Final Report

EVALUATION OF CAUSE

Decline in Upper Fording River Westslope Cutthroat Trout Population

December 2021

Citation for the Evaluation of Cause Report

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Executive Summary

Background

This report focuses on the upper Fording River, located in the Elk Valley in the southeast corner of British Columbia, Canada. The Elk Valley contains the main stem of the Elk River (220 km long) and many tributaries, including the Fording River (70 km long). The upper Fording River starts at Josephine Falls, 20 km upstream from its confluence with the Elk River. The lands in this region (Qukin ?amakʔis, Elk Valley) have been occupied by the Ktunaxa Nation for more than 10,000 years. Wuʔu (water) and ʔa·kxamis ʼqapi qapsin (All Living Things) continue to be highly valued by the Ktunaxa people.

The upper Fording River watershed is a high-elevation watershed. Such watersheds are typically associated with long winters and short summers (resulting in a short growing season) and high potential for adverse weather conditions. The upper Fording River is influenced by various human-caused disturbances, including roads, a railway, a natural gas pipeline, forest harvesting and coal mining. Teck Coal Limited (Teck Coal) operates three open pit coal mines within the upper Fording River watershed upstream of Josephine Falls: Fording River Operations, Greenhills Operations and Line Creek Operations.

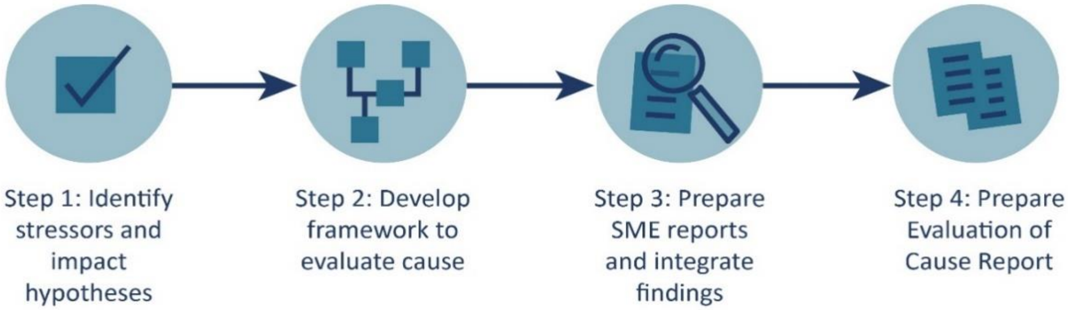
The upper Fording River has only one fish species, a genetically pure population of Westslope Cutthroat Trout *(Oncorhynchus clarkii lewisi)* that is iconic and highly valued in the area. Westslope Cutthroat Trout are of Special Concern under legislation and policy. This population, in addition to living at a relatively high elevation, is physically isolated because Josephine Falls is a natural barrier that prevents fish from moving. As a result, the population's resilience is naturally reduced compared to populations that have access to greater amounts and diversity of habitats. Even in a pre-mining condition, the total amount of stream accessible to the fish population was limited by Josephine Falls, and it was further reduced by industrial development.

Fish monitoring conducted for Teck Coal in fall 2019 found that the abundance of Westslope Cutthroat Trout adults and sub-adults in the upper Fording River had declined substantially since previous sampling in fall 2017. In addition, there was evidence that juvenile fish density had decreased. In response, Teck Coal initiated an *Evaluation of Cause process* to investigate and report on the cause of the decline in the upper Fording River Westslope Cutthroat Trout population.

Approach

As part of the process, Teck Coal established an Evaluation of Cause Team. The Team was composed of 18 Subject Matter Experts (all of whom are Qualified Professionals) and coordinated by a Team Lead. Representatives from the Ktunaxa Nation Council, various regulatory agencies and the Independent Scientist of the Environmental Monitoring Committee (Permit 107517) provided input throughout the process.

To conduct the Evaluation of Cause, the Team used a systematic and objective approach with four main steps:



Step 1. The Evaluation of Cause identified and examined numerous impact hypotheses (explanations) to determine if and to what extent various stressors and conditions played a role in the population decline. These explanations are detailed in this report.

Step 2. The Subject Matter Experts used a systematic tabular approach (referred to as a Framework) to synthesize their findings on individual stressors and determine the degree to which the stressors may have contributed to the decline.

Step 3. Subject Matter Expert reports were prepared. Given that the purpose of the investigation was to evaluate the cause of the decline in fish abundance from 2017 to 2019, it was necessary to identify not only stressors or conditions that changed or were different during that period but also the potential stressors or conditions that did not change but that may, nevertheless, have constrained the population's ability to respond to or recover from the stressors. This was covered in the individual reports; summaries of the Subject Matter Expert findings are provided in this report. Once the stressors or conditions had been identified, interactions between them had to be considered in an integrated fashion. Where an impact hypothesis depended on, or may have been exacerbated by interactions among stressors or conditions, the interaction mechanisms were also considered.

The Team ultimately concluded that the decline was likely due to interactions among stressors and between stressors and the pre-existing conditions in the watershed. Integrating the findings to evaluate the cause of the decline required a process over and above the work done by the Subject Matter Experts, because the efforts of the individual experts focused on specific stressors and were not designed to consider all possible interactions with other stressors and conditions. To identify and explore potential scenarios that could explain the decline, the experts discussed stressors and their interactions. These iterative discussions, together with feedback from the Ktunaxa Nation Council, regulatory agencies and committees (including the Environmental Monitoring Committee's Independent Scientist) and Teck Coal, led to the development of an integrated hypothesis for the decline, which is summarized below.

Step 4. The Evaluation of Cause report (this report) was prepared. This is a capstone report that summarizes all the work done for the Evaluation of Cause. It is supported by the 21 Subject Matter Expert reports and four supporting reports and memos listed in the Acknowledgements section. All the reports are available on Teck's website.

Findings

The Evaluation of Cause Team hypothesizes that the decline in abundance of Westslope Cutthroat Trout occurred during winter 2018/2019, and that it was caused by extreme winter conditions and associated ice formation, natural conditions in the watershed and the ongoing effects of development in the upper Fording River. Although all river segments (standardized river stretches) appear to have experienced substantial fish losses, the decline appears to have been most severe in Segments S5 through S9 (within and immediately downstream of Fording River Operations property). The core hypothesis is described below.

Overwintering migration (fish passage)

Fish, in general, are believed to have experienced challenges migrating to overwintering areas before winter 2018/2019. Overwintering areas are sparse in the upper Fording River, and they are spatially separate from some summer rearing areas. Abundance and distribution of overwintering areas, as well as access to them, have been affected by channel widening and aggradation, by water use and by loss of tributary habitats, particularly in Segments S7 to S9 where mining-related changes to the stream channel are most pronounced. In essence, mining development has made fish passage to overwintering areas more challenging.

Specific to the decline window, flows were low in late summer 2018, which, combined with water use and earlier drying in the drying reaches, likely made the fish's passage to their preferred overwintering areas more challenging than usual. These challenges may have occurred at multiple locations and may have influenced a substantial portion of the population. For example, the available telemetry data across all fish and all periods suggest that the movement of up to 25% of the population may have been restricted in some way if the southern drying reach or the multi-plate culvert became and remained fully impassable. If the barrier was intermittent, the percentage of affected fish would have been lower. However, the actual number of fish affected and the outcome of this interaction are unknown.

Winter conditions and low flows

Extreme cold air temperatures in February through early March 2019, combined with warm preceding conditions, a lower than normal snowpack and seasonal low flows in winter, led to extreme ice conditions. The extreme weather occurred throughout the upper Fording River, but its effects would have varied spatially depending on the width and depth of the river and ice formation processes specific to the site. Nonetheless, data show that ice formed abundantly throughout the upper Fording River. Fish that were confined to relatively shallow overwintering habitats in winter 2018/2019 would likely have been more susceptible to the potential direct and indirect effects of ice and low flows than fish that occupied deeper, low velocity water. However, even fish that successfully reached preferred, deeper, overwintering lotic areas may have been displaced, because low flows and ice reduced the amount of usable habitat and, in doing so, concentrated the fish in smaller volumes of water. Water use may have exacerbated these conditions.

Potential mechanisms of mortality

Considering the combined effect of the challenges the fish experienced with overwintering migration, extreme winter conditions and low winter flows, mortality could have occurred in several ways. Ice could have caused mortality directly by entombing the fish or by injuring or suffocating them due to frazil ice forming. These ice effects would have been more likely to affect fish that were unable to reach preferred, deeper overwintering areas. In addition, other related causes or contributors are possible, either alone or in combination. These include:

- Fish stress and energy deficits associated with winter conditions and the preceding fall migration
    - Examples of stress and energy deficits associated with winter conditions include cold, movements to avoid ice conditions, crowding due to ice conditions or challenges in accessing food.
    - Examples of stress and energy deficits associated with the preceding fall migration include higher energy demands associated with challenges in accessing overwintering areas, or reduced foraging time or efficiency, resulting in lower energy storage going into winter.
- Shortages of dissolved oxygen due to flow blockages or other mechanisms

- Stranding
- Ongoing stress attributed to mining-related water quality constituents, and
- Predation

The stressors and conditions underlying the integrated hypothesis could have affected both adult and juvenile fish; however, the magnitude of mortality for different life stages would have likely differed.

Relative contributions of stressors and conditions to the fish decline

It is difficult to characterize the relative contributions of various stressors and conditions to the decline because the stressors and conditions are interdependent and cannot, therefore, be characterized in isolation. The Evaluation of Cause Team believes that of all the stressors, the most unique element during the decline window compared to previous years was extreme winter (cold and ice). However, it is not possible to estimate the effect of the extreme winter alone, because its effect depended on interactions with other stressors.

Conclusion

A widespread decline in Westslope Cutthroat Trout abundance from 2017 to 2019 was observed in the upper Fording River. The decline appears to have been most severe in Segments S5 through S9 (within and immediately downstream of Fording River Operations property), although all river segments appear to have experienced substantial losses. The Evaluation of Cause Team hypothesizes that the decline occurred in February–March 2019 and was caused by the interaction of extreme ice conditions (due to extreme, prolonged, cold air temperatures; seasonal, winter low flows; and low winter snowpack), sparse overwintering habitats and restrictive fish passage conditions during the preceding migration period in fall 2018. While stressors such as cold weather are natural, mining development has altered the availability of overwintering habitats in portions of the river and has exacerbated the challenges to fish passage through water use, channel widening and aggradation.

Way Forward

The Evaluation of Cause is being published concurrent with Westslope Cutthroat Trout recovery plans that are being prepared by the Ktunaxa Nation Council, regulatory agencies and Teck Coal. The final chapter of this report serves, therefore, as a bridge from the findings of the Evaluation of Cause to next steps that will support recovery of the Westslope Cutthroat Trout population in the upper Fording River. The recommendations in Chapter 9 are intentionally high level to complement and inform ongoing initiatives to support this population’s recovery.

We conclude by acknowledging that the upper Fording River is a dynamic system and that building the resilience of this important Westslope Cutthroat Trout population will require an adaptive management approach. This approach will need to carefully explore, test and monitor management actions to learn which actions best support the restoration objectives of the recovery plans.

Acknowledgements

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The Evaluation of Cause is underpinned by the Subject Matter Expert (SME) reports and other supporting reports and memos which, in many cases, are coauthored by other qualified professionals and scientists. We acknowledge the contributions of the following authors.

Report Title	Authors
Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	M. Hocking, PhD, RBio A. Tamminga, PhD T. Arnett, BSc, RPBio M. Robinson, MSc, RPBio H. Larratt, BSc, RPBio T. Hatfield, PhD, RPBio
Subject Matter Expert Report: Channel Dewatering. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	T. Hatfield, PhD, RPBio J. Ammerlaan, BA, PMP H. Regehr, PhD, RPBio J. Carter, MRM S. Faulkner, MSc, RPBio
Subject Matter Expert Report: Climate, water temperature, streamflow and water use trends. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	N. Wright, PhD, PWS, PGeo D. Greenacre, MSc T. Hatfield, PhD, RPBio
Subject Matter Expert Report: Coal Dust and Sediment Quality. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	M. DiMauro, MRM M. Branton, PhD, PAg E. Franz, MSc
Subject Matter Expert Report: Cyanobacteria, Periphyton and Aquatic Macrophytes. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	H. Larratt, BSc, RPBio J. Self, BSc, RPBio
Subject Matter Expert Report: Disease. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	T. Bollinger, DVM, DVSc
Subject Matter Expert Report: Fish Handling. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	S. Cope, MSc, RPBio
Effects of Capture and Handling on Westslope Cutthroat Trout in the Upper Fording River: A Brief Review of Cope (2020) and Additional Calculations.	J. Korman, PhD M. Branton PhD, PAg

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Subject Matter Expert Report: Food Availability. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	P. Orr, MSc J. Ings, PhD, RPBio
Subject Matter Expert Report: Habitat Availability. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	K. Healey, MSc, PGeo P. Little, MSc, PAg T. Hatfield, PhD, RPBio
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Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	T. Hatfield, PhD, RPBio C. Whelan, MSc, RPBio
Subject Matter Expert Report: Industrial Chemicals, Spills and Unauthorized Discharges. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	J. Van Geest, PhD, RPBio V. Hart, MSc, RPBio EJ. Costa, MSc A. de Bruyn, PhD, RPBio
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Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.	D. Dean, BSc, RPBio, P Biol
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Foreword

Leading the team of Subject Matter Experts that evaluated the decline of this important Westslope Cutthroat Trout population was a privilege. I feel fortunate to have worked with such dedicated professionals across a broad array of disciplines, united by a shared purpose. It was a team effort, and I would like to recognize all the Subject Matter Experts and their co-authors for their contributions.

I am confident that the conclusions drawn in this report and those of the supporting expert reports are free of bias. I have reviewed Conflict of Interest declarations made by all Subject Matter Experts. In addition, the collaborative process and reviews conducted during this work give me confidence that our findings and recommendations are well-vetted. We addressed comments from reviewers on the draft report comprehensively, within the bounds of data and information available.

As laid out in the Acknowledgements, our work benefited greatly from feedback received from representatives of and advisors to the Ktunaxa Nation Council and various agencies and committees. Teck Coal staff are recognized for providing data, information and feedback.

The fish that are the subject of this report are a relatively well-studied population, and the upper Fording River watershed has various ongoing environmental monitoring programs, so a vast amount of data was available for use. Having said that, the work required to address the question — *what happened to the fish?* — was complicated for several reasons. Like any detective story, we encountered dead ends and were missing key pieces of information. However, as you will learn when you read this report, we followed the clues to the extent possible and concluded the story by describing our explanation for what happened.

I ask readers to keep an open mind and follow the line of sight, from the report's findings back through our analysis presented herein and through to the available data, all of which are provided in the underpinning Subject Matter Expert reports.

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Acronyms

Abbreviation	Term
BC	British Columbia
BCCOS	British Columbia Conservation Officer Services
BOD	biological oxygen demand
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DO	dissolved oxygen
DU	Designatable Units
EIA	Environmental Impact Assessment
EMC	Permit 107517 Environmental Monitoring Committee
ENV	BC Ministry of Environment and Climate Change Strategy
EoC	Evaluation of Cause
EV-CEMF	Elk Valley Cumulative Effects Management Framework Working Group
EVFFHC	Elk Valley Fish and Fish Habitat Committee
FRO	Fording River Operations
GHO	Greenhills Operations
IFR	Instream Flow Requirements
IPA	Implementation Plan Adjustment
KNC	Ktunaxa Nation Council
LCO	Line Creek Operations
masl	metres above sea level

MIBC	methyl isobutyl carbinol
PAH	polycyclic aromatic hydrocarbon
PEM	predictive ecosystem mapping
PIT	passive integrated transponder
PODs	Points of Diversion
SARA	Species at Risk Act
SEV	severity of ill effects
SME	Subject Matter Expert
SQG	sediment quality guideline
SRB	sulphur reducing bacteria
TDS	total dissolved solids
TP	total phosphorus
TSS	total suspended solids
UFR	upper Fording River
WCT	Westslope Cutthroat Trout

1. Introduction

The Elk Valley is located in the southeast corner of British Columbia (BC), Canada. It contains the main stem of the Elk River (220 km long) and many tributaries, including the Fording River (70 km long). This report focuses on the upper Fording River (UFR), which starts 20 km upstream from its confluence with the Elk River at Josephine Falls.

Ktunaxa people have occupied Qukin ʔamakʔis (Elk Valley) for over 10,000 years. The value and significance of ʔa·kxamis ʼqapi qapsin (All Living Things) to the Ktunaxa Nation and in Qukin ʔamaʔkis must not be understated (see Chapter 2 for more details).

The upper Fording River watershed, described in Chapter 2, is a high-elevation watershed with a short growing season. The UFR is influenced by various human-caused disturbances, including roads, a railway, a natural gas pipeline, forest harvesting and coal mining. Teck Coal Limited (Teck Coal) operates three open pit coal mines within the UFR watershed upstream of Josephine Falls: Fording River Operations, Greenhills Operations and Line Creek Operations.

The UFR has only one fish species, a genetically pure population of Westslope Cutthroat Trout *(Oncorhynchus clarkii lewisi; WCT)* that is physically isolated because Josephine Falls is a natural barrier to fish movement. This fish species, as described in Chapter 3, is iconic and highly valued in the area, and it is listed under various statutes (see Section 3.2).

Fish monitoring conducted for Teck Coal in fall 2019 found that the abundance of WCT adults and sub-adults in the UFR had declined substantially since previous sampling in fall 2017 (Chapter 4). In addition, there was evidence that juvenile fish density had decreased. Teck Coal initiated an Evaluation of Cause process to investigate and report on the cause of the decline of the UFR WCT population that occurred between September 2017 and September 2019 (herein referred to as the Westslope Cutthroat Trout Population Decline Window, or decline window). The objectives of the Evaluation of Cause were to:

1. Design and implement an approach that was thorough, transparent and objective.
2. Deliver a report that would:
   a) Describe the findings
   b) Provide recommendations and identify additional data and/or monitoring that would close pre-existing and newly identified gaps.

When the fish decline was identified, and as part of the Evaluation of Cause process, Teck Coal established an Evaluation of Cause Team (the Team). The Team was composed of 18 Subject Matter Experts (SMEs), all of whom are Qualified Professionals, and it was coordinated by a Team Lead.

- The Team Lead liaised with Teck Coal, led the overall process and supported Teck Coal's engagement with Ktunaxa Nation Council, regulators and technical committees.
- The SMEs contributed to the causal evaluation in their areas of expertise and collaborated with other team members, as needed. The SME team and their qualifications and experience are summarized in Appendix A.

Throughout the process, the Team collaborated with the Ktunaxa Nation Council and the agencies and committees whose representatives and advisors are recognized in this report’s Acknowledgements. The key organizations involved included:

- Ktunaxa Nation Council (KNC)
- BC Ministry Environment and Climate Change Strategy
- BC Ministry of Energy, Mines and Low Carbon Innovation
- Forests, Lands, Natural Resource Operations and Rural Development
- Environmental Assessment Office
- Permit 107517 Environmental Monitoring Committee (EMC)
- Elk Valley Fish and Fish Habitat Committee (EVFFHC)

Throughout the process, Teck Coal (see Acknowledgements) supported the Team by:

- Providing information and data to the SMEs as required and when requested
- Reviewing deliverables for facts and accuracy and, where applicable, providing technical input
- Providing funding for the Evaluation of Cause Team to perform their work
- Leading engagement with KNC, regulators and technical committees (EVFFHC and EMC)

The Evaluation of Cause, described in Chapters 5 to 8, examined numerous impact hypotheses to determine if and to what extent various stressors and conditions played a role in the UFR WCT population’s decline. Parallel to the Evaluation of Cause, fish population recovery efforts and environmental improvements in the UFR are ongoing. Proposed next steps to support the ongoing health of this important fish population are outlined in Chapter 9.

Here is an overview of the nine chapters contained in this report:

Chapter	Description	Why it's important
1. Introduction	Background information to the Evaluation of Cause	Sets the stage
2. The Upper Fording River Watershed	Overview of the UFR watershed	Understanding the watershed is key to understanding what happened
3. Westslope Cutthroat Trout	Overview of WCT biology and how these fish are monitored in the UFR	WCT are the focus of this report
4. Understanding the Decline in Westslope Cutthroat Trout	A detailed analysis of the timing and magnitude of the WCT decline	Learning about the WCT population decline provides clues to what happened
5. Approach to Evaluating the Cause of the Decline	An overview of the Evaluation of Cause process	Describes the systematic approach that underpins our findings
6. Hypothesizing Stressors and Pathways	What we did	Describes the evidence base that supports the report's conclusions
7. What Did We Learn?	Summary of SME report findings	Documents the findings of the Subject Matter Experts
8. Integrated Findings	SME findings are integrated to support this report's findings	Answers the question about what may have happened to the WCT
9. The Way Forward	Next steps, after the Evaluation of Cause	Makes recommendations

2. The Upper Fording River Watershed

2.1. INTRODUCTION

In this chapter, we describe the history of the UFR watershed to set the scene for the Evaluation of Cause and the stressors that we evaluated. An important part of that history is occupation of Qukin ?amakʔis (Elk Valley) by the Ktunaxa people for over 10,000 years (see text box for a statement from the Ktunaxa Nation Council).

Statement by Ktunaxa Nation Council Provided to Evaluation of Cause Team

Ktunaxa people have occupied Qukin ʔamakʔis (Elk Valley) for over 10,000 years. There have been significant impacts to ʔa·kxamis’qapi qapsin (All Living Things) in this area due to coal mining and other activities like forestry. The Ktunaxa Nation Council (KNC) is actively engaged in addressing the considerable challenges we face with impacts to wuʔu (water) and ʔa·kxamis’qapi qapsin which includes all the beings that swim, like qustit̓ (trout).

The value and significance of ʔa·kxamis’qapi qapsin to the Ktunaxa Nation and in Qukin ʔamaʔkis must not be understated. The Ktunaxa Nation Council will continue to be a voice for those who cannot speak for themselves — for the sake of qustit̓, wuʔu, our future generations, and for ʔa·kxamis’qapi qapsin. It is a critical part of our role and responsibility in Qukin ʔamaʔkis as is given to us by Creator. We remain the stewards of these lands and will continue to honour our relationships in the ways we’ve been taught for generation upon generation.

We think of this population of qustit̓, known as the Westslope Cutthroat Trout, as being interconnected with ʔa·kxamis’qapi qapsin (All Living Things) — if this population is impacted, so is everything else. The Ktunaxa Nation includes an illustration (Figure 2-1) to visually represent Ktunaxa “lifeways” within Qukin ʔamakʔis.

Figure 2-1. Ktunaxa “lifeways” within Qukin ʔamakʔis.

This image is a product of Ktunaxa community participatory research drawn by two Ktunaxa artists, Darcy Luke and Marisa Phillips. It is meant to symbolize "Ktunaxa being Ktunaxa on the land" and the tangible and intangible connection between ʔamak ȼ wuʔu (the land and water) and ʔa'kxam̓ is q̓ api qapsin.

Josephine Falls, at 25 m tall, is a defining feature of the UFR and represents the most downstream point in the watershed. This barrier to fish passage isolates the UFR WCT population and, as a result the habitat that is available to support the population is restricted to the habitat present upstream of the falls. Fish habitats have been created, altered and lost in the UFR over thousands of years by natural forces and, more recently, by anthropogenic change. Understanding the natural and anthropogenic constraints associated with fish habitat in the UFR watershed is important for understanding resilience of the UFR WCT population and for providing context for the Evaluation of Cause.

Resilience has become a central tenet in conservation and ecology, with different nuances depending on whether the concept is applied to individuals, populations, communities or ecosystems (Hodgson, McDonald & Hosken, 2015; Capdevila et al., 2020). The two key components of demographic resilience are resistance and recovery. Resistance represents the ability to buffer the magnitude of abundance decline following disturbance, and recovery represents the magnitude or rate of population increase after the disturbance lessens. Populations with high resistance can withstand greater disturbance before declining, and populations with high recovery will bounce back from a perturbation sooner.

For WCT in the UFR, resilience is strongly influenced by habitat factors — including the quantity, quality and spatial distribution of habitats — and by the connectivity among habitats. Habitat factors influence the UFR's total WCT carrying capacity, how individual WCT move among habitats and whether the population is dispersed or concentrated. They dictate the number of individuals that can be supported in the system and the life stages that are exposed to a disturbance. Ultimately, they determine how well the population can resist or recover from a disturbance. In addition to habitat factors, inherent characteristics of the species play a key role in resilience, because they influence how susceptible the species is to a disturbance (e.g., through physiological tolerances) or the rate at which it will recover (e.g., reproductive potential).

> ***Resilience***
>
> *"A measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables."*
>
> *Holling (1973)*

The purpose of this chapter is to set the stage for the overall Evaluation of Cause by describing the evolution of the UFR and its fish habitat, from the last glaciation up to 2017–2019 (i.e., the period immediately prior to or during the UFR WCT population decline[1]), with a focus on the implications for UFR WCT population resilience. Other chapters describe UFR WCT habitat use (Chapter 3) and population change over time (Chapter 4). This chapter is arranged as follows:

- First, to orient the reader, we present an overview of the UFR watershed as it was at the time of the WCT population decline.

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[1] In addition to this chapter, Teck Coal has summarized major mine infrastructure/development activities that occurred specifically within the period of decline in the UFR WCT to support the Evaluation of Cause (see Appendix C, Table C-2).

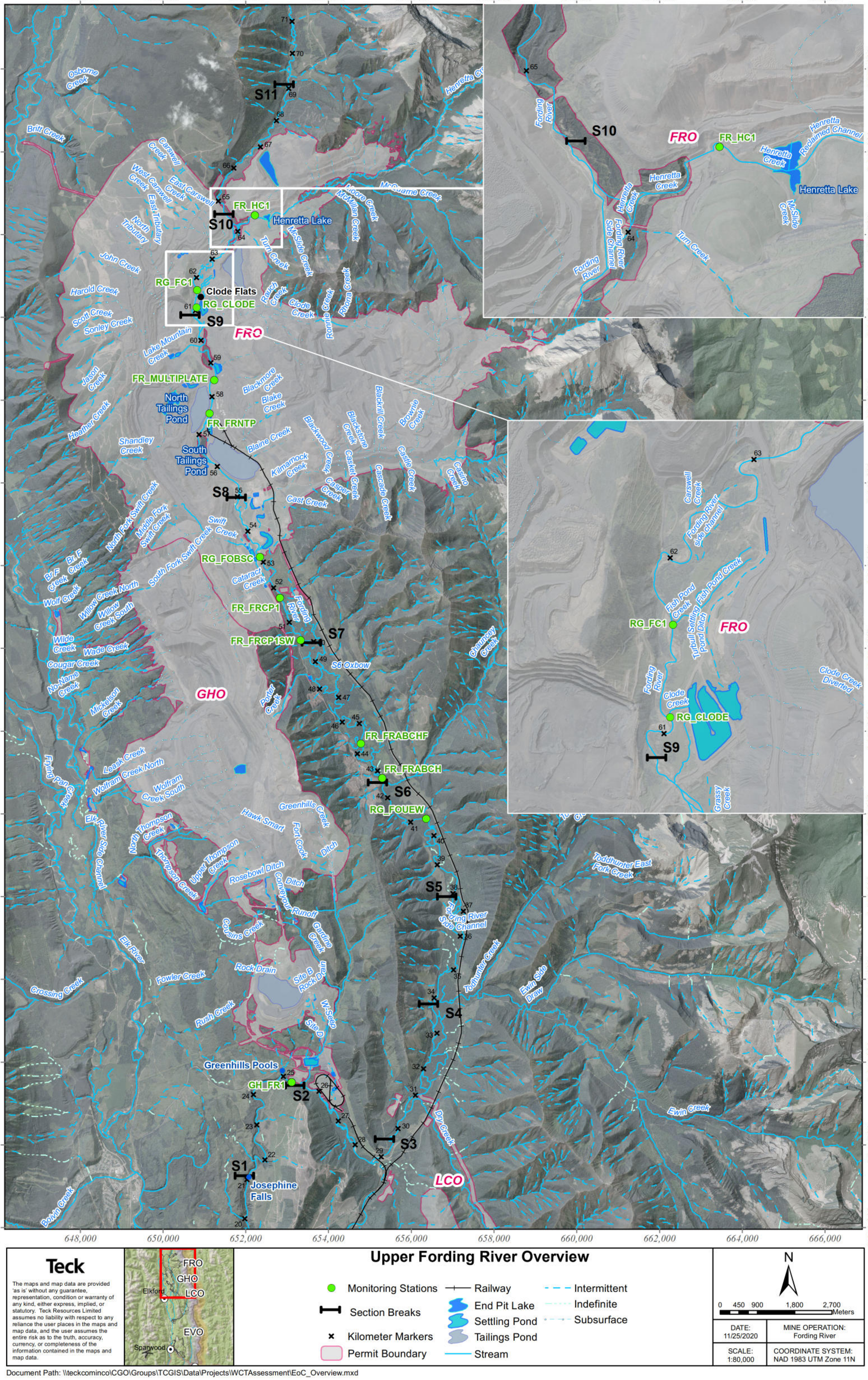
- Second, we describe the geologic, hydrologic and climatic context of the UFR in terms of how fish habitats were formed prior to industrial anthropogenic disturbances (i.e., prior to the early 1900s) and how natural factors continue to affect the watershed today.
- Third, we describe anthropogenic disturbances that occurred after 1900. These include the large-scale mining and forestry activities that influenced the habitat available to WCT in the UFR up to the time of the population decline.
- Fourth, we quantify and describe changes in WCT habitat relative to a pre-mining condition — to the extent possible with available data.
- Finally, we summarize the information presented in this chapter and discuss UFR WCT resilience (including habitat availability, distribution and redundancy), the WCT population trajectory up to 2017–2019 and other factors.

2.2. THE UPPER FORDING RIVER WATERSHED

The map of the UFR watershed (Figure 2-2) illustrates key features referred to in this chapter as they existed during the decline window and throughout the Evaluation of Cause report. The UFR watershed is a 42,600 ha catchment that is topographically diverse and ranges in elevation from approximately 1,430 m above sea level at the lowest portion of the valley to more than 3,000 m. The Fording River originates near Mount Maclaren on the British Columbia/Alberta border and flows south to its confluence with Henretta Creek at the northern end of the Fording River Operations (FRO) mine property. From there, it flows through the mine site where waters from Clode Creek and several smaller tributaries enter before it is joined downstream by Kilmarnock Creek and Swift Creek (Figure 2-2). Further downstream, Cataract Creek enters the UFR, along with other small tributaries; this portion of the UFR loses water to the subsurface through infiltration. The UFR then enters a gaining reach, adding Porter Creek, after which it enters a net-neutral reach, moving in a downstream direction to its confluence with Chauncey Creek (Figure 2-3). Below Chauncey Creek, main tributaries to the Fording River include Todhunter Creek, Ewin Creek, Dry Creek and Greenhills Creek. For reference in the Evaluation of Cause, the UFR mainstem has been broken into segments (Segments S1 to S11; see Figure 2-2) as per Cope et al. (2016). These segments are referenced throughout the document to orient readers to river locations.

Figure 2-2 is presented, alone, on the following page. Its caption is:

Figure 2-2. Map of upper Fording River, illustrating key features and river segments referred to in this Evaluation of Cause.



Upper Fording River Overview

The maps and map data are provided 'as is' without any guarantee, representation, condition or warranty of any kind, either express, implied, or statutory. Teck Resources Limited assumes no liability with respect to any reliance the user places in the maps and map data, and the user assumes the entire risk as to the truth, accuracy, currency, or completeness of the information contained in the maps and map data.

