



Horsefly River Watershed

Secwepemcúl'ecw

Connectivity Remediation Plan: 2021 - 2040

Nick Mazany-Wright, Simon M. Norris, Joshua Noseworthy, Betty Rebellato,
Sarah Sra, and Nicolas W. R. Lapointe
August 2021, Version 1.0

CANADIAN WILDLIFE
FEDERATION



FÉDÉRATION
CANADIENNE DE LA FAUNE

Canadian Wildlife Federation

350 Michael Cowpland Drive

Kanata, Ontario K2M 2W1

Telephone: 1-877-599-5777 | 613-599-9594

www.cwf-fcf.org

© 2021

Suggested Citation:

Mazany-Wright, N., S. M. Norris, J. Noseworthy, B. Rebellato, S. Sra, and N. W. R. Lapointe. 2021. Horsefly River Watershed Connectivity Remediation Plan: 2021- 2040. Canadian Wildlife Federation. Ottawa, Ontario, Canada.

Cover Photo: © Fernando Lessa

Acknowledgements

This plan represents the culmination of a collaborative planning process undertaken in the Horsefly River watershed over many months of work with a multi-partner planning team of individuals and groups passionate about the conservation and restoration of freshwater ecosystems and the species they support. Plan development was funded by the BC Salmon Restoration and Innovation Fund, Canada Nature Fund for Aquatic Species at Risk, and the RBC Bluewater Project. We were fortunate to benefit from the feedback, guidance, and wisdom of many groups and individuals who volunteered their time throughout this process — this publication would not have been possible without the engagement of our partners and the planning team (see Table 1).

We recognize the incredible fish passage and connectivity work that has occurred in the Horsefly River watershed to date, and we are excited to continue partnering with local groups and organizations to build upon existing initiatives and provide a road map to push connectivity remediation forward over the next 20 years and beyond.

The Canadian Wildlife Federation recognizes that the lands and waters that form the basis of this plan are the traditional unceded territory of the Northern Secwepemc people. We are grateful for the opportunity to learn from the stewards of this land and work together to benefit Pacific Salmon. A special thank you to Nishitha Singi for sharing the traditional Secwepemctsin names use in this plan.

Table of Contents

CONNECTIVITY PLAN PURPOSE AND APPROACH	3
VISION STATEMENT	4
PLANNING TEAM	4
KEY ACTORS.....	5
PROJECT SCOPE	6
TARGET SPECIES	9
KEY ECOLOGICAL ATTRIBUTES AND CURRENT CONNECTIVITY STATUS.....	12
BARRIER TYPES	14
SITUATION ANALYSIS	16
GOALS	18
STRATEGIES & ACTIONS	19
THEORIES OF CHANGE & OBJECTIVES	23
.....	25
PROGRESS TRACKING PLAN	28
OPERATIONAL PLAN	30
FUNDING SOURCES	33
REFERENCES	37
APPENDIX A: MODELLED ANADROMOUS SALMON HABITAT MAPS	40
APPENDIX B: CONNECTIVITY STATUS ASSESSMENT METHODS.....	41
APPENDIX C: HORSEFLY RIVER WATERSHED BARRIER PRIORITIZATION SUMMARY ..	43

Connectivity Plan Purpose and Approach

The following Watershed Connectivity Remediation Plan (WCRP) represents the culmination of a six-month collaborative planning effort, the overall aim of which is to build collaborative partnerships within the Horsefly River watershed to improve connectivity for anadromous salmon and the livelihoods that they support, including the continued sustenance, cultural, and ceremonial needs of the Northern Secwépemc people. This 20-year plan was developed to identify priority actions that the Horsefly River WCRP planning team (see Table 1 for a list of team members) will undertake between 2021-2040 to conserve and restore fish passage in the watershed, through crossing remediation, lateral barrier remediation, dam remediation, and barrier prevention strategies.

WCRPs are long-term, actionable plans that blend local stakeholder and rightsholder knowledge with innovative GIS analyses to gain a shared understanding of where remediation efforts will have the greatest benefit for anadromous salmon. The planning process is inspired by the [Conservation Standards](#) (v.4.0), which is a conservation planning framework that allows planning teams to systematically identify, implement, and monitor strategies to apply the most effective solutions to high priority conservation problems. There is a rich history of connectivity and fish habitat planning and remediation work in the Horsefly River watershed that this WCRP builds upon, including work undertaken by the BC Fish Passage Technical Working Group, the Northern Secwepemc te Qelmucw (NStQ) and member communities, the Horsefly River Roundtable, and other local organizations (Masse Environmental Consultants Ltd. 2018; S. Hocquard, Steve Hocquard Consulting, pers. comm.).

The planning team compiled existing barrier location and assessment data, habitat data, and previously identified priorities, and combined this with local and Indigenous knowledge to create a strategic watershed-scale plan to improve connectivity. To expand on this work the Horsefly River WCRP planning team applied the WCRP planning framework to define the "thematic" scope of freshwater connectivity and refine the "geographic" scope to identify only those portions of the watershed where barrier prioritization will be conducted, and subsequent remediation efforts will take place. Additionally, the team selected target fish species, assessed their current connectivity status in the watershed, defined concrete goals for gains in connectivity, and developed a priority list of barriers for remediation to achieve those goals. While the current version of this plan is based on the best-available information at the time of publishing, WCRPs are intended to be "living plans" that are updated regularly as new information becomes available, or if local priorities and contexts change. As such, this document should be interpreted as a current snap-shot in time, and future iterations of this WCRP will build upon the material presented in this plan to continuously improve barrier remediation for migratory fish in the Horsefly River watershed. For more information on how WCRPs are developed, see Mazany-Wright et al. 2021c.

Vision Statement

Healthy, well-connected streams and rivers within the Horsefly River watershed support thriving populations of migratory fish, improving the overall ecosystem health of the watershed. In turn, these fish provide the continued sustenance, cultural, and ceremonial needs of the Northern Secwépemc people, as they have since time immemorial. Both residents and visitors to the watershed work together to mitigate the negative effects of anthropogenic aquatic barriers, improving the resiliency of streams and rivers for the benefit and appreciation of all.

Planning Team

Table 1. Horsefly River watershed WCRP planning team members. Planning team members contributed to the development of this plan by participating in a series of workshops and document and data review. The plan was generated based on the input and feedback of the local groups and organizations listed in this table.

Name	Organization
Betty Rebellato	Canadian Wildlife Federation
Nick Mazany-Wright	Canadian Wildlife Federation
Nick O’Hanley	Canadian Wildlife Federation
Nicolas Lapointe	Canadian Wildlife Federation
Sarah Sra	Canadian Wildlife Federation
Colin McGregor	Department of Fisheries and Oceans Canada
Guy Scharf	Department of Fisheries and Oceans Canada
Thomas Gristey	Department of Fisheries and Oceans Canada
Simon Norris	Hillcrest Geographics
Brian Englund	Horsefly River Roundtable
Helen Englund	Horsefly River Roundtable
Judy Hillaby	Horsefly River Roundtable
Mike Ramsay	Ministry of Forests, Lands and Natural Resource Operations
Kate Hewitt	Northern Shuswap Tribal Council
Edna Boston	Soda Creek Indian Band
Mike Stinson	Soda Creek Indian Band
John Walker	Williams Lake First Nation

Nishitha Singi	Williams Lake First Nation
Josh Noseworthy	Global Conservation Solutions

Key Actors

Table 2. Additional Key Actors in the Horsefly River watershed. Key Actors are the individuals, groups, and/or organizations, outside of the planning team, with influence and relevant experience in the watershed, whose engagement will be critical for the successful implementation of this WCRP.

Individual / Organization Name	Role and Primary Interest
Cariboo Mining Association	A mining company that has been operating in central BC since the 1950's and can help provide data and facilitate remediation work.
Consus Management Ltd.	Local wildlife consultants in the watershed to consider for future work.
Dawson Road Maintenance Ltd	A road design and maintenance company at the roadway-watershed interface.
DWB Consulting Services Ltd.	Local wildlife consultants in the watershed to consider for future work.
Freshwater Fisheries Society of British Columbia	This group can provide project assistance with non-anadromous species.
Larry Davis	A biologist and local wildlife consultant in the watershed.
Local ranchers	These individuals can facilitate construction as well as consent/facilitate complimentary works on private property to improve fish habitat upstream and downstream.
Ministry of Forests, Lands and Natural Resource Operations (FLNRO)	FLNRO can assist with providing local knowledge, data, expertise and can facilitate remediation work.
Ministry of Transportation and Infrastructure (MOTI)	MOTI may own barriers and can play a role in improving and replacing barriers at highway crossings.
Property owners along river and tributaries	These individuals can facilitate construction as well as consent/facilitate complimentary works on private property to improve fish habitat upstream and downstream.

Quesnel River Research Centre	This group can help with field assessments and project implementation.
Steve Hocquard	A local consultant (Steve Hocquard Consulting) that provided valuable review of barrier and habitat data to inform the spatial models used in this plan, and can help with field assessments and project implementation.
Tolko Industries Ltd.	A privately owned Canadian forest products company that maintains forest service road-stream crossings in the Horsefly River watershed.
Upper Fraser Fisheries Conservation Alliance	This group can be contacted for advice and assistance.
West Fraser	A integrated forestry and diversified wood products company that maintains forest service road-stream crossings in the Horsefly River watershed.

Project Scope

Connectivity is a critical component of freshwater ecosystems that encompasses a variety of factors related to ecosystem structure and function, such as the ability of aquatic organisms to disperse and/or migrate, the transportation of energy and matter (e.g., nutrient cycling and sediment flows), and temperature regulation (Seliger & Zeiringer 2018). Though each of these factors are important when considering the health of a watershed, for the purposes of this WCRP the term "connectivity" is defined as the degree to which aquatic organisms can disperse and/or migrate freely through freshwater systems. Within this context, connectivity is primarily constrained by physical barriers, including anthropogenic infrastructure such as dams, weirs, and stream crossings, and natural features such as waterfalls and debris flows. This plan is intended to focus on the direct remediation and prevention of localized, physical barriers instead of the broad land-use patterns that are causing chronic connectivity issues in the watershed. The planning team decided that the primary focus of this WCRP is addressing barriers to both longitudinal connectivity (i.e., along the upstream-downstream plane) and lateral connectivity (i.e., connectivity between the mainstem and adjacent riparian wetlands and floodplains) due to the importance of maintaining fish passage to spawning, rearing, and overwintering habitat in the watershed.



Figure 1. The primary geographic scope — the Horsefly River watershed — located in the Fraser River system.

