/hfd/library/FIA/2008/FSP_Y081231.pdf.
QGIS Development Team. 2009. *QGIS Geographic Information System*. Open Source Geospatial Foundation. http://qgis.osgeo.org.
R Core Team. 2020. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.
Rabnett, K., and L. Williams. 2004. “Highway #16 Fish Passage Assessment in Middle Skeena Watershed.”https://data.skeenasalmon.info/lv/dataset/raabnett-williams-2004-middle-skeena-fish-passage-pdf.
Reavie, Euan D, John P Smol, Ian D Sharpe, Lisa A Westenhofer, and Marie Roberts. 2000. “Paleolimnological Analyses of Cultural Eutrophication Patterns in British Columbia Lakes” 78: 16.
Resources Inventory Committee. 2001. “Reconnaissance (1:20 000) Fish and Fish Habitat Inventory: Standards and Procedures. Version 2.0.”Resources Inventory Committee; Prepared by BC Fisheries Information Services Branch. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/nr-laws-policy/risc/recce2c.pdf.
Roberge, M, J M B Hume, C K Minns, and T Slaney. 2002. “Life History Characteristics of Freshwater Fishes Occurring in British Columbia and the Yukon, with Major Emphasis on Stream Habitat Characteristics,” 262.
Rosenfeld, Jordan, Marc Porter, and Eric Parkinson. 2000. “Habitat Factors Affecting the Abundance and Distribution of Juvenile Cutthroat Trout (Oncorhynchus Clarki) and Coho Salmon (Oncorhynchus Kisutch)” 57: 9.
Rysavy, Shauna, Ian Sharpe, Lisa A Westenhofer, and Eloise Gaudreau. 1999. “Tyhee Lake Management Plan.”BC Environment. https://www.rdbn.bc.ca/application/files/3015/4526/1890/Tyhee-Lake-Draft-LMP.pdf.
Schell, Chris. 2003. “A Brief Overview of Fish, Fisheries and Aquatic Habitat Resources in the Morice TSA.”Morice Land and Resource Management Plan. https://www.for.gov.bc.ca/hfd/library/ffip/Schell_C2003.pdf.
Shaw, Edward A., Eckart Lange, James D. Shucksmith, and David N. Lerner. 2016. “Importance of Partial Barriers and Temporal Variation in Flow When Modelling Connectivity in Fragmented River Systems.”*Ecological Engineering* 91: 515–28. https://doi.org/10.1016/j.ecoleng.2016.01.030.
Simpson, F. 1986. “Ducks Unlimited Preliminary Development Proposal, Coffin Lake, 1986.”https://a100.gov.bc.ca/pub/acat/documents/r54857/DucksUnlimitedPreliminaryDevelopmentProposal,Coff_1542766817365_2765305620.pdf.
SKR Consultants Ltd. 2006. “Fish Passage Culvert Inspection Where Yellowhead Highway 16 Crosses Station (Alias Mission) Creek. Contract 356cs0561.”

Slaney, P. A, Daiva O Zaldokas, and Watershed Restoration Program (B.C.). 1997. *Fish Habitat Rehabilitation Procedures*. Vancouver, B.C.: Watershed Restoration Program. https://www.for.gov.bc.ca/hfd/library/FFIP/Slaney_PA1997_A.pdf.

Sloat, Matthew R., Gordon H. Reeves, and Kelly R. Christiansen. 2017. “Stream Network Geomorphology Mediates Predicted Vulnerability of Anadromous Fish Habitat to Hydrologic Change in Southeast Alaska.”*Global Change Biology* 23 (2): 604–20. https://doi.org/10.1111/gcb.13466.

Smith, Jason J. 2018. “Assessing Barriers To Fish Passage Within The Wetsuweten First Nation Traditional Territory.”LGL Limited environmental Research associates and Yinka Dene Economic Development Limited Partnership Inc.

Swales, Stephen, and C. Levings. 1989. “Role of Off-Channel Ponds in the Life Cycle of Coho Salmon (Oncorhynchus Kisutch) and Other Juvenile Salmonids in the Coldwater River, British Columbia.”*Canadian Journal of Fisheries and Aquatic Sciences - CAN J FISHERIES AQUAT SCI* 46: 232–42. https://doi.org/10.1139/f89-032.

Tamblyn, Gregory C. 2005. “A Plan to Conserve and Protect Morice Watershed Fish Populations,” 78.

Thompson, Richard. 2013. “Assessing Fish Passage at Culverts â€“ the Method, Its Metrics and Preliminary Findings from over 4,000 Assessments.”https://www2.gov.bc.ca/assets/gov/environment/plants-animals-and-ecosystems/fish-fish-habitat/fish-passage/assessing_fish_passage_at_culverts.pdf.

Tredger, C. D. 1982. “Upper Bulkley River Reconnaissance with Reference to Juvenile Steelhead Carrying Capacity,” 77.

Wang, Tongli, Andreas Hamann, D. Spittlehouse, and Trevor Murdock. 2012. “ClimateWNAâ€”High-Resolution Spatial Climate Data for Western North America.”*Journal of Applied Meteorology and Climatology* 51 (January): 16–29. https://doi.org/10.1175/JAMC-D-11-043.1.

Washington Department of Fish & Wildlife. 2009. “Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual.”Washington Department of Fish and Wildlife. Olympia, Washington.https://wdfw.wa.gov/sites/default/files/publications/00061/wdfw00061.pdf.

Westcott, Bob. 2020. “Upper Bulkley River Watershed Temperature Monitoring 2016-19 Data Report.”

Wilson, Tim, and Ken Rabnett. 2007. “Fish Passage Assessment of Highway 16 and CN Rail in the Bulkley Watershed,” 124. https://data.skeenasalmon.info/dataset/fish-passage-assessment-highway-16-cn-rail-bulkley.

Woll, Christine, David Albert, and Diane Whited. 2017. “Salmon Ecological Systems.”The Nature Conservancy.

Xie, Yihui. 2016. *Bookdown: Authoring Books and Technical Documents with R Markdown*. Boca Raton, Florida: Chapman; Hall/CRC. https://github.com/rstudio/bookdown.