DATE: 11/25/2020	MINE OPERATION: Fording River
SCALE: 1:80,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

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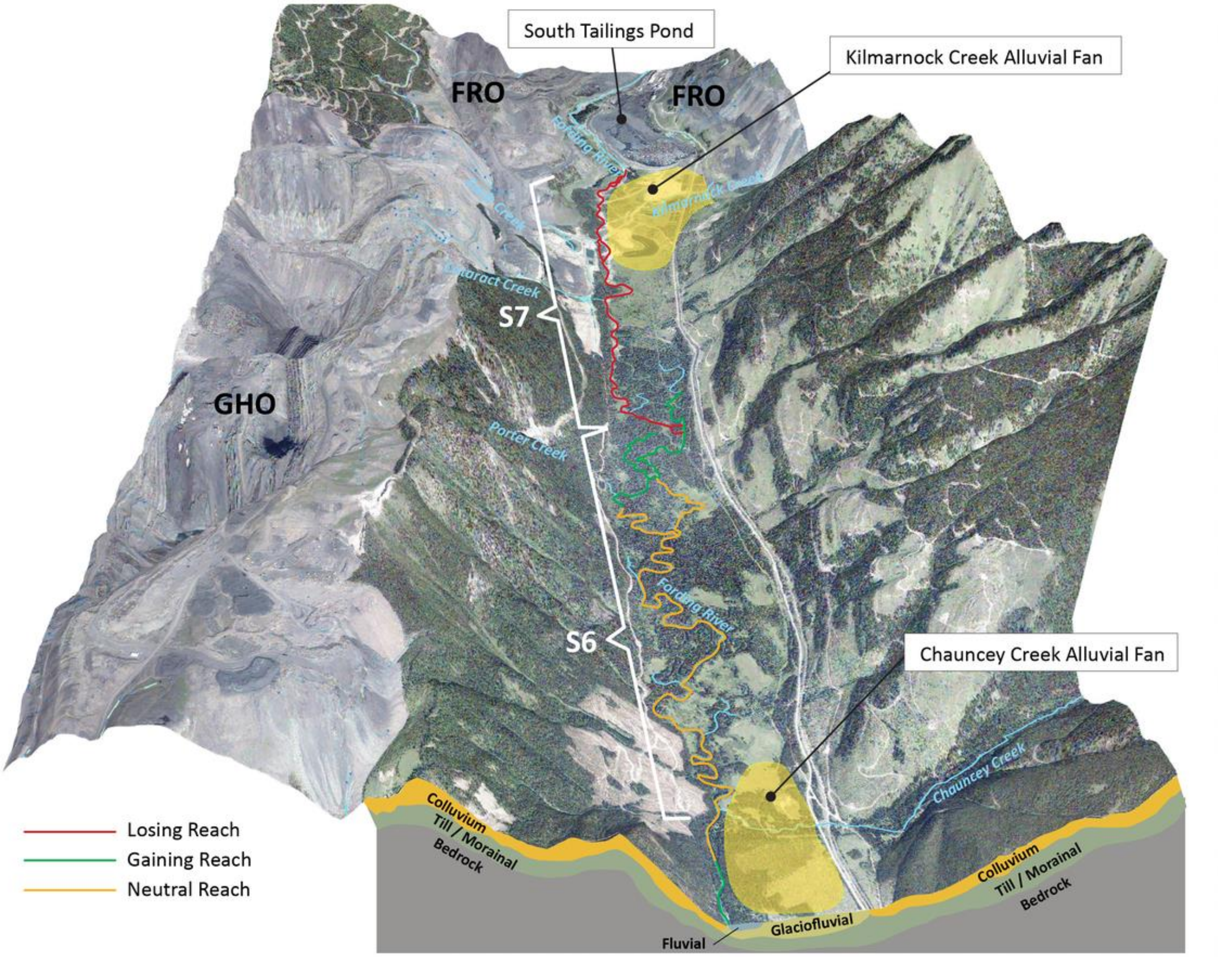

Figure 2-3. Upper Fording River Watershed, focal area for the Evaluation of Cause.

Figure labels: FRO = Fording River Operations; GHO = Greenhills Operations; S6 = Segment 6; S7 = Segment 7

2.3. SETTING: GEOLOGY, HYDROLOGY AND CLIMATE

The form and function of a stream are products of complex watershed interactions over space and time between climate, vegetation, soils, geology and topography. Therefore, understanding how the current UFR watershed functions requires an understanding of its environmental context. This context, in turn, is a product of the watershed's natural history. In other words, watershed functionality is defined by historical and contemporary disturbance, both natural and anthropogenic. Changes to the landscape, both in ecology and forest cover, and changes to soils and surficial geology, affect how aquatic habitats change over time and space.

2.3.1. Geological History

The UFR is located in what is referred to as the Rocky Mountain Foreland Belt. The area is specifically referred to as the Elk Valley coalfield (Grieve, 1993). Approximately 120–150 million years ago (Upper Jurassic to Lower Cretaceous period), sand, silt, mud and plant matter were deposited on the sea floor and adjacent continental shelf of the proto-Pacific Ocean. They were then buried and compacted into sedimentary rocks. Between 80 and 55 million years ago, these sedimentary rocks were folded and faulted, as a series of island arc complexes drifted eastward and collided with the North American Plate, creating the Rocky Mountains. This collision exposed coal seams in the Mist Mountain Formation, and it thickened and concentrated coal deposits in several locations across the Elk Valley.

The Elk Valley was fully glaciated up to approximately 2,200 m above sea level during the height of the Last Glacial Maximum (15,000 years ago). The ice sheet began to retreat approximately 13,000–11,000 years ago (Ferguson & Osborn, 1981; Clague, 1982; George et al., 1986). A large valley glacier extended from near Mount Joffre to below Elko, BC, where the glacier would have joined with a much larger glacier extending down the Rocky Mountain Trench (Osborn & Luckman, 1988). At the end of the Last Glacial Maximum, the Elk Valley glacier thinned and retreated as it separated from the much larger Rocky Mountain Trench glacier. During this retreat, ice damming occurred, and numerous glacial lakes and related surficial deposits formed (George et al., 1986).

2.3.2. Contemporary Geomorphologic Change

This legacy of glaciation has shaped the topography of the Elk Valley and the UFR, resulting in steep U-shaped valleys, moraine-dammed lakes and hanging valleys, glacial debris (till) and several glacial meltwater channels along the length of the valley. These characteristics determine how the Fording River is supplied with fine sediment, which plays an influential role in defining river channel morphology (Montgomery & Buffington, 1997; Fulton, 1995).

The surficial geological deposits of this region also dictate groundwater flows and the interaction between groundwater and surface water. Groundwater flows are strongly controlled by the permeability of these deposits (i.e., their ability to transmit water), and the presence of low permeability bedrock and/or basal till can limit the depth at which higher groundwater flows occur (Hutchinson & Moore, 2000). Since basal till has been subject to intense pressure due to glaciation, it is relatively impermeable and can control the vertical migration of groundwater, predominantly restricting water to travelling via near-surface pathways into river networks. The valley-bottom sediments in the Fording River valley can be minimal or greater than 100 m thick (Harrison, 1974) and comprise a heterogenous mixture of silt and clay and highly porous gravel deposits at the surface (George et al., 1986). These gravel units typically result in the greatest interaction between groundwater and surface water.

This Quaternary history also shaped, in part, the composition and structure of the vegetation in the UFR valley, and this has implications for the hydrology of the watershed. Forests create and amplify hydrologic pathways in a watershed, and they act as both a storage medium and a conveyor of water through the system. Initially, the forest canopy intercepts a fraction of rain and snow precipitation, which reduces the amount of water that is contributed to streamflow (Bond et al., 2008). Some of the intercepted water is stored in the canopy, while some is lost via evaporation or sublimation and transpiration from plant leaves (Varhola et al., 2010). The remaining water slowly falls through the forest canopy and eventually reaches the ground. As forest cover changes, hydrologic and geomorphic conditions respond, creating a broad range of conditions and resulting in diverse fish habitats forming within the UFR.

2.3.3. Hydrogeomorphic Regime

Contemporary hydrologic conditions in the UFR reflect the continental climate of the region. Flows in the Fording River follow a strongly nival (snowmelt) regime, and winter air temperatures are low, with average temperatures below 0°C from November through March (see Wright et al., 2021, for more information on climate). Precipitation during this period falls predominantly as snow and generates a deep winter snowpack. As air temperatures rise in the spring, the deep winter snowpack begins to melt, creating high runoff from April through July. Following snowmelt, late summer flows are lower, supplied by ephemeral summer rainstorms and base flow from groundwater (see Henry & Humphries, 2021, for more information on groundwater). During the winter months, streamflow is low and is supplied primarily by periodic melt or rainfall events and groundwater base flows.

Instream flows determine the habitats available to aquatic organisms. At the spatial scale of reaches and channels, instream flows are often a function of interactions between groundwater, soil water and surface water, which are driven by the geomorphic regime. The interactions that occur between shallow groundwater and surface water in the alluvial sediments surrounding the Fording River are referred to as hyporheic exchange flow. These localized exchanges can vary substantially over time and space, with hydraulic gradients changing rapidly in response to hydrologic conditions at watershed to channel scales. The Fording River has an abundance of coarse sediments; therefore, hyporheic exchange can change rapidly over time and space, resulting in portions of the river that ultimately become dry at the surface as the stream transitions from gaining water to losing it relative to the alluvial aquifers (Figure 2-4).

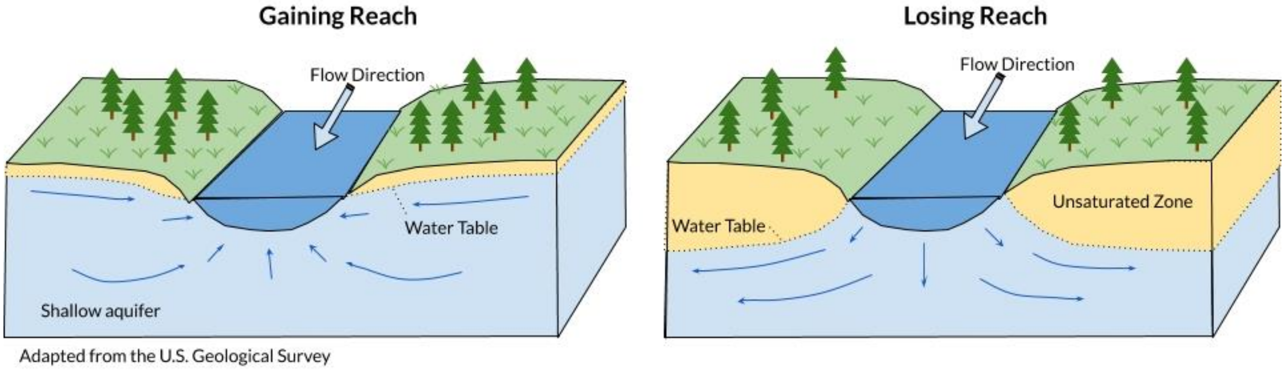

Figure 2-4. Diagram showing the conceptual relationship between losing and gaining streams. *(Adapted from the U.S. Geological Survey. Sustainable Groundwater).*

In some parts of the UFR, there are groundwater discharge areas from the alluvial aquifers, where deeper (or older) groundwater flow has much greater influence than shallow groundwater. This situation contributes to consistently gaining reaches that can span many kilometres. Conversely, losing portions of the UFR can result in drying reaches where the groundwater table is situated below the river level (Figure 2-4). These conditions are largely influenced by subsurface hydraulic conductivities and bedrock/aquitard topography (Henry & Humphries, 2021). Groundwater flows predominantly through coarse-grained fluvial and glaciofluvial deposits overlying the bedrock. Water flow converges toward the valley bottom from the valley flanks. It then transitions to down-valley flow, either parallel or sub-parallel to the river or creek, depending on local hydraulic gradients, permeability and surface water interaction, and, ultimately, it discharges to the river. The depth of the bedrock or aquitard surface contributes to the natural gaining and losing reaches of the UFR. Readers can refer to Henry and Humphries (2021) to further understand the hydrogeologic controls on gaining and losing reaches.

Drying of the UFR mainstem during fall and winter months has been observed since the 1970s. More recent UFR survey work is documented in Zathey and Robinson (2021). During the Evaluation of Cause, the question, whether drying sections in the UFR are natural or mine related, arose frequently. Based on literature reviewed and discussed in Hocking et al. (2021a), a variety of natural and anthropogenic factors contribute to stream drying. These large- and small-scale influences include climate, watershed area, position in the river network (e.g., headwaters versus mainstem), channel gradient, abundance of instream wood, substrate composition and structure, thickness of alluvial aquifers, groundwater and hyporheic flows and water diversions and withdrawals (Lake, 2003; Tolonen et al., 2019). In addition, it is possible that drying reaches are linked to larger-scale, mine-related changes in interactions between groundwater and surface water.

The UFR's hydrologic and geomorphic regime changes over time. Floods and droughts represent extreme events that can shape watersheds and affect how the aquatic ecosystem functions. The high variability and strong seasonal patterns in the Fording River streamflow measured at the mouth of the river are shown in Figure 2-5. The years 1995 (blue line) and 2013 (purple line) represent the highest daily average streamflow on record, which formed and shaped the recent conditions in UFR. The years 1970 (red line) and 2001 (green line) had lower than average annual flows. Low flow years present challenges for aquatic species, such as losses of habitat connectivity and low habitat availability. To provide context for years leading up to the WCT decline, 2017 is shown in orange, 2018 in yellow and 2019 in brown.

Streamflow measurements for the Fording River below Clode Creek ended in 1995, and there are no recent data to evaluate the hydrologic regime at the smaller scale. Historical daily average streamflow measured at two hydrometric stations on the Fording River are compared in Figure 2-6 and show a similar seasonal pattern. For both stations, the lowest flows occur in winter relative to mean annual discharge. However, an important distinction is that the Fording River at the mouth is approximately five times larger in terms of discharge than the upper Fording River below Clode Creek.

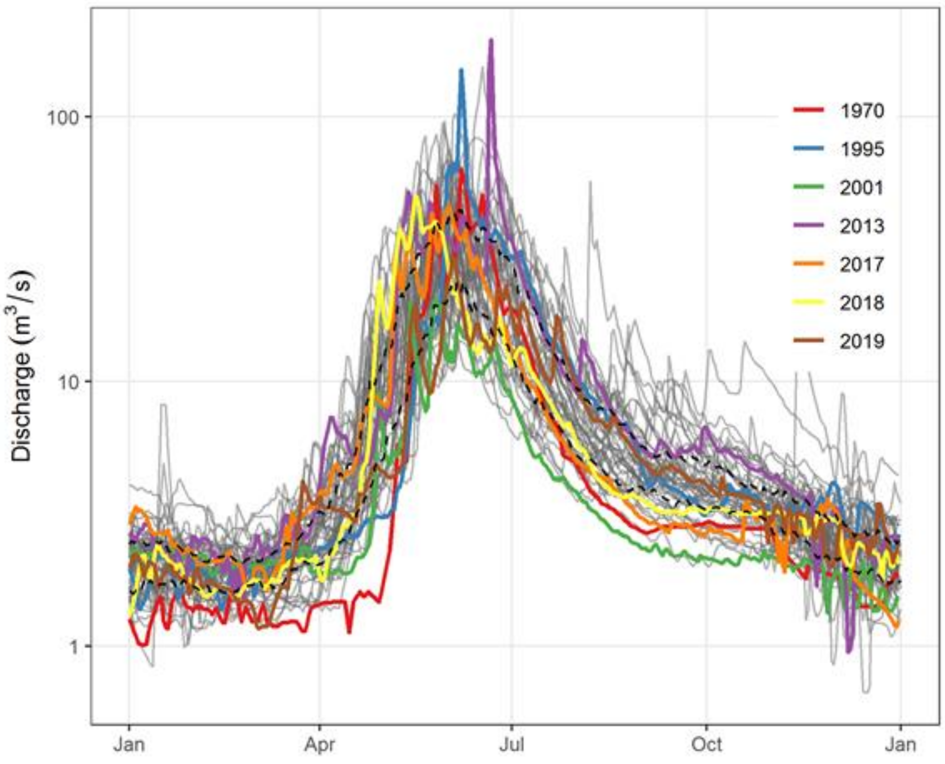

Figure 2-5. Daily average streamflow at the mouth of the Fording River, Water Survey of Canada Station, from 1970 to 2019, inclusive.

Coloured lines represent years of note (see text), with the darker black dashed lines representing average range (the dashed lines are 25–75% quantiles/quartiles).

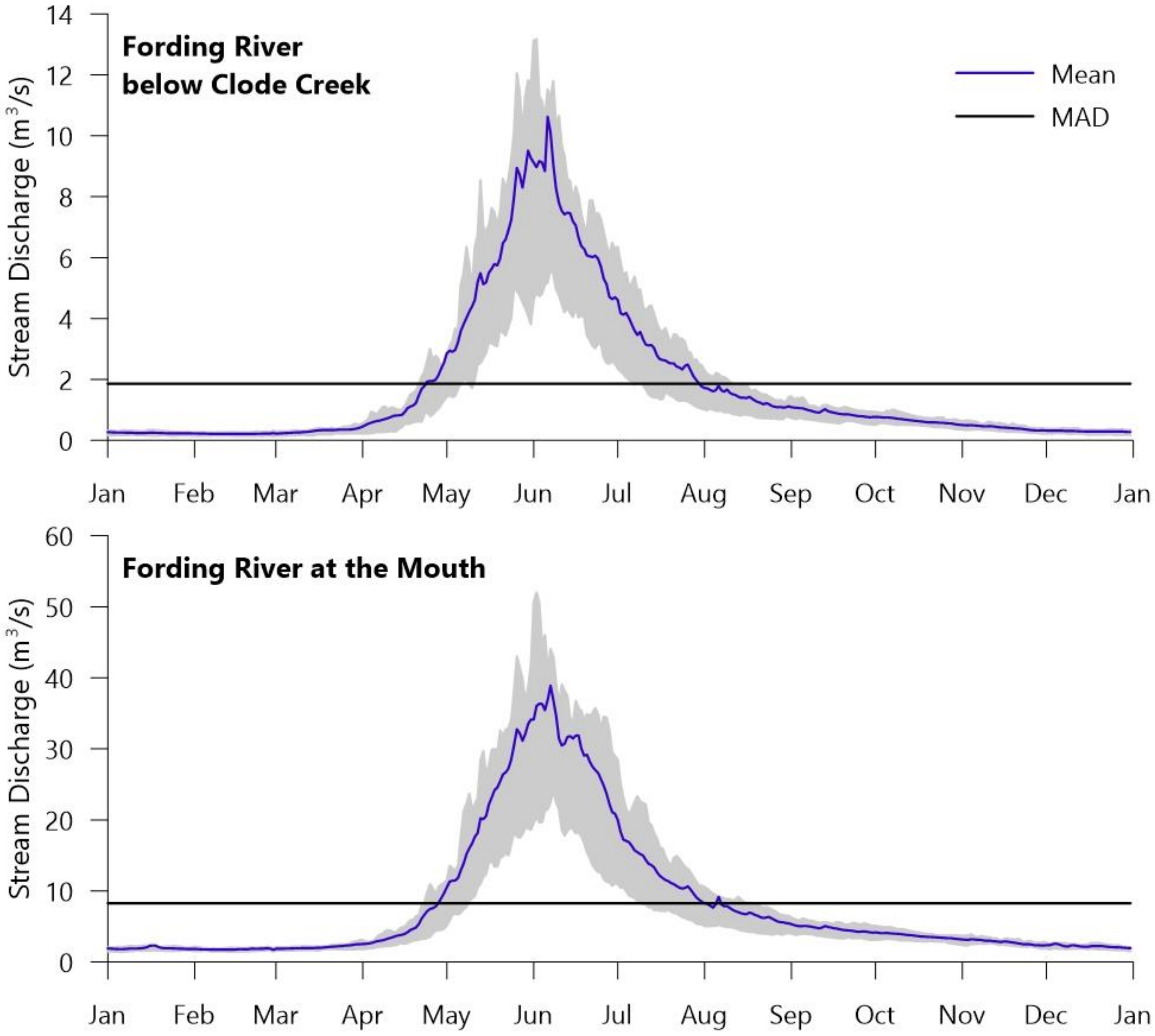

Figure 2-6. Daily average streamflow at the mouth of the Fording River and Fording River below Clode Creek, Water Survey of Canada Station, from 1971 to 1995, inclusive.

MAD = Mean Annual Discharge

2.3.4. Natural Disturbance Regime

Over time, many of the changes to the UFR hydrologic conditions and river morphology can be attributed to natural disturbance. Natural disturbance includes factors that govern how water and sediment flow throughout the watershed. Examples are wildfire and insect outbreaks, and extreme hydrologic events like flooding.

Historically, the dominant landscape disturbances that affected streamflow and channel morphology have been wildfires and insect outbreaks. In snowmelt-dominated watersheds such as the UFR, post-disturbance landscapes tend to undergo enhanced snowmelt due to decreased shading and faster storm response. These watersheds can experience higher peak flows because there is less canopy to intercept rain and snow and less canopy from which water can evaporate. Wildfire disturbances can also result in soil hydrophobicity, which leads to a decrease in water infiltrating the ground and results in increased overland flow.

By altering streamflow regimes, natural disturbance events, like the large wildfires of the 1930s in the UFR, can have a large effect on channel stability. Stream channels can become less stable following natural disturbance events because the riparian vegetation loses root strength (Eaton et al., 2010). This loss of stability increases the potential for debris to move and, in doing so, supply additional sediment and wood to streams (Phillips & Eaton, 2009). Unlike wildfire, no documentation on insect outbreaks dating back to the 1930s exists. Even so, it is unlikely that insect outbreaks in the UFR have resulted in substantial hydrologic effects.

Floods are a major geomorphological driver in river systems, and extreme flood events have been recorded recently, with notable observed changes. The UFR has seen three major floods in the last 50 years (1974, 1995 and 2013). These floods were caused by large precipitation events that occurred during near-peak snowmelt. The 1974 flood was noted at the river gauge located at the mouth of the Fording River, which recorded a daily flow 2.9 times the median peak annual daily flow (Walker et al., 2016). The June 1995 and 2013 floods were marked by extremely high rainfall and rapidly melting alpine snow (Pomeroy et al., 2016). These three flooding events created watershed-scale changes to the morphology of the Fording River, and general channel characteristics such as width and depth were altered, driven by erosion and lateral migration of the channel.

2.4. WATERSHED-SCALE ANTHROPOGENIC CHANGE

The Ktunaxa people have occupied the Elk Valley for more than 10,000 years, as described earlier. The Ktunaxa already knew coal (qukin nuʔkiyʔis or Raven’s Rock) as “the rock that burns” when William Fernie described it as a mineable resource around the 1890s, and miners migrated to the first coal mines at Coal Creek (Finch, 2012). Over the last 150 years, the UFR watershed has been substantially altered by industrial anthropogenic disturbances, especially coal mining, forestry and associated linear development (e.g., roads, railways and utility corridors). Relative to Teck Coal’s 1950s Predictive Ecosystem Model (PEM; based on 2019 disturbance dataset), disturbance data from 2019 demonstrate that approximately

12,747 ha (30%) of the UFR have been impacted by mining, clearcutting, roads, railroads or other anthropogenic disturbance.

2.4.1. Forestry

The Bush Fire Act was enacted in 1905, resulting in one of the first fire wardens being appointed in the East Kootenay region. Since then, fire suppression activities have occurred in the area and have reduced the role of fire and insects as the dominant disturbance factors. Currently, most of the change to forested ecosystems occurs through conventional timber harvest activities, where cutblocks and an extensive road network have disturbed approximately 13% of the UFR watershed.

Forest disturbance can affect aquatic habitat, primarily by changing water quality, flow regimes, instream wood and sediments. Activities such as harvesting timber and building roads alter the landscape and supply additional sediment to surface waterbodies (Reid et al., 2016; Beschta, 1978; Slaymaker, 2000). These activities can also reduce riparian vegetation and stream shading (Moore & Scott, 2005), thereby affecting thermal conditions in the streams (Leach & Moore, 2010). Forests immediately adjacent to the river are the main source of instream wood (also referred to as large woody debris), which is important for maintaining stream channel form and function (Redding et al., 2008; Pike et al., 2010). These forests also buffer water runoff and related soil losses, thereby reducing releases of suspended solids.

An analysis of disturbance in the PEM-defined riparian area suggests approximately 10% of the riparian habitat in the UFR has been disturbed by forestry activities, primarily in the upper reaches of tributaries to the Fording River.

2.4.2. Mining

Coal mining began in the region over 120 years ago with underground mines, and in the 1960s the industry shifted to open pit extraction. Open pit mining involves exposing coal seams by removing surface soil and overburden/interburden (materials overlying the coal resource, which are placed in spoil disposal areas). The coal is then extracted and processed. Later, when the mines are decommissioned, most disturbed areas will be reclaimed. The coal, which is used primarily to make steel, is carried to port by rail and then shipped to Asia-Pacific markets. The mining activities for accessing and transporting the coal require supporting infrastructure such as roads and railways, sediment ponds, tailings ponds and operational buildings. Mining is the single largest type of anthropogenic disturbance in the UFR, directly impacting over 7,030 ha (17%) of the watershed.

Open pit metallurgical coal mining began in the UFR watershed in 1971. In 2008, Teck Resources acquired the mine properties (now operated as FRO, Greenhills Operations and Line Creek Operations; Figure 2-2) and assets from Fording Canadian Coal Trust.

In addition to the area disturbed, open pit mining has modified the UFR's elevation profile (Figure 2-7). In general, the highest elevation areas (i.e., > 2,200 m above sea level) have been reduced because mining has removed coal and rock from peaks and deposited waste rock at lower elevations (1,900–2,100 m). Changes in watershed elevation profiles have the potential to alter large-scale hydrologic and geomorphic processes (Villeneuve et al., 2017). While hydrologic response to mining is generally poorly understood, we know that mining can alter the interaction of surface and groundwater by changing water movement and storage dynamics at landscape levels (Miller & Zegre, 2014).

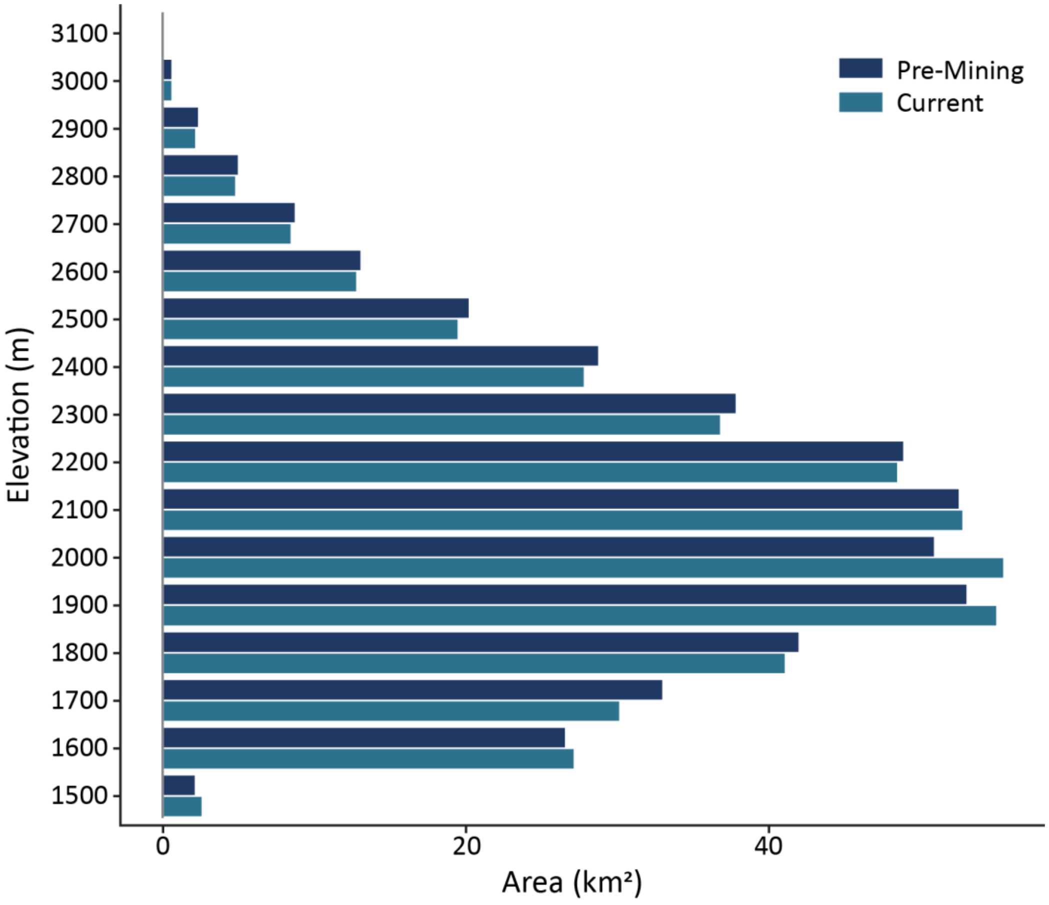

Figure 2-7. Elevation profile derived from the pre-mining condition (1950) and current condition.

Digital Elevation Models of the Fording River watershed above Josephine Falls (D. Vasiga, Teck Coal, personal communication).

Mining in the UFR has also modified aquatic habitats by realigning and armouring some stream sections (in some cases, creating pit lakes) and changing channel width and depth through aggradation. These changes can have varying impacts (see Section 2.5.2), and in some cases those impacts can be mitigated by offsetting (see Section 2.5.3). Nevertheless, the overall effect of the changes to habitat is generally expected to be negative, as discussed in Section 2.5.2 and summarized in Section 2.6.

2.5. CHANGES TO WESTSLOPE CUTTHROAT TROUT HABITAT

Habitats that had been available to WCT in the UFR in a pre-mining condition were altered by relatively recent natural and anthropogenic factors. This section describes WCT habitat in a pre-mining condition and the adverse and positive effects that have occurred since mining began.

2.5.1. Pre-Mining Conditions

Habitat suitable for WCT in the UFR developed 13,000 to 11,000 years ago, after the glaciers retreated from the Elk Valley. Post glaciation, habitat changes over long timescales would have been considerable, as erosion, changes in vegetation and periodic flood events altered the watercourses. Reconstructing stream habitat using pre-mining images from the 1950s, pre-mining digital elevation models and stream layers available from the Province of British Columbia, shows that approximately 990 linear km of above-ground stream and river would have existed in the UFR (Figure 2-8). WCT would not have had access to this entire network due to limitations in gradient (too steep or with barriers), flow (ephemeral or intermittent) and, potentially, temperature (too cold). However, based on habitat use patterns observed during recent population monitoring, WCT can reasonably be assumed to have primarily used habitat in the mainstem of the river, associated side channels and accessible tributaries of suitable gradient (e.g., < 20%). Higher gradient streams or streams with barriers would not have been fish bearing.

Before mining began, the Fording River mainstem from Josephine Falls north to the confluence of Henretta Creek measured approximately 45 km. The entire mainstem would have been fish bearing. Contrasting 1950s air photos with present-day images suggests that the 1950s habitat would have resembled that of the present day in reaches undisturbed by mining (e.g., primarily downstream of FRO). Fish use, which refers to occupancy by fish in areas of the UFR during key activity periods[2], is, therefore, also assumed to have resembled present-day use, at least where the mainstem habitat is unchanged. Mainstem reaches are the primary adult habitat for life history stages such as rearing, overwintering and migrations. Changes in habitat from pre-mining conditions are discussed in Section 2.5.2.

The types and amounts of fish habitat in the larger UFR tributaries are difficult to quantify in a pre-mining condition, but data are available for the linear kilometres of fish habitat in each tributary watershed in 1980 (Minnow, 2016). From this, it is estimated that approximately 180 km of fish-bearing tributary habitat existed in the UFR watershed pre-mining. Main tributaries would have included: the Fording River and Henretta Creek upstream of their confluence, Clode Creek, Kilmarnock Creek, Chauncey Creek, Ewin Creek, Dry Creek and Greenhills Creek, among other, smaller, fish-bearing water courses.