The primary geographic scope of this WCRP is the Horsefly River watershed, located in the upper Fraser River drainage basin in central British Columbia (Figure 1). The scope constitutes the Horsefly River "watershed group" as defined by the [British Columbia Freshwater Atlas](#) (FWA). A consistent spatial framework was necessary to undertake a watershed selection process at the provincial scale to identify target watersheds to improve connectivity for salmon. The Horsefly River watershed was identified by the BC Fish Passage Restoration Initiative as one of four target watersheds for WCRP development (Mazany-Wright et al. 2021b). The Horsefly River watershed has a drainage area of 276,603 ha, spanning from the Quesnel Highlands in the southeast to the confluence with Quesnel Lake in the northwest. Culturally and economically important populations of Chinook Salmon, Coho Salmon, and Sockeye Salmon are all found in the watershed, which historically supported Indigenous sustenance and trading economies (Table 3; Williams Lake First Nation 2021, Xat'sull First Nation 2021).

Table 3. Target fish species in the Horsefly River watershed. The Secwepemctsin and Western common and scientific species names are provided.

Secwepemctsin	Common Name	Scientific Name
Kekèsu	Chinook Salmon	<i>Oncorhynchus tshawytscha</i>
Sxeyqs	Coho Salmon	<i>Oncorhynchus kisutch</i>
Sqlelten7ùwi	Sockeye Salmon	<i>Oncorhynchus nerka</i>

The Horsefly River watershed comprises parts of Secwepemcúl’ecw, the traditional territory of the Northern Secwepemc te Qelmucw (NStQ), represented by the Northern Shuswap Tribal Council and four member communities or autonomous nations:

- Xat’sùll Cmetem’ (Soda Creek First Nations)
- Stswēceṛnc Xgāt’tem (Canoe Creek/Dog Creek First Nations)
- T’ēxelc (Williams Lake First Nation)
- Tsq’ēsceñ (Canim Lake First Nation)

The NStQ steward the land and the waters of the Horsefly River watershed based on balance and respect between the people, the animals and fish, the land, and the plants (N. Singtha, Williams Lake First Nation, pers. comm.). It is necessary to receive permission from the member communities for any work to occur on their territory.

The geographic scope of this WCRP was further refined by identifying “potentially accessible” stream segments, which are defined as streams that target species should be able to access in the absence of anthropogenic barriers (Figure 2). Potentially accessible stream segments were spatially delineated using fish species observation and distribution data, as well as data on “exclusionary points”. These include waterfalls greater than 5 m in height, gradient barriers based on species-specific swimming abilities, and watershed exclusion areas, which are portions of the watershed where barrier remediation efforts should not occur. These maps were explored by the planning team to incorporate additional local knowledge, ensure accuracy, and finalize the constraints on potentially accessible stream segments. The planning team identified certain tributaries to the mainstem Horsefly River as “watershed exclusion areas”, which were excluded from further consideration under this plan, due to intermittent or insufficient flows to support restoring connectivity for the target species. The geographic scope was further refined based on several confirmed impassable waterfalls and modelled gradient barriers. Specifically, there are two impassable waterfalls that severely limit potentially accessible habitat: one on the mainstem Horsefly River approximately 4 km upstream of the confluence with McKinley Creek, and the second on Moffat Creek approximately 5 km upstream from where it flows into the Horsefly River. All stream segments not identified as

potentially accessible were removed from the scope for further consideration. The "constrained geographic scope" formed the foundation for all subsequent analyses and planning steps, including mapping and modelling useable habitat types, quantifying the current connectivity status, goal setting, and action planning (Mazany-Wright et al. 2021a).



Figure 2. Potentially accessible stream segments within the Horsefly River watershed. These do not represent useable habitat types, but rather identifies the stream segments within which habitat modelling and barrier mapping and prioritization was undertaken.

Target Species

Target species represent the ecologically and culturally important species for which habitat connectivity is being conserved and/or restored in the watershed. In the Horsefly River watershed, the planning team selected *Anadromous Salmon* as the target species group, which comprises Chinook Salmon, Coho Salmon, and Sockeye Salmon. The selection of these target species was driven primarily by the targets species of the primary fund supporting this planning work.

Anadromous Salmonids

Anadromous salmon are cultural and ecological keystone species that contribute to productive ecosystems by contributing marine-derived nutrients to the watershed and forming an important food source for other species. Salmon species are sacred to the NStQ, having sustained life, trading economies, and culture since time immemorial (Williams Lake First Nation 2021, Xat'sūll First Nation 2021, N. Singi pers. comm.). The stewardship of the resources and fisheries in their traditional territories are imbued in the spirit of the NStQ through a symbiotic relationship based on respect – the NStQ never take more salmon than is needed and there is no waste. The entirety of the salmon is used - smoked and dried to sustain the NStQ through the winter months, the roe harvested for consumption, salmon oil rendered to be stored and traded, and the skin used to store the oil (Wilson et al. 1998, Xat'sūll First Nation 2021, N. Singi pers. comm.). The salmon runs begin to return to the Horsefly River watershed in early August, and the NStQ traditionally celebrate and feast at this time. The harvest of the salmon strengthens the cultural connection to the land and the waters, providing an important food source for communities and the opportunity to pass knowledge and ceremony to future generations through fishing and fish processing (Xat'sūll First Nation 2021, Williams Lake First Nation 2021).

Anadromous salmon populations in the Horsefly River watershed have declined significantly in the past few decades, with the populations of all three focal species being listed as Threatened or Endangered by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). This has been exacerbated by the Big Bar landslide on the Fraser River in 2019, leading the four NStQ communities to voluntarily close the salmon fishery temporarily (NStQ 2019). The stewardship of their waters continues through the work of the NStQ member communities and the Northern Shuswap Tribal Council. See Appendix A for maps of modelled anadromous salmon habitat in the Horsefly River Watershed.

Chinook Salmon | Kekèsu | *Oncorhynchus tshawytscha*

Table 4. Chinook Salmon population assessments in the Horsefly River watershed. Conservation Unit assessments were undertaken by the [Pacific Salmon Foundation \(2020\)](#). Designated Unit assessments were undertaken by [COSEWIC \(2018\)](#).

Conservation Unit	Biological Status	Run timing	Trend in spawner abundance (all available data)	Trend in spawner abundance (last 3 generations)
Middle Fraser River (Spring 5-2, 1.3)	Data Deficient/Poor	Data Deficient	Data Deficient	Data Deficient

COSEWIC Designated Unit	Status	Trend	Median percent change (last 3 generations)	Median percent change (historic)	Generation length
9- Middle Fraser, Stream, Spring (MFR+GStr) population	Threatened	Declining	-28%	-49%	4.5 years

Chinook Salmon are the first to return each year, usually in early August (DFO 1991), and have the most limited distribution within the watershed. Known spawning occurs in parts of the Horsefly River mainstem above the confluence with the Little Horsefly River and throughout McKinley Creek as far as Elbow Lake (DFO 1991, S. Hocquard, pers. comm.). Important rearing systems include Patenaude Creek, Kroener Creek, Black Creek, Woodjam Creek, Deerhorn Creek, and Wilmot Creek (S. Hocquard, pers. comm.).

Coho Salmon | Sxeyqs | *Oncorhynchus kisutch*

Table 5. Coho Salmon population assessments in the Horsefly River watershed. Conservation Unit assessments were undertaken by the [Pacific Salmon Foundation \(2020\)](#). Designated Unit assessments were undertaken by [COSEWIC \(2016\)](#).

Conservation Unit	Biological Status	Run timing	Trend in spawner abundance (all available data)	Trend in spawner abundance (last 3 generations)
Interior Fraser	Data Deficient/Fair	Data Deficient	Data Deficient	Data Deficient

COSEWIC Designated Unit	Status	Trend	Median percent change (last 3 generations)	Median percent change (historic)	Generation length
Interior Fraser – Mid/Upper Fraser population	Threatened	Declining	Not estimated	+119% estimated based on last 10 years of escapement data -21% estimated based on entire escapement time series	3 years

Coho Salmon are the most widely distributed of the three focal species in the watershed, with the ability to migrate into smaller, upper tributary systems (DFO 1991). Spawning occurs in the Little Horsefly River between Gruhs Lake and Horsefly Lake, McKinley Creek below McKinley Lake, Woodjam Creek, Patenaude Creek, Tisdall Creek, and Black Creek. Rearing fry and juveniles have been observed in the Little Horsefly River, Patenaude Creek, and McKinley Creek up to Bosk Lake (DFO 1991, S. Hocquard pers. comm.).

Sockeye Salmon | S̓q̓lelten7ùwi | *Oncorhynchus nerka*

Table 6. Sockeye Salmon population assessments in the Horsefly River watershed. Conservation Unit assessments were undertaken by the [Pacific Salmon Foundation \(2020\)](#). Designated Unit assessments were undertaken by [COSEWIC \(2017\)](#).

Conservation Unit	Biological Status	Run timing	Trend in spawner abundance (all generations)	Trend in spawner abundance (last 3 generations)
Quesnel-Summer (cyclic)	Data Deficient/Fair-Poor	July-September	Data Deficient	Data Deficient

COSEWIC Designated Unit	Status	Trend	Median percent change (last 3 generations)	Median percent change (historic)	Generation length
16 -Quesnel-S population	Endangered	Declining	260,974	-97%	+272%

Sockeye Salmon have historically been the most abundant of the three focal species in the watershed, though the population has seen significant declines in recent years (DFO 1991, S. Hocquard pers. comm.). Sockeye Salmon spawning is known to occur throughout the Horsefly River (up to the impassable falls), in the Little Horsefly River between Gruhs Lake and Horsefly Lake, Moffat Creek (up to the impassable falls), and McKinley Creek up to Elbow Lake (PSF 2018, DFO 1991, S. Hocquard pers. comm.). Additionally, a spawning channel aimed at enhancing the Sockeye Salmon population was constructed by Fisheries and Oceans Canada in 1989 (DFO 1991). Currently, there are no Sockeye Salmon rearing in the Horsefly River watershed – all emergent fry migrate down to Quesnel Lake.

Key Ecological Attributes and Current Connectivity Status

The planning team devised two Key Ecological Attributes (KEAs) and associated indicators to assess the current connectivity status of the watershed – Accessible Habitat and Accessible Overwintering Habitat (Table 7). KEAs are the key aspects of anadromous salmon ecology that are being targeted by this WCRP. The connectivity status of Anadromous Salmon was used to

establish goals to improve habitat connectivity in the watershed and will be the baseline against which progress is tracked over time.

The current connectivity status assessment relies on GIS analyses to map known and modelled barriers to fish passage, identify stream reaches that have potential spawning and rearing habitat, estimate the proportion of habitat that is currently accessible to target species, and prioritize barriers for field assessment that would provide the greatest gains in connectivity. To support a flexible prioritization framework to identify priority barriers in the watershed, two assumptions are made: 1) any modelled (i.e., passability status is unknown) or partial barriers are treated as complete barriers to passage and 2) the habitat modelling is binary, it does not assign any habitat quality values. As such, the current connectivity status will be refined over time as more data on habitat and barriers are collected. For more detail on how the connectivity status assessments were conducted, see Appendix B.

Table 7. Connectivity status assessment for (a) linear habitat (spawning and rearing) and (b) overwintering habitat in the Horsefly River watershed. The Available Habitat KEA is evaluated by dividing the length of linear habitat that is currently accessible to target species by the total length of all linear habitat in the watershed. The Available Overwintering Habitat KEA is evaluated as the sum of all areal overwintering habitat that is accessible to target species.

a

Target Species	KEA	Indicator	Indicator Ratings			
			Poor	Fair	Good	Very Good
Anadromous Salmon	Available Habitat	% of total linear habitat accessible	<80%		81 – 90%	>90%
Current Status:					81%	
Comments: Indicator rating definitions are based on the consensus decisions of the planning team, including the decision not to define “Fair”. The current status is based on the CWF Barrier Prioritization Model output, which is current as of August 2021.						

b

Target Species	KEA	Indicator	Indicator Ratings			
			Poor	Fair	Good	Very Good
Anadromous Salmon	Available Overwintering Habitat	Total area (m ²) of overwintering habitat accessible	?	?	?	?
Current Status:						
Comments: No baseline data exists on the extent of overwintering habitat in the watershed. A priority action is included in the plan to develop a habitat layer, and this will be used to inform this connectivity status assessment in the future.						

Barrier Types

The following table highlights which barrier types pose the greatest threat to anadromous salmon in the watershed. The results of this assessment were used to inform the subsequent planning steps, as well as to identify knowledge gaps where there is little spatial data to inform the assessment for a specific barrier type.

Table 8. Barrier Types in the Horsefly River watershed and barrier rating assessment results. For each barrier type listed, "Extent refers to the proportion of anadromous salmon habitat that is being blocked by that barrier type, "Severity" is the proportion of structures for each barrier type that are known to block passage for target species based on field assessments, and "Irreversibility" is the degree to which the effects of a barrier type can be reversed and connectivity restored. The amount of habitat blocked used in this exercise is a representation of total amount of combined spawning and rearing habitat.

Barrier Types	Extent	Severity	Irreversibility	Overall Threat Rating:
Small Dams (<3m height)	Low	Very High	High	Low
Road-stream Crossings	Very High	Very High	Medium	Very High
Trail-stream Crossings	Low	Low	Medium	Low
Lateral Barriers	High	Very High	High	High
Natural Barriers	Medium	High	Low	Low

Large Dams (>3m height) and Small Dams (<3m height)

There are nine mapped small dams on “potentially accessible” stream segments in the watershed, blocking a total of 9.53 km (9.1% of the total blocked habitat) of modelled spawning and rearing habitat for anadromous salmon, resulting in a Low extent. The extent rating of these structures was confirmed by the planning team. There are two known fish-passage structures in the watershed, including on the dam at the outlet of McKinley Lake. The remaining dams likely block passage for anadromous salmon and would require significant resources to remediate. However, due to the limited extent of dams in the watershed, a final pressure rating of Low was assigned. Despite the low-pressure ranking, four small dams were identified on the priority barrier list (see Appendix C) and require further assessment and confirmation of upstream habitat quality.

Road-stream Crossings

Road-stream crossings are the most abundant barrier type in the watershed, with 540 assessed and modelled crossings located on “potentially accessible” stream segments. Demographic road crossings (highways, municipal, and paved roads) block 8.18 km of habitat (7.8% of the

total blocked habitat), with 74% of assessed crossings having been identified as barriers to fish passage. Resource roads block 86.72 km of habitat (83%), with 65% of assessed crossings having been identified as barriers. The planning team felt that the data was underestimating the severity of road-stream crossing barriers in the watershed, and therefore decided to update the rating from High to Very High. The planning team also felt that an irreversibility rating of Medium was appropriate due to the technical complexity and resources required to remediate road-stream crossings.

Trail-stream crossings

There is very little spatial data available on trail-stream crossings in the watershed, so the planning team was unable to quantify the true Extent and Severity of this barrier type. However, the planning team felt that trail-stream crossings are not prevalent within the watershed and that, where they do exist, they do not significantly impact passage for anadromous salmon. As most crossings will be fords or similar structures, remediation may not be required, or remediation costs associated with these barriers would be quite low. Overall, the planning team felt that the pressure rating for trail-stream crossings was likely Low; however, the lack of ground-truthed evidence to support this rating was identified as a knowledge gap within this plan.

Lateral Barriers

There are numerous types of lateral barriers that potentially occur in the watershed, including dykes, berms, and linear development (i.e., road and rail lines), all of which can restrict the ability of anadromous salmon to move into floodplains, riparian wetlands, and other off-channel habitats. No comprehensive lateral barrier data exists within the watershed, so pressure ratings were based on qualitative local knowledge. Lateral barriers are not thought to be as prevalent as road- or rail-stream crossings but are likely very severe where they do exist. Significant lateral barriers are known to occur along the mainstem of the Horsefly River, which disconnect the mainstem river from historic floodplain and off-channel habitat. Overall, the planning team decided that a High pressure rating adequately captured the effect that lateral barriers are having on connectivity in the watershed.

Natural Barriers

Natural barriers to fish passage can include debris flows, log jams, sediment deposits, etc., but natural features that have always restricted fish passage (e.g., waterfalls) are not considered under this barrier type. Natural barriers are difficult to include in a spatial prioritization framework due to their transient nature. The planning team identified known natural barriers that occur throughout the watershed, such as beaver dams and log jams. Generally, these natural barriers are only severe impediments to fish passage during low-flow years, but reduced baseflows have become more common in recent years. Based on this, the planning team felt that natural barriers will be severe most years where they exist, but are mostly reversible, resulting in an overall pressure rating of Low.

Situation Analysis

The following situation model was developed by the WCRP planning team to “map” the project context and brainstorm potential actions for implementation. Green text is used to identify actions that were selected for implementation (see Strategies & Actions), and red text is used to identify actions that the project team has decided to exclude from the current iteration of the plan, as they were either outside of the project scope, or were deemed to be ineffective by the planning team.

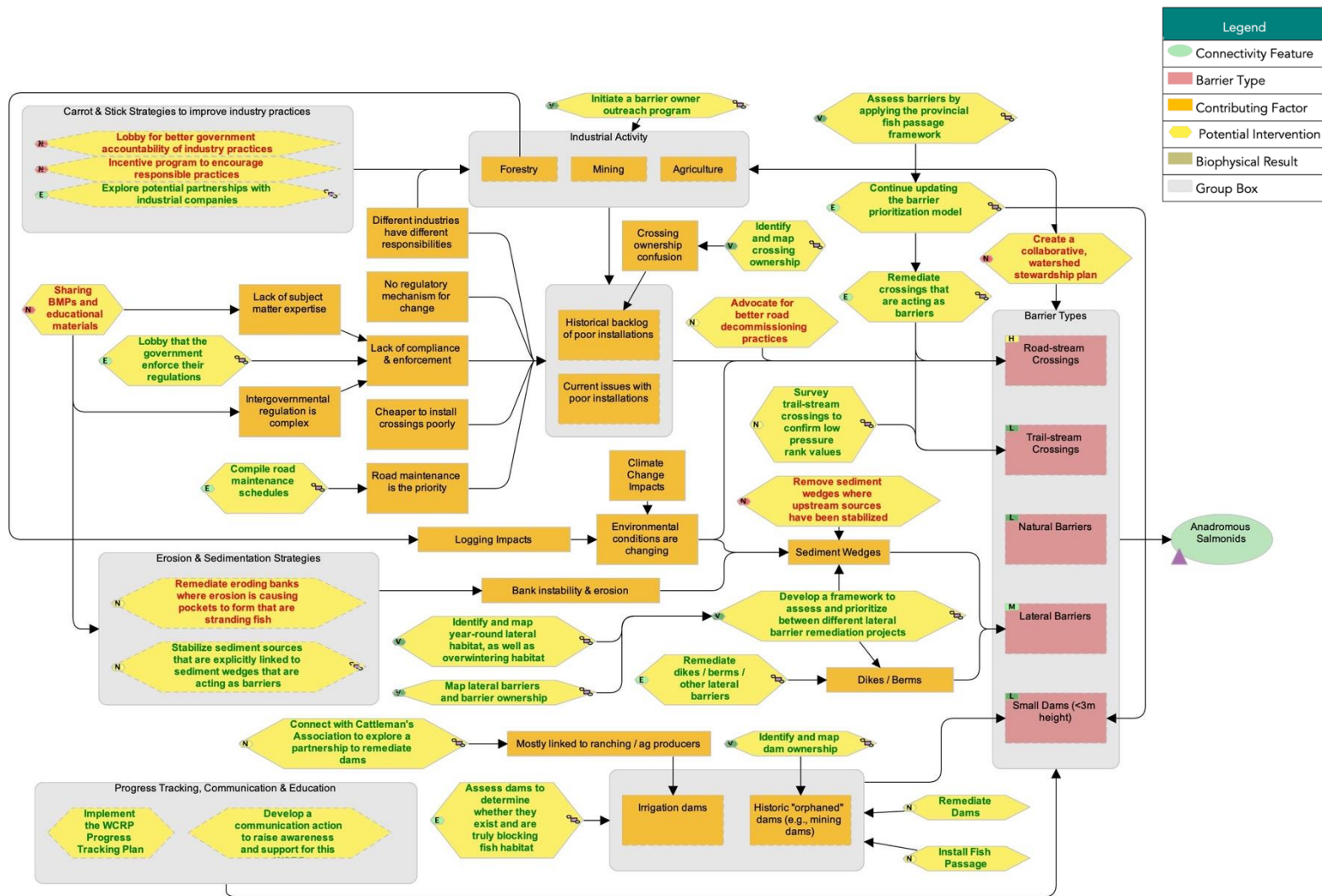


Figure 3. Situation analysis developed by the planning team to identify factors that contribute to fragmentation (orange boxes), biophysical results (brown boxes), and potential strategies/actions to improve connectivity (yellow hexagons) for target species in the Horsefly River watershed.

Goals

Table 9. Goals to improve (1) spawning and rearing and (2) overwintering habitat connectivity for target species in the Horsefly River watershed over the lifespan of the WCRP (2021-2040). The goals were established through discussions with the planning team and represent the resulting desired state of connectivity in the watershed. The goals are subject to change as more information and data are collected over the course of the plan timeline (e.g., the current connectivity status is updated based on barrier field assessments).

Goal #	Goal
1	By 2040, the percent (%) of total linear habitat accessible to anadromous salmon will increase from 81% to 91% within the Horsefly River watershed (i.e., reconnect at least 57.3 km of habitat).
2	By 2023, the total area of overwintering habitat accessible to Anadromous Salmon will increase by 1,500 m ² within the Horsefly River watershed.