Like the mainstem, it is assumed that fish use in the tributaries would have resembled that documented in recent monitoring, where the current habitat and connectivity appear to be similar to pre-mining. Tributary habitat was likely primarily juvenile rearing habitat, with some adult use for spawning and overwintering. Juvenile use of tributary habitat versus mainstem reaches is well-documented for this species. The highest juvenile densities tend to be observed in tributaries (Robinson, 2011; Cope et al., 2016); however, juvenile use likely varied between tributaries (Robinson, 2014) and localized high-use areas can occur in mainstem reaches. Some of these tributary habitats may not have supported large numbers of fish. For instance, Ewin Creek, which was the single largest contributor to available fish-bearing tributary habitat in 1980, supports few fish under existing conditions, despite being unaffected by mining. Cope et al. (2016) suggests this is a thermal limitation. Other tributary habitats may have been isolated from the mainstem UFR, at least periodically. For example, early studies indicate that Kilmarnock Creek and its tributaries, including Brownie Creek, contained fish habitat that was isolated by dry reaches present from November to mid-April (Fording Coal Limited, 1985). However, Fording Coal Limited’s (1985) Kilmarnock Dragline Environmental Impact Assessment indicates that Kilmarnock Creek supported overwintering fish and that “in the fall period, trout migrate from the Fording River into Kilmarnock Creek for the winter period.” This is an example of adult use of tributary habitat.

Overall, there is some uncertainty about the amount and condition of fish habitat that was present in the mainstem in a pre-mining condition, and there is considerable uncertainty around tributary habitat. However, the ecology of this species and pre-mining air photos do allow for a qualitative interpretation of pre-mining use. Available evidence suggests that of

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[2] Fish use describes occupancy by fish in river segments of the UFR during key activity periods such as overwintering, spawning, incubation, rearing and migration. Fish use is typically confirmed through field observations, captures or radio-tagging studies.

the 990 km of above-ground stream present in the UFR prior to mining, less than 30% would have been fish bearing, based on a gradient filter[3].

Figure 2-8 is presented on the following page. Its caption is:

Figure 2-8. Upper Fording River pre-mining, showing sub-watersheds.

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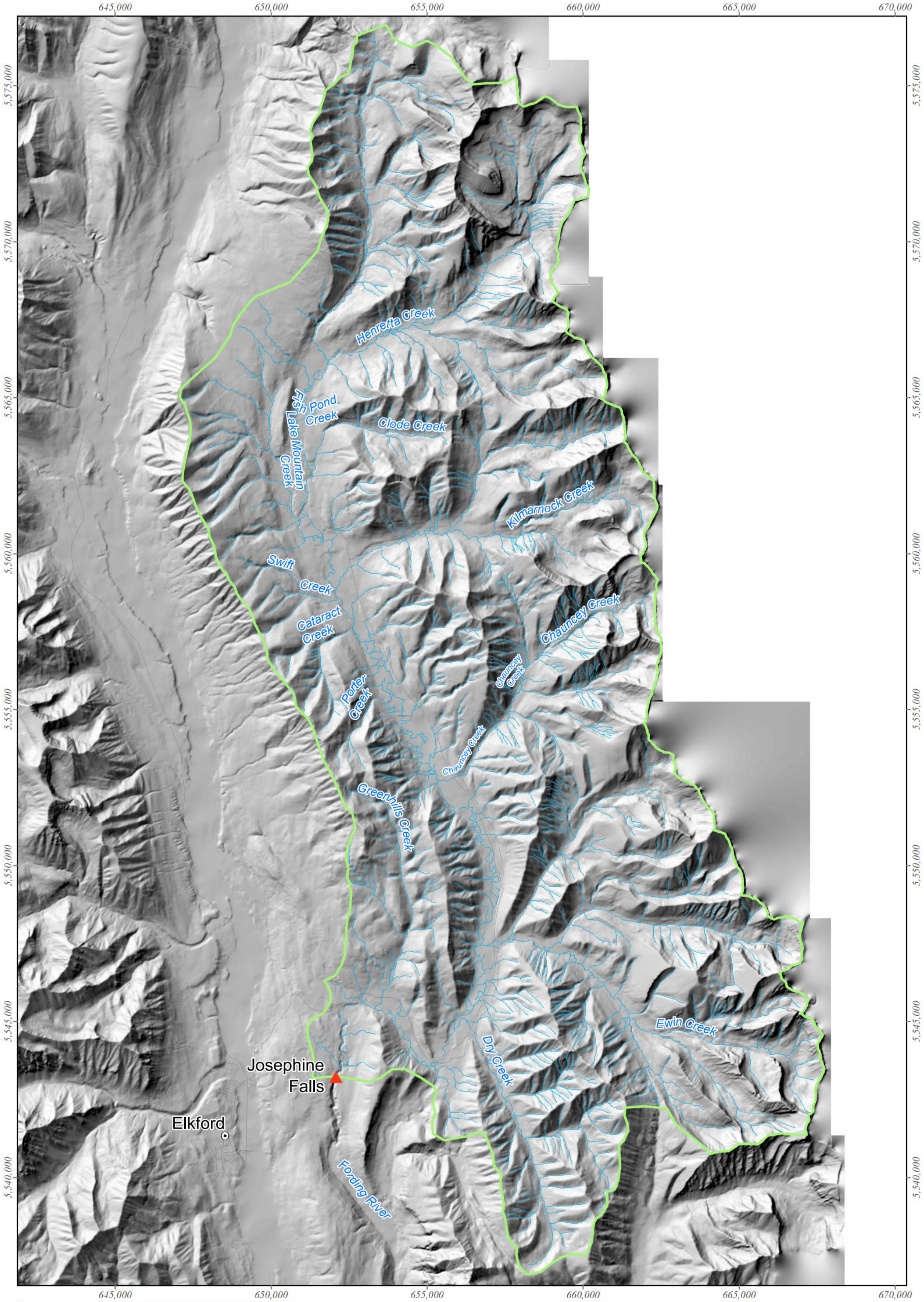
[3] A gradient filter of 25% was used for perennial streams and a filter of 10% was used for intermittent streams (Minnow, 2016).



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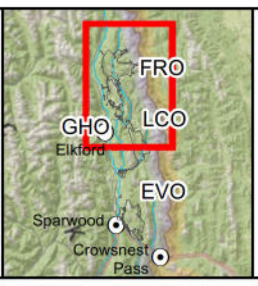

Upper Fording River Overview

🟩 Upper Fording River Watershed

~ Pre-Mining Water Network

N

0 650 1,300 2,600 3,900 Meters

DATE: 3/24/2021

MINE OPERATION: FRO

SCALE: 1:110,000

COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

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2.5.2. Adverse Habitat Effects

At the watershed-scale, relative to a pre-mining condition, changes resulting from natural and anthropogenic disturbance up to the present day have adversely affected WCT habitat in several ways. These are summarized below.

- **Direct loss of stream habitat.** Depositing waste rock at lower elevations and in valley bottoms has resulted in direct loss of above-ground stream habitat in the UFR. Our analysis shows that by 2019 the amount of above-ground stream present in the UFR had declined to 878 linear km (a loss of approximately 11%) and that this was due primarily to mining[4] (Figure 2-9). Most of this loss consisted of steep, high-elevation streams that would not have been suitable for WCT. A few notable streams known or likely to have been occupied by WCT have been mostly removed from the UFR system due to mining (Minnow, 2016). These streams include Clode Creek, Lake Mountain Creek and Kilmarnock Creek (including Brownie Creek). Greenhills Creek has also been substantially modified (Minnow, 2016). The specific habitats lost in many of these creeks are not well understood. According to Minnow (2016), approximately 24.5 km (~14%) of the fish-bearing tributary habitats present in 1980 had been permanently lost due to mining by 2016. Although the 1980 values are considered the most accurate approximation of fish-bearing tributaries available in the UFR pre-mining, additional fish-bearing habitat would have been permanently lost prior to 1980.

  Channel straightening typically results in a loss of habitat length and complexity, and the mainstem of the UFR has lost sinuosity in sections that were straightened to accommodate mining. For example, two sections were straightened to facilitate construction of the North Tailings Pond and South Tailings Pond.

- **Indirect loss (i.e., reduced habitat connectivity).** Although 89% of the linear stream length present in the 1950s was still present at the time of the UFR WCT population decline, habitat connectivity had been substantially altered and fragmented. Understanding what habitat was available to the mainstem population, including connectivity with tributaries, is key to understanding resilience. The Minnow (2016) estimate of 14% loss of fish-bearing habitat in tributaries does not account for fragmentation. Table 2-1 lists the changes to tributary habitat that have resulted in losses to fish inhabiting in the Fording River mainstem. When considering fragmentation, the tributary loss (direct and fragmented) is closer to 80 km (i.e., 45%). Beyond this, these direct and indirect tributary losses would have caused additional losses to non-fish-bearing habitat.

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[4] Approximately 147 linear km of streams present prior to mining were impacted by mines (i.e., 15%), but not all of these were lost or buried by spoils. Some streams were moved and continue to flow above ground.

Although waste rock deposition has created some of the most obvious habitat fragmentation (e.g., Kilmarnock Creek) relative to pre-mining conditions, roads associated with mining and forestry activities have also fragmented WCT habitat. In particular, culverts, which are constructed under roads where they intersect with streams, impede fish passage in some cases. Two instances on the mainstem Fording River are the multi-plate culvert (Segment S7) and the Henretta Culverts (Henretta Creek). Both crossings have been identified as sites where connectivity issues exist, and both received some fish passage improvements in 2016 (Baranowska & Robinson, 2017). Other notable barriers are on the tributaries of Chauncey Creek and Greenhills Creek, and potentially Dry Creek as a partial or seasonal barrier. Settling ponds, and specifically the outlet structures, are another example of anthropogenic disturbance that has fragmented fish habitat in the UFR. Ponds exist on Clode Creek, Porter Creek, Greenhills Creek and Eagle Creek. Each contributes to habitat loss and fragmentation. The role of habitat connectivity and fish passage at shallow riffles in the Fording mainstem and the inferred passage success at Henretta and multi-plate culverts is addressed by Harwood et al. (2021). Connectivity and passage at other locations was not assessed by Harwood et al. (2021).

Table 2-1. Fish-bearing habitat in upper Fording River tributaries in 1980 and 2017.

Tributary Name	Fish-Bearing Habitat in 1980 (km)	Connected Fish-Bearing Habitat in 2017 (km)	Relative Status 1980 to 2017
Fording River (above Henretta Creek confluence)	19.8	19.8	No change
Henretta Creek	24.0	24.0	No change
Clode Creek	4.8	0.1	Loss
Lake Mountain Creek	6.5	0.0	Loss
Kilmarnock Creek	31.6	0.0	Loss
Swift Creek	0.1	0.1	No change
Cataract Creek	0.0	0.0	No change
Porter Creek	0.7	0.2	Fragmentation
Chauncy Creek	21.9	0.6	Fragmentation
Ewin Creek	45.8	45.8	No change

Tributary Name	Fish-Bearing Habitat in 1980 (km)	Connected Fish-Bearing Habitat in 2017 (km)	Relative Status 1980 to 2017
Line Creek Operations, Dry Creek	10.2	5.0	Loss
Greenhills Creek	12.4	0.3	Fragmentation
Total	**178.7**	**96.6**	

- **Riparian habitat loss and alteration.** An evaluation of footprint and forest cover in the PEM-defined riparian habitat suggests that slightly more than 30% of the riparian habitat in the UFR has been lost or altered, compared to a pre-mining condition. Of this, almost 18% of the total riparian habitat in the UFR has been lost due to mining, and another 1% has been disturbed (not lost) by mining activities. Forestry has resulted in 10% of the riparian habitat being altered, but the extent to which riparian habitats altered by forestry may have recovered is unknown. Approximately 2% of the riparian habitat has been altered by land uses other than mining or forestry. The proportion of lost riparian area along fish-bearing streams is unknown, but it would include the same streams where fish habitat was lost. In some cases, mining disturbance abuts both sides of the stream and little or no riparian vegetation is present, including along portions of the Fording River mainstem.
- **Altered channel conditions.** Mining has changed stream morphology in some areas, especially at lower elevations in reaches that WCT occupy, and these changes have led to reduced habitat quality. Both Henretta Creek and the Fording River mainstem contain sections that have been straightened and armoured near mining facilities and infrastructure. Two sections were discussed above, where the Fording River was relocated to accommodate the North and South Tailings Ponds.

  Perhaps the most apparent change in mainstem habitat quality is the channel aggradation, overwidening and loss of large woody debris in certain reaches of the UFR. Although data on pre-mining habitat quality are unavailable, air photos from the 1950s and the present can be compared and the differences interpreted. In the 1950s, the Fording River had a sinuous channel, established riparian habitat and a typical amount of bedload movement, as evidenced by exposed gravel bars. In recent air photos, the segments that do not run through FRO (e.g., Segments S1 to S6) appear relatively unchanged in both channel morphology and riparian habitat, whereas segments through the FRO mine (Segments S7 to S9) do not have substantial riparian habitat, braided channels or extensive gravel bar development. These onsite sections are considered to be aggrading, and this is likely to be, in part, a response to anthropogenic changes. Data from 2012 (Table 2-2, see grey shading) show that sections of the UFR that flow through FRO exhibit fewer pools, extensive riffles, low LWD counts and high channel width-to-depth ratios (Cope et al., 2016). In 2013, the UFR then experienced a large flood, which resulted in further bank erosion, streambed movement and redistribution of LWD. Aggradation, low instream habitat diversity and the lack of LWD have been the focus of much of Teck Coal's rehabilitation efforts on FRO property (e.g., Bransfield et al., 2021). It is estimated that approximately 10 km (22%) of the upper Fording River mainstem is adversely impacted by channel aggradation, which resulted in part from a lack of riparian vegetation exacerbated by the large-scale flood in 2013.

Aggradation at this scale has the potential to reduce population resilience by:

- Reducing the amount of overwintering and rearing habitat, by filling in pools
- Increasing vulnerability to predation, due to loss of pools and LWD cover
- Increasing the potential for dry conditions to develop

Table 2-2. Summary of habitat metrics by segment (from Cope et al., 2016).

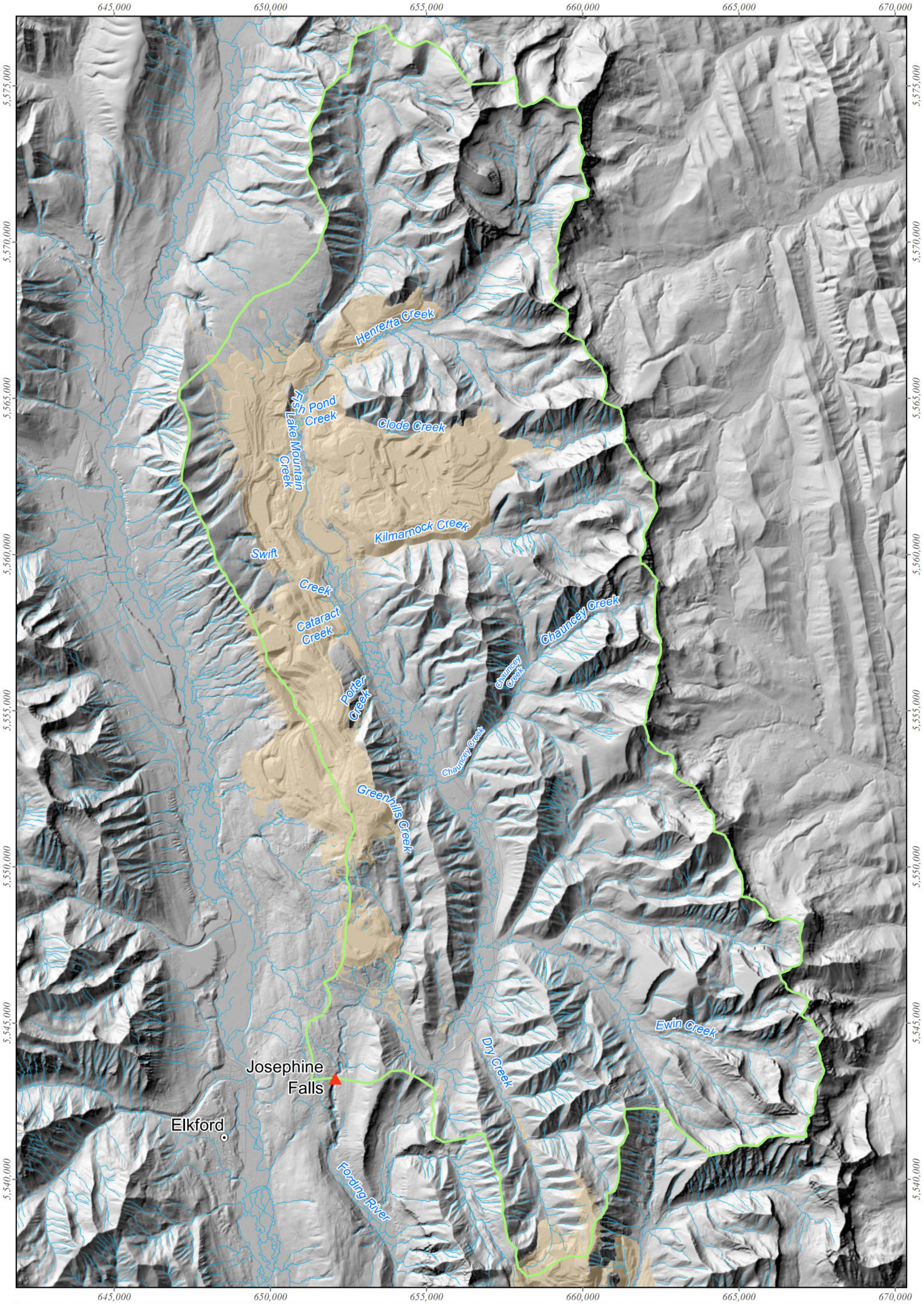
Data collected from 2012 imagery. Grey shading indicates poor conditions.

Segment	% Pools	% Riffle	LWD Tally	Width-to-Depth Ratio
S1	20.7	24.9	209	-
S2	34.3	28.5	984	17.6
S3	33.9	25.3	840	-
S4	27.9	28.7	458	-
S5	28.5	34.6	371	-
S6	71.3	15.3	1146	24.2
S7	5.6	48.4	0	110.2
S8	4.1	79.9	0	90.8
S9	18.7	48.8	243	51.1

Segment	% Pools	% Riffle	LWD Tally	Width-to-Depth Ratio
S10	3.4	3.9	0	-
S11	0.8	3.0	7	-

Figure 2-9 is presented on the following page. Its caption is:

Figure 2-9. Upper Fording River 2019.



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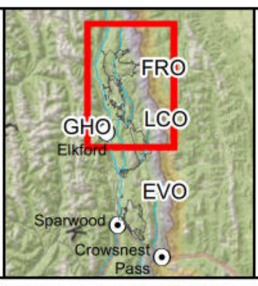

Upper Fording River Overview

🟩 Upper Fording River Watershed
〜 2019 Water Network
▨ Mining Disturbance

N

0 650 1,300 2,600 3,900 Meters

DATE: 3/24/2021	MINE OPERATION: FRO
SCALE: 1:110,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

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- **Calcite.** Calcite is naturally occurring calcium carbonate precipitate that deposits onto the streambed. Although it occurs naturally, mining exacerbates the degree of deposition to the extent that in some parts of the UFR watershed, calcite has caused rocks to be cemented together (a process referred to as concretion), thereby impairing aquatic habitat. An increasing trend in the Calcite Index from 2013 to 2019 (McCabe & Robinson, 2020) indicates that calcite increased in both the tributaries and mainstem of the UFR, but in the mainstem and most of the fish-bearing reaches, concretion values remain low (McCabe & Robinson, 2020). For a detailed discussion of calcite as part of the Evaluation of Cause, see Hocking et al. (2021b).
- **Water quantity.** Hydrologic change in response to mining in the UFR watershed can occur as a function of water management (e.g., water diversion and consumption), landscape alterations (e.g., soil and vegetation removal, pit development and rock fill) and reclamation. The recent Fording River Operations Swift Project Environmental Assessment Certificate Application used a hydrologic model to simulate expected hydrologic response to mine development. That modelling suggests that development is likely to result in marginal increases in streamflow during all seasons, at the scale of the Fording River. Streamflow in smaller tributaries like Swift Creek, Cataract Creek, Lake Mountain Creek and Kilmarnock Creek is expected to reduce 100% in the next 100 years. Conversely, streamflow in Fish Pond Creek is expected to increase (Teck Coal Limited, 2014). Teck Coal is the primary water user in the UFR, with 22 licensed Points of Diversion (PODs) associated with FRO, located upstream of Chauncey Creek. This includes PODs from pits, ponds, local drainages and the river system. A summary of water use data for the UFR is provided in Wright et al. (2021).
- **Water quality.** Water from precipitation and runoff flows through the waste rock piles and carries constituents (e.g., nitrate, sulphate, selenium) that negatively affect the water quality in tributaries and the mainstem UFR. This presents a challenge that requires a long-term approach to address water quality related to both historical and future mining activity (Elk Valley Water Quality Plan, 2014). Teck Coal is commissioning, constructing and/or operating water treatment facilities to reduce levels of constituents, including selenium, in the UFR. For a discussion of the role of water quality in this Evaluation of Cause, see Costa and de Bruyn (2021) and Bollinger (2021a).

2.5.3. Positive Habitat Effects

Teck Coal has rehabilitated and created habitat by altering stream configuration and creating offsets. As detailed below, efforts to rehabilitate and create habitat have treated approximately 6 km of channel length. Rehabilitation projects have been undertaken in accordance with applicable permits and with input from KNC and relevant agencies.

Henretta Lake is an example of altered stream configuration that provides habitat (in that case overwintering and rearing habitat) for WCT. Offsets are specific projects to rehabilitate/create habitat, implemented to counter the adverse effects caused by mining, which include direct and indirect habitat losses, reduced habitat quality in remaining reaches and connectivity issues. Major rehabilitation projects to date in the UFR include the following:

1990s.

- In 1991, approximately 400 m of the Fording River upstream of Henretta Creek was enhanced (Minnow, 2016).
- In 1993, Fish Pond Creek, a stream and pond system, was constructed to provide approximately 900 m of tributary habitat with a series of ponds for overwintering habitat. Rafts were floated on the ponds to provide overhead cover. Spawning was documented in the lotic sections of this habitat.

1998 (Berdusco et al., 2006).

- The Henretta Lake and the Henretta Creek Reclaimed Channel were completed in 1998 and 1999, following dragline mining of a pit that required Henretta Creek to be temporarily diverted through a series of culverts. Following mining, the pit was reclaimed to become Henretta Lake and the inlet and outlet channel were constructed to provide additional habitat. The project provided approximately 1.2 km of channel and 2.5 ha of lake.

2016 (Baranowska & Robinson, 2017).

- Henretta culvert fish passage improvement: Two riffles were installed downstream of the three grouted weirs at the culvert outlets, improving approximately 100 m of channel. Fish passage through the Henretta culvert was documented within the first year of passive integrated transponder (PIT) tag monitoring.
- Fording River rehabilitation at the concrete arch: 1,200 m of overwidened channel was rehabilitated. Instream LWD jams, riffles and bar top structures were installed to promote a narrower channel and less lateral migration and to give riparian vegetation a chance to establish on the bars. Rehabilitation is progressing, but it will take 5–10 years to see any notable riparian vegetation.
- Multi-plate culvert fish passage improvement: A series of five riffles was created over 200 m, downstream of the culvert.
- Fording River rehabilitation at the North Tailings Pond: A series of 15 riffles was created over 800 m of channelized river. Riffles have restored the complex riffle-pool sequence from the homogenous riffle that existed before, but the channel still lacks LWD or overhead vegetation cover.

2017 (Smeaton & Robinson, 2018).

- Henretta Outlet channel and Lake: Between the lake and culverts, 400 m of channel were rehabilitated. Rehabilitation was aimed at reconstructing floodplains from an incised channel. Treatments included instream LWD jams, riffles and floodplain planting. The goal of habitat reconstruction was to improve the habitat originally constructed in 1998/99.
- Fish Pond Creek: The 2013 flood damaged the original Fish Pond Creek and shortened its overall length. A series of three ponds and interconnecting channels was rehabilitated after they were damaged in the 2013 flood. A second set of three ponds and channels was created to increase the amount of usable habitat. Overall, this project rehabilitated/created 500 m of channel and 1 ha of pond habitat.

2018 (Bransfield & Robinson, 2019).

- Henretta inlet channel rehabilitation: A 900 m of section of channel was rehabilitated to address overwidened sections and areas lacking floodplain. Instream LWD jams, riffles and bar top structures were used to promote channel stability. The goal of habitat reconstruction was to improve the habitat originally constructed in 1998/99.
- Fording River rehabilitation near Swift Creek: Using instream LWD jams, riffles and bar top structures, 1,400 m of overwidened channel were rehabilitated to promote a narrower channel and less lateral migration. This work then was augmented with a 175 m extension to the meander at the downstream end.

2.6. SUMMARY

The UFR has undergone substantial change over several thousand years, with mining playing a major role for the last half century. Landscape-scale anthropogenic disturbance has fundamentally altered the form of the UFR and affected watershed function. The Elk Valley Cumulative Effects Management Framework (EV-CEMF Working Group, 2018) identified the UFR watershed as having the highest estimates of aquatic hazard in the Elk Valley. Changes in the UFR watershed from a pre-mining condition include hydrologic changes due to the landscape being altered, habitat loss caused by waste rock being deposited over streams at the bottom of valleys, reduced habitat quality related to mining through constituents being released, habitat alteration and fragmentation caused primarily by mining and forestry, and habitat gain though rehabilitation and offsetting actions.

The WCT population inhabiting the UFR has always been constrained and disconnected from broader populations in the Elk Valley by Josephine Falls. As a result, this isolated population has naturally reduced resilience compared to populations with access to greater abundance and diversity of habitats. Even in a pre-mining condition, the total amount of fish-bearing stream available to support WCT was limited by Josephine Falls. Fish habitat was further reduced through industrial development. WCT habitat changed in the UFR between a pre-mining 1950 condition and the condition present leading into the WCT population decline window. Nearly half of the tributary habitat had been lost or fragmented by 2017. No single tributary remains that is longer than 5 km, except for Ewin Creek, the Fording River upstream of Henretta Creek and Henretta Creek. While proportionally lower direct habitat loss has occurred in the mainstem, approximately one-quarter of the mainstem habitat is considered impaired, largely because of channel aggradation and a lack of riparian habitat. From the data available, and acknowledging some limitations in records from earlier years, approximately 90 km of fish-bearing mainstem and tributary habitat has been lost, fragmented or impaired. Recent habitat rehabilitation and creation efforts have treated approximately 6 km of channel length.

Despite data being available to quantify loss in linear, above-ground stream length and naturally vegetated riparian habitat, there is less certainty about the net outcomes of losses and gains for specific habitat types, such as spawning habitat or overwintering habitat. Some habitat types, such as overwintering habitat, are suspected to have been naturally uncommon in this system, and actions undertaken by Teck Coal have both reduced and added overwintering habitat to the UFR. The overall implications of these changes for WCT resilience are likely negative.

This chapter's description of natural and anthropogenic change to the UFR sets the stage for understanding the watershed conditions that are considered in Chapters 5 to 8. Importantly, most of the documented change in the UFR identified in this chapter occurred prior to the WCT population decline, and populations were increasing immediately prior to the decline (Chapter 4). Immediately prior to the decline, the UFR supported a population of approximately 4,000 fish longer than 200 mm (i.e., adult fish) in the Fording River mainstem (Chapter 4).

The changes in habitat quantity or quality documented here did not occur during the period of WCT decline and were, therefore, unlikely to have been a direct cause of the decline. However, these changes may have reduced the ability of the WCT population in the UFR to accommodate additional change or impacts, i.e., changes in habitat quantity and/or quality may have affected the population's resilience by decreasing its resistance to decline.

3. Westslope Cutthroat Trout

This chapter describes the WCT broadly at a species level, and it summarizes pertinent details of the population in the UFR from a biological and ecological perspective.

3.1. TAXONOMY & DISTRIBUTION

The Westslope Cutthroat Trout, *Oncorhynchus clarkii lewisi,* is a subspecies of Cutthroat Trout (*Oncorhynchus clarkii*) endemic to North America. The *Oncorhynchus* genus is made up of Pacific salmon and trout and is one of three North American genera within the subfamily Salmoninae, all of which are cold water species that breed in freshwater[5].

Two subspecies of Cutthroat Trout are endemic to BC, the WCT of inland BC and the Coastal Cutthroat Trout (*O. c. clarkii*) of coastal BC[6]. The WCT's range straddles the Continental Divide and includes drainages in both Canada (BC and Alberta) and the U.S. (Montana, Idaho, Washington, Oregon and Wyoming) (Figure 3-1 inset), giving WCT the most northerly distribution of the Cutthroat Trout subspecies[7]. In BC, endemic WCT populations are concentrated in the southeastern corner of the province, primarily in the East Kootenay region, but there are reports of transplanted and stocked populations as far north as the BC Peace region and as far west as the Pacific coast (Figure 3-1). Publicly available data from Alberta's Fish and Wildlife Management Information System on fish observations show that WCT in the vicinity of the Elk River watershed are distributed approximately 800–2,000 m above sea level, with the UFR's WCT distribution being at the upper end of this range (Figure 3-2a; data accessed through BC ENV [2021] and Government of Alberta [2021]). The same trend is seen when comparing the UFR WCT population to other WCT populations in BC (Figure 3-2b; data accessed through BC ENV [2021])

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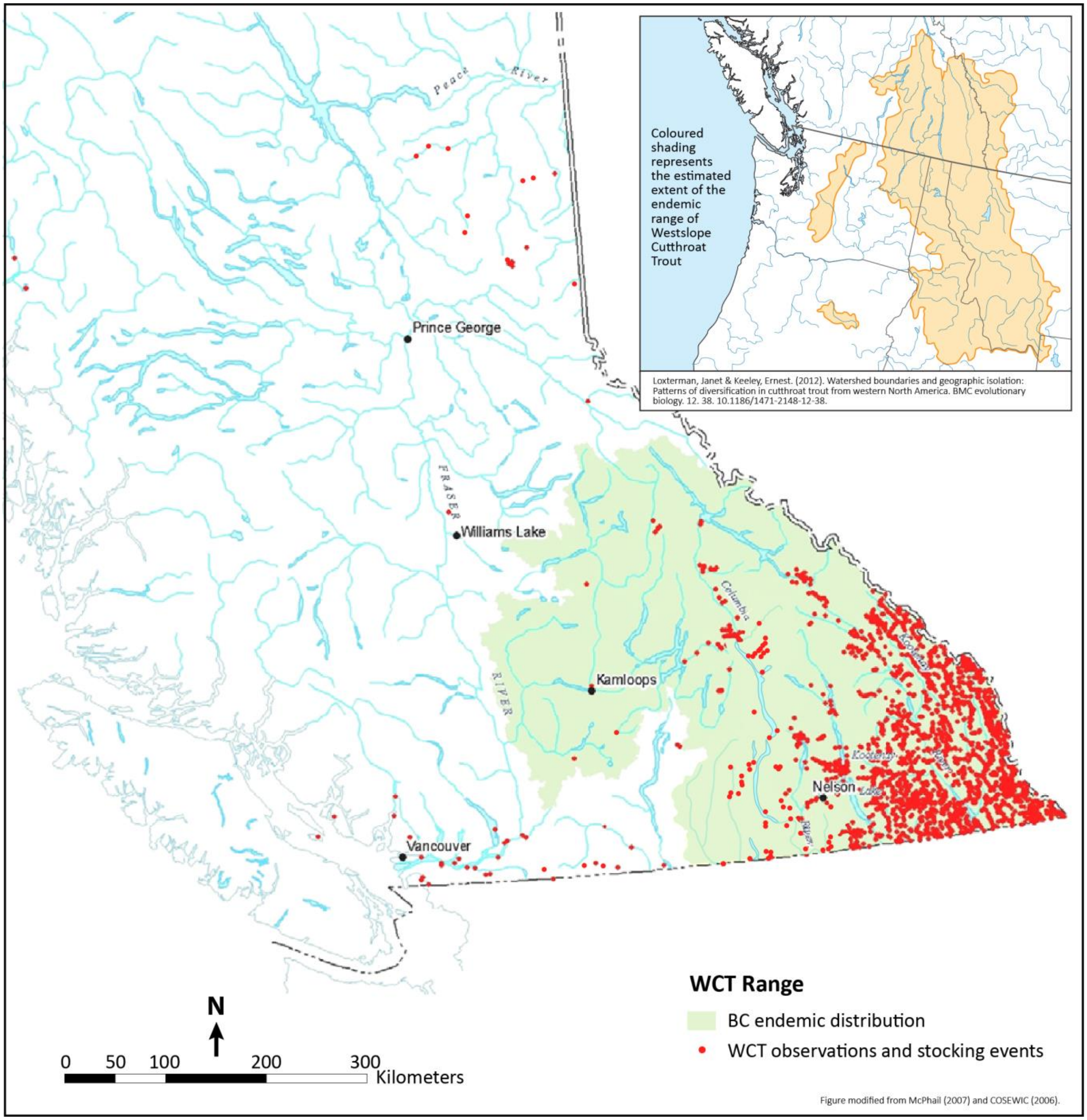
[5] Other North American genera of Salmoninae are *Salmo* (Atlantic salmon) and *Salvelinus* (Char).