Strategies & Actions

Table 10. Effectiveness evaluation of identified conservation strategies and associated actions to improve connectivity for target species in the Horsefly River watershed. The planning team identified five broad strategies to implement through this WCRP, 1) crossing remediation, 2) lateral barrier remediation, 3) dam remediation, 4) barrier prevention, and 5) communication and education. Individual actions were qualitatively evaluated based on the anticipated effect each action will have on realizing on-the-ground gains in connectivity. Effectiveness ratings are based on a combination of "Feasibility and "Impact", Feasibility is defined as the degree to which the project team can implement the action within realistic constraints (financial, time, ethical, etc.) and Impact is the degree to which the action is likely to contribute to achieving one or more of the goals established in this plan.

Strategy 1: Crossing Remediation					
ID	Actions	Details	Feasibility	Impact	Effectiveness
1.1	Remediate crossings that are acting as barriers	This action represents some projects that would be led by the planning team with conservation funds (e.g., orphaned barriers or those owned by individuals), while other remediation projects would be the responsibility of the barrier owner. Industry will have to be engaged to successfully implement this intervention.	High	Very high	Effective
1.2	Lobby that the government enforce their regulations	This can apply to both provincial and federal governments. For example, advocating for increased discretionary decisions to remove barriers to fish. One action could be to submit barrier assessment data to show proof that regulations are not being followed.	Very high	High	Effective

1.3	Initiate a barrier owner outreach program	Work with landowners / users (e.g., ATV groups) to identify and remediate their aquatic barriers. Education component can help prevent barriers in the first place.	Very high	Very high	Very effective
1.4	Knowledge Gap: Continue updating the barrier prioritization model	The model process will be finalized, and prioritizations will be updated as new information becomes available. This can also include data related to flows.	Very high	High	Effective
1.5	Knowledge Gap: Assess barriers by applying the provincial fish passage framework	The first three steps are, (1) barrier assessments, (2) habitat confirmations, and (3) remediation designs.	Very high	Very high	Very effective
1.6	Knowledge Gap: Identify and map crossing ownership	Focus on identifying ownership of priority crossings that we want to remediate in the short-term.	Very high	Very high	Very effective
1.7	Knowledge Gap: Compile road maintenance schedules	Ground-truthing is important, as the schedules do not always reflect what happens in the field.	High	High	Effective
1.8	Knowledge Gap: Survey trail-stream crossings to confirm low pressure rating values	Need to access detailed trail maps in the watershed to prioritize our time and resources. This should be accomplished as people are out surveying for other reasons rather than spending time and resources specifically to fill this knowledge gap.	Very high	Medium	Need more information

Strategy 2: Lateral Barrier Remediation					
ID	Actions	Details	Feasibility	Impact	Effectiveness
2.1	Remediate dikes / berms / other lateral barriers		High	Very high	Effective
2.2	Initiate a barrier owner outreach program		Very high	Very high	Very effective
2.3	Knowledge Gap: Identify and map year-round lateral habitat, as well as overwintering habitat	Explore the use of a drone to identify lateral habitat.	Very high	Very high	Very effective
2.4	Knowledge Gap: Map lateral barriers and barrier ownership	Focus on identifying ownership of priority lateral barriers that we want to remediate in the short-term.	Very high	Very high	Very effective
2.5	Knowledge Gap: Develop a framework to assess and prioritize between different lateral barrier remediation projects		Very high	Very high	Very effective

Strategy 3: Dam Remediation					
ID	Actions	Details	Feasibility	Impact	Effectiveness
3.1	Remediate Dams		Medium	Very high	Need more information
3.2	Install Fish Passage		Medium	High	Need more information

3.3	Connect with Cattleman's Association to explore a partnership to remediate dams	This may involve exploring alternative water management actions that would allow for the remediation of irrigation dams.	High	Medium	Need more information
3.4	Knowledge Gap: Continue updating the barrier prioritization model	The model process will be finalized, and prioritizations will be updated as new information becomes available. This can also include data related to flows.	Very high	High	Effective
3.5	Knowledge Gap: Assess dams to determine whether they exist and are truly blocking fish habitat	Focus on identifying ownership of priority dams that we want to remediate in the short-term.	Very high	High	Effective
3.6	Knowledge Gap: Identify and map dam ownership		Very high	Very high	Very effective

Strategy 4: Barrier Prevention

ID	Actions	Details	Feasibility	Impact	Effectiveness
4.1	Explore potential partnerships with industrial companies	Invite industrial players to a workshop on how to apply crossing / lateral barrier BMPs. BMPs could include those that minimize the need for road-stream crossings.	Very high	High	Effective
4.2	Stabilize sediment sources that are explicitly linked to sediment wedges or erosion that are acting as barriers	This could include numerous bank stabilization techniques, including restoring riparian vegetation. This applies to some tributaries that have altered confluence areas - the link needs to be made between confluence alterations and timing of movement for juvenile fish. Local	Very high	Medium	Need more information

		ranchers and Cattleman's association could be engaged, as well as forestry licensees.			
--	--	---	--	--	--

Strategy 5: Communication and Education

ID	Actions	Details
5.1	Implement the WCRP Progress Tracking Plan	The WCRP Progress Tracking Plan will help the team determine if we are achieving our goals and objectives.
5.2	Develop a communication strategy to raise awareness and support for this WCRP	This intervention includes communicating both the WCRP and the collaborative process in developing it, as well as communicating outcomes (e.g., barrier remediations).

Theories of Change & Objectives

Theories of Change are explicit assumptions around how the identified actions will achieve gains in connectivity and contribute towards reaching the goals of the plan. To develop Theories of Change, the planning team developed explicit assumptions for each strategy which helped to clarify the rationale used for undertaking actions and provided an opportunity for feedback on invalid assumptions or missing opportunities. The Theories of Change are results oriented and clearly define the expected outcome. The following theory of change models were developed by the WCRP planning team to “map” the causal (“if-then”) progression of assumptions of how the actions within a strategy work together to achieve project goals.

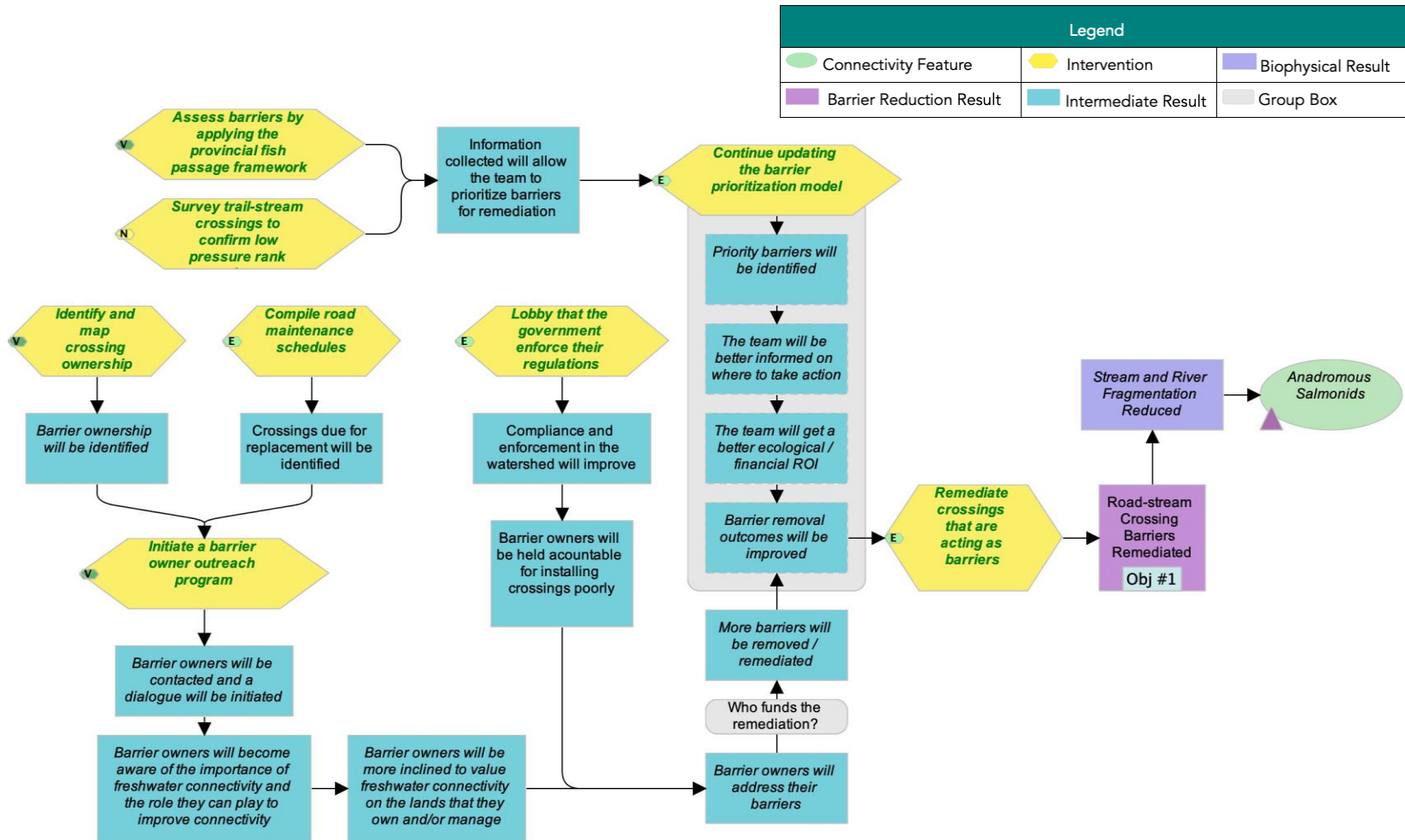


Figure 4. Theory of change developed by the planning team for the actions identified under Strategy 1: Crossing Remediation in the Horsefly River watershed.

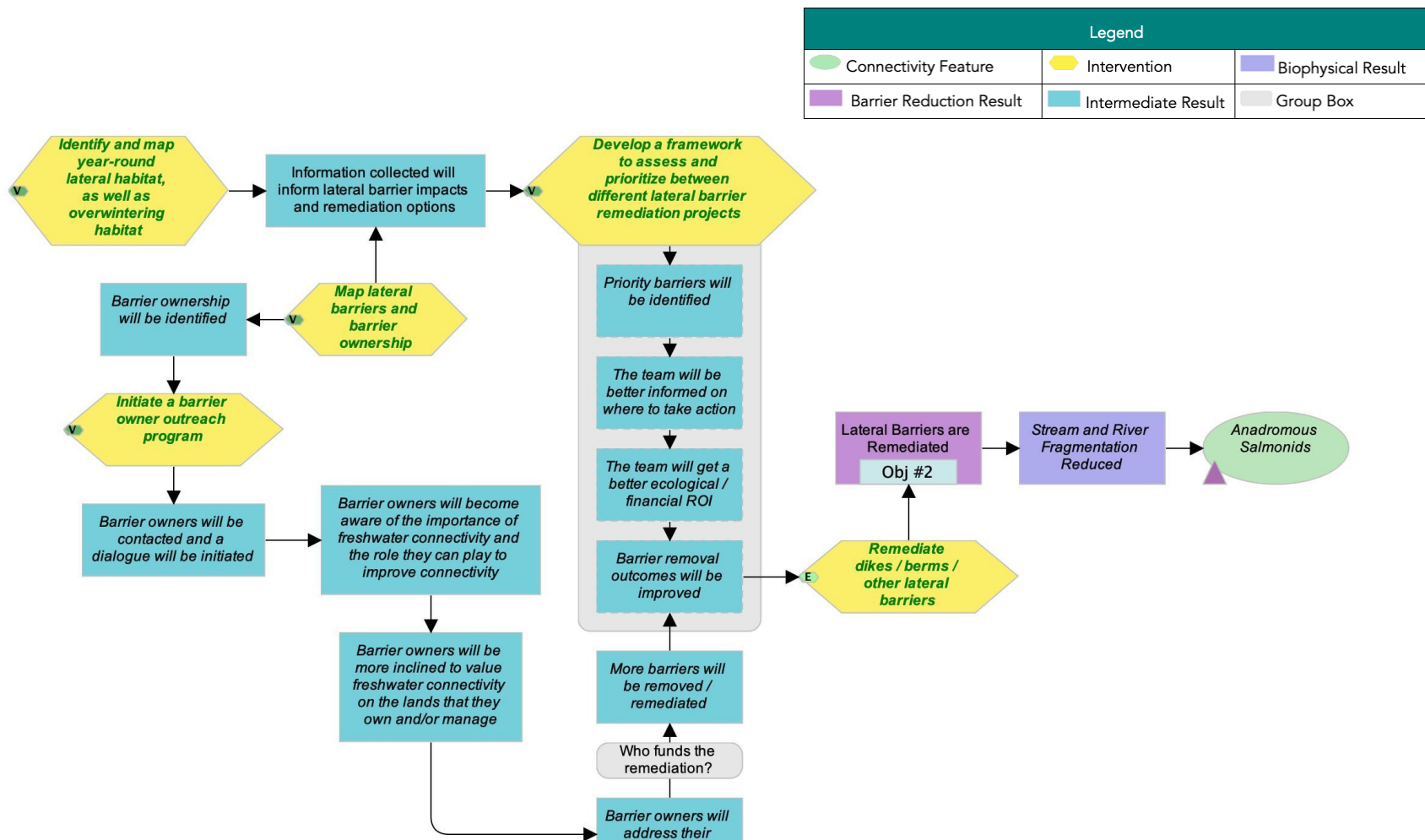


Figure 5. Theory of change developed by the planning team for the actions identified under Strategy 2: Lateral Barrier Remediation in the Horsefly River watershed.

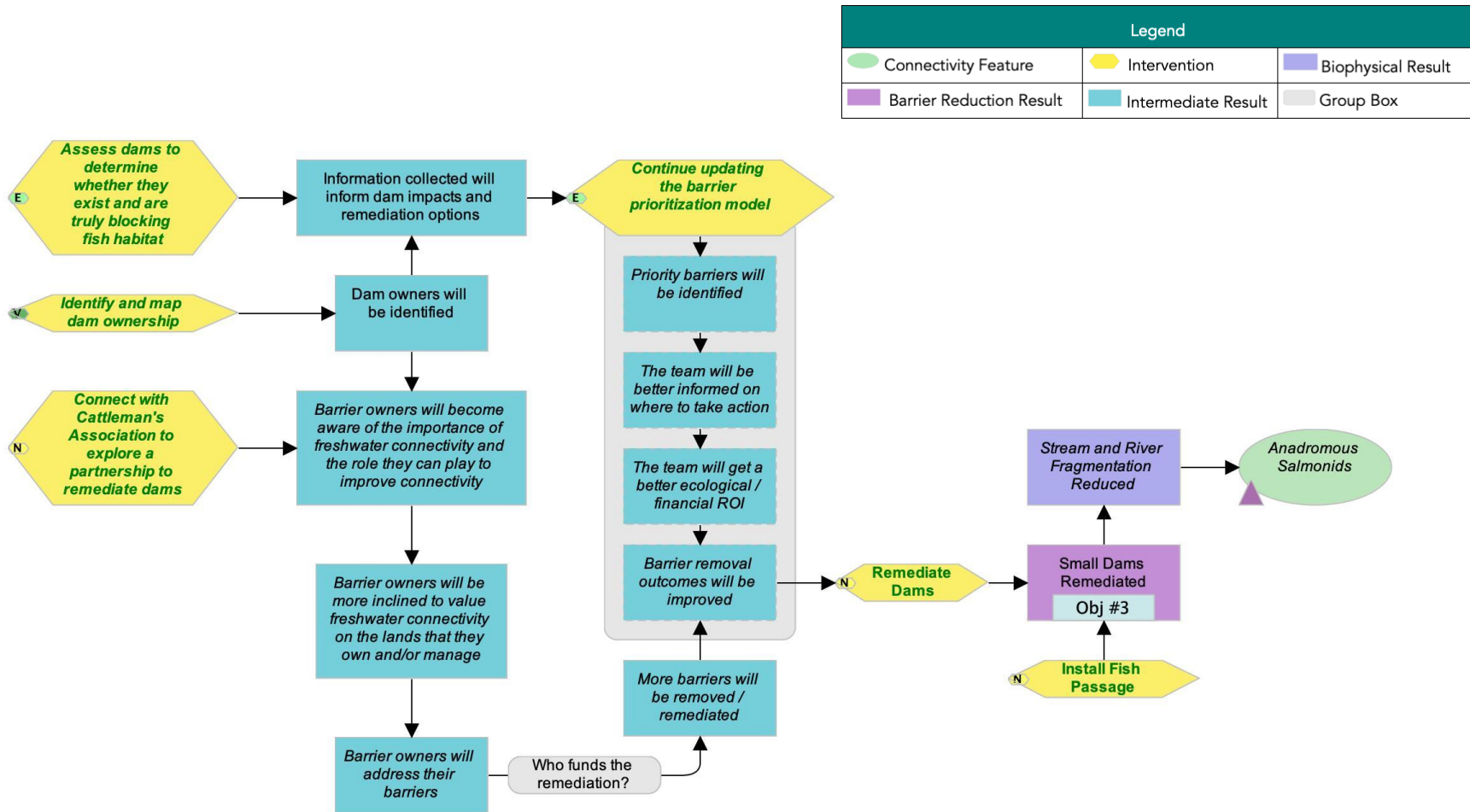


Figure 6. Theory of change developed by the planning team for the actions identified under Strategy 3: Dam Remediation in the Horsefly River watershed.

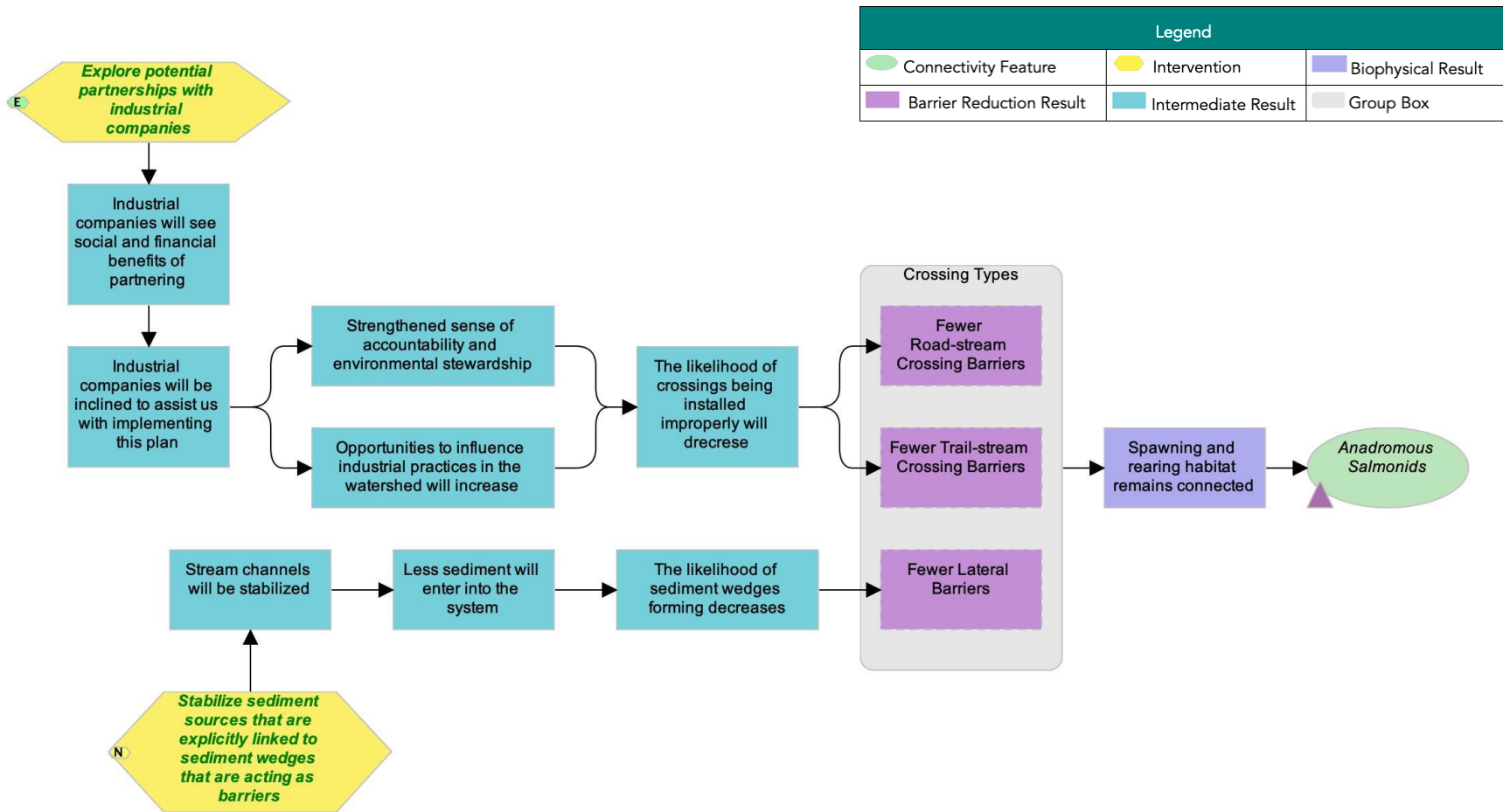


Figure 7. Theory of change developed by the planning team for the actions identified under Strategy 4: Barrier Prevention in the Horsefly River watershed.