[6] Historically, the WCT was thought to be the same as another Cutthroat Trout subspecies, the Yellowstone Cutthroat Trout (*O. c. bouvieri*), due to morphological similarities. However, the discovery of genetic and chromosomal differences led to their being treated as separate subspecies with overlapping distributions in the US (McPhail, 2007).

[7] As opposed to Coastal Cutthroat Trout subspecies, which are found on the Pacific coast and have a distribution that extends as far north as Alaska.



Coloured shading represents the estimated extent of the endemic range of Westslope Cutthroat Trout

Loxterman, Janet & Keeley, Ernest. (2012). Watershed boundaries and geographic isolation: Patterns of diversification in cutthroat trout from western North America. BMC evolutionary biology. 12. 38. 10.1186/1471-2148-12-38.

Figure modified from McPhail (2007) and COSEWIC (2006).

Figure 3-1. Westslope Cutthroat Trout distribution in BC.

Endemic populations are red dots over green shading; translocated populations are red dots outside green shading. Figure inset shows endemic distribution throughout North America.

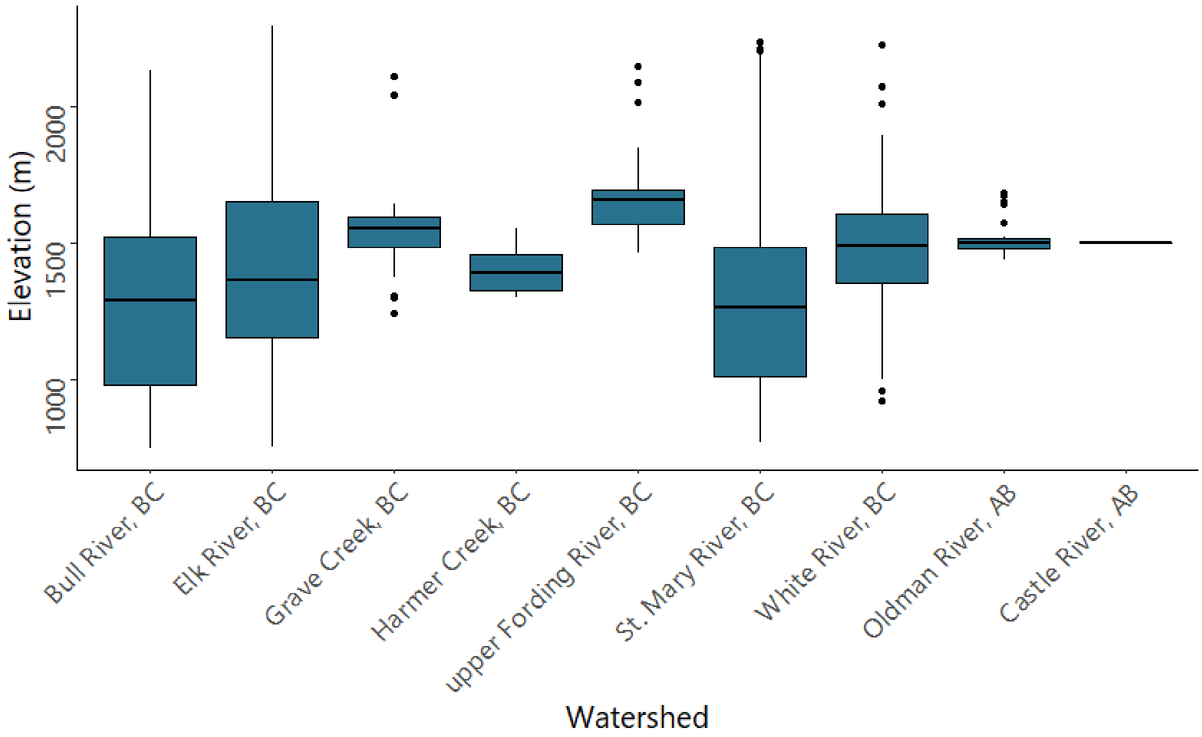


Figure 3-2a.

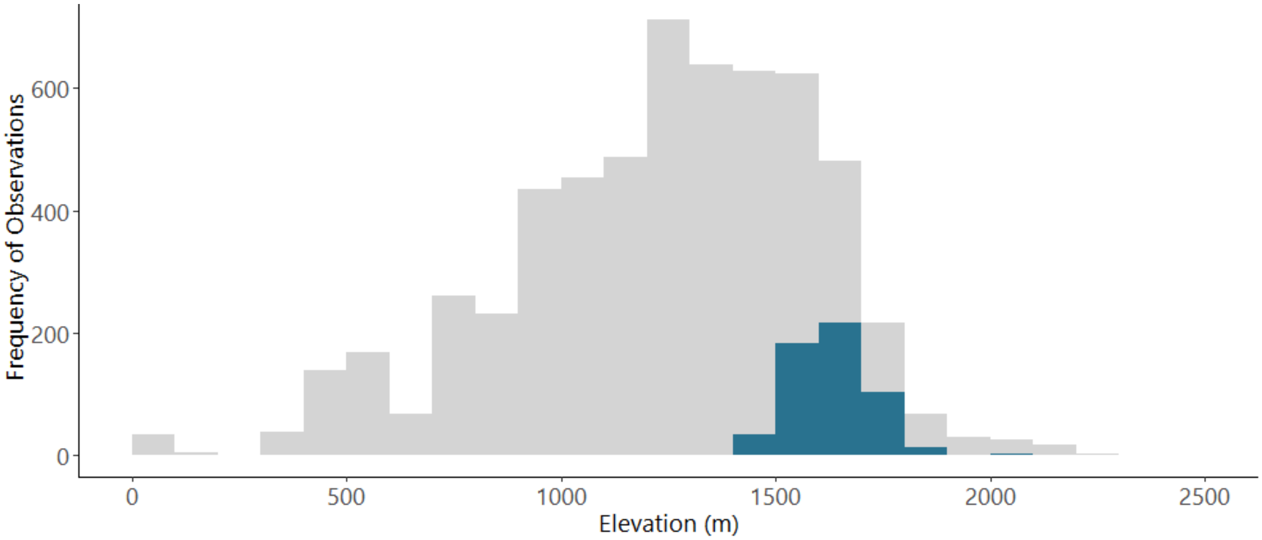


Figure 3-2b.

Figure 3-2. Elevations where Westslope Cutthroat Trout were observed.

(a) Box plot showing elevations where WCT were observed in the Elk River watershed: upper Fording River and neighbouring Bull River, Elk River (excluding Fording River), St. Mary River, White River, Harmer Creek and Grave Creek (data from BC ENV, 2021), Oldman River and Castle River (data from Government of Alberta, 2021). (b) Histogram of WCT observations by elevation for the UFR (in teal) and for BC (in grey) (data from BC ENV, 2021).

Hybridization (Cross-breeding)

Rainbow Trout (O. mykiss) and Cutthroat Trout (O. clarkii) are often found in the same waterbodies. The two species diverged taxonomically about 2 million years ago but did not develop behaviours to prevent or reduce hybridization with each other. Rainbow Trout are a species that is commonly stocked; therefore, where Rainbow Trout have been introduced into waters containing only WCT, introgression, the transfer of genetic information from one species to another, has occurred. As a result, Rainbow Trout genes have infiltrated WCT populations to the extent that only 20–30% of WCT populations are now considered genetically pure (Shepard et al., 2005; Rubidge et al., 2001).

Watersheds in BC’s East Kootenay region are home to WCT populations that are either hybridized or genetically pure endemic trout (see text box). The UFR is inhabited by a genetically pure WCT population that is positioned near the latitudinal limit (Figure 3-1) and elevational limit (Figure 3-2) for WCT. This watershed begins at headwaters and runs to Josephine Falls (inset; photo credit, Teck Coal). Below Josephine Falls, the Fording River runs to the Elk River, one of seven major tributaries of the upper Kootenay River watershed. Josephine Falls isolates the only known species of fish in the UFR, the WCT population, from fish in the lower Fording River, and this means the UFR population is protected from hybridization. From a conservation perspective, the genetic purity of the UFR WCT population heightens the need to protect it.

Within the UFR mainstem there is a population of WCT, and in some tributaries there are fragmented sub-populations that live above constructed barriers. During the decline period, Chauncey Creek had a fragmented sub-population (Cope et al., 2016), but a culvert was replaced by a bridge in fall 2020, so WCT are now able to move upstream and downstream. Greenhills Creek has a fragmented population (Beswick, 2007), due to a settling pond and spillway. The sub-population in Kilmarnock Creek[8] is permanently fragmented. In other areas, such as Dry Creek and Henretta Creek (M. Robinson and L. Watson, personal communication, 2020) and UFR mainstem river Segment 8, structures exist that impede fish movement but do not fragment the population; WCT in these areas are referred to as impeded.

3.2. PROTECTIONS FOR WESTSLOPE CUTTHROAT TROUT

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessed the status of two Designatable Units (DUs) of Westslope Cutthroat Trout in Canada, the "Pacific populations Designatable Unit" (i.e., the BC DU) and the "Saskatchewan-Nelson Rivers populations Designatable Unit" (i.e., the Alberta DU). COSEWIC assessed the BC DU as Special Concern in 2016 (COSEWIC, 2016). The federal Species at Risk Act (SARA) lists the BC DU as Special Concern under Schedule 1 of SARA and the Conservation Data Centre (CDC), in 2018, categorized the BC WCT as S2S3 — *imperilled or of special concern, vulnerable to extirpation or extinction* (BC CDC, 2003).

The BC Ministry of Environment and Climate Change Strategy (ENV) developed a Management Plan for WCT in BC (BC ENV, 2014) that was subsequently adopted by Fisheries and Oceans Canada and SARA, under Section 69 (Fisheries and Oceans Canada, 2017). Similarly, the Province of Alberta developed a plan for WCT in that province (The Alberta Westslope Cutthroat Trout Recovery Team, 2013), which was adopted by Fisheries and Oceans Canada and SARA, under Section 41, and was recently updated as the Recovery Strategy and Action Plan (Fisheries and Oceans Canada, 2019).

In BC, the Province regulates recreational freshwater fishing. Anglers in the East Kootenays require a Basic Licence and, in some cases, a Classified Waters Licence (Class II) (Freshwater Fishing Regulations Synopsis, 2019–2021). While the Fording River below Josephine Falls is open to non-retention recreational fishing from June 15 through March 31 for people holding both Basic and Class II Licences, the UFR (the Fording River above Josephine Falls) is closed to all recreational fishing year-round and has been since 2010. There have been anecdotal accounts of WCT poaching in the UFR in recent years, but no reported fishing violations are on record with the BC Conservation Officer Service (Dean, 2021).

3.3. IDENTIFICATION AND MATURITY

Key identifying traits of WCT are shown in Figure 3-3. As the common name suggests, all Cutthroat Trout have a slash of red colour under the mouth. This slash, along with teeth

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[8] Surveys conducted in 2018 and 2019 concluded that there is no viable population of WCT in Kilmarnock Creek (Browne & Harwood, 2020)

behind the tongue (known as basibranchial teeth), distinguishes them from other trout species, such as Rainbow and Brook trout. The primary distinguishing characteristic between the two Cutthroat Trout subspecies in BC, the Coastal and Westslope, is that Westslope tend to have more small spots by the tail and none on the pectoral fins.

Figure 3-3. Westslope Cutthroat Trout (spawning male): Distinguishing features.

(Image used with permission; see Acknowledgements.)

Distinguishing between the WCT sexes is difficult outside of the breeding season, because WCT have no sexual dimorphism. During spawning, however, males develop rosy-red bellies and dusky-black shading on the upper and lower jaws, while the females' colour remains subdued.

Males reach sexual maturity as early as their third summer and females typically reach sexual maturity by their fourth or fifth summers (Downs & White, 1997). Some WCT are repeat spawners, but the proportion that spawns more than once varies among populations (McPhail, 2007). In some drainages, repeat spawning occurs predominantly in alternate years (Liknes & Graham, 1998).

3.4. LIFE HISTORY AND HABITAT OF WESTSLOPE CUTTHROAT TROUT

3.4.1. Life History Strategies

Three broad life history forms of WCT have been identified across North America, based on their migration patterns (BC Ministry of Environment, 2014):

- **Fluvial-resident.** Headwater stream populations that live above barriers, complete their life cycle within a restricted distribution and remain relatively small (i.e., < 200 mm) due to the cold, nutrient-poor nature of these small streams.
- **Fluvial-migratory.** Migratory populations that move between small spawning/rearing tributaries and larger, more productive adult-rearing rivers. As adults, they are generally larger than fluvial-residents (> 400 mm).
- **Adfluvial-migratory.** Populations that migrate between spawning/rearing tributaries and adult-rearing lakes. Adults can exceed 500 mm in length if productivity in lakes is high.

Dividing WCT into these categories is convenient, but it is overly simplistic because there can be crossover between the strategies. Cutthroat Trout alter their behaviour, morphology and physiology in response to changes in their environment, and in relatively large, intact watersheds it is typical for multiple WCT life history strategies to co-occur (Cope & Prince, 2012; Oliver, 2009; Morris & Prince, 2004; Prince & Morris, 2003). This diversity of life history strategies is often considered a sign of a healthy fish population, because in dynamic environments like the UFR it can indicate that the population is resilient. The relative percentages of the UFR population that are resident and migratory have been estimated at approximately 50/50 (Cope et al., 2016).[9]

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[9] The home range of an individual Westslope Cutthroat Trout is defined by that fish's life-history strategy; > 8 km home range is a migratory fish and < 8 km home range is a resident fish (Cope et al., 2016).

3.4.2. Habitat and Home Range in the Upper Fording River

The map in Figure 3-4 shows the major geographic features and UFR river segments referred to throughout this report.

Westslope Cutthroat Trout of the UFR reside in the section of the Fording River located above Josephine Falls, with the falls preventing the fish below from moving upstream (Figure 3-4)[10]. Upper Fording River WCT are distributed over 57.5 km of mainstem river habitat, from river kilometre (rkm) 20.5 at Josephine Falls to the headwaters between rkm 73.0 and 78.0. In the UFR, fish home range (the total area required by a WCT to complete its life requirements) is, on average, 11.54 km +/- 1.51 km (95% Confidence Interval, n=111), with an individual fish range of 0.68–31.59 km[11].

Overall, WCT are adapted to cold, unproductive environments, and they are long lived and slow growing (Behnke, 1992; McPhail, 2007). They feed primarily on aquatic insects and zooplankton.

Habitat use by WCT varies by life history form (see previous section), season and time of day. An assessment of habitat use in the UFR and its tributaries found that habitat use by the different life history forms and juveniles

Core habitat areas that Westslope Cutthroat Trout use in the UFR, as described by Cope et al. (2016); see Figure 3-4 for segments

Upper Watershed. *The 6.5 km of stream channel of river between Henretta Lake and the multiplate culvert plunge pool (Segments S8 and S9). This area supports critical spawning, overwintering and juvenile rearing habitat. Groundwater influences have been identified here.*

Mid Watershed. *The 7.0 km stretch of river Segment S6 (with pools and including the side-channel and Chauncey Creek). This segment contains critical spawning, overwintering and rearing areas. Groundwater influences have been identified here.*

Lower Watershed. *The 6.3 km of stream extending from upper Segment S1 through lower Segment S3, including Greenhills Creek and Dry Creek. In this area, log jam, bedrock pools and stream confluences form critical overwintering, spawning and rearing habitat.*

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[10] A small percent of the UFR WCT population may emigrate over Josephine Falls into the Fording River (Cope et al., 2016).

[11] Estimated from telemetry study data collected by Cope et al. (2016) of UFR WCT sub-adult and adult fish.

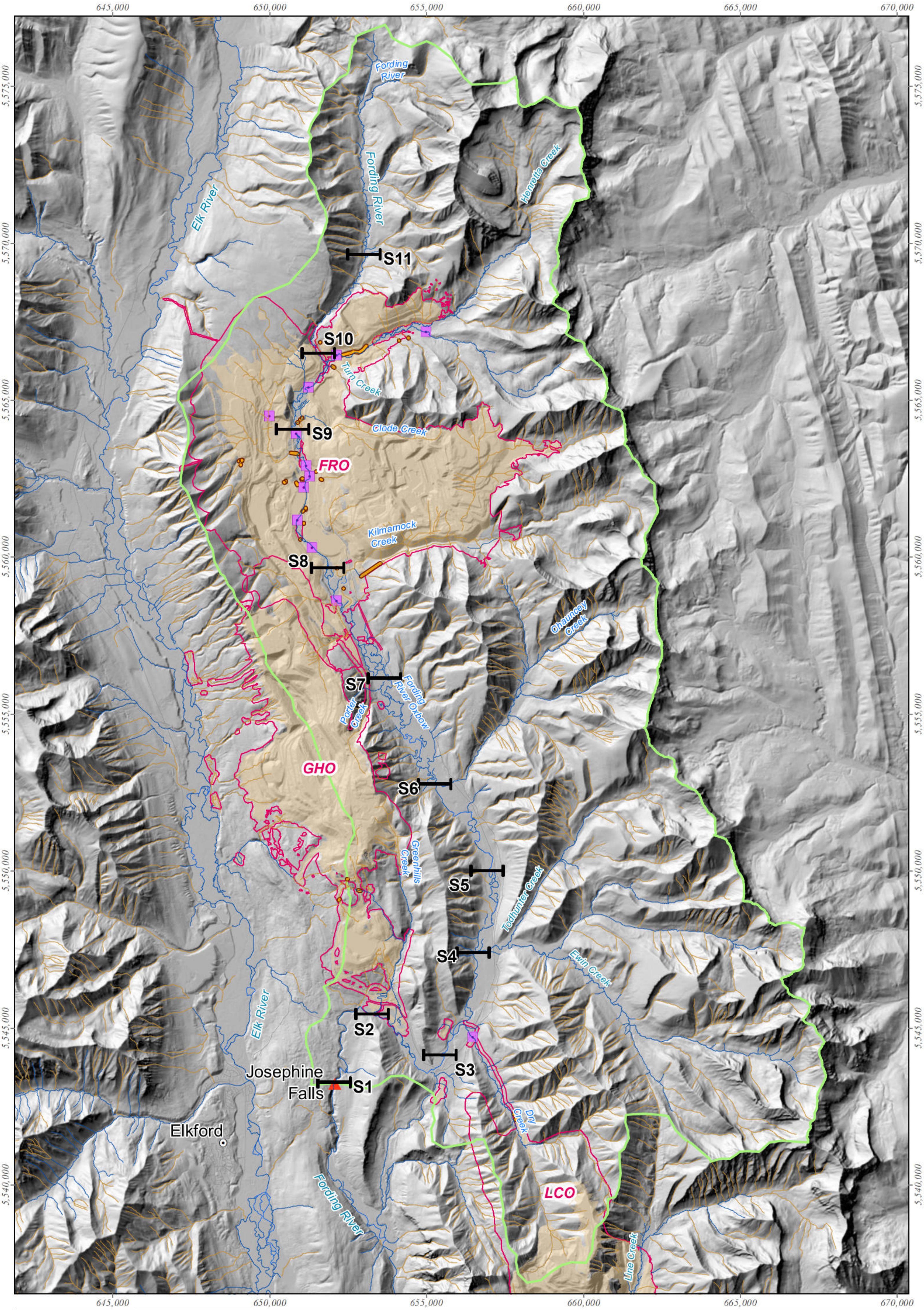
overlapped in the three core areas, upper watershed, mid watershed and lower watershed (see textbox).

For the Evaluation of Cause, the telemetry data collected by Cope et al. (2016) were analyzed. The fish movement patterns evident in the telemetry data were described both temporally (when do fish move with respect to the assumed timing of their life history activities?) and spatially (where do fish that overwinter in a certain area go over the course of a year, and how far do they move?) (Akaoka & Hatfield, 2021). Temporally, use of each area of the UFR was generally consistent across the three years of telemetry data. It is noted that relying on these data carries the implicit assumption that fish use during the decline window followed the same temporal and spatial patterns as in 2012–2016.

The telemetry data suggest that the fish have varied movement patterns and remain broadly spread out in the UFR watershed. Spatially, most (~82%) fish do not inhabit the most downstream segments (Segments S1 to S3), though fish that use those areas tend to stay there or use portions of the river only up to Segment S8 (see Figure 3-4 for segment locations). Fish that overwintered in Segments S5 to S8 tended to also use Segments S8 to S11 and Henretta Creek during the year; and the fish that overwintered in Segments S8 to S11 and Henretta Creek tended to stay there throughout the year.

Figure 3-4 is presented on the following page: Its caption is:

Figure 3-4. Map of the upper Fording River showing major habitat features and river segments.



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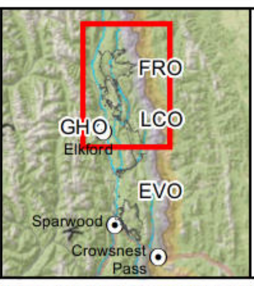

Upper Fording River Overview

- ▪ Bridge
- ▬ Culvert
- ～ Major Streams
- — Non-Fish Bearing
- — Fish Bearing
- ▭ Upper Fording River Watershed
- ▭ Mining Disturbance

N

0 650 1,300 2,600 3,900 Meters

DATE: 3/19/2021	MINE OPERATION: FRO
SCALE: 1:110,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

Resident WCT use the same core areas of the watershed, i.e., upper, mid or lower, while the migratory WCT move between at least two areas. Telemetry data indicate that both resident and migratory forms co-occur during spawning season, which suggests that the resident and migratory life history forms interbreed. This is supported by genetic analysis (Cope et al., 2016).

The major life history events of the WCT life cycle are typical of the Salmonidae family (Figure 3-5). The timing and duration of these events, together with ecological factors that influence habitat (e.g., ice cover), are summarized in a periodicity chart for the WCT UFR population (Figure 3-6) that the Evaluation of Cause Team prepared. For more detail on the fish periodicity chart, see Appendix C.

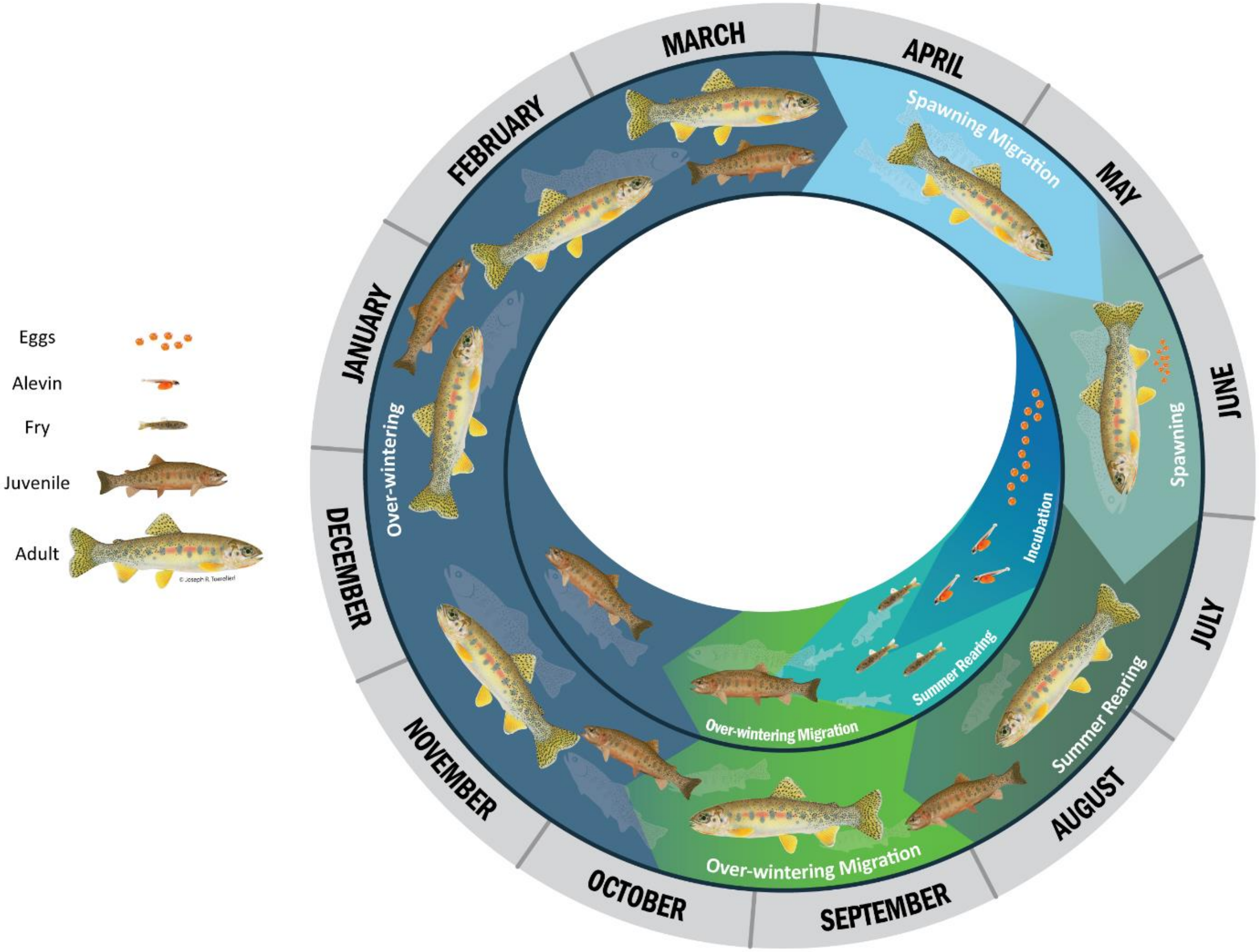

Figure 3-5. An illustration of the life cycle of Westslope Cutthroat Trout.

(Adult WCT image used with permission; see Acknowledgements.)

How the WCT use the UFR habitat for each major life history stage is summarized below.

Spawning habitat

Westslope Cutthroat Trout in the UFR use both mainstem and tributary areas as spawning habitat. Spawning habitat was identified using two sampling methods: telemetry to monitor the reproductive homing of adults and visual observations to count redds. Relative percentages of fish usage[12] are reported in Appendix C.

Telemetry data showed the four mainstem segments with the highest spawning use to be: Segment S9 (10% of the population), Segment S8 (20%), Segment S6 (22%) and Segment S2 (9%).

Visual observations showed the four mainstem segments with the highest percentages of redds to be: Segment S9 (12% of observed redds), Segment S8 (12%), Segment S6 (47%) and Segment S2 (9%).

The remaining fish were shown to be distributed across the other mainstem segments and tributaries (e.g., Henretta Creek, Fish Pond Creek, Clode Creek, Kilmarnock Creek, Dry Creek and Greenhills Creek). For mainstem WCT, i.e., those that were not remnant fragmented sub-populations, spawning habitat in tributaries was restricted to the lower 1 km or less (Cope et al., 2016).

Overwintering habitat

For overwintering, WCT usually use areas without anchor ice, such as deep pools and/or areas with groundwater influx (Cope & Prince, 2012; Brown et al., 2011; Morris & Prince, 2004; Prince & Morris, 2003; Brown & Stanislawski, 1996; Brown & Mackay, 1995; Boag & McCart, 1993).

Areas that were found to support most of the overwintering adult and sub-adult UFR WCT are listed below. The remaining fish were distributed across the other segments. Percentages[12] are reported in Appendix C.

- Henretta Lake (12%, of the population; 1.0 km upstream from the Henretta confluence, in river Segment S9 at 62.9 rkm)
- River Segments S8 (20% of the population) and S9 (3%) in the Clode Flats (58.4 rkm to 61.6 rkm) and the multi-plate culvert plunge pool (Segment S8, 57.5 rkm)

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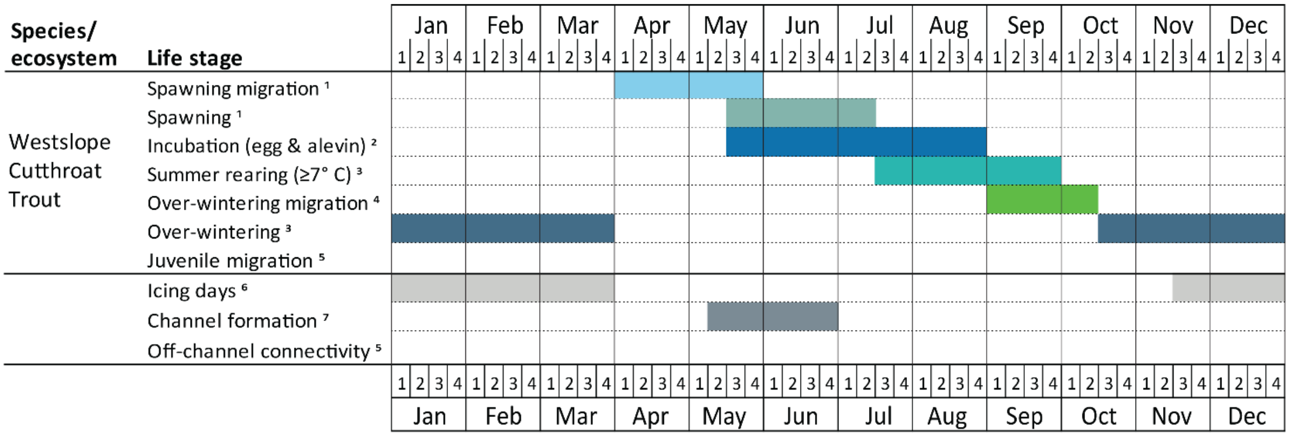
[12] Relative percentages of fish use were calculated for each river segment by counting all scans of radio tagged fish, or observed redds, in each segment and dividing by the total number of scanned fish over a three-year-period between 2012 and 2015. These percentages are assumed to be representative of the population, but they actually represent the total number of fish that were tagged.

- River Segment S6 oxbows (40% of the population) (42 rkm to 48 rkm)
- River segments from upper Segment S1 (24.2 rkm) through lower Segment S3 (30.5 rkm) log jams and bedrock pools (14% of the population)

Although the specific locations where juveniles overwinter is not known, juveniles are assumed to prefer pool habitats with cover (Bonneau & Scarnecchia, 1998).

Summer rearing habitat

The distribution of summer rearing habitat in the UFR is much more diverse than spawning or overwintering habitat (Cope et al., 2016). Pools are the dominant feature that sub-adult and adult WCT select for rearing. These are distributed throughout the mainstem UFR between upper Segment S1 and Segment S10. Lower densities of summer rearing fish were found in Segment S11 and the tributary Henretta Creek, and summer rearing was also seen in Henretta Lake. For a detailed breakdown of summer rearing habitat that fish use, see Appendix C.