Table 11. Objectives to improve connectivity for target species in the Horsefly River watershed. Objectives are formal statements of the desired future outcomes of plan implementation and are used to track progress towards those outcomes.

Objective #	Objective
1	By 2040, 16 road-stream crossing barriers will be remediated in the Horsefly River watershed
2	By 2023, a minimum of 1 lateral barrier will be remediated in the Horsefly River watershed
3	By 2040, 4 dams will be remediated in the Horsefly River watershed

Progress Tracking Plan

Table 12. Progress Tracking Plan for the Horsefly River watershed to capture results of plan implementation.

Goals / Objectives	Indicator	Methods	Timeframe	Who	Comments
Goal 1: By 2040, the percent (%) of total linear habitat accessible to anadromous salmon will increase from 81% to 91% within the Horsefly River watershed.	Percent (%) of total linear habitat accessible	Field reports & as-built drawings informing the CWF Barrier Prioritization Model	Annually	CWF – Nick M.	See CWF companion document for detailed GIS procedures
Goal 2: By 2023, the total area of overwintering habitat accessible to anadromous salmon will increase by 1,500 m ² within the Horsefly River watershed.	Total area (m ²) of overwintering habitat accessible	TBD	TBD	CWF – Nick M.	Identified as a knowledge gap. Specifics are TBD.
Objective 1: By 2040, 16 road-stream crossing barriers will be remediated in the Horsefly River watershed.	The number (#) of road-stream crossings remediated	CWF tracking within the Barrier Prioritization Model + PSCIS database	Annually	CWF - Nick M. & Betty	See CWF companion document for

					detailed GIS procedures
Objective 2: By 2023, a minimum of 1 lateral barrier will be remediated in the Horsefly River watershed.	The number (#) of lateral barriers remediated	<i>TBD</i>	<i>TBD</i>	CWF - Nick M. & Betty	Identified as a knowledge gap. Specifics are TBD.
Objective 3: By 2040, 4 dams will be remediated in the Horsefly River watershed.	The number (#) of dams remediated	CWF tracking within the Barrier Prioritization Model	Annually	CWF - Nick M. & Betty	See CWF companion document for detailed GIS procedures

Operational Plan

The operational plan represents a preliminary exercise undertaken by the planning team to identify the potential leads, potential participants, and estimated cost for the implementation of each action in the Horsefly River watershed. The table below summarizes individuals, groups, or organizations that the planning team felt could lead or participate in the implementation of the plan and should be interpreted as the first step in on-going planning and engagement to develop more detailed and sophisticated action plans for each entry in the table. The individuals, groups, and organizations listed under the "Lead(s)" or "Potential Participants" columns are those that provisionally expressed interest in participating in one of those roles or were suggested by the planning team for further engagement (denoted in bold), for those that are not members of the planning team. The leads, participants, and estimated costs in the operational plan are not binding nor an official commitment of resources, but rather provide a roadmap for future coordination and engagement to work towards implementation of the WCRP.

Table 13. Operational plan to support the implementation of strategies and actions to improve connectivity for target species in the Horsefly River watershed.

Strategy / Actions	Lead(s) ¹	Participants ³	Total Budget
Strategy 1: Crossing Remediation			\$3,666,300.00
1.1 – Remediate crossings that are acting as barriers	CWF	Horsefly River Roundtable, Fisheries and Oceans Canada (DFO)	\$3,500,000.00
1.2 – Lobby that the government enforce their regulations	<i>TBD</i>	CWF, Horsefly River Roundtable, Williams Lake First Nation (WLFN)	\$10,000.00

¹ Leads and participants denoted in **bold** represent those that will be invited to participate but are currently unconfirmed.

1.3 – Initiate a barrier owner outreach program	TBD	CWF, DFO	TBD
1.4 – Knowledge Gap: Continue updating the barrier prioritization model	CWF	TBD	\$100,000.00
1.5 – Knowledge Gap: Assess barriers by applying the provincial fish passage framework	CWF	Horsefly River Roundtable, DFO	\$50,300.00
1.6 – Knowledge Gap: Identify and map crossing ownership	TBD	CWF, DFO	\$1,500.00
1.7 – Knowledge Gap: Compile road maintenance schedules	DFO	CWF, WLFN, DFO, FLNRORD	\$2,000.00
1.8 – Knowledge Gap: Survey trail-stream crossings to confirm low pressure rating values	WLFN	CWF, DFO	\$2,500.00
Strategy 2: Lateral Barrier Remediation			\$80,000.00
2.1 – Remediate dikes / berms / other structures that are acting as barriers	CWF	DFO, Horsefly River Roundtable	TBD
2.2 – Initiate a barrier owner outreach program	TBD	CWF, DFO	TBD
2.3 – Knowledge Gap: Identify and map year-round lateral habitat, as well as overwintering habitat	TBD	CWF, DFO, Horsefly River Roundtable Northern Shuswap Tribal Council (NSTC), WLFN	\$65,000.00
2.4 – Knowledge Gap: Map lateral barriers and barrier ownership	CWF	DFO, Horsefly River Roundtable	\$5,000.00
2.5 – Knowledge Gap: Develop a framework to assess and prioritize between different lateral barrier remediation projects	CWF	DFO	\$10,000.00
Strategy 3: Dam Remediation			\$1,305,000.00

3.1 - Remediate Dams	TBD	TBD	\$1,305,000.00
3.2 - Install Fish Passage	TBD	TBD	TBD
3.3 - Connect with Cattleman's Association to explore a partnership to remediate dams	TBD	TBD	TBD
3.4 - Knowledge Gap: Continue updating the barrier prioritization model	CWF	TBD	\$0.00
3.5 - Knowledge Gap: Assess dams to determine whether they exist and are truly blocking fish habitat	TBD	TBD	TBD
3.6 - Knowledge Gap: Identify and map dam ownership	TBD	TBD	TBD
Strategy 4: Barrier Prevention			\$110,000.00
4.1 – Explore potential partnerships with industrial companies	TBD	CWF, DFO, Horsefly River Roundtable, WLFN	\$10,000.00
4.2 – Stabilize sediment sources that are explicitly linked to sediment wedges or erosion that are acting as barriers	TBD	DFO	\$100,000.00
Strategy 5: Progress Tracking Plan			TBD
5.1 - Implement the WCRP Progress Tracking Plan	TBD	CWF	TBD
5.2 - Develop a communication action to raise awareness and support for this WCRP	CWF	TBD	TBD
Total:			\$5,161,300.00
Fundraising total:			\$2,508,800
Proponent/government contribution total:			\$2,652,500

Funding Sources

Table 14. Potential funding sources for plan implementation in the Horsefly River watershed. The Canadian Wildlife Federation and the planning team can coordinate proposal submission through these sources.

Funding Source	Spending Restrictions and Other Consideration
Land Based Investment Strategy	Assessment and remediation of fish passage using provincial strategic approach. Primarily for remediation of Ministry-owned/orphaned barriers on forest service roads.
Environmental Enhancement Fund	Fish and wildlife passage improvements and restoration at stream and animal crossings at MOTI roads including culvert retrofits and replacement to restore Pacific salmon and trout access, and wildlife tunnels. Primarily for crossings linked to highway infrastructure.
Community Salmon Program	For projects supporting the protection, conservation and enhancement or rehabilitation of Pacific salmonids and their habitat. Funding for volunteer and not-for-profit community-based groups. Applicant must have a significant volunteer component to their group and to the project. Requires 50% match for funding (volunteer, in-kind, donation or other grants).
Southern Boundary Restoration and Enhancement Fund	Supports 3 activities: (1) develop improved information for resource management; (2) Rehabilitate and restore marine and freshwater habitat; and (3) enhance wild stock production through low technology techniques. Emphasis for funding is on stocks of conservation concern, particularly those contributing to a fishery and stocks of bilateral fishery relevance.
Habitat Conservation Trust Foundation Enhancement and Restoration Grants	Projects that focus on freshwater wild fish, native wildlife species and their habitats, have the potential to achieve a significant conservation outcome, while maintaining or enhancing opportunities for fishing, hunting, trapping, wildlife viewing and associated outdoor recreational activities. Primary focus is on provincially managed fisheries such as Steelhead and Westslope Cutthroat Trout. Requires 50% funding match.
Environmental Damages Fund	Direct funds received from fines, court orders and voluntary payments to priority projects that will benefit Canada's natural environment, under 4 categories of improvement (in order of preference):

	(1) restoration, (2) environmental quality improvement, (3) research and development, and (4) education and awareness.
Habitat Stewardship Program for Aquatic Species at Risk	Program for non-profits, Indigenous governments, academic institutions for activities that align with recovery actions identified in SARA recovery documents and/or COSEWIC assessment documents. Project must address one or more of 3 broad categories: (1) Important habitat for aquatic species at risk is improved and/or managed to meet their recovery needs; (2) Threats to aquatic species at risk and/or their habitat are stopped, removed, and/or mitigated; (3) Collaboration and partnerships support the conservation and recovery of aquatic species at risk. Limited to at-risk species listed under COSEWIC and/or SARA as threatened, endangered or special concern.
Canada Nature Fund for Aquatic Species at Risk	Funding program aimed at addressing priority threats for aquatic species at risk listed as endangered, threatened or Special Concern by COSEWIC, as they align with existing federal, provincial or other local recovery plans. Limited to species in the Columbia and Fraser basins in BC, among other priority areas across Canada. Focus on multi-year, multi-partner initiatives that apply an ecosystem or multi-species approach and create a legacy by enabling recovery actions that carry beyond the life of the funding program. Amounts from \$100K-\$1M available per year.
BC Salmon Restoration and Innovation Fund	Funding for Indigenous enterprises, academia, industry associations, stewardship groups and commercial groups to support initiatives that support the protection and restoration of wild Pacific salmon and other BC fish stocks or ensure fish and seafood sector in BC is environmentally and economically sustainable. Five main priorities including species of concern rebuilding through habitat restoration with priority for projects that are part of a watershed-scale restoration plan/prioritization effort; build on successful previous restoration efforts; focus on critical habitat and/or the rehabilitation of natural ecosystem processes.
Aboriginal Fund for Species at Risk	Program for Indigenous groups for activities that align with recovery actions identified in SARA recovery documents and/or COSEWIC assessment documents for species listed as Endangered, Threatened, or Special Concern by SARA or COSEWIC. Project must address one or more of 4 broad categories: (1) Habitat for species at risk is improved and/or managed to meet their recovery needs; (2) Threats to species at risk and/or their habitat are stopped, removed and/or mitigated; (3) Collaboration, information sharing and partnership between Indigenous communities, governments

	and organizations and other interested parties (e.g. federal/provincial/territorial governments, academia, industry, private sector) is enhanced; and (4) Capacity within Indigenous communities, to lead in the stewardship of species at risk and contribute to broader SARA implementation, is strengthened.
Federal Gas Tax Fund - Community Works Fund	Funding available to local governments from federal gas tax, with funds to be allocated for a variety of municipal projects/initiatives, including local roads/bridges and disaster mitigation.
Disaster Mitigation and Adaptation Fund	For those projects where flood risk is high: Funding available to local, regional and provincial governments, private sector, non-profit organizations, and Indigenous groups for projects aimed at reducing the socio-economic, environmental and cultural impacts triggered by natural hazards and extreme weather events and taking into consideration current and future impacts of climate change in communities and infrastructure at high risk. Includes both new construction of public infrastructure and modification/reinforcement of existing infrastructure. Projects must have a minimum of \$20 M in eligible expenditures and can be bundled together.
Community Gaming Grants	Funding for non-profit organizations (check funding program guidelines for specific eligibility requirements) for programs that help to protect and improve the environment by: (1) Conserving or revitalizing local ecosystems, (2) Reducing greenhouse gas emissions, (3) Providing community education or engagement opportunities related to the environment and agriculture or (4) Supporting the welfare of domestic animals and/or wildlife. Grants range from \$100K-250K per year.
Sitka Foundation	Funding for registered charities, universities, and government agencies (qualified Canadian organizations) for projects related to coastline and watershed conservation and climate change in 4 key areas: <ol style="list-style-type: none"> 1. land, water, and ocean conservation 2. scientific research for nature and the environment 3. public engagement around the importance of a healthy environment 4. innovative conservation efforts in Canadian communities, at the local, provincial, and federal levels
TULA Foundation	Supports various environmental programs of interest to the Foundation on a case-by-case basis.

Vancouver Foundation	Granting agency for community, social and environmental initiatives for qualified Canadian organizations (charitable organizations, universities, government agencies). Granting programs change on an annual basis.
BC Conservation Foundation Small Project Fund	Funding available to Non-profits, fish and wildlife clubs (sportsmen's associations), businesses, local/regional governments, public organizations and First Nations for projects with demonstrated positive impact for fish, wildlife and habitat, including outreach programs. Preference given to projects where BCCF is not the sole funder.
Real Estate Foundation of BC General Grants	Funding for First Nations, charities and societies, non-governmental organizations, universities and colleges, trade associations, local and regional governments, and social enterprises registered as C3s for sustainable land use and real estate practices in BC. Funds up to 50% of cash portion of a project.

References

- Agrawal, A., R. S. Schick, E. P. Bjorkstedt, R. G. Szerlong, M. N. Goslin, B. C. Spence, T. H. Williams, and K. M. Burnett. 2005. Predicting the potential for historical Coho, Chinook, and Steelhead habitat in northern California. National Oceanic and Atmospheric Administration, NOAA-TM-NMFS-SWFSC-379.
- Bjornn, T. C., and D. W. Reiser. 1991. Habitat requirements of salmonids in streams. In Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19: 83-138.
- Burnett, K. M., G. H. Reeves, D. J. Miller, S. Clarke, K. Vance-Borland, K. Christiansen. 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. Ecological Applications 17: 66-80.
- Busch, D. S., M. Sheer, K. Burnett, P. McElhany, and T. Cooney. 2011. Landscape-level model to predict spawning habitat for lower Columbia River fall Chinook Salmon (*Oncorhynchus tshawytscha*). River Research Applications 29: 291-312.
- Cooney, T., and D. Holzer. 2006. Appendix C: Interior Columbia basin stream type Chinook Salmon and Steelhead populations: habitat intrinsic potential analysis. National Oceanic and Atmospheric Administration, Northwest Fisheries Center.
- COSEWIC. 2016. COSEWIC Assessment and Status Report on the Coho Salmon *Oncorhynchus kisutch*, Interior Fraser Population, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/coho-salmon-interior-fraser-2016.html>.
- COSEWIC. 2017. COSEWIC Assessment and Status Report on the Sockeye Salmon *Oncorhynchus nerka*, 24 Designatable Units in the Fraser River Drainage Basin, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. https://www.sararegistry.gc.ca/virtual_sara/files/cosewic/srSockeyeSalmon2017e.pdf.
- COSEWIC. 2018. COSEWIC Assessment and Status Report on the Chinook Salmon *Oncorhynchus tshawytscha*, Designatable Units in Southern British Columbia (Part One – Designatable Units with no or low levels of artificial releases in the last 12 years), in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ontario. <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/chinook-salmon-2018/document-info-summaries.html>.
- [DFO] Fisheries and Ocean Canada. 1991. Fish habitat inventory and information program - stream summary information.
- Lake, R. G. 1999. Activity and spawning behaviour in spawning Sockeye salmon. Thesis, University of British Columbia.

- Masse Environmental Consultants Ltd. 2018. Fish Habitat Confirmation Assessments Horsefly River Watershed. Prepared for Ministry of Environment & Climate Change Strategy.
- Mazany-Wright, N., S. M. Norris, N. W. R. Lapointe, and B. Rebellato. 2021a. A Freshwater Connectivity Modelling Framework to Support Barrier Prioritization and Remediation in British Columbia. Canadian Wildlife Federation, Ottawa, Ontario.
- Mazany-Wright, N., S. M. Norris, N. W. R. Lapointe, and B. Rebellato. 2021b. B.C. Fish Passage Restoration Initiative Target Watershed Selection Process: Technical Documentation. Canadian Wildlife Federation, Ottawa, Ontario.
- Mazany-Wright, N., J. Noseworthy, S. Sra, S. M. Norris, and N. W. R. Lapointe. 2021c. Breaking Down Barriers: a Practitioners' Guide to Watershed Connectivity Remediation Planning. Canadian Wildlife Federation, Ottawa, Ontario.
- McMahon, T. E. 1983. Habitat suitability index models: coho salmon. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.49. 29 pp.
- Neuman H. R., and C. P. Newcombe. 1977. Minimum acceptable stream flows in British Columbia: a review. Fisheries Management Report No. 70.
- [NStQ] Northern Secwepemc to Qelmuw. 2019. Saving the Salmon. Lexéy'em – Fall 2019. https://nstq.ca/wp-content/uploads/2019/09/Lexeyem_Fall-2019_Final.pdf.
- Pacific Salmon Foundation. 2020. Methods for Assessing Status and Trends in Pacific Salmon Conservation Units and their Freshwater Habitats. The Pacific Salmon Foundation, Vancouver, British Columbia. https://salmonwatersheds.ca/libraryfiles/lib_459.pdf.
- Porter, M., D. Pickard, K. Wieckowski, and K. 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 Environment.
- Raleigh, R. F., and W. J. Miller. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish and Wildlife Service Biological Reports 82. 64pp.
- Roberge, M., J. B. M. 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. Fisheries and Oceans Canada, Marine Environment and Habitat Science Division, Cultus Lake, British Columbia.
- Rosenfeld, J., M. Porter, and E. Parkinson. 2000. Habitat factors affecting the abundance and distribution of juvenile cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 57: 766-774.
- Seliger, Carina, and Bernhard Zeiringer. 2018. River Connectivity, Habitat Fragmentation and Related Restoration Measures. In Riverine Ecosystem Management: Science for Governing Towards a Sustainable Future, edited by Stefan Schmutz and Jan Sendzimir, 171–86. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-73250-3_9.
- Sheer, M. B., D. S. Busch, E. Gilbert, J. M. Bayer, S. Lanigan, J. L. Schei, K. M. Burnett, and D. Miller. 2009. Development and management of fish intrinsic potential data and

methodologies: State of the IP 2008 summary report. Pacific Northwest Aquatic Monitoring Partnership Series 2009—4, 56 pp.

Sheer, M. B., and E. A. Steel. 2006. Lost watersheds: barriers, aquatic habitat connectivity, and salmon persistence in the Willamette and Lower Columbia basins. *Transactions of the American Fisheries Society* 135: 1654-1669.

Sloat M. R., G. H. Reeves, and K. R. Christiansen. Stream network geomorphology mediates predicted vulnerability of anadromous fish habitat fish habitat to hydrologic change in southeast Alaska.

Williams Lake First Nation. 2021. Secwepemc Land Use Patterns. <https://www.wlfn.ca/about-wlfn/history/>.

Wilson, I. R., K. Twohig, and B. Dahlstrom. 1998. Archaeological Overview Assessment Northern Secwepemc Traditional Territory. [https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/archaeology/forms-publications/aoa - williams lake - northern secwepemc traditional territory - 1998 report.pdf](https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/natural-resource-use/archaeology/forms-publications/aoa_-_williams_lake_-_northern_secwepemc_traditional_territory_-_1998_report.pdf).

Woll, C., D. Albert, and D. Whited. 2017. A Preliminary Classification and Mapping of Salmon Ecological Systems in the Nushagak and Kvichak Watersheds, Alaska. The Nature Conservancy.

Xat'sull First Nation. 2021. Traditional History. <https://xatsull.com/history/>.

Appendix A: Modelled Anadromous Salmon Habitat Maps

High-resolution PDF maps of the Horsefly River watershed and model results can be accessed [here](#). The watershed is divided into multiple maps sheets to allow for detailed examination of modelled spawning and rearing habitat, multiple barrier types, and priority barriers identified through this planning process. The locations of WCRP priority barriers and associated map sheet numbers are shown below. In each individual map sheet, priority barriers are symbolized using the following notation: 123456 Priority crossing label .