Notes

[1] based primarily on information in Cope et al., 2016

[2] assumed to start coincident with spawning

[3] defined in Cope et al., 2016

[4] Nov 1 - Feb 28 is the core season defined in Cope et al., 2016; shoulder seasons have been added where there is likely to be ice cover in some areas

[5] no defined periodicity

[6] based on typical ice cover in most years

[7] typical maximum freshet occurs in this period

Figure 3-6. Fish periodicity chart for Westslope Cutthroat Trout in the upper Fording River.

3.5. HISTORY OF FISH MONITORING AND HANDLING IN THE UPPER FORDING RIVER

Westslope Cutthroat Trout monitoring and handling events in the UFR began in the 1970s and continued intermittently throughout the 1980s, 1990s, 2000s and 2010s. During this time, industry, government and academia carried out WCT studies relating to mining activities and other development, provincial fish inventory and sportfish management. A timeline of recent milestones related to WCT monitoring in the UFR is shown in Figure 3-7.

Studies of fish may involve some form of fish handling. In the UFR, fish handling has included (but has not been limited to) fish salvage, population and density assessments, biological assessments and spawning surveys. Fish handling is the topic of Subject Matter Expert reports in support of the Evaluation of Cause (Cope, 2020b; Korman & Branton, 2021).

Fish handling has been used in all field methods for assessing UFR WCT in recent years, except for habitat mapping, which used high resolution (10 cm) aerial photography reviews and ground-truthing. The methods that involved fish handling included telemetry, snorkel surveys, Floy and Passive Integrated Transponder (PIT) tag mark-recapture and juvenile density surveys at representative removal-depletion locations.

The UFR WCT Population Assessment and Telemetry Study (Cope et al., 2016) provided the most complete understanding of the population’s status, the current habitat availability and its use. This study collected 3 years of data for sub-adults and adults (2012, 2013, 2014) and 3 years of data for juveniles (2013, 2014, 2015). Researchers used snorkel mark-recapture methods and calibrated observer efficiencies by implanting a subset of the marked sub-adults and adults with radio transmitters. For juveniles, they used removal-depletion electrofishing of representative habitats, a method where fish in a specific section are captured and removed, and then the area is sampled again until an estimate can be made.

As part of this work, WCT life history was investigated, habitat was mapped and the population was monitored between August 2012 and October 2015. A recommendation from this study was to continue monitoring the WCT population every 2 years, starting in 2017 (Cope et al., 2016).

When population monitoring results from 2017 (reported in Cope et al., 2017) were compared with those from 2019 (reported in Cope, 2020a), the comparison led to the conclusion that the UFR WCT population had declined. This finding of population decline is described in detail in Chapter 4.

To investigate the population decline, the next scheduled monitoring event was moved up from 2021 to 2020. The 2020 fish population results became available as the Evaluation of Cause was in the final stages of drafting. The findings were reviewed at a high level and do not change the conclusions of the Evaluation of Cause.

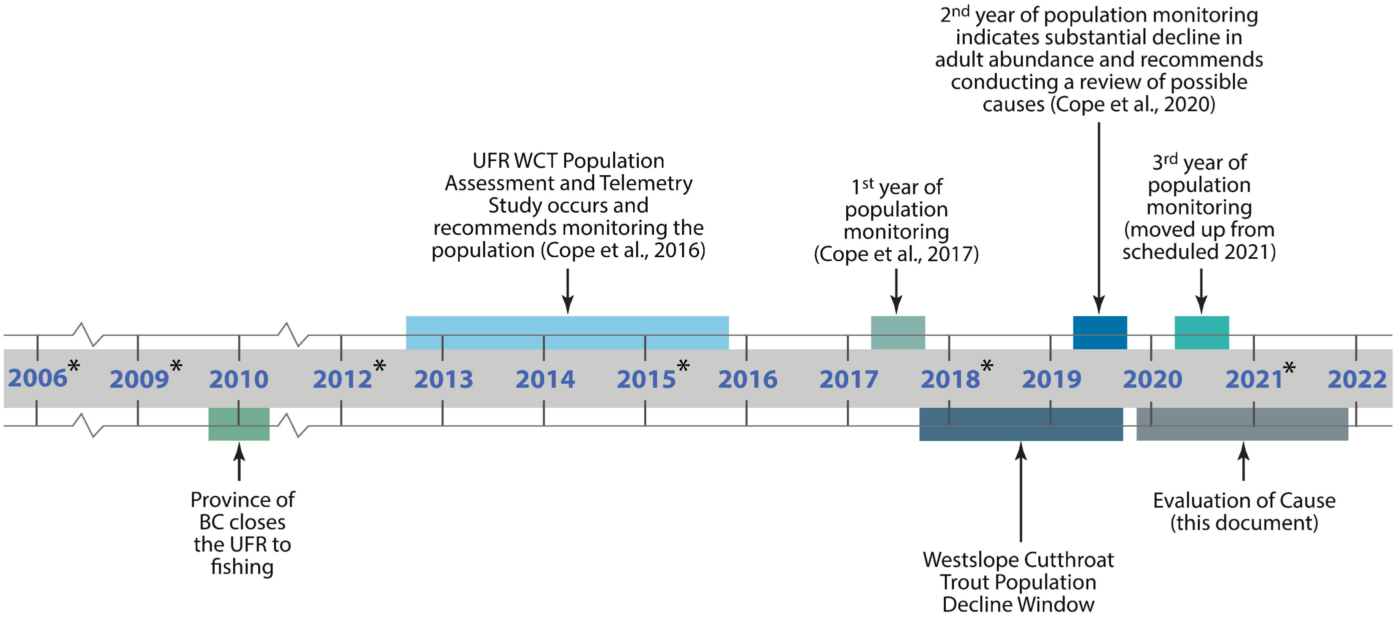


Figure 3-7. A timeline of select monitoring events for Westslope Cutthroat Trout in the upper Fording River.

In addition to fish population monitoring, fish tissue selenium was measured. An asterisk (*) indicates tissue sampling events.

4. Understanding the Decline in Westslope Cutthroat Trout

4.1. MONITORING FISH ABUNDANCE

In this chapter, we review the WCT fish population data for the UFR and determine its utility in quantifying temporal and spatial changes in the population, particularly the population decline that occurred between the 2017 and 2019 surveys when both juvenile and adult stages of WCT declined substantively (Cope, 2020a)[13]. We begin by reviewing the data and highlighting the strengths and weaknesses of each data source for quantifying the size of the decline, when it occurred and where. We then estimate the magnitude of decline, from the most reliable data sources, and the areas where the decline was potentially most severe. Finally, we estimate the time period when the decline occurred.

4.2. DATA SOURCES, TRENDS AND RELIABILITY

Two main data sources were reviewed for this analysis. These were:

- Snorkel surveys, which quantify system-wide abundance of adults (fish > 200 mm and ~ > age 4 years) in the UFR, and
- Electrofishing surveys, which quantify juvenile abundance at a limited number of small sites.

Other information we used included:

- Passive Integrated Transponder (PIT) tag detections at fixed antenna locations, and
- Anecdotal observations of fish presence, fish mortality and redds.

4.2.1. Snorkel Surveys — Adults

Data from snorkel surveys were used to estimate population size of WCT 200–500 mm long in 2012, 2013, 2014, 2017 and 2019 (Cope et al., 2016, Cope, 2020a). Surveys were conducted in early to mid-September, when four biologists floated approximately 48 km of the UFR and Henretta Creek, covering 80% of available habitat upstream of Josephine Falls.

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[13] The 2020 juvenile and adult monitoring data became available to the Evaluation of Cause Team as we were preparing this report. Our review of the 2020 data confirmed the decline that was reported in Cope, 2020a. It is our understanding that Teck Coal has qualified professionals interpreting the 2020 data and we do not address it in this report.

They counted WCT by 100-mm size class in 12 mainstem river segments or tributary locations.

Estimating abundance

From 2012 to 2014, WCT were Floy- or radio-tagged. Later each year, the snorkel team conducted the annual surveys and recorded the number of tagged fish they observed as they floated the UFR. The ratio of tags observed to tags present in the survey area each year provided estimates of the proportion of fish the snorkel team observed. This proportion is referred to as detection probability or observer efficiency.

Detection probabilities in the UFR were 42% in 2012, 25% in 2013 and 32% in 2014. Not surprisingly, detection probability was higher in years when the water was clear and flow was lower. Conditions for observing fish were excellent in 2012 (> 6 m visibility), moderate in 2013 (3–6 m) and poor in 2014 (< 3 m). To estimate WCT abundance in the UFR, the total number of fish longer than 200 mm or 300 mm was divided by the detection probability in each year.

Snorkel surveys were conducted in 2017 and 2019, but no tagging was done in these years. This adds additional, but unaccounted for, uncertainty in abundance estimates for these years. The measured visibility in 2017 and 2019 was used to select the most applicable detection probability from the 2012–2014 estimates to expand counts into abundance estimates in 2017 (45%) and 2019 (25%).

Uncertainty in abundance estimates from snorkel surveys

The annual estimates of abundance from snorkel surveys have three sources of uncertainty:

1. **Sampling error in counts of unmarked fish.** Given imperfect detection (detection probability < 100%), sampling error will result in variation in the number of fish counted across swims, even though the same number of fish are present. For example, if detection probability was 50% and 100 fish were present, one would not expect the snorkel team to observe exactly 50 fish on repeat swims. Sampling error therefore affects abundance estimates derived from expanded counts. The lower the detection probability and the lower the number of fish counted, the greater the sampling error. This would be reflected by wider confidence intervals around the annual abundance estimates.
2. **Error in detection probability in years of tagging.** Sampling error also influences uncertainty in detection probability, and when counts are expanded this affects uncertainty in abundance estimates (abundance = count/detection probability). For

example, if detection probability is 25% and 100 tags are known to be present, the number of detected tags will not always be exactly 25.

3. **Extrapolation error associated with detection probability in years without tagging.** One of three available detection probability estimates from 2012–2014 was applied to count data in 2017 and 2019, and the true detection probability in these latter years is uncertain.

Cope et al. (2016) and Cope (2020a) used standard mark-recapture methods to calculate abundance from count data and detection probability estimates. The approach accounts for uncertainty resulting from error sources (1) and (2) but not (3). Extrapolation error was approximated by expanding the 2017 and 2019 count data by detection probabilities from each year that they were available (2012, 2013 and 2014). The maximum range among the resulting abundance estimates was used to approximate the uncertainty bounds for 2017 and 2019. The limitation of this approach is that the extrapolation error may be greater than the range of the three detection probabilities estimated, and the range does not account for error sources (1) and (2). Therefore, the uncertainty range in abundance estimates for 2017 and 2019 should be considered minimum values. When expanding counts to abundance using detection probability, Cope (2020a) used a closed Peterson mark-recapture estimator, which underestimates uncertainty if detection probability and densities over the length of the survey area are variable.

WCT detection probability in the UFR likely varies by river segment due to differences in counting conditions. For example, some segments may be more turbid when areas of fine sediments are disturbed by snorkellers during surveys. Other segments may be more complex, for instance where log jams are prevalent. Both cases create conditions that would make it more difficult to detect fish. To estimate detection probability for each river segment and expand the counts to determine abundance in each segment, Cope et al. (2016) used a stratified estimator. The abundance estimates for each segment were then summed to estimate abundance for the UFR. The utility of this approach was limited because sample sizes of counts and tag detections in telemetry years (2012–2014) in each segment were low and, consequently, adjacent segments needed to be arbitrarily pooled, which can lead to bias. To address pooling and minimize bias, Cope et al. (2016) used a statistical model (i.e., a hierarchical Bayesian approach).

Uncertainty is also associated with determining how many Floy-tagged fish were present in each segment, so movement models were required to predict how many of these tags were present in each segment during the surveys, thereby adding additional error to estimates of abundance. The stratified estimator, the hierarchical stratified estimator and a movement-based estimator were compared to the pooled estimator in Cope et al. (2016, their Figure 3.2.9). All estimators provided roughly similar abundance levels, partly because they all had relatively wide confidence intervals. The population estimates provided in Cope (2020a) and used here are based on the pooled estimator.

Snorkel-survey-based abundance estimates for fish greater than 200 mm (sub-adults and adults) showed increasing values between 2012 (2,546) and 2014 (3,664), despite considerable overlap in the confidence intervals over the three years (Figure 4-1). Estimates in 2017 ranged from 3,690 — based on applying the highest detection probability (2012) to the count data — to 6,240 — based on applying the lowest detection probability (2013). Estimates for 2019 ranged from 246 to 416 based on 2012 and 2013 detection probabilities, respectively. The minimum estimate of the change in population size between 2017 and 2019 was calculated based on the 2012–2017 average abundance of 3,304, using the lowest estimate for 2017, which was 3,690, and the highest estimate for 2019, which was 416. These statistics indicate that adult abundance declined eight-fold between 2017 and 2019. The population is estimated to have declined 16-fold based on the 2012–2017 average, using the highest value for 2017, of 6,240, and the lowest value for 2019, of 246.

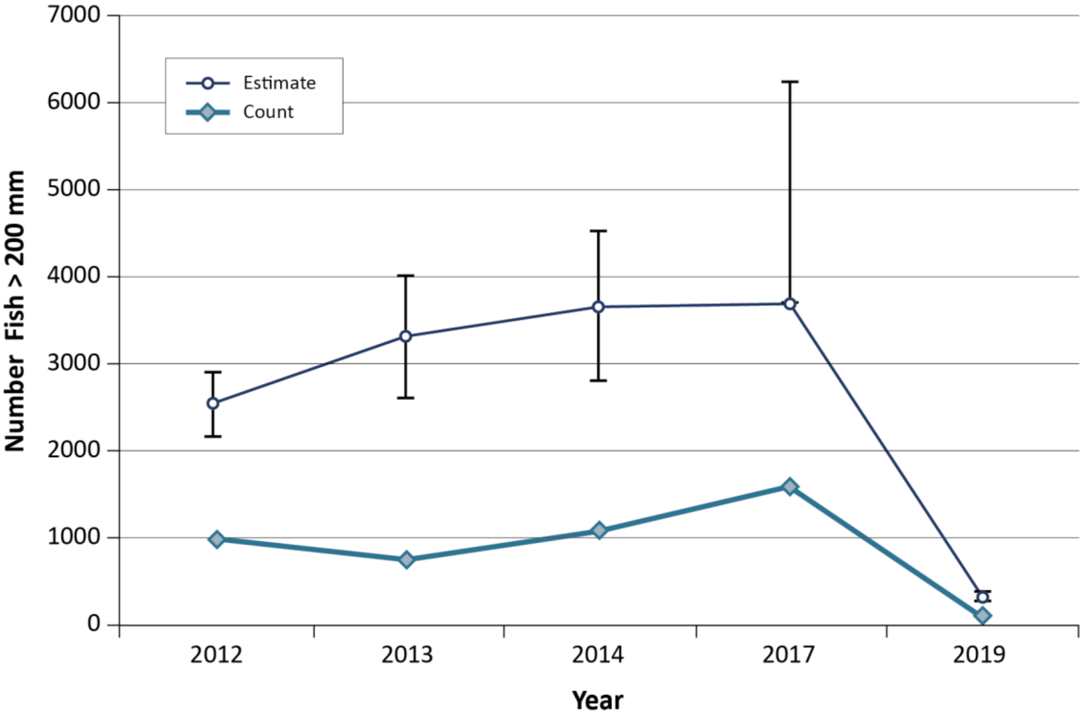

Figure 4-1. Counts and estimated abundance for Westslope Cutthroat Trout > 200 mm in the upper Fording River.

Counts based on snorkel surveys from Cope, 2020a (adapted from Figure 3.1 in Cope, 2020a). Error bars for 2012–2014 abundance estimates represent 95% confidence intervals, while the error bars for 2017 and 2019 represent the range of estimates calculated by dividing the 2017 and 2019 counts by the lowest and highest detection probabilities between 2012 and 2014.

Regardless which averaging method is used, the population in 2019 was substantially lower than past years. Although some uncertainty about the extent of error in annual abundance estimates exists, the estimated declines are almost certainly considerably greater than the error in abundance estimates (see Figure 3.2.9 in Cope et al., 2016). Therefore, the much lower abundance in 2019 relative to past years is considered a real and substantive change and not an artifact resulting from uncertainty in adult abundance estimates.

Natural variation in recruitment and survival rates can cause the number of animals in a population to fluctuate substantially from year to year. This means that to determine whether abundance in a particular year (in this case 2019) is unusually low, we need to estimate the true, natural variation in population abundance. True variation in abundance is often called process error, because fluctuations in processes like recruitment to the population (fry emergence) and survival rates of older life stages cause the variation.

Estimating the true variation in abundance of the UFR WCT population across years before 2019 is problematic because only four abundance estimates are available at the time of report preparation. This sample size is too low to reliably quantify natural variation in the UFR population’s annual abundance. Based on the UFR data alone, therefore, it would not be possible to rule out natural variation as the cause of low abundance in 2019. However, Cope (2020a) addressed this uncertainty by comparing the density of WCT in the UFR (abundance estimates divided by length of stream surveyed) with densities from other WCT populations in the East Kootenay River over similar periods (Figure 4-2). This comparison showed that the density in the UFR in 2019 was extremely low relative to other populations assessed in 2019 and in previous years. In the upper St. Mary River and Skookumchuck Creek in 2019, WCT densities were similar to densities in previous years, while density in the UFR in 2019 was much lower (see Table 3.4 in Cope, 2020a). Cope’s analysis found that the reduced abundance in the UFR WCT population in 2019 was unlikely to have been caused by natural variation and that the population’s abundance was, therefore, anomalously low.

When explaining the decline based on these findings, it may be tempting to conclude that regional stressors (influences such as air temperature or precipitation trends that occur over a broader geographic range than the UFR) are unlikely to have played a major role in the decline, because only the UFR population was anomalously low in 2019. It is reasonable to conclude that a regional stressor, acting alone, would have caused a similar biological response in all similar rivers exposed to that stressor, and, therefore, it would have been unlikely to have caused or substantially contributed to the UFR decline. However, for the Evaluation of Cause, regional stressors are thought to have interacted with other stressors, some of which are specific to the UFR (Chapter 8). Furthermore, regional conditions like climate would not necessarily be expected to have the same implications, such as the extent to which ice forms on different rivers. For example, the three comparator populations with 2019 data plotted in Figure 3.2 in Cope (2020a) were in systems that were either at different elevations or which had more overwintering options. Of these, the upper St. Mary River's elevation is much lower than the UFR and its population has access to a lake. The Skookumchuck River system is also lower, and its population has unrestricted access to the Kootenay River. The upper Bull River is most similar to the upper Fording River in terms of elevation and isolation above a barrier, but, in a similar monitoring program, Cope and Prince (2013) reported that the WCT population in this system was not limited by overwintering habitat.

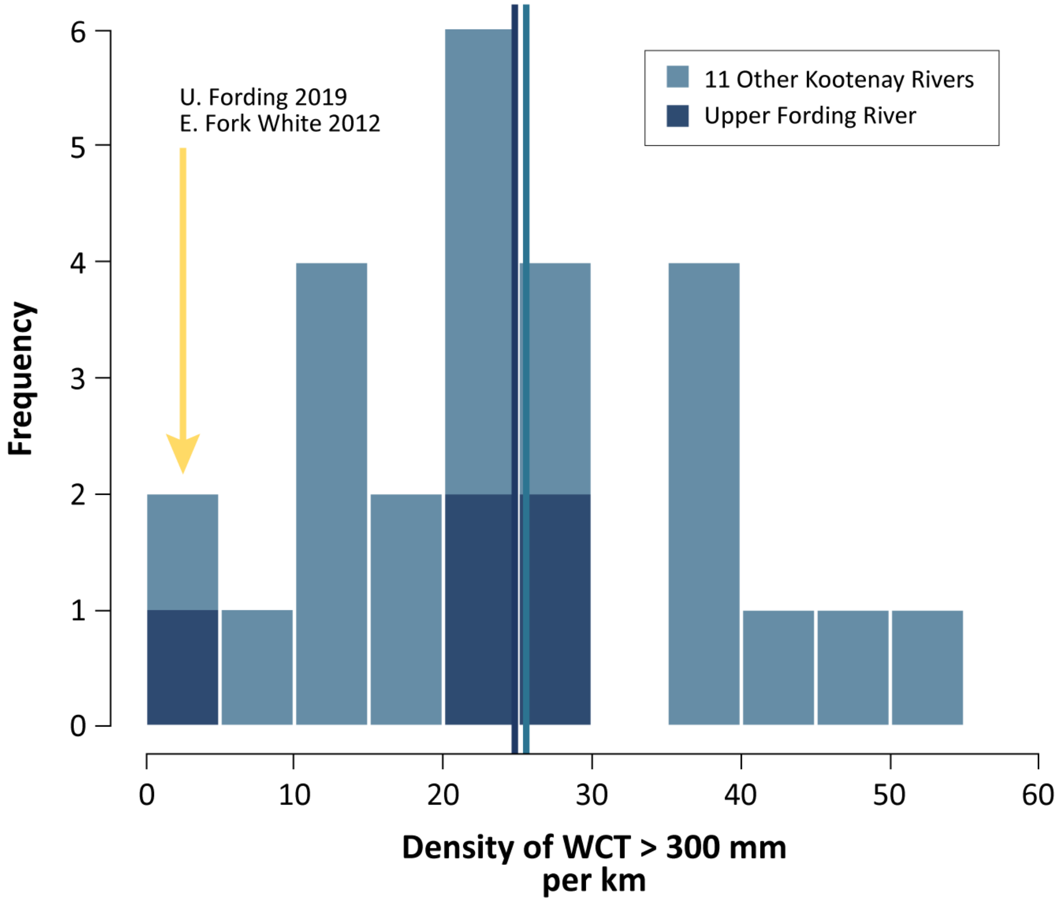

Figure 4-2. Histogram of densities of Westslope Cutthroat Trout > 300 mm from the upper Fording River population and other populations in the East Kootenays.

The y-axis is the number of observations in each density class shown on x-axis. UFR fish are dark blue rectangles; other populations in the East Kootenays are light blue (calculated from data in Table 3.4 of Cope, 2020a). Vertical blue lines show the mean densities using all years except 2019. Dark blue = UFR; light blue = other East Kootenay rivers.

Spatial distribution

Changes in WCT counts among segments of the UFR potentially indicate where the population may have been impacted most. Differences in the spatial distribution of fish counts across years can result from a combination of movement, mortality and variation in section-specific detection probability from one year to another. Radio telemetry studies have shown that some individuals in the UFR move considerable distances across seasons to access spawning and overwintering areas.

Cope et al. (2016) classified radio-tagged fish as either migratory or resident based on the distance they travelled. The authors further divided these life history types into upper-, mid- and lower watershed groups. Most fish spend most of their life in one of these three broad locations, which means that differences in counts among segments should, in part, reflect differences in mortality. We therefore computed the proportion of snorkel counts by river segment, using counts from 2012 to 2017, and compared them to the proportions in 2019 (Figure 4-3). Out of the 104 fish greater than or equal to 200 mm counted in 2019, only four fish were observed in Segment 8, representing 3.8% of the total; no fish were observed in Segments S5, S6, S7 and S9. In contrast, an average of 603 fish were observed in Segments S5 to S9 from 2012 to 2017, representing 55% of the total counts. Comparing these, the proportion of fish in Segments S5 to S9 in 2019 was 10-fold lower than it was in earlier years. This pattern holds if the pre-2019 period is limited to 2015–2017 surveys, which excludes effects of the large flood in 2013.

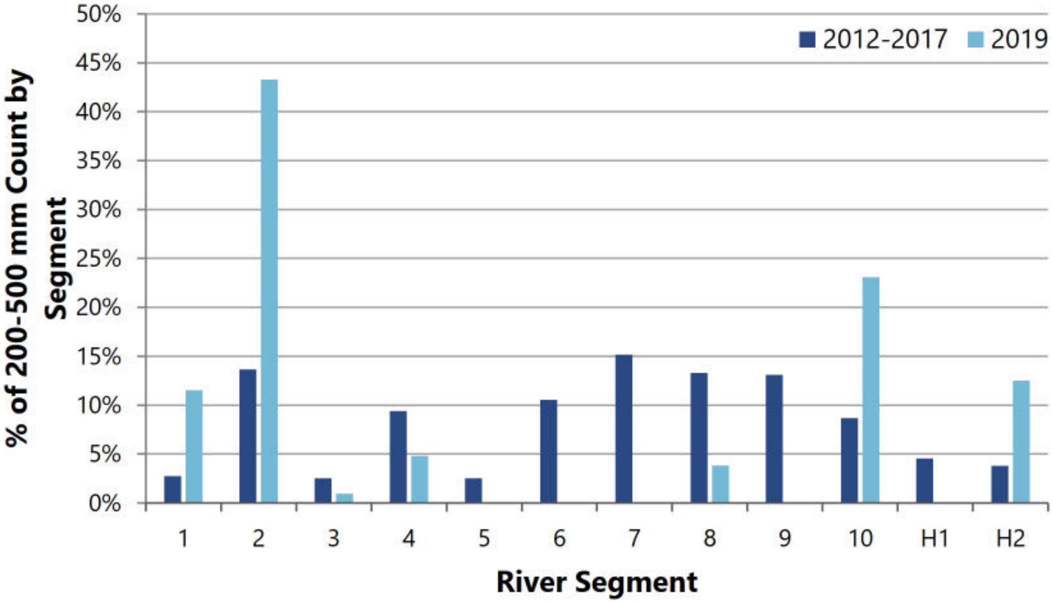

Figure 4-3a.

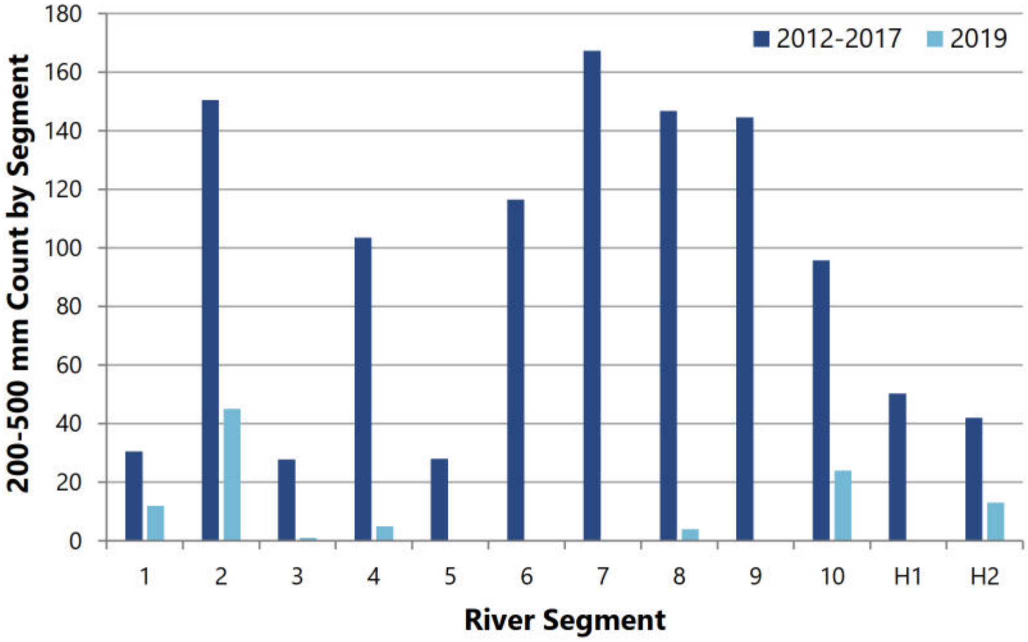

Figure 4-3b.

Figure 4-3. The percentage and number of Westslope Cutthroat Trout sampled during snorkel surveys.

(a) the percentage and (b) the number of WCT ≥ 200 mm that were counted in each river segment sampled during snorkel surveys in the UFR in 2019. Percentages and numbers are based on the mean of counts from 2012–2017.

4.2.2. Electrofishing Surveys — Juveniles

Electrofishing surveys in 2013, 2014, 2015, 2017 and 2019 provided density estimates of juveniles at a limited number of small sites (100–150 m^2), sampled between late August and early October.

Sampling

Surveys consisted of visiting 15 to 19 locations each year and sampling three meso-habitat types (riffle, cascade, glide, run, pool or side-channel), each type being about 100 m^2. The number and location of sites sampled each year varied, but 10 locations were consistently sampled in all study years.

Sampling consisted of enclosing each site with a block net and conducting three electrofishing passes. The number and size of fish captured on each pass were recorded, and fish were held in buckets until all sampling at the site was complete. Scales taken from a sub-sample of fish were used to determine their age and develop size ranges for each age class (Cope et al., 2016, Figure 3.2.4). Each fish from the electrofishing sample was then assigned an age, based on its size. The sample sizes for age 0+ and older juvenile ages (age 1+ to 3+) were low, so these fish were grouped into fry and juvenile classes, respectively. The depletion in catch for fry and juveniles across three successive passes was used to estimate both the capture probability and the total number of fish, i.e., abundance, in each class present in the site. Abundance was divided by site area to calculate density per site. Average density across sites was used to index the abundance of fry and juveniles for each year.

Reliability of estimating the abundance or average density of the juvenile population

The sampling approach to estimate juvenile densities follows protocols recommended by the BC Ministry of Environment, as outlined by Ptolemy et al. (2006) and referenced by Cope (2020a). However, issues with that approach limit the usefulness of the data for making inferences about changes in the abundance of the juvenile population. These issues include: (1) non-random selection of sampling locations that requires a biologist to select "representative" or optimal habitat based on their professional judgment; (2) non-random selection of sampling units at these locations, which requires biologists to consistently define meso-habitat types and not bias the location of sampled areas within these types; (3) sampling a very small proportion of the total habitat juveniles use; and (4) using a depletion-based rather than mark-recapture–based estimator to calculate abundance at each site. These sampling issues mean the derived density estimates are not a reliable index of WCT juvenile abundance in the UFR for the following reasons:

- The non-random location and sample site selection approach violates a fundamental principal of statistical sampling. It depends, instead, on a biologist's judgment. Judgment varies not only across biologists but also within biologists over time, and error in judgment is not quantified. Owing to this limitation, density estimates may substantively over- or underestimate the average density for the system.
- Biologists trained using the provincial methodology are encouraged to select high-quality habitat and locations where the gear is effective. It is therefore likely that these sites have higher densities than an average site would, but the extent of this bias and its consistency over years is unknown. More importantly, high-quality sites tend to show less variation in juvenile abundance over time compared to average sites, because the fish select them preferentially (Gibson et al., 2008). As a result, changes in high-quality sites selected in the UFR likely underestimate the extent of population decline between 2017 and 2019.
- Only one location can be sampled per day by a field crew, because of the laborious methods involved in the sampling approach (block netting and collecting a lot of habitat data that is rarely used). As a result, annual surveys typically consist of less than 15 locations and represent a tiny fraction of the total habitat (much lower than 1% in case of UFR). Even if the sites were sampled randomly to avoid judgment biases, the sample size and area sampled are much too small to provide a reliable index of system-wide abundance, because the site-to-site variation in fish densities is considerable (Korman et al., 2016).
- Depletion-based abundance estimators assume that capture probability is constant across passes. However, numerous studies have clearly demonstrated that capture probability declines with successive passes, because the most vulnerable fish are removed in early passes, which increases the proportion of less vulnerable fish on later passes (Korman et al., 2009; Peterson et al., 2004, Rosenberger & Dunham, 2005). Violating the constant capture probability assumption overestimates capture probability and underestimates abundance.

Electrofishing survey results

Across the 10 locations consistently sampled in years when sampling was conducted, the average density of juvenile WCT shows an increasing trend from 2012 to 2017 and a substantive drop in 2019 (Figure 4-4; both panels). The error bars reported in the Figure 4-4a (recreated Figure 3 of Cope, 2020a) are too narrow, given the reported variation in densities across locations shown in Table 3.5 of Cope (2020a). For example, in 2013, densities ranged from 0–11.4 fish/100 m^2, yet the 95% confidence interval in Figure 3.3 of Cope (2020a) is +/- 0.2 fish/100 m^2. We therefore recomputed the 95% confidence intervals by calculating the standard error (SE) of the annual means from the reported site-specific density estimates and adding or subtracting 1.96*SE (Figure 4-4b). Figure 4-4b shows considerable overlap in confidence intervals in some years. However, the means for 2015 and 2017 are substantively higher than the means for 2013 and 2019. Therefore, the juvenile data still indicate a substantive decline in mean density in 2019 compared to 2015 and 2017.

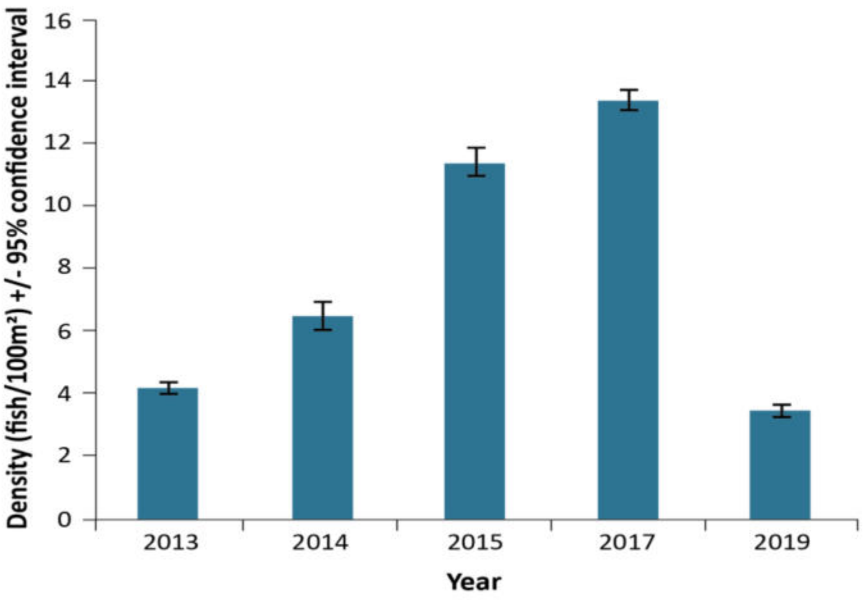

Figure 4-4a.

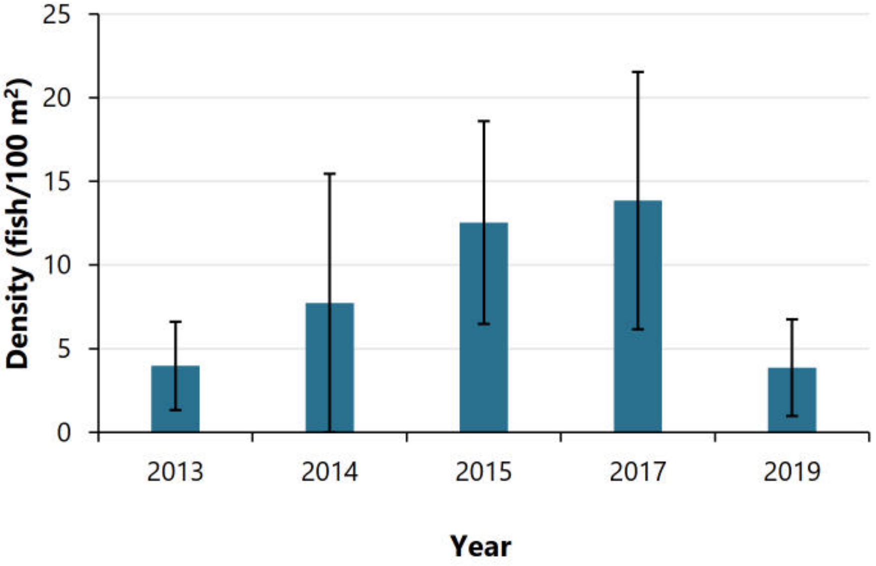

Figure 4-4b.

Figure 4-4. Average density of juvenile Westslope Cutthroat Trout in the upper Fording River in Cope (2020a) compared to the analysis in this report (see text).

*Density is based on 10 locations that were consistently sampled between 2012 and 2019. Figure 4-4a is recreated from Figure 3.3 from Cope (2020a), with error bars reported to represent the 95% confidence intervals in the average density. Figure 4-4b, prepared by the Evaluation of Cause Team is based on the same densities, with confidence intervals computed as +/- 1.96 * the standard error of the mean of density estimates presented in Table 3.5 of Cope (2020a). The difference in these two figures is discussed in text under the previous heading – Electrofishing Survey Results.*

Using electrofishing results to refine the estimated extent of decline window

While the sampling design problems summarized above considerably limit the possible inferences that can be made about population change from electrofishing data, the data are useful for narrowing the period when high mortality occurred in the WCT population. The proportion of different juvenile ages in the electrofishing catch can provide a rough index of changes in abundance of spawners under certain assumptions, such as:

- Fish spawning from May to July of 2017 would have produced age 0+ juveniles in the September 2017 sample, age 1+ juveniles in the September 2018 sample and age 2+ juveniles in the 2019 sample (Table 4-1a and Figure 4-5).
- Fish spawning from May to July of 2018 would have produced age 0+ juveniles in the September 2018 sample and age 1+ juveniles in the 2019 sample.

Therefore, the ratio of the catch of age 1+ fish to the sum of age 1+ and 2+ catch (i.e., the proportion of age 1+ fish) in 2019 partly reflects differences in the number of spawners in 2017 and 2018.

Credit: Minnow Environmental

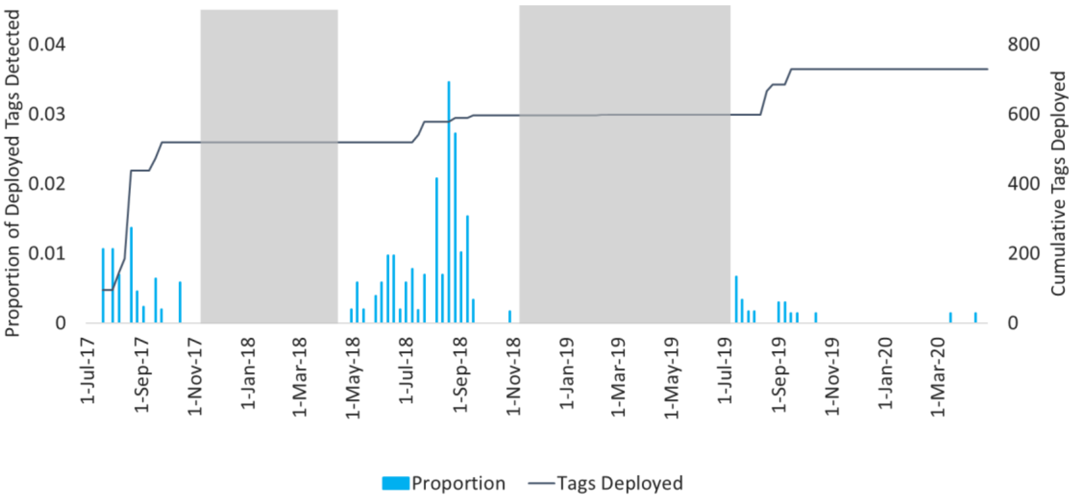

Figure 4-5a. Multi-plate antenna array

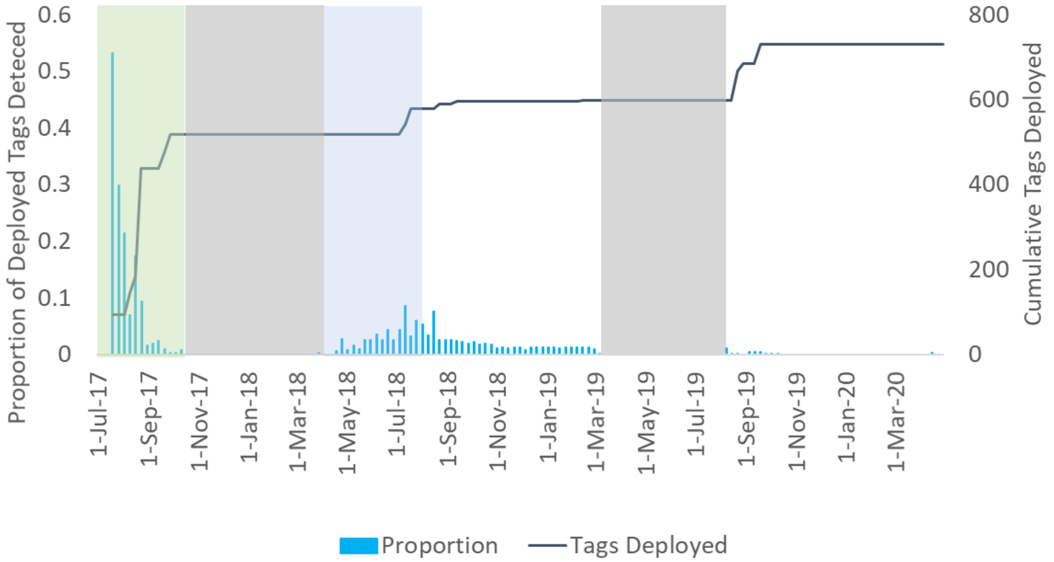

Figure 4-5b. Henretta Creek array

Figure 4-5. The cumulative number of PIT tags applied in Westslope Cutthroat Trout in the upper Fording River watershed north of Kilmarnock Creek.

PIT (Passive Integrated Transponder) tags were detected at the multi-plate antenna array (a) and at the array in Henretta Creek (b), (see Harwood et al., 2021). The green box indicates the time period before the upstream portion of the paired antenna was installed, the grey boxes indicate when the array was intermittent or non-functional and the blue box indicates the period when only the upstream antenna was intermittent.

If the severe reduction in the 200–500 mm WCT population occurred before spawning in 2018, we would expect the age 1+ proportion in 2019 to have been lower because few spawners would have been present in 2018. However, age 2+ fish in 2019 would have been at normal levels, because spawner abundance in 2017 was similar to previous years. Thus, we would expect the age 1+ proportion to be very low in 2019 if the adult population collapsed prior to spawning in 2018. Alternatively, if the population change happened after spawning in 2018, the age 1+ proportion would be consistent with previous years.

The data show that the age 1+ proportion in 2019 was very similar to 2017 and similar to the proportion in other years (Table 4-1b). This suggests that the severe reduction in the WCT population between 2017 and 2019 occurred sometime after the May 15 to July 15 spawning period in 2018.

Table 4-1. (a) The relationship between the year of spawning and year when age 0+, 1+ and 2+ Westslope Cutthroat Trout were present in September; (b) The number of age 0+, 1+ and 2+ trout captured each year juvenile sampling was conducted.

Consistent proportions of age 1+ fish (relative to the sum of catch of 1+ and 2+ fish) in 2017, 2019 and other years indicate that the reduction in abundance of the adult WCT population occurred sometime after spawning in 2018.

Table 4-1a.

May–July	September		
Spawning	Age 0+	Age 1+	Age 2+
2017	2017	2018	2019
2018	2018	2019	2020

Table 4-1b.

Age	2013	2014	2015	2017	2019
0+	37	48	181	237	8
1+	59	100	192	226	103
2+	34	41	128	173	67
1+/(1+ + 2+) Proportion	0.63	0.71	0.60	0.57	0.61

Although the juvenile electrofishing data are not useful for quantifying the magnitude of decline in UFR juvenile WCT, these data are useful for narrowing the high mortality window based on the age 1+ proportion method. This may seem like a paradox, but it is a logical use of data because the assumptions required in the age 1+ proportion method are more valid than the assumptions required for density estimates to be a reliable measure of juvenile abundance. The key assumptions in the age 1+ proportion method are:

1. The relative impact of higher-than-normal juvenile mortality between 2017 and 2019 would be the same for age 1+ and age 2+ juveniles
2. Differences in vulnerability of age 1+ and 2+ fish to electrofishing were similar during 2017 and 2019 sampling periods; and
3. The abundance of age 1+ and 2+ populations depends in part on the number of spawners that produced them, i.e., spawner abundances over the study period were on a relatively linear part of the spawner – age 1+ stock-recruitment curve, so changes in spawner abundance translate to changes in 1+ abundance.

Age 1+ and age 2+ would be expected to have similar susceptibility to any stressors causing mortality in the mainstem, regardless of how much time they spend in the mainstem vs. tributaries between age 1+ and age 2+ (assumption 1). A basin-wide, high mortality event affecting both the mainstem and the tributaries would also not be expected to cause differential mortality between these two juvenile ages. Sampling protocols were the same in all electrofishing survey years, so there is no reason to suspect changes in age-specific vulnerabilities (assumption 2). There are few data to support assumption 3 because the relationship between spawner abundance and juvenile abundance has not been determined. However, it seems reasonable to assume that an eight-fold reduction in spawner abundance would translate to a large change in juvenile abundance.

Trends from electrofishing surveys in the age 0+ catch compared to adult abundance suggest that adult abundance was likely already low before spawning from May to July 2019. The average age 0+ catch at 10 sites consistently sampled in 2013, 2014 and 2017 was 107. The age 0+ catch in 2019 was eight fish, which is 13-fold lower. Adult abundance (> 200 mm) in 2019 declined nine-fold relative to the average of the 2013, 2014 and 2017 surveys. The substantive and somewhat similar declines in spawner abundance and age 0+ catch in 2019 relative to earlier years suggests that spawner abundance in 2019 was already very low and caused the reduced age 0+ catch in 2019. Therefore, by May of 2019, adult abundance in the UFR was likely already much reduced.

This conclusion of low spawner abundance in 2019 should be considered more uncertain than the conclusion based on the age 1+ proportion method (normal spawner abundance in 2018), because the age 0+ catch is considered an unreliable index of fry abundance. In late summer, only a small proportion of fry produced by spawners in the same year would have been vulnerable to electrofishing when the late August electrofishing survey was done (Cope et al., 2016). At the time of the survey, most fry would have been very small and would have depended heavily on interstitial spaces in the stream bottom. Differences in spawn timing or water temperature among years could also have led to differences in the proportion of fry vulnerable during electrofishing surveys. Nonetheless, the 13-fold decrease in age 0+ abundance in 2019 relative to earlier years is likely greater than any decrease caused by inter-annual variation in the vulnerability of fry to sampling.

4.2.3. Passive Integrated Transponder Tag Detections

The vast majority of PIT tags in the UFR were implanted in juvenile fish captured by electrofishing during annual surveys and during salvage and other activities. A smaller number were implanted in larger fish captured by angling or electrofishing. Originally, PIT tagging was intended to estimate the growth and movement of fish based on their size and location when they were recaptured, later. More recently, PIT tagging has been used together with fixed-location antenna arrays to evaluate the passage of fish at culverts on Henretta Creek and in the mainstem near Lake Mountain Creek. The number of WCT that have received PIT tags since September 2017 (north of Kilmarnock), and the proportion of those tags that have been detected at the antenna arrays were summarized by Harwood et al. (2021) and are shown in Figure 4-5. The plots clearly show that at both antenna locations the proportion of tags detected in the summer and fall of 2019 was substantially lower than the previous year. The trends indicate that a potential high mortality event occurred sometime between November 1, 2018, and July 15, 2019. This timing is consistent with the age 0+ analysis that indicates there was limited spawning from May to July 2019, which resulted in few spawners.

In theory, changes in the number of PIT tags detected at these antennas over time can be used to index changes in survival rates. However, detections depend on other factors, including: (1) the number of PIT tags deployed over time; (2) the location where fish were PIT-tagged relative to the location of the antennas; (3) the movement of PIT-tagged fish; and (4) the detection probability at the antennas. The analysis by Harwood et al. (2021) partially accounts for these factors by showing the cumulative number of tags that have been deployed, which it does by eliminating tags south of Kilmarnock and by showing the time periods when the antennas were not operating. In a data-rich environment, a multi-state mark-recapture model could be used to predict the number of PIT tags present over space and time as a function of tag deployments, survival and movement rates (e.g., as was done by Yackulic et al., 2014). However, developing such a model for UFR WCT is not feasible with the available data. Changes in movement rates, tag deployments and detection probabilities of the antennas confound estimating changes in survival rates. As a result, confidence in inferences about survival rates based on PIT tag detections is limited. Nevertheless, the large reduction in the number of PIT tag detections likely indicates high mortality sometime between the summers of 2018 and 2019.

4.2.4. Anecdotal Observations

Westslope Cutthroat Trout redds, live adults and mortalities can be observed during ice-free periods on the UFR and tributaries. The number of observations of fish mortality depends on river conditions (e.g., presence of ice, turbidity), the number of field staff working on the river (which varies over time and space), how observant the field staff are and how reliably they record anecdotal information.

Three observations are worth noting.

- First, redds were observed during habitat surveys from May to July 2018. This provides some support for the age 1+ proportion result (see Section 4.2.2), which indicates that spawning was likely at normal levels in 2018 and that the mortality occurred after the 2018 spawning season. However, redd counts are a highly uncertain measure of spawner abundance, so this inference is, admittedly, weak.
- Second, high numbers of mortalities were not observed during the spring to fall periods in 2018 and 2019. At that time, numerous monitoring and restoration activities were taking place on the UFR, which means that biologists or environmental monitors were working on the river (Figure 4-6), and if a large fish kill event occurred, the probability of detection would have been higher than other times of year. If a very large mortality event occurred after spawning in 2018, it is more likely to have occurred during the late fall and winter period (November 2018 to March 2019) when the river was covered by ice and few observers were present. This is the only period when high levels of mortality would likely have gone undetected.
- Third, during angling from March 25 to 29, 2019, WCT were neither observed nor captured at Clode Flats, the Segment S6 oxbow area or the Greenhills pools, even though radio telemetry data collected over several years shows these areas are used for overwintering. In previous winters, WCT were routinely observed in the oxbow area, suggesting that few fish were present in 2019 (Cope, 2019). Eight WCT were captured in overwintering habitat in Henretta Lake in March 2019.

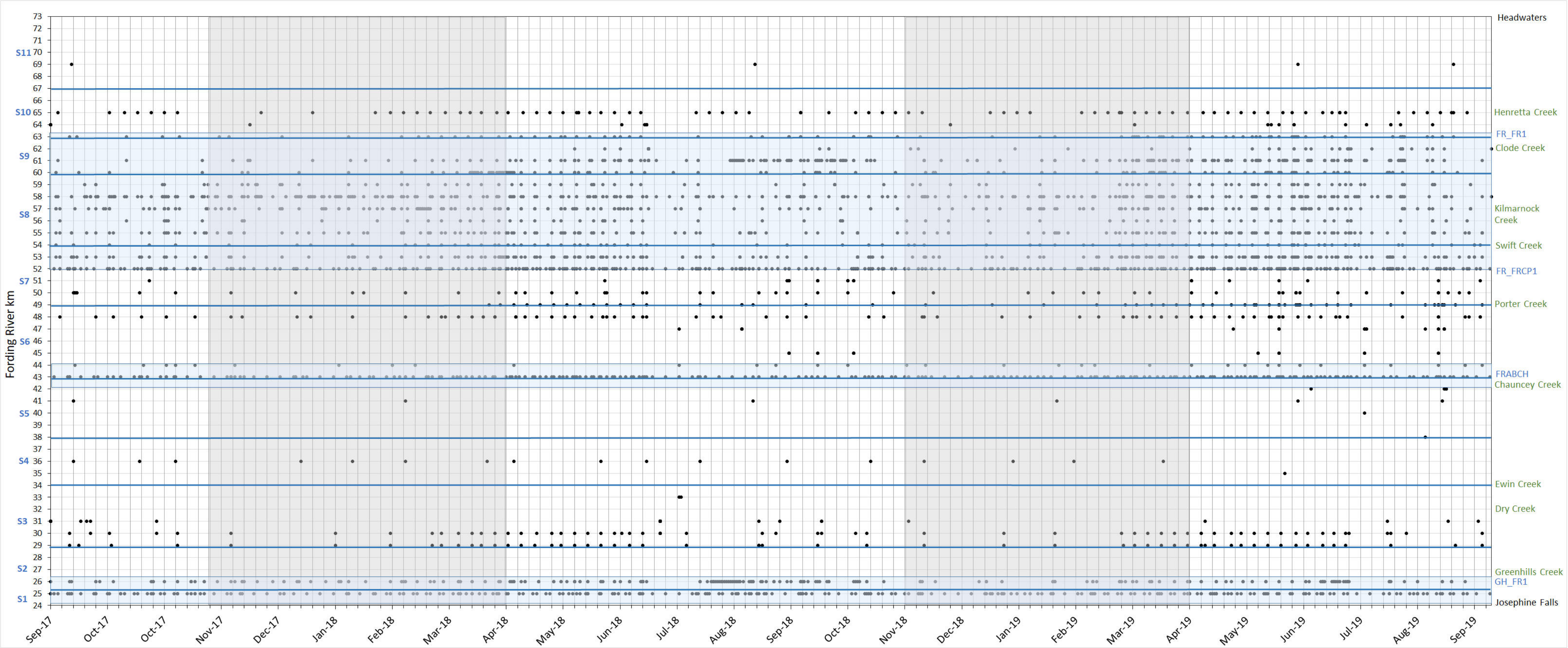

Figure 4-6. Eyes on the River, a representation of observers on the UFR.

Locations (river km shown on y-axis) and weeks (x-axis) between September 1, 2017, and September 21, 2019, when biologists and technicians were present on the UFR (as denoted by •) and could potentially have observed fish mortalities (see Appendix C for details on this information summary).

4.2.5. When Did the Decline Occur?

Using the data sources reviewed and the analysis presented in the previous sections, we can define the following five potential periods, or windows, between the 2017 and 2019 snorkel surveys when high mortality may have occurred (Figure 4-7).

a) **September 1, 2017 – September 1, 2019 (fall 2017 to fall 2019)**
  - This period is based on snorkel-survey-derived estimates of abundance of larger WCT (200–500 mm).
  - Mortality could have occurred anytime between the 2017 and 2019 snorkel survey dates.
  - These surveys occurred between ~ August 25 and September 15; a midpoint of September 1 is therefore used to define this window.

b) **September 1, 2017 – May 15, 2019 (fall 2017 to spring 2019)**
  - This period is based on snorkel-survey-derived abundance of larger WCT, age 0+ abundance from electrofishing surveys and PIT tag detections.
  - Age 0+ abundance was much lower in fall 2019 compared to fall 2017, indicating a likely spawning failure (i.e., due to few spawners) in 2019.
  - Because spawning occurs from May 15 to July 15 (Cope et al., 2016), this shortens the mortality window so that it ends prior to spawning in 2019.
  - This window is supported by the PIT tag detection data. Fewer PIT tags were detected in the summer of 2019, which indicates that mortality had already occurred.

c) **July 15, 2018 – May 15, 2019 (summer 2018 to spring 2019)**
  - This period is based on snorkel-survey-derived abundance of large WCT, age 0+ abundance from electrofishing surveys, the age 1+ proportion method[14] and PIT tag detections.
  - The 2019 PIT tag data show detections in the summer and fall of 2018 were relatively normal, but they were reduced in both summer and fall of 2019.
  - Anecdotal observations of redds in 2018 further support this timing window (T. Hatfield, personal communication).

d) **July 15, 2018 – March 30, 2019 (summer 2018 to winter 2019)**
  - This window is based on snorkel-survey-derived abundance of large WCT and age 0+ abundance from electrofishing surveys, the age 1+ proportion method,

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[14] Age 1+ proportion = $\frac{\text{age 1+}}{\text{age 1+ + age 2+}}$

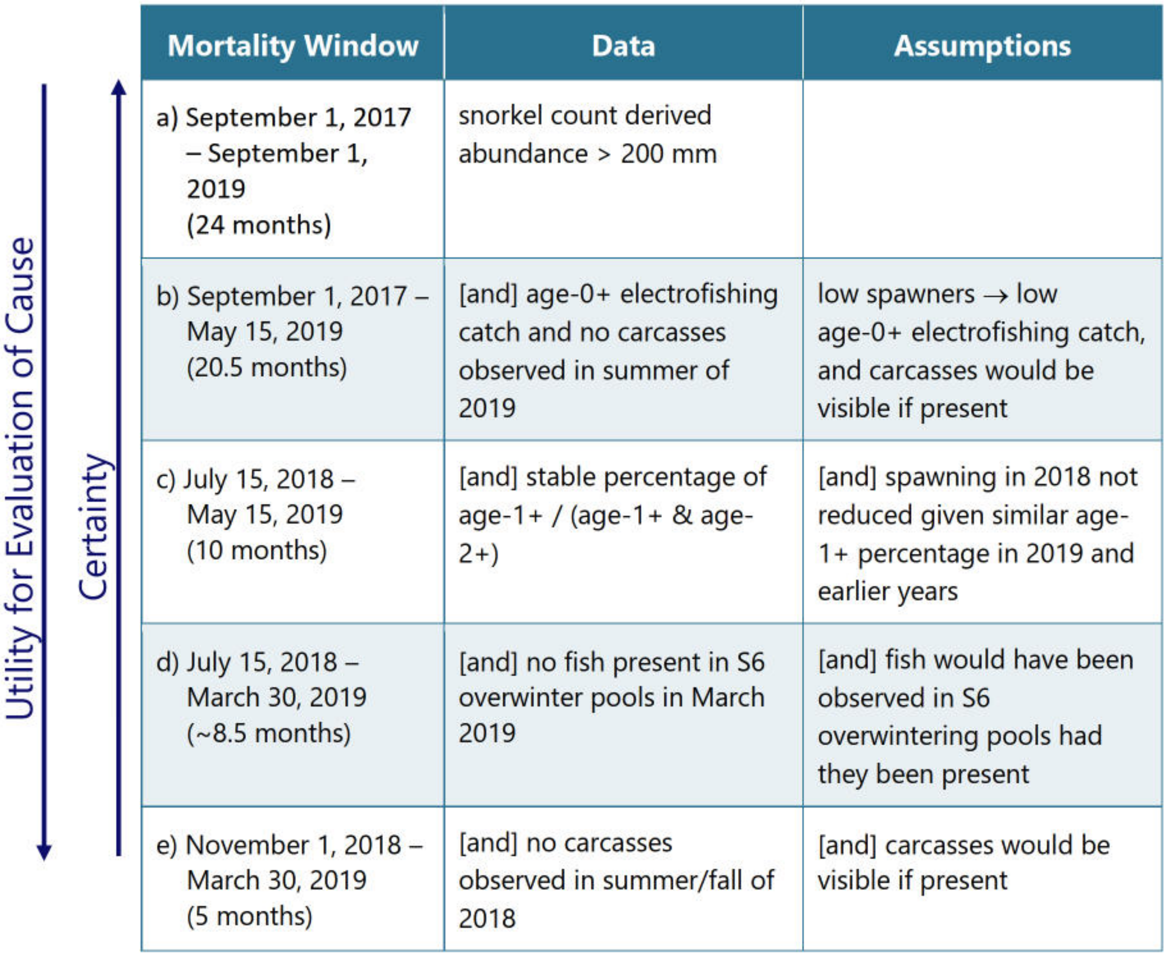
PIT tag detections and the observation that no fish were present in Segment S6 overwintering pools in March 2019.

- Not only do telemetry studies clearly show high and repeated use of the Segment S6 overwinter pools in previous years, but fish had also been routinely observed at this location during ice-free conditions in previous winters. There is, therefore, some confidence that the lack of fish observations in this pool in March 2019 (by a Qualified Professional with years of site-specific experience) indicates that a higher mortality event had already occurred.

e) November 1, 2018 – March 30, 2019 (winter 2018/2019)

- This window is based on snorkel-survey-derived abundance of large WCT, age 0+ abundance from electrofishing surveys, the age 1+ proportion method, PIT tag detections and the lack of anecdotal observations of fish mortality in the spring–summer of 2018 and 2019.
- The key assumption here is that high adult mortality during the summer and fall in 2018 — a period when no ice was present and when crews were often working on the river — would have been noted (see more information, Appendix C – Eyes on the River and Fish Mortality Events).

The level of certainty in the timing-of-mortality window decreases from (a) to (e) as shown in Figure 4-7. That is, we are most sure about the broadest timing window (a) because it relies on the most reliable data and the fewest assumptions. In contrast, the narrowest timing window (e) relies on much less certain anecdotal observations. In our view, there is relatively strong support for timing windows (b) and (c) and to some extent (d), and there is more limited support for the narrowest window (e). While (e) relies on less certain data and more assumptions, the narrower window of decline aligns with findings about the timing of stressor signals presented in Chapters 7 and 8.



Mortality Window	Data	Assumptions
a) September 1, 2017 – September 1, 2019 (24 months)	snorkel count derived abundance > 200 mm	
b) September 1, 2017 – May 15, 2019 (20.5 months)	[and] age-0+ electrofishing catch and no carcasses observed in summer of 2019	low spawners → low age-0+ electrofishing catch, and carcasses would be visible if present
c) July 15, 2018 – May 15, 2019 (10 months)	[and] stable percentage of age-1+ / (age-1+ & age-2+)	[and] spawning in 2018 not reduced given similar age-1+ percentage in 2019 and earlier years
d) July 15, 2018 – March 30, 2019 (~8.5 months)	[and] no fish present in S6 overwinter pools in March 2019	[and] fish would have been observed in S6 overwintering pools had they been present
e) November 1, 2018 – March 30, 2019 (5 months)	[and] no carcasses observed in summer/fall of 2018	[and] carcasses would be visible if present

Figure 4-7. Five potential mortality windows for Westslope Cutthroat Trout in the upper Fording River.

The table shows the five potential mortality windows for WCT in the UFR and the data and assumptions that justify these windows. The reliability (certainty) is greater for the broader windows shown at the top of the table because they are based on more reliable data and fewer assumptions. However, narrower windows, which depend on less certain data and more assumptions, are more useful for evaluating the cause of the decline.

4.3. DID LOW SURVIVAL RATES OF JUVENILES CAUSE THE DECLINE IN ADULT ABUNDANCE, AND DID LOW ADULT ABUNDANCE CAUSE THE DECLINE IN JUVENILES?

The adult snorkel-survey-based data clearly show that the abundance of WCT > 200 mm in the UFR declined substantively between the surveys of 2017 and 2019. The juvenile electrofishing-based data also indicate a substantive decline between 2017 and 2019, although the magnitude of juvenile decline is less certain than for adults, due to the sampling issues described earlier. Given the similarities in the timing of the declines, it is likely both arose from a common cause. We can also say with some certainty that (1) lower survival rates for juveniles were not the proximal cause for the decline in adults; and (2) lower spawner numbers due to elevated mortality of adults was not the proximal cause of the decline in juvenile abundance.

Age-length data (Figure 4-8a) indicate that WCT > 200 mm in the UFR are likely ≥ 4 years old. A simple spreadsheet model was used to calculate the trajectory of the 2017 adult population over future years, assuming that survival rates for early life stages (egg, alevins, fry) were zero (Figure 4-8b). In this scenario, the adult population (> 200 mm) shows a steady decline over time, because the loss of adults due to natural annual survival rates (75–85%) is not replaced by juveniles growing into adults. The collapse would not be immediate, because the adult population is composed of many annual age classes (perhaps 10 or more). As a result, the rate of decline would be gradual and not nearly fast enough to explain the observed rapid decline in the adult population’s abundance between 2017 and 2019 (points in Figure 4-8b). This means that the rapid decline in abundance between 2017 and 2019 was caused by high mortality over this two-year period, and it was not caused by a decline in juvenile survival rates.