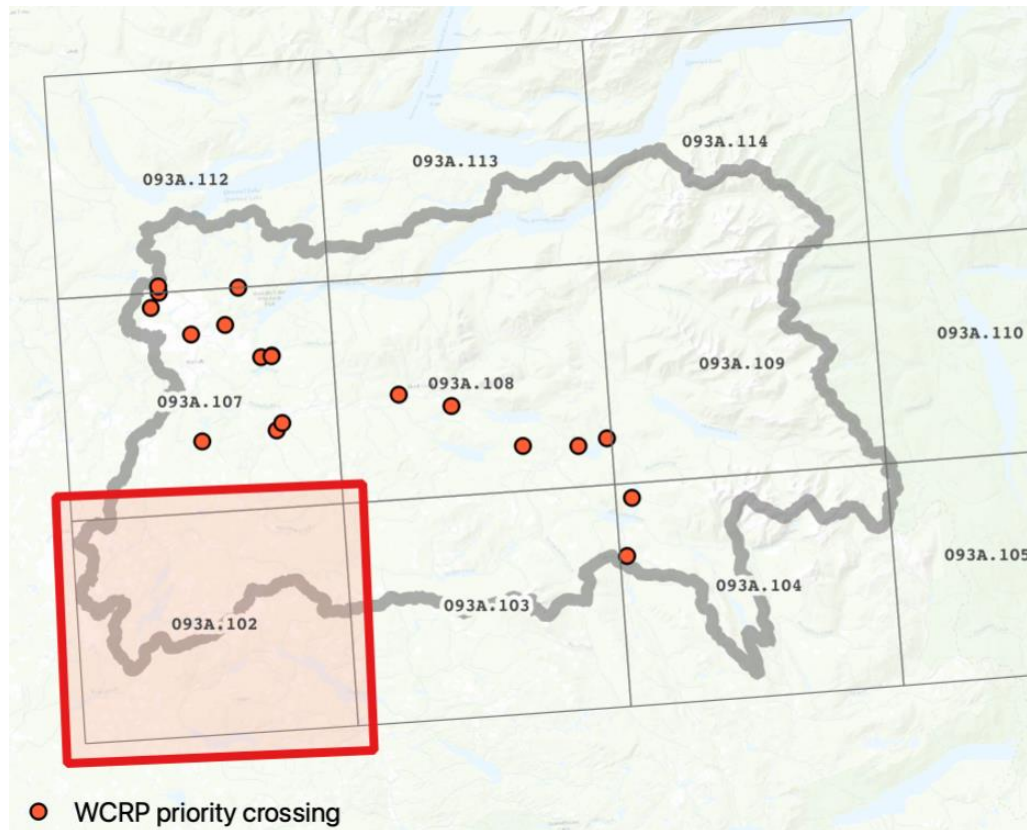


Figure 8. Horsefly River watershed overview map identifying the portions of the watershed covered by each map sheet (grey squares) and the prioritized barriers on the intermediate barrier list (orange points; see Appendix C).

Appendix B: Connectivity Status Assessment Methods

The connectivity status assessment for anadromous salmonids in the Horsefly River watershed builds on existing connectivity modelling work undertaken by the BC Fish Passage Technical Working Group, resulting in a flexible, customizable open-source spatial model called "[bcfishpass](#)". The model spatially locates known and modelled barriers to fish passage, identifies potential spawning and rearing habitat for target species, and estimates the amount of habitat that is currently accessible to target species. The model uses an adapted version of the Intrinsic Potential (IP) fish habitat modelling framework (see Sheer et al. 2009 for an overview of the IP framework). The habitat model uses two geomorphic characteristics of the stream network — channel gradient and mean annual discharge — to identify potential spawning habitat and rearing habitat for each target species. The habitat model does not attempt to definitively map each habitat type nor estimate habitat quality, but rather identifies stream segments that have high potential to support spawning or rearing habitat for each species based on the geomorphic characteristics of the segment. For more details on the connectivity and habitat model structure and parameters, please see Mazany-Wright et al. 2021a. The variables and thresholds used to model potential spawning and rearing habitat for each target species are summarized in Table 15. The quantity of modelled habitat for each species was aggregated for each habitat type and represents a linear measure of potential habitat. To recognize the rearing value provided by features represented by polygons for certain species (e.g., wetlands for Coho Salmon and lakes for Sockeye Salmon) a multiplier of 1.5x the length of the stream segments flowing through the polygons was applied.

Table 15. Parameters and thresholds used to inform the Intrinsic Potential habitat model for spawning and rearing habitat for each target species in the Horsefly River watershed.

Species	Spawning Habitat		Rearing Habitat			
	Channel Gradient (%)	Mean annual discharge (m3/s)	Channel Gradient (%)	Mean annual discharge (m3/s)	Minimum Lake area (ha)	Multiplier (1.5x)
Chinook Salmon	0-3 (Busch et al. 2011, Cooney)	0.46-322.5 (Bjornn and Reiser 1991, Neuman and Newcombe 1977, Woll et al. 2017,	0-5 (Woll et al. 2017, Porter et al. 2008)	0.28-100 (Agrawal et al. 2005)	NA	NA

	and Holzer 2006)	Roberge et al. 2002, Raleigh and Miller 1986)				
Coho Salmon	0-5 (Roberge et al. 2002, Sloat et al. 2017)	0.164-59.15 (Bjornn and Reiser 1991, Sloat et al. 2017, Neuman and Newcombe 1977, Woll et al. 2017, McMahon 1983)	0-5 (Porter et al. 2008, Rosenfeld et al. 2000)	0.03-40 (Agrawal et al. 2005, Burnett et al. 2007)	NA	Wetland
Sockeye Salmon	0-2 (Lake 1999, Hoopes 1972)	0.175-65 (Bjornn and Reiser 1991, Woll et al. 2017, Neuman and Newcombe 1977, Roberge et al. 2002)	NA	NA	200 (Woll et al. 2017)	Lake

Appendix C: Horsefly River Watershed Barrier Prioritization Summary

The primary conservation outcome of the WCRP will be the remediation of barriers to connectivity in the Horsefly River watershed. To achieve Goal 1 in this plan, it is necessary to prioritize and identify a suite of barriers that, if remediated, will provide access to a minimum of 57.31 km of spawning or rearing habitat (Table 16):

Table 16. Spawning and rearing habitat connectivity gain requirements to meet WCRP goals in the Horsefly River watershed. The measures of currently accessible and total habitat values are derived from the Intrinsic Potential habitat model described in Appendix B.

Habitat Type	Currently accessible (km)	Total (km)	Current Connectivity Status	Goal	Gain required (km)
Spawning and rearing	450.7	558.25	81%	91%	57.31

The barrier prioritization analysis ranked barriers by the amount of habitat blocked to produce an "intermediate barrier list" comprising more barriers than are needed to achieve the goals. A longer list of barriers is needed due to the inherent assumptions in the connectivity model, habitat model, and gaps in available data. Barriers that have been modelled (i.e., points where streams and road/rail networks intersect) are assumed to be barriers until field verification is undertaken and structures that have been assessed as "potential" barriers (e.g., may be passable at certain flow levels or for certain life history stages) require further investigation before a definitive remediation decision is made. Additionally, the habitat model identifies stream segments that have the potential to support spawning or rearing habitat for target species but does not attempt to quantify habitat quality or suitability (see Appendix B), which will require additional field verification once barrier assessments have completed. As such, the intermediate list of barriers below (Table 17) should be considered as a starting point in the prioritization process and represents structures that are a priority to evaluate further through barrier assessment and habitat confirmations because some structures will likely be passable, others will not be associated with usable habitat, and others may not be feasible to remediate because of logistic considerations. A web map displaying the location of each priority barrier can be found at: https://www.hillcrestgeo.ca/projects/cwf_wcrp/. For more details on the barrier prioritization model, please see Mazany-Wright et al. 2021a.

Table 17. Intermediate barrier list resulting from the barrier prioritization analysis in the Horsefly River watershed. The barriers on this list were prioritized to exceed the connectivity goals of the plan. Barriers highlighted in the same colour represent sets of barriers that have been prioritized as a group. In the Barrier Status column, P = potential barrier and B = confirmed barrier. All barrier assessment data is compiled from the BC Provincial Stream Crossing Inventory System.

ID	Stream name	Data source	Barrier type	Assessment status (completed to date)	Barrier status	Number of downstream barriers	Spawning and rearing habitat blocked – all species (km)
1006800520	Woodjam Creek	Modelled crossing	Road-stream crossing - Resource		P	0	22.58
57292	Bassett Creek	PSCIS	Road-stream crossing - Resource	Habitat Confirmation	B	1	11.07
57596	Tributary to McKinley Creek	PSCIS	Road-stream crossing - Resource	Assessed	B	0	9.43
1006800319	Niquidet Creek	Modelled crossing	Road-stream crossing - Resource		P	0	4.36
197701	Tributary to McKinley Creek	PSCIS	Road-stream crossing - Resource	Assessed	B	0	3.43
1100000243	Gibbons Creek	BC Dams	Dam		B	0	2.67
1100001822	Gibbons Creek	BC Dams	Dam		B	2	2.42
126511	Tributary to Horsefly River	PSCIS	Road-stream crossing - Resource	Assessed	B	1	2.21
124150	Tributary to Deerhorn Creek	PSCIS	Road-stream crossing - Resource	Assessed	B	0	1.89
57317	Tributary to McKinley Creek	PSCIS	Road-stream crossing - Resource	Assessed	B	0	1.79

1006800240	Tributary to Horsefly River	Modelled crossing	Road-stream crossing - Resource		P	0	1.7
57507	Wilmot Creek	PSCIS	Road-stream crossing - Municipal/paved	Habitat Confirmation		0	1.65
1006800487	Divan Creek	Modelled crossing	Road-stream crossing - Resource		P	0	1.44
1100000814	Tributary to Horsefly River	BC Dams	Dam		B	0	1.41
1006800657	Niquidet Creek	Modelled crossing	Road-stream crossing - Resource		P	2	1.34
57168	Tributary to Bosk Lake	PSCIS	Road-stream crossing - Resource	Habitat Confirmation	B	0	0.97
124272	Tributary to Woodjam Creek	PSCIS	Road-stream crossing - Resource	Habitat Confirmation	B	0	0.93
124268	Vedder Creek	PSCIS	Road-stream crossing - Municipal/paved	Assessed	B	0	0.87
1006800648	Gibbons Creek	Modelled crossing	Road-stream crossing - Resource		P	1	0.22
1100000763	Niquidet Creek	BC Dams	Dam		B	1	0.01
						Total gain	72.39

Out of the 20 barriers on the intermediate list, 16 require further field assessment before selection as a final barrier to pursue for remediation:

Table 18. Field assessment requirements for the intermediate barrier list in the Horsefly River watershed. The cost per barrier values are estimates based on previously completed field work. The habitat confirmation count is based on the assumption that the 10 barriers requiring barrier assessments will also require a subsequent confirmation. In the case that some barriers are identified as unsuitable candidates for habitat confirmations, the total cost will be reduced.

Field assessment	Cost per barrier	Count	Total costs
Barrier Assessment	\$230	10	\$2,300
Habitat Confirmation	\$3,000	16	\$48,000
Total:		26	\$50,300

Based on the results of the prioritization analysis, 10 barriers from the intermediate barrier list are required to be remediated to achieve the connectivity goals in this plan:

Table 19. Preliminary barrier remediation cost estimate to reach connectivity goals in the Horsefly River watershed. Cost per barrier values are estimated based on the average cost of previously completed projects. Barrier counts and total costs are subject to change as more information is collected through the implementation of this plan.

Barrier Type	Cost per barrier	Count	Total Cost
Dam	\$435,000	3	\$1,305,000
Resource road	\$500,000	7	\$3,500,000
Total		10	\$4,805,000