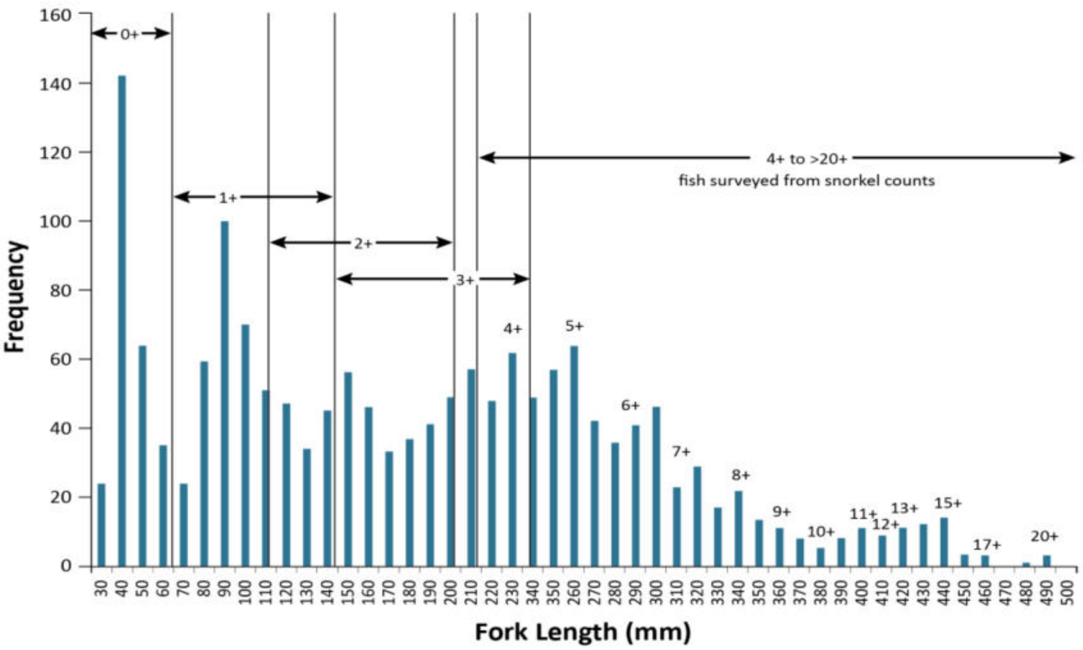


Figure 4-8a.

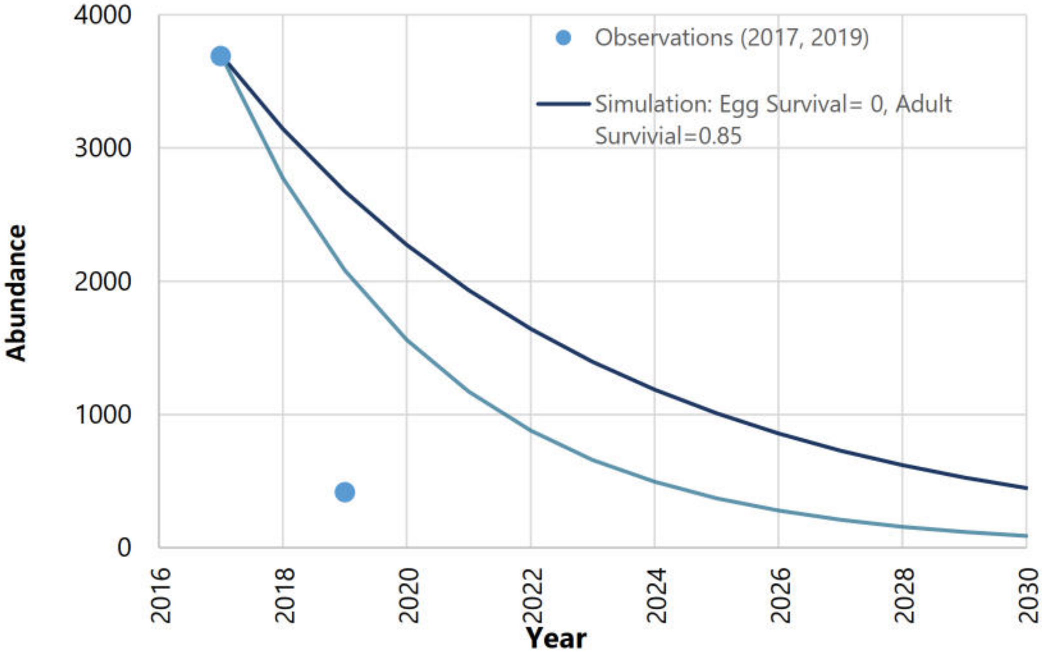


Figure 4-8b.

Figure 4-8. Annual age of Westslope Cutthroat Trout and expected rate of decrease in abundance (if survival rates for early life stages [egg, alevins, fry] had been zero).

(a) The number of WCT in the UFR whose annual age was determined, categorized by fish size (figure is recreated from Figure 3.2.4 in Cope [2020a]); (b) The rate at which the adult population would be expected to decrease if the survival rate of early life stages of WCT was zero.

The reduced abundance of adults, which likely occurred between 2018 and 2019 (Figure 4-7) can also not explain the decline in abundance of juveniles between 2017 and 2019. As reviewed in Section 4.2.2, spawner numbers in 2018 were likely normal, so the only age of fish that would be influenced in 2019 by the adult decline that followed sometime after spawning in 2018 would be age 0+ fish (Table 4-2). Given that age 1+ and age 2+ catch in 2019 was lower (Table 4-1), the reduction must therefore have been caused by a sudden mortality event between 2017 and 2019 (likely 2018–2019) and not by reduced spawner abundance in 2019.

Table 4-2. Relationship between an index of spawner abundance and age 0+ catch from electrofishing in the same year, for Westslope Cutthroat Trout in the upper Fording River.

Year	Index of Spawners	Age-0+ Catch	Average
	(> 200 mm from snorkelling)	**(electrofishing)**	**Age-0+ Catch**
			2013, 2014, 2017
2013	3318	37	107
2014	3664	48	
2017	3690	237	
2019	415	8	
Expected/Actual Age-0+ Catch (107/8)			13
(2013, 2014, 2017) Spawners/2019 spawners			9

4.4. SUMMARY

Snorkel survey-based abundance estimates for WCT ≥ 200 mm indicate a decline of at least eight-fold occurred between September 2017 and 2019. These data also indicate that the greatest declines in abundance occurred in Segments S5 to S9. The period between 2017 and 2019 when high mortality occurred can be narrowed by using information from juvenile electrofishing surveys, PIT tag detections and anecdotal observations. Although sampling issues mean that WCT juvenile density estimates obtained by electrofishing do not provide a reliable index of abundance in the UFR, juvenile data were helpful for narrowing the period of decline based on both the very large reduction in age 0+ catch in September 2019 and the age 1+ proportion method. The analysis indicates that the mortality event occurred after July 15, 2018, or November 15, 2018, and that it almost certainly occurred before March 30, 2019.

5. Approach to Evaluating the Cause of the Decline

5.1. A PROCESS WAS DEVELOPED

To conduct the Evaluation of Cause, the Team developed a systematic and objective approach with four main steps, as shown in Figure 5-1.

Figure 5-1. Conceptual approach to the Evaluation of Cause for the upper Fording River Westslope Cutthroat Trout population decline.

The following subsections describe each of the four steps, which were to some degree concurrently delivered.

5.1.1. Step 1: Identify Stressors and Pathways

With input from the Ktunaxa Nation Council and various regulatory agencies, the Team identified potential stressors and impact hypotheses that might explain the cause of the population decline. Two overarching hypotheses (essentially, questions for the Team to test) were used:

- **Overarching Hypothesis #1.** The significant decline in the UFR WCT population was a result of a single acute stressor[15] or a single chronic stressor[16].

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[15] Implies September 2017 to September 2019.

[16] Implies a chronic, slow change in the stressor (using 2012–2019 timeframe).

- **Overarching Hypothesis #2.** The significant decline in the UFR WCT population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced fish numbers but cumulatively caused the decline.

During the Evaluation of Cause, numerous impact hypotheses were examined to determine if and to what extent various stressors and conditions played a role in the WCT's decline. Given that the purpose was to evaluate the cause of the decline in abundance from 2017 to 2019[17], it was important to identify stressors or conditions that changed or were different during that period. It was equally important to identify the potential stressors or conditions that did not change during the decline window but that may, nevertheless, have constrained the population's ability to respond to or recover from the stressors. Finally, interactions between stressors and conditions had to be considered in an integrated fashion. Where an impact hypothesis depended on or may have been exacerbated by interactions among stressors or conditions, the interaction mechanisms were also considered.

Step 1 — identifying stressors and impact hypotheses — is reported in Chapter 6.

Terminology

Impact hypothesis *describes how a stressor may have influenced the WCT population (note that hypothesis is not the traditional form of a null hypothesis). The Evaluation of Cause framework (Appendix B) has separate columns for* ***causal pathway*** *and* ***impact hypothesis****, so in the SME reports these two terms may be distinguished slightly. These two columns are also distinguished in a summary table in Chapter 6, but the causal pathway component is not carried forward to results.*

Stressor *is used in a general way to describe the main cause of potential impact hypotheses, such as water quality or calcite. The phrase* ***stressors and conditions*** *is used more broadly to encompass not only the particular stressors that have been evaluated using the formal Evaluation of Cause framework, but also the broad conditions in the UFR that may constrain the WCT population or be relevant to the decline (i.e., the kind of information summarized in Chapter 2).*

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[17] Abundance estimates for adults/sub-adults are based on surveys conducted in September of each year, while estimates for juveniles are based on surveys conducted in August.

5.1.2. Step 2: Develop Framework to Evaluate Cause

A tabular framework, *Evaluation of Cause: Framework for Overarching Hypothesis #1* was prepared in early 2020 and reviewed by Teck Coal, regulators, KNC and technical committees. It was then revised based on feedback from the reviewers. The framework provided a systematic approach for SMEs to synthesize their findings on individual stressors (i.e., under Overarching Hypothesis #1) and determine the degree to which the stressors may have contributed to the decline in UFR WCT. Each SME completed this table for the impact hypotheses they were responsible for (results presented in Appendix B: Evaluation of Cause Framework table).

A different approach was used to evaluate Overarching Hypothesis #2 and is described in Chapters 6–8. This approach involved integrating findings across stressors by building on the results for individual impact hypotheses and evaluating interactions between the most important contributors to the observed decline in the WCT population during the decline window.

5.1.3. Step 3: Prepare Subject Matter Expert Reports and Integrate Findings

Individual Subject Matter Expert reports focused on impact hypotheses under Overarching Hypothesis #1 (a list of reports is provided in Appendix A). Most SME reports have the same overall format and cover: (1) rationale for impact hypotheses, (2) methods, (3) analysis, (4) findings — with a focus on determining whether the requisite conditions were met for the stressor(s) to have been either the sole cause of the fish population decline or a contributor to it. In addition to the reports, the SMEs provided summaries of findings that were compiled and tabulated (Step 2; see Chapter 7).

Integrating the findings involved an iterative process. SMEs worked in small, informal groups to extract the key findings from SME reports and carry them forward to the Evaluation of Cause report. Initially, a scenario document was developed for discussion by SMEs. The resulting feedback and discussion about the scenario evolved into the integrated hypothesis presented in Chapter 8. This integrated hypothesis

Terminology

Requisite conditions *is used in the framework to describe the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT.*

Cumulative effects *is a term used sparingly and in particular contexts. More specific terms are used where possible, such as stressor interactions.*

was presented at a workshop to the KNC, agencies and committees for discussion, and it was then revised to reflect feedback.

Integrating the findings to evaluate the cause of the decline required a process over and above the work done by the SMEs. The individual SME reports (and the resulting summaries in Chapter 7) focused on specific stressors and were not designed to consider all possible interactions with other stressors and conditions. The Evaluation of Cause Team recognized that the decline was likely due to interactions among stressors and between stressors and the pre-existing conditions in the watershed (summarized in Chapter 2). Consequently, using the knowledge base from the SME reports, the Evaluation of Cause Team discussed stressors and their interactions to identify and explore potential scenarios that could explain the decline. These discussions led to improvements in the way individual SME results were characterized and, most importantly, they led to the development of an integrated hypothesis for the decline. The integrated hypothesis was initially coarse, but it was refined and elaborated on through iterative discussions and feedback from the KNC, agencies and committees (including the EMC's Independent Scientist). The final integrated hypothesis for the decline is presented in Chapter 8.

The Evaluation of Cause was supported by a wealth of scientific literature and reports relating to the UFR, all of which are cited in individual SME reports. In addition, the Evaluation of Cause Team prepared summaries of key information for SMEs to use. The summaries are listed below and are described in more detail in Appendix C. They were developed to ensure consistency across SME reports (e.g., naming conventions, spatial reference within the watershed, congruency across SME reports in the understanding of water connectivity and where fish spend time [fish use]) and to answer specific questions that arose during the Evaluation of Cause process (e.g., How do the WCT move with the seasons? What activities were happening in the UFR during the decline window?).

Information Summaries provided in Appendix C	Description
Fish Periodicity Chart	Developed to ensure that work relating to fish life stage was consistent across SME reports
Location Concordance Table	Developed to align the naming conventions for locations when interpreting and describing the data from Teck Coal's various monitoring programs
Water Connections Figure	Developed to standardize place names and summarize water connections in a watershed context
Decline Window Events Table	Developed to document significant operational (e.g.,

Information Summaries provided in Appendix C	Description
	construction) and environmental (e.g., fire) events that occurred in the UFR during the decline window by river segment
Eyes on the River	Developed to show the activities that took place along the UFR during the decline window that may have provided field crews with opportunities to detect fish mortalities
Regional Populations Table	Developed to summarize meta-information about the various studies and, from that, identify if any populations have been studied intensively enough (e.g., over multiple years or at multiple sites) to be comparable to the UFR WCT
Fish-Use Maps	Developed to plot telemetry data and visual observations of spawning locations of the UFR for each fish-use period, including spawning, summer rearing and overwintering

Through the Evaluation of Cause process, 21 SME reports and 4 other documents (memoranda or reports appended to SME reports) were prepared and then reviewed as described in Section 5.2. The reports and documents are listed in Appendix A.

5.1.4. Step 4: Prepare Evaluation of Cause Report

The Evaluation of Cause report (this document) was prepared by a core group of SMEs (see Acknowledgements), with input from the entire Evaluation of Cause Team.

5.2. EXTENSIVE REVIEWS WERE CONDUCTED

The documents produced through the Evaluation of Cause process were subjected to a multi-phase review process. This included:

- Azimuth Reviewers who focused on document organization (for Evaluation of Cause use) and high-level technical review of the reports
- Internal Peer Reviewers who are SMEs that reviewed reports prepared by other SMEs within their area of expertise
- Independent Peer Reviewers (i.e., reviewers outside of the Team and Teck Coal), recognized for their expertise, who provided third-party review

- Participant Reviewers who were technical reviewers from the Ktunaxa Nation Council, committees (including the EMC's Independent Scientist) and agencies listed in Chapter 1
- Teck Coal Reviewers who reviewed for site-specific accuracy and confirmed that SMEs had been provided the available and relevant data.

5.3. MEETINGS AND WORKSHOPS WERE HELD

Engagement and collaboration took place throughout the Evaluation of Cause process. Across the SME team this involved:

- Roughly 30 bi-weekly, full-team meetings with SMEs
- About 50 other SME meetings for technical discussions on key topics, as needed
- Three SME workshops
- Engagement with the agencies, KNC and committees (including the EMC's Independent Scientist). This involved:
    - Roughly 30 bi-weekly meetings to share progress and make presentations
    - Twenty SME overview presentations, where initial questions about SME reports were raised
    - Roughly ten discussions on SME reports, after drafts had been issued for discussion
    - Four workshops, including discussions of how Evaluation of Cause findings were reached
    - Addressing review comments provided on a draft of this Evaluation of Cause report by the KNC, agencies and the EMC's Independent Scientist

Note: The Evaluation of Cause took place largely during the COVID-19 pandemic, so the meetings, discussions and workshops took place remotely. While this posed communication challenges, these were mitigated to some extent by communicating more frequently, as evidenced by the numerous meetings.

6.

Hypothesizing Stressors and Pathways

Teck Coal engaged with established working groups (EMC and EVFFHC) and with a number of the SMEs — as described in Chapter 5 — to discuss and explore the available evidence. Through this engagement, a suite of potential stressors was identified that may have caused or contributed to the decline of the WCT population in the UFR. SMEs then thoroughly examined each stressor by evaluating the available information. Their detailed methods and results are documented in the individual SME reports listed in Appendix A, and their findings are summarized in the Evaluation of Cause Framework table, Appendix B.

Collectively, 25 stressors were identified as possible causes of or contributors to the WCT population decline. For each stressor, SMEs evaluated causal pathways and impact hypotheses, which are described in Chapter 5. The stressors and their hypothesized impacts are illustrated in Figure 6-1. In the figure, each stressor is represented by a coloured box, and each impact hypothesis is represented by an arrow coloured and coded to match the stressor. The codes are alpha-numeric and unique to each stressor and arrow. The codes match those in Table 6-1, which summarize the potential causal pathway and the hypothesized impact on WCT for each arrow, along with relevant information for the hypotheses, including WCT life stage, UFR location, habitat or temporal information. Table 6-1 identifies the SME reports where readers can find further details.

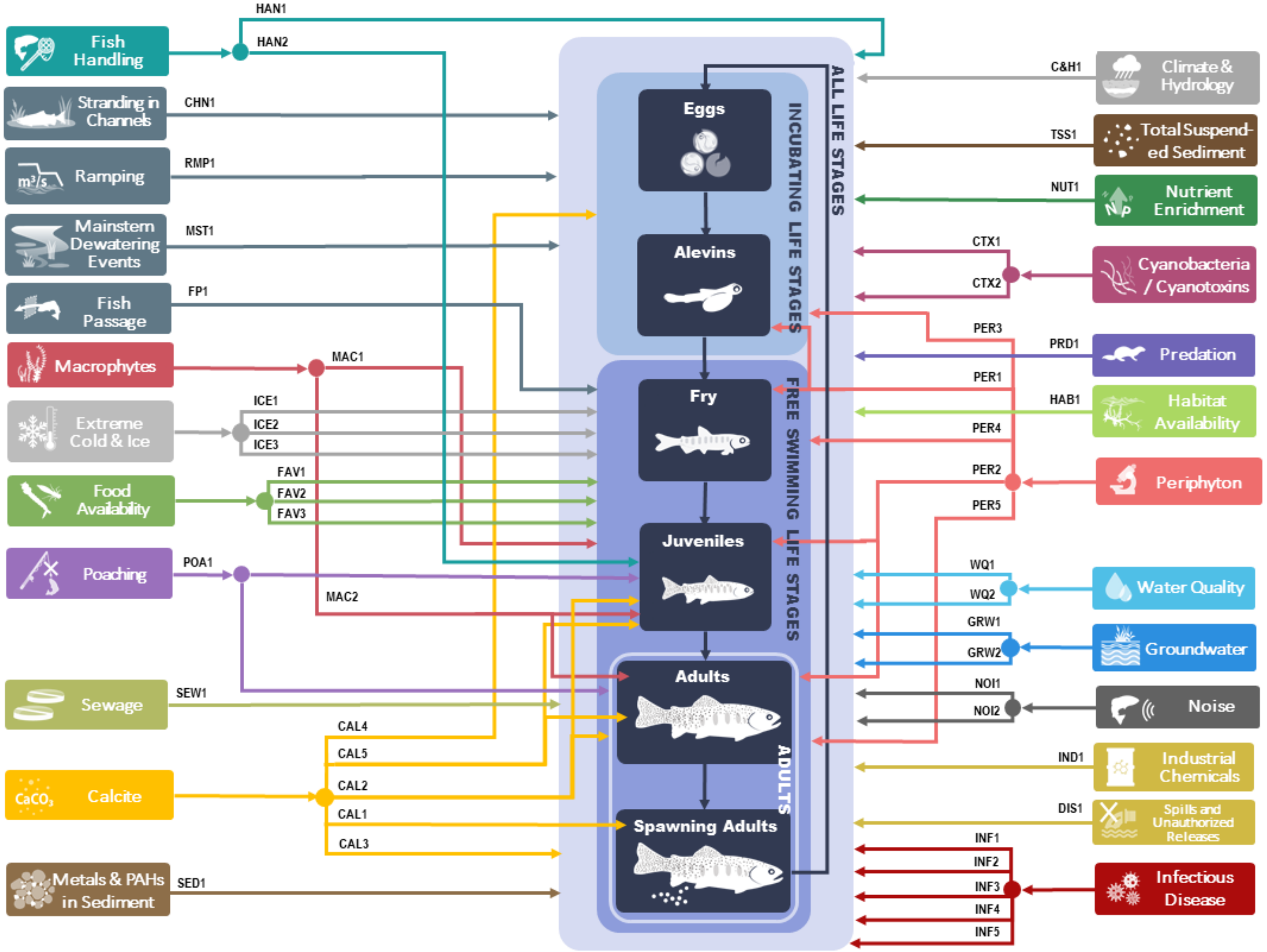

Figure 6-1. Impact hypothesis diagram for the stressors considered in the Evaluation of Cause.

Table 6-1. Summary of the stressors and potential causal pathways, SME reports where readers can find further details.

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Calcite (CAL)	Calcite accumulation → lower spawning habitat quality → lower spawning success → lower recruitment → lower fish abundance	**CAL1** Did recruitment decrease as a result of calcite effects on spawning success?	Relevant to spawning and spawning success. Limited to spawning habitats and fry production throughout UFR.	Hocking, M., Tamminga, A., Arnett, T., Robinson M., Larratt, H., & Hatfield, T. (2021). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd.
	Calcite accumulation → lower invertebrate production → lower fish growth rates → lower survival and recruitment → lower fish abundance	**CAL2** Did fish mortalities increase due to calcite effects on food supply (invertebrate prey)?	Relevant to juvenile and adult rearing and overall WCT productivity in UFR across age classes.	
	Calcite accumulation → dissolution → release of cyanotoxins → acute or chronic toxicity → lower fish abundance	**CAL3** Did fish mortalities increase as a result of increased exposure to cyanotoxins during calcite dissolution?	Relevant to all life stages of WCT throughout UFR downstream of calcite accumulations.	
	Calcite accumulation → reduced incubation success → lower fish abundance	**CAL4** Did fish mortalities increase as a result of calcite effects on egg incubation?	Relevant to incubation success. Limited to spawning habitats and fry production throughout UFR.	
	Calcite accumulation → restricted access to interstitial overwintering habitat → increase in overwinter mortality → lower fish abundance	**CAL5** Did overwinter fish mortalities increase because calcite accumulation reduced the amount of overwinter habitat?	Relevant to juvenile and, to a lesser extent, adult overwintering survival throughout the UFR.	

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Climate and Hydrology (C&H)	Extreme weather (climate) and flow → increase in mortality → lower fish abundance	**C&H1** Did anomalies occur in climatic factors, streamflow or water use during the decline window, in comparison to previous years? Note: Analysis of climate, streamflow and water use data was intended mainly to support evaluation of other stressors by identifying anomalies (i.e., notable departures from average conditions).	Relevant to multiple life stages; focused on most sensitive life stages.	Wright, N., Greenacre, D., & Hatfield, T. (2021). *Subject Matter Expert Report: Climate, temperature and streamflow trends. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by by Ecofish Research Ltd.
Stranding in Channels (CHN)	Channel dewatering → stranding of fish → increase in mortality → lower fish abundance	**CHN1** Did fish mortalities increase because dewatering of natural and constructed channels caused stranding?	Relevant to all life stages: spawning, incubation and rearing; potential for effect is related to channel characteristics (channels differ in the quality of habitat for fish and in their sensitivity to stranding).	Hatfield, T., Ammerlaan, J., Regehr, H., Carter, J., & Faulkner, S. (2021). *Subject Matter Expert Report: Channel dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Cyanobacteria and Cyanotoxins (CTX)	Cyanobacterial proliferation → conditions promoting cyanotoxin release → acute or chronic exposure → indirect toxicity to fish food base (invertebrates) or direct toxicity to fish	**CTX1** Are cyanotoxins in the UFR at sufficient concentrations and for long enough to cause adverse effects to benthic invertebrates or mortality in juvenile and/or adult life stages of WCT in the UFR during the decline window?	Cyanotoxins can be a potential concern for all WCT age classes but especially to alevins/fry when they are living and feeding on minute prey at sites with high cyanobacteria counts.	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Larratt Aquatic Consulting Ltd.
		CTX2 Did fish mortalities increase because cyanotoxins stored in sediments and calcite were released during winter low flows?	Cyanobacteria and cyanotoxins stored in the sediments and calcite in depositional areas could affect invertebrates and WCT during very low flows at overwintering sites (e.g., RG_MP1 rkm 58.5, Segment S6).	
Spills and Unauthorized Releases (DIS)	Spills and unauthorized releases → acute or chronic effects on fish	**DIS1** Did fish mortalities increase due to unauthorized releases (e.g., spills)?	Not restricted; depends on when and where unauthorized releases occurred relative to where WCT were located in time and in space.	Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.
Food Availability (FAV)	Reduction in aquatic or terrestrial food → starvation → increased mortality → lower fish abundance	**FAV1** Did fish mortalities increase because food availability was reduced and caused starvation?	Relevant to any externally feeding life stage (fry, juvenile, adult) and any locations within UFR utilized by WCT. Occurrence after	Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper*

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
		FAV2 Did fish mortalities increase because of a decrease in aquatic invertebrates?	September 2017 because WCT were in good condition in September 2017 compared to previous years and other upper Kootenay populations (Cope, 2020a).	*Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Minnow Environmental Inc.
		FAV3 Did fish mortalities increase because of a decrease in terrestrial invertebrates?		
Fish Passage (FP)	Low water levels in streams → limited access to overwintering habitat → confinement of fish to suboptimal overwintering habitats → increased mortality in winter → lower fish abundance	**FP1** Did fish mortalities increase because low flows limited access to suitable overwintering habitats?	Relevant to mobile life stages: fry, juveniles, adults. Assessed critical riffles and areas subject to shallowing/drying during low flows that may impede fish migration within the UFR mainstem. Focused on the fall migration window from September 1 to October 15, but evaluated conditions from August 1 to October 30 to get a better understanding of the variability in conditions among years. Evaluated conditions at potential riffle barriers on the UFR mainstem during this period in different years.	Harwood, A., Suzanne, C., Whelan, C., & Hatfield, T. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Groundwater Quality and Quantity (GRW)	Changes in upgradient groundwater flows → change in discharge area, spatial distribution of surface water or flows	**GRW1** Were there changes in upgradient groundwater flows that may have led to changes to discharge areas, spatial distribution of surface water or its flows?	Life stage not restricted, but spawning and overwintering may have higher exposure.	Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by SNC-Lavalin Inc.
	Changes in upgradient groundwater quality → change in hyporheic or surface water quality	**GRW2** Was there a change in upgradient groundwater quality that may have led to changes to hyporheic or surface water quality?	Life stage not restricted, but spawning and overwintering may have higher exposure.	
Habitat Availability (HAB)	Restricted distribution of suitable habitat → confinement of fish to smaller area → increased competition (lower carrying capacity) OR increased exposure to predation/spill/other factors → decline in growth or increase in mortality → lower fish abundance	**HAB1** Did fish mortalities increase as a direct result of limited habitat availability or because confinement increased exposure to an acute stressor?	Relevant to multiple life stages: spawning, incubation, juvenile rearing, adult rearing, juvenile overwintering, adult overwintering.	Healey, K., Little, P., & Hatfield, T. (2021). *Subject Matter Expert Report: Habitat availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Fish Handling: Sampling, Salvage and Relocation (HAN)	Scientific fish sampling (electro-shocking, angling, trapping, Floy tags, PIT tags, radio tags and tissue sampling) → immediate or latent mortality	**HAN1** Did fish mortalities increase as a result of fish sampling?	Not restricted; depends on sampling type and study locations.	Cope, S. (2020b). *Subject Matter Expert Report: Fish handling. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
	Fish salvage and relocation → immediate or latent mortality	**HAN2** Did fish mortalities increase as a result of fish salvage or relocation?	Primarily juveniles, in tributaries and isolated pools (salvage locations) and relocation habitats, during salvage/relocation events.	prepared for Teck Coal Ltd. by Westslope Fisheries Ltd. Korman, J., & Branton, M. (2021). *Effects of capture and handling on Westslope Cutthroat Trout in the upper Fording River: A brief review of Cope (2020) and additional calculations.* Report prepared for Teck Coal Ltd. by Ecometric Research.
Extreme Cold and Ice (ICE)	Extreme cold → entombment or freezing in ice → increased mortality	**ICE1** Did fish mortalities increase as a result of freezing?	Relevant to multiple life stages; focused on most sensitive life stages.	Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
	Formation of anchor, frazil or surface ice → exclusion of fish from suitable overwintering habitat → increased mortality in winter	**ICE2** Did fish mortalities increase because ice formation excluded fish from suitable overwintering habitat?		
	Extreme cold → ice formation → physiological stress on fish → increased mortality	**ICE3** Did fish mortalities increase as a result of physiological stress from exposure to extreme cold and/or ice?		

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Industrial Chemicals (IND)	Exposure to industrial chemicals → direct lethal or sublethal effects on fish	**IND1** Did fish mortalities increase due to exposure to industrial chemicals?	Not restricted; depends on when and where industrial chemicals were used relative to where WCT were located at the time.	Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. 2021. *Subject Matter Expert Report: Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.
Infectious Disease (INF)	Viral diseases → direct mortality to fish	**INF1** Did fish mortalities increase as a result of viral disease(s)?	Relevant to all life stages, but younger age classes more susceptible. UFR location not restricted. Outbreaks occur after a drop in temperature or during the winter when fish are thermally stressed.	Bollinger, T. (2021b). *Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited.
	Bacterial diseases → direct mortality to fish	**INF2** Did fish mortalities increase as a result of bacterial disease(s)?	Stressed fish are more susceptible. UFR location not restricted. More likely in warm summer months.	
	Oomycete diseases → direct mortality to fish	**INF3** Did fish mortalities increase as a result of oomycete disease(s)?	Relevant to all life stages. UFR location not restricted. Outbreaks occur after a drop in temperature or during the winter when fish are thermally stressed.	

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
	Parasitic diseases (Whirling) → direct mortality to fish	**INF4** Did fish mortalities increase as a result of parasitic Whirling Disease?	Relevant to all life stages. UFR location not restricted. Warmer temperatures promote disease development.	
	Parasitic diseases (Proliferative Kidney Disease) → direct mortality to fish	**INF5** Did fish mortalities increase as a result of parasitic Proliferative Kidney Disease?	Relevant to all life stages. Eutrophication and environmental degradation have also been shown to promote disease, and these combined factors likely explain its emergence. Warmer temperatures promote disease development.	
Aquatic Macrophytes and Bryophytes (MAC)	Constituents of interest → accumulation in macrophyte tissue → accumulation in benthic invertebrate grazer tissue → consumed by fish → increased mortality	**MAC1** Did fish mortalities increase due to ingestion of benthic invertebrates that accumulated metals bioconcentrated by macrophytes?	Benthic invertebrates that are food for free swimming WCT can accumulate some metals after grazing on macrophytes but only at the few UFR depositional sites with macrophyte stands or sites with significant bryophyte coverage.	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Larratt Aquatic Consulting Ltd.
	Decomposition of macrophytes, periphyton and sediments in lentic habitats or pools → combined with ice cover → lower dissolved oxygen → increased mortality	**MAC2** Did fish mortalities increase due to low oxygen stress associated with decomposing macrophytes and from the sediments they accumulated?	Decomposing macrophytes may have contributed to low dissolved oxygen for overwintering juvenile/adult WCT in extreme cold in February 2019. Sediment deposition caused by macrophyte drag in pools and shallows may restrict use by early life stages.	

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Mainstem Dewatering Events (MST)	Mainstem dewatering → stranding of fish → increase in mortality → lower fish abundance	**MST1** Did dewatering of UFR mainstem habitats cause or contribute to the observed WCT population decline?	Relevant to all life stages: spawning, incubation and rearing; potential for effect is related to the timing and location of drying within the UFR mainstem.	Hocking, M., Ammerlaan, J., Healey, K., Akaoka, K., & Hatfield, T. (2021). *Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.
Noise (NOI)	Noise → fish barotrauma → direct mortality	**NOI1** Did fish mortalities increase as a result of direct exposure to noise?	Relevant for all life stages. UFR location not restricted, and timing is dependent on mine activity. If during overwintering (when fish are concentrated), effects would potentially be larger.	Bollinger, T. (2021a). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd.
	Noise → fish movement from suitable habitats to suboptimal locations to avoid noise or prolonged stress responses → indirect mortality	**NOI2** Did fish mortalities increase as a result of indirect exposure to noise?	Relevant for all mobile life stages (movement), all life stages (stress). UFR location not restricted, and timing is dependent on mine activity.	

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Nutrient Enrichment (NUT)	Increased nutrient concentrations → increased primary or secondary productivity → direct or indirect effects	**NUT1** Did fish mortalities increase due to nutrient enrichment and consequent productivity changes?	Not restricted; depends on where WCT were located in time and in space.	Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.
Periphyton (PER)	Filamentous algae blooms → isolation of gravel from the water column → reduced habitat quality and hyporheic exchange	**PER1** Did filamentous algae blooms reduce hyporheic exchange, particularly during the decline window?	Relevant where harmful filamentous algae blooms have developed and may affect alevins/fry through the summer rearing stage.	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Larratt Aquatic Consulting Ltd.
	Filamentous algae blooms such as Didymo → poor forage and degraded physical habitat (altered DO, pH, redox) in low velocity UFR reaches → effects on benthic invertebrates and fish	**PER2** Did filamentous algae blooms provide poor forage and degrade physical habitat for benthic invertebrates and WCT?	Relevant when stable low flows occur throughout the growing season without a fall flushing flow. This allows filamentous algae blooms to develop, persist and potentially affect juvenile and/or adult WCT at winter refugia such as Segment S6, through oxygen demand, but only in an unusually cold winter.	

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
	Periphyton → entrapment of TSS and calcite → bio-clogging → restricted hyporheic exchange → reduced bioreactor function → reduced habitat quality including dissolved oxygen → effects on fish	**PER3** Did restriction of hyporheic exchange by periphyton reduce habitat quality more than usual in the decline window?	Bio-clogging mechanisms can limit valuable bioreactor functions of the UFR. They are most relevant to early life stages of WCT in growing seasons with stable low flows and to overwintering WCT in depositional reaches such as Segment S6.	
	Periphyton metal accumulation and bacterially mediated processes → bioconcentration in macroinvertebrates → effects in fish	**PER4** Did periphyton metal bioaccumulation and bacterially mediated processes increase metal concentrations in aquatic invertebrates?	Relevant when metals bioconcentrate from water into periphyton to macroinvertebrate tissues, potentially affecting the WCT age classes that utilize benthic invertebrates.	
	Nitrification and denitrification in periphyton-influenced hyporheic zone → effects on water quality or dissolved oxygen concentrations → impacts on fish	**PER5** Did nitrogen transformations in the periphyton-influenced hyporheic zone affect UFR water quality and dissolved oxygen enough to have an impact on WCT, particularly the young of the year?	Nitrification could contribute to adult WCT dissolved oxygen stress in slow-flowing UFR habitats during long ice cover/low flows such as in February 2019.	

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Poaching (POA)	Illegal fishing by human anglers → reduced fish population abundance	**POA1** Did fish mortalities increase as a result of poaching?	Primarily adult life stages, but also juveniles, anywhere along the UFR. Mostly likely during the snow-free period; however, there is a potential for illegal harvest during the winter period.	Dean, D. (2021). *Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by VAST Resource Solutions Inc.
Predation (PRD)	Increased wildlife predator foraging → increased mortality → lower fish abundance	**PRD1** Did fish mortalities increase as a result of increased wildlife predation?	Relevant to all life stages, spawning areas, overwintering areas and locations where there are barriers to fish passage that cause congregations. Some predators potentially reside year-round, while others are present just during the growing season.	Dean, D. (2021). *Subject Matter Expert Report: Wildlife predation. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by VAST Resource Solutions Inc.
Ramping (RMP)	Rapid change in water level → stranding of fish → increase in mortality → lower fish abundance	**RMP1** Did fish mortalities increase because ramping caused stranding?	More relevant to younger life stages because shallow habitats are more susceptible to dewatering and are preferred habitat for fry and juveniles. But adult stranding can also occur. August to October is the most likely time when stranding could occur because fry are present. Water use can be high as a proportion of total streamflow and streams have low flows.	Faulkner, S., Carter, J., Sparling, M., Hatfield, T., & Nicholl, S. (2021). *Subject Matter Expert Report: Ramping and stranding. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Metals and Polycyclic Aromatic Hydrocarbons in Sediment (SED)	Mine-influenced sediment → increase in metals and Polycyclic Aromatic Hydrocarbons (PAHs) in sediment → acute or chronic exposure of fish → increased mortality	**SED1** Were concentrations of metals and/or PAHs in sediment present during the decline window sufficient to result in adverse effects to WCT that could have increased mortality?	Relevant to all life stages in overwintering and rearing areas during the decline window.	DiMauro, M., Branton, M., & Franz, E. (2021). *Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Azimuth Consulting Group Inc.
Unauthorized Sewage Discharge (SEW)	Release of TSS and/or toxic constituents, or increase in biochemical oxygen demand from sewage → acute or chronic effects on fish	**SEW1** Did fish mortalities increase due to unauthorized discharge(s) of sewage?	Given the timing of the discharges, the life stages that would be present in the UFR would be egg/alevin and fry (August 2017), or juveniles and adults (February 2020). The discharge would have to have reached tributary or mainstem habitat where WCT may occur.	Branton, M., & Power, B. (2021). Stressor Evaluation – Sewage. In Van Geest et al. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.

Stressor	Potential Causal Pathways	Impact Hypotheses	Relevant WCT Life Stage, UFR Location, Habitat or Temporal Information	Report Citation
Total Suspended Sediments (TSS)	Release or runoff of sediment laden water → exposure to elevated TSS → behavioural, physiological, habitat effects → decline in growth or increase in mortality → lower fish abundance	**TSS1** Did fish mortalities increase as a result of behavioural, physiological or habit effects from elevated levels of TSS?	Evaluated all life stages: adult, juvenile, eggs and larvae. Routine TSS data were collected from water quality stations in the receiving environment (i.e., UFR and tributaries) and from authorized discharge locations in the UFR and tributaries from January 2012 to December 2019. Event-based TSS data were collected for unauthorized discharge events in the UFR and tributaries from September 2017 to September 2019. Modelling certainty and spatial and temporal understanding depends on available spot-measurement TSS data.	Durston, D., Greenacre, D., Ganshorn, K., & Hatfield, T. (2021). *Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Water Quality (WQ)	Release of mine-influenced water → exposure of fish → increased mortality	**WQ1** Did exposure to releases of mine-influenced water contribute to or cause fish mortality?	Not restricted; depends on where water was discharged into fish-accessible waters in the UFR watershed in the decline window.	Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd by Golder Associates Ltd.
	Mine-influenced water → increase in constituent concentrations in fish-accessible surface water → exposure of fish → increased mortality	**WQ2** Did exposure to constituents in fish-accessible surface water contribute to or cause fish mortality?	Not restricted; depends on where constituent concentrations were elevated relative to benchmarks and screening values and where WCT were located in time and space.	

Numerous potential stressors and causal pathways were investigated, so to summarize the results that are presented in the next chapter, the hypotheses were grouped into four categories. The categories are listed below, and the stressors that fit into each category are illustrated in Figure 6-2.

- **Change in Physico-Chemical Habitat Quality**. This category includes the causal pathways for physical and chemical stressors that had potential to negatively affect fish physiology or behaviour during the population decline window. Stressors that were investigated include extreme cold, total suspended solids, calcite, cyanotoxins and a variety of chemicals in water or sediment.
- **Limitations on Fish Movement or Habitat Quantity.** This category includes causal pathways relating to the potential that fish had less available habitat or less access to it during the population decline window. When evaluating these pathways, the habitat requirements of WCT during different life stages were considered, as were factors such as low water flow and ice formation, which may have limited seasonal movement among habitats.
- **Change in Aquatic Ecosystem Biology or Ecology.** This category includes the causal hypotheses related to a potential change in the relationship between WCT and other aquatic ecosystem components, including prey (food), predators and infectious agents.
- **Other Human Disturbances.** This category includes causal pathways that represent human activities that had potential to negatively affect fish during the decline window but did not fit easily within the other categories (i.e., poaching, fish handling and noise).

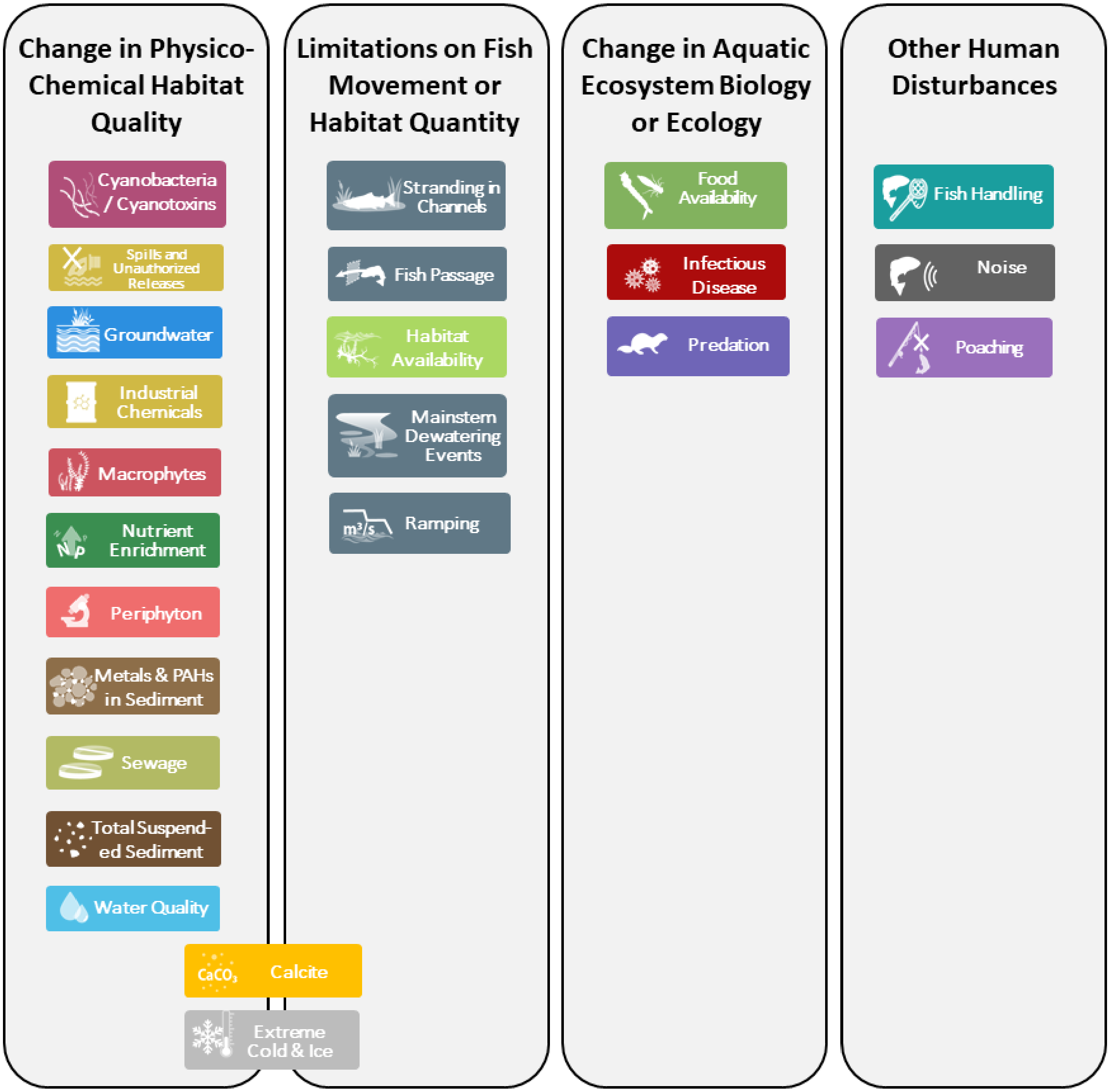

Figure 6-2. Stressor categories.

7. What Did We Learn?

Numerous stressors and associated impact hypotheses were considered as possible causes or contributors to the WCT population decline, as detailed in Chapter 6. Chapter 7 summarizes the findings for each stressor and impact hypothesis. These findings and the confidence associated with them are based on available site-specific information, information from other systems and the scientific literature (as detailed in SME reports). For integration of these findings to address the purpose of the Evaluation of Cause, see Chapter 8.

For ease of reference across text, tables and figures, stressor codes (in brackets) are used, consistent with the Evaluation of Cause Framework table (Appendix B).

7.1. SUMMARY

The impact hypotheses have been carried forward from Chapter 6 and the summary results are provided in Table 7-1. These results answer each of the two overarching hypotheses identified in Chapter 5, namely, whether an impact hypothesis associated with a specific stressor *could have been the sole cause* of the decline, and, if not, whether the impact hypothesis *could have contributed* to the decline. Results are based on the various SME reports, as summarized in the Evaluation of Cause Framework table (Appendix B).

In this chapter, evidence for sole cause of the 2017 to 2019 decline is categorized for each impact hypothesis as:

Weak/None	Requisite conditions are not met and the impact hypothesis cannot be the sole cause of the WCT population decline
Possible	Evidence is mixed or uncertain and suggests that the impact hypothesis could be the sole cause of the decline
Strong	Requisite conditions were met and evidence suggests that the impact hypothesis is likely the sole cause of the WCT population decline
Indeterminant	SME was unable to make any judgment about whether the impact hypothesis could be the sole cause of the WCT population decline, due to lack of relevant data and information

No impact hypotheses had strong evidence for being the sole cause and, therefore, every impact hypothesis was carried forward to determine its estimated contribution to the decline, as follows:

1. Estimated contribution to the 2017 to 2019 decline:

Negligible	Unlikely to contribute meaningfully to the decline
Minor	A small proportion of the decline is believed to be attributable to the impact hypothesis
Moderate	A moderate proportion of the decline is believed to be attributable to the impact hypothesis
Major	This impact hypothesis is believed to explain most of the decline

2. Confidence in estimated contribution to the 2017 to 2019 decline:

Low	Reducing uncertainty could change the results for estimated contribution to decline by two or three levels (e.g., “negligible” changing to “moderate or “major”)
Moderate	Reducing uncertainty could change the results for estimated contribution to the decline by one or possibly two levels
High	Reducing uncertainty is unlikely to change the results for estimated contribution to decline

The summary table (Table 7-1) considers information about the population decline from Chapter 4, as follows:

- First, any stressor or impact hypothesis that is specific to early life stages of WCT would not have been responsible for the observed declines in older age classes over such a short period[18] of time.

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[18] The juvenile (age 1+ to 3+) and adult population is made up of numerous year classes; therefore, any stressor that affected only young-of-the-year fish could not have led to the observed magnitude of decline over such a short period. See Chapter 4 for details.

- Second, the magnitude of the decline indicates that the spatial impact of contributing stressors and conditions was widespread.
- Finally, evidence suggests that the decline likely occurred after the 2018 spawn, most likely between July 2018 and spring 2019.

Based on the findings summarized in Table 7-1, there are no impact hypotheses for which there is strong evidence for sole cause of the decline and, consequently, the decline is likely a result of multiple stressors or conditions in the UFR. For most impact hypotheses, the estimated contribution to the decline was negligible or minor, but for a few impact hypotheses it was moderate. This was particularly so for hypotheses related to extreme cold and ice formation and to fish passage. It is difficult to account for all possible interactions among the many stressors and conditions, and the individual SME reports that provided the results in Chapter 7 were not designed to consider all possible interactions. Interactions are considered more explicitly in Chapter 8. For this reason, none of the stressors or impact hypotheses are completely ruled out in Chapter 7. The Evaluation of Cause Team decided this was appropriate, given there were no carcasses observed during February and March 2019, and, therefore, the cause of mortality could not be unequivocally determined.

The results in Table 7-1, together with our understanding of broad conditions in the UFR watershed summarized in Chapter 2, are considered in Chapter 8 to develop an integrated evaluation of the cause of the decline.

Table 7-1. Results of Subject Matter Expert reports by impact hypothesis.

Stressor Category	Stressor	Impact Hypothesis	Strength of Evidence that Hypothesis is Sole Cause of the Decline	Contribution to Decline	
				Estimated Contribution to Decline	Confidence in Estimated Contribution
	Climate and Hydrology (C&H)	Analysis of climate, streamflow and water use data was intended mainly to support evaluation of other stressors by identifying anomalies (i.e., notable departures from average conditions). Requisite conditions were therefore developed for the purpose of identifying anomalies, rather than for drawing conclusions on influence of the anomalies on specific stressors. In preceding chapters, Climate and Hydrology were described as C&H1. In Chapters 7 and 8, the focus is on the anomalies that were identified.			
Limitations on Fish Movement or Habitat Quantity	**Calcite (CAL)** (note: CAL1 – CAL4 are under Habitat Quality)	**CAL5:** Did overwinter fish mortalities increase because calcite accumulation reduced the amount of overwinter habitat?	Weak/None	Minor/Negligible	Moderate
	Stranding in Channels (CHN)	**CHN1:** Did fish mortalities increase because dewatering of natural and constructed channels caused stranding?	Weak/None	Moderate	Moderate
	Fish Passage (FP)	**FP1:** Did fish mortalities increase because low flows limited access to suitable overwintering habitats?	Weak/None	Moderate	Moderate
	Habitat Quantity (HAB)	**HAB1**: Did fish mortalities increase as a direct result of limited habitat availability, or because confinement increased exposure to an acute stressor?	Weak/None	Minor/Negligible	Moderate
	Extreme Cold and Ice (ICE) (note: ICE 1 & ICE3 are under Habitat Quality)	**ICE2**: Did fish mortalities increase because ice formation limited access to preferred overwintering habitat?	Possible	Moderate	Low
	Mainstem Dewatering Events (MST)	**MST1:** Did dewatering of UFR mainstem habitats cause or contribute to the observed WCT population decline?	Weak/None	Moderate	Low
	Ramping (RMP)	**RMP1:** Did fish mortalities increase because ramping caused stranding?	Weak/None	Minor/Negligible	High
Change in Aquatic Ecosystem Biology or Ecology	**Food Availability (FAV)**	**FAV1:** Did fish mortalities increase because food availability was reduced and caused starvation?	Weak/None	Negligible to Moderate	Moderate
		FAV2: Did fish mortalities increase because of a decrease in aquatic invertebrates?	Weak/None	Negligible	High
		FAV3: Did fish mortalities increase because of a decrease in terrestrial invertebrates?	Weak/None	Negligible	High
	Infectious Diseases (INF)	**INF1**: Did fish mortalities increase as a result of viral disease(s)?	Weak/None	Negligible	High
		INF2: Did fish mortalities increase as a result of bacterial disease(s)?	Weak/None	Minor/Negligible	Moderate
		INF3: Did fish mortalities increase as a result of oomycete disease(s)?	Weak/None	Minor/Negligible	Moderate
		INF4: Did fish mortalities increase as a result of parasitic Whirling Disease?	Weak/None	Negligible	High
		INF5: Did fish mortalities increase as a result of parasitic Proliferative Kidney Disease?	Weak/None	Negligible	High

Stressor Category	Stressor	Impact Hypothesis	Strength of Evidence that Hypothesis is Sole Cause of the Decline	Contribution to Decline	
				Estimated Contribution to Decline	Confidence in Estimated Contribution
	Predation (PRD)	**PRD1:** Did fish mortalities increase as a result of increased wildlife predation?	Indeterminant	Minor/negligible	Moderate
Change in Physico-Chemical Habitat Quality	**Calcite (CAL)** (note: CAL5 is under Habitat Quantity)	**CAL1:** Did recruitment decrease as a result of calcite effects on spawning success?	Weak/None	Minor/Negligible	High
		CAL2: Did fish mortalities increase due to calcite effects on food supply (invertebrate prey)? [see also FAV]	Weak/None	Minor/Negligible	High
		CAL3: Did fish mortalities increase as a result of increased exposure to cyanotoxins during biogenic calcite dissolution? [see also CTX2]	Weak/None	Minor/Negligible	Moderate
		CAL4: Did fish mortalities increase as a result of calcite effects on egg incubation?	Weak/None	Minor/Negligible	High
	Cyanotoxicity (CTX)	**CTX1:** Are cyanotoxins in the UFR at sufficient concentrations and for long enough to cause adverse effects to benthic invertebrates or mortality in juvenile and adult life stages of WCT?	Weak/None	Minor/Negligible	Moderate
		CTX2: Did fish mortalities increase because cyanotoxins stored in sediments and calcite was released during winter low flows?			
	Spills and Unauthorized Releases (DIS)	**DIS1:** Did fish mortalities increase due to unauthorized releases (e.g., spills)?	Weak/None	Minor/Negligible	Moderate to High
	Groundwater (GRW)	**GRW1**: Were there changes in upgradient groundwater flows that may have led changes to discharge areas, spatial distribution of surface water or its flows?	Weak	Minor	Moderate
		GRW2: Was there a change in upgradient groundwater quality that may have led to changes to hyporheic or surface water quality?	Weak	Minor	Moderate
	Extreme Cold and Ice (ICE) (note: ICE2 is under Habitat Quantity)	**ICE1:** Did fish mortalities increase as a result of freezing?	Possible	Moderate	Low
		ICE3: Did fish mortalities increase as a result of physiological stress from exposure to extreme cold and/or ice?	Possible	Moderate	Low
	Industrial Chemicals (IND)	**IND1:** Did fish mortalities increase due to exposure to industrial chemicals?	Weak/None	Negligible	Moderate to High
	Macrophytes and Bryophytes (MAC)	**MAC1:** Did fish mortalities increase due to ingestion of benthic invertebrates that accumulated metals biomagnified by macrophytes?	Weak/None	Negligible	Moderate
		MAC2: Did fish mortalities increase due to low oxygen stress associated with decomposing macrophytes and from the sediments they accumulated?	Indeterminant	Negligible to Moderate	Low
	Nutrient Enrichment (NUT)	**NUT1:** Did fish mortalities increase due to nutrient enrichment and consequent productivity changes?	Weak/None	Negligible	High
	Periphyton (PER)	**PER1:** Did filamentous algae blooms reduce hyporheic exchange, particularly during the decline window?	Weak/None	Minor/Negligible	Moderate
		PER2: Did filamentous algae blooms provide poor forage and degrade physical habitat for benthic invertebrates and WCT?	Weak/None	Minor/Negligible	Moderate
		PER3: Did restriction of hyporheic change by periphyton reduce habitat quality more than usual in the decline window?	Weak/None	Minor/Negligible	Moderate

Stressor Category	Stressor	Impact Hypothesis	Strength of Evidence that Hypothesis is Sole Cause of the Decline	Contribution to Decline	
				Estimated Contribution to Decline	Confidence in Estimated Contribution
		PER4: Did periphyton metal bioaccumulation and bacterially mediated processes increase metal concentrations in aquatic invertebrates?	Weak/None	Negligible	Moderate
		PER5: Did nitrogen transformations in the periphyton-influenced hyporheic zone affect UFR water quality and DO enough to have an impact on WCT?	Weak/None	Negligible	High
	Metals and Polycyclic Aromatic Hydrocarbons in Sediment (SED)	**SED1:** Were concentrations of metals and/or PAHs in sediment present during the decline window sufficient to result in adverse effects to WCT that could have caused or contributed to the population decline?	Weak/None	Negligible	High
	Unauthorized Sewage Discharge (SEW)	**SEW1:** Did fish mortalities increase due to unauthorized discharge(s) of sewage?	Weak/None	Negligible	High
	Total Suspended Solids (TSS)	**TSS1**: Did fish mortalities increase as a result of behavioural, physiological or habit effects from elevated levels of TSS?	Weak/None	Minor/Negligible	Moderate to High
	Water Quality (WQ)	**WQ1**: Did exposure to releases of mine-influenced water contribute to or cause fish mortality?	Weak/None	Negligible	Moderate to High
		WQ2: Did exposure to constituents in fish-accessible surface water contribute to or cause fish mortality?	Weak/None	Overall: Minor (Moderate in specific localized areas – see Water Quality sub-section, Section 7.2)	Moderate to High
Other Human Disturbances	**Fish Handling (HAN)**	**HAN1**: Did fish mortalities increase as a result of fish sampling?	Weak/None	Minor	High
		HAN2: Did fish mortalities increase as a result of fish salvage or relocation?	Weak/None	Minor	High
	Noise (NOI)	**NOI1:** Did fish mortalities increase as a result of direct exposure to noise?	Weak/None	Negligible	Moderate
		NOI2: Did fish mortalities increase as a result of indirect exposure to noise?	Weak/None	Negligible	Moderate
	Poaching (POA)	**POA1:** Did fish mortalities increase as a result of poaching?	Weak/None	Negligible	High

7.2. SUPPORTING DETAILS

This section summarizes supporting information for the findings in Table 7-1, and is organized by stressor. These summaries include an overview of methods, findings, life stages affected and consideration of interactions with other stressors. Additional detail is available in the Evaluation of Cause Framework table (Appendix B). The information is summarized by stressor in the alphabetical order used in Chapter 6. For ease of reference across text, tables and figures, stressor codes (in brackets) are used.

Climate and hydrology (C&H)

Note: Climate and hydrology have been considered differently from other stressors in the Evaluation of Cause, because analysis of climate, streamflow and water use data was intended mainly to support evaluation of other stressors, by identifying anomalies (i.e., notable departures from average conditions). Requisite conditions were therefore developed for the purpose of identifying anomalies, rather than for drawing conclusions on influence of the anomalies on specific stressors.

- **Findings.** Anomalous cold weather occurred in February and March 2019 and was flagged for special consideration in the individual stressor evaluations.
- **Life Stages.** Results are considered relevant to all life stages of WCT and any stressor that has potential to interact with climate and streamflow.
- **Interactions.** Climate and streamflow can influence many of the stressor pathways, so possible interactions with other stressors are numerous and were evaluated within the individual stressor evaluation reports, where relevant.

Calcite (CAL)

- **Methods.** Spatial and temporal trends were evaluated for five separate pathways of effect (spawning, incubation, juvenile overwintering, invertebrate food supply and cyanobacteria and cyanotoxins).
- **Findings.** Calcite index and concretion during the decline window were not markedly different from before the decline window, and they remained of relatively low intensity in WCT habitat. Evaluation of effects did not satisfy requisite conditions for sole contribution to the WCT decline and did not indicate a substantial contribution from any of the five pathways, although partial contribution could not be ruled out confidently.
- **Life Stages.** The evaluation considered pathways of relevance for juveniles, adults or both.

- **Interactions.** Potential interactions with other stressor pathways are thought to be minimal; thus, there was no need to invoke interactions with other stressors as part of the evaluation.

Stranding — Channels (CHN)

- **Methods.** Potential for fish to have been stranded was assessed for each tributary channel by examining presence of fish, quality of habitat, habitat stranding sensitivity, quantity of habitat (relative to available habitat in the UFR) and evidence of dewatering. A comparison was then made between results within the decline window vs. prior to it.
- **Findings.** There was evidence of dewatering in some areas, and stranding was documented within the decline window; however, dewatering occurred over a small area of total occupied habitat. Spatial and temporal trends of stranding in channels was therefore rejected as a sole cause of the decline. However, channel dewatering may have contributed to the WCT decline because dewatering was documented for channels that were accessible to fish and sensitive to stranding. Discontinuous water level data and limited temporal coverage mean that some anomalous events may have been missed.
- **Life Stages.** Separate analyses were not conducted for juvenile and adult life stages of WCT, but this stressor pathway is considered more applicable to juveniles. This is because juveniles are small and, relative to adults, tend to occupy habitats where stranding is more likely to occur.
- **Interactions.** Potential interactions with other stressor pathways are thought to be minimal.

Cyanobacteria and cyanotoxins (CTX)

- **Methods.** Fording River Operations data from earlier surveys and from winter 2020 samples were used, because data from FRO over the 2017–2019 period were not available to evaluate this impact hypothesis directly.
- **Findings.** Earlier work showed cyanobacteria were common before the decline window, and some taxa contributed to porous calcite-periphyton crusts (biogenic calcite). Based on the literature and on the experience of the SME, low flows in summer through fall favour cyanobacteria accumulation. Low flows in winter may allow invertebrates and WCT to be exposed to cyanotoxins during localized biogenic calcite dissolution concurrent with decomposition of periphyton mats. Also, low flow or other factors could prevent fish from moving to avoid cyanotoxins. See also CAL3. The strength of evidence that cyanotoxicity was the sole cause of the decline was classified as

weak/none. The estimated contribution to the decline was classified as minor/negligible, with moderate confidence.

- **Life Stages.** Cyanotoxins may affect overall fish health. Because early WCT life stages are more susceptible to cyanotoxins than older age classes are, cyanotoxicity would not account for the observed decline in WCT adults and is unlikely to have played an important contributing role.
- **Interactions.** Cyanotoxins could co-occur with ice-affected conditions, thereby creating a composite of undesirable winter conditions.

Spills and unauthorized releases (DIS)

- **Methods.** The evaluation of spills followed the two-step process used for industrial chemicals. First, a screening approach was used to identify spills that warranted further investigation. Second, for spills carried forward for further investigation, available information was summarized relevant to use, monitoring, transport, fate and the potential for acute or chronic effects. This information was used to evaluate the possibility that one or more spills may have contributed to or caused the decline.
- **Findings.**
  - Most recorded spills in the decline window were to ground surface, and the evidence shows that the spills had a negligible or low likelihood of reaching a watercourse where WCT could have been exposed.
  - Five spills were evaluated in detail because they involved a direct release to fish-accessible waters or waters with a surface connection to fish-accessible waters, or, in the case of the Maxam event (see Van Geest et al., 2021), because Teck Coal identified the event as an incident that merited more detailed assessment because it occurred during the decline window.
    - In three of the five spills (including the Maxam event), concentrations of relevant constituents in the spilled material were below relevant water quality guidelines or screening values for fish. These results indicate a negligible likelihood that the constituents contributed to the decline.
    - Two of the five spills could not be ruled out as contributors because relevant water chemistry samples were not collected. However, evidence for potential contribution was interpreted as weak because the spills occurred in the lower end of the watershed at GHO and at the end of the decline window, in August 2019. The role of these spills in the decline was interpreted as negligible to minor, with uncertainty dependent on the spilled material.
  - The strength of evidence that this stressor was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as

minor to negligible, with moderate confidence for the two spills that could not be ruled out as potential contributors and high confidence for all other spills.

- **Life stages.** The analysis did not separate different life stages of WCT, but findings are considered applicable to all life stages.
- **Interactions.** For spills to ground, there is potential for interactions with the groundwater pathway. For spills directly to fish-accessible waters or to waters with a surface connection to fish-accessible waters, there is potential for interactions with the surface water pathway (discussed further in the surface water quality section).

Food availability (FAV)

- **Methods**. Potential starvation of fish caused by a reduction in available food was evaluated using three data sets:
  - Body condition of juvenile and adult WCT during the decline window compared to previous years and compared to WCT from nearby watersheds
  - The abundance of total benthic invertebrates and specific dietary taxa during the decline window compared to previous years, and
  - Total undisturbed and riparian habitat within the watershed in 2019 compared to 2015, to indicate a potential change in terrestrial invertebrate inputs during the decline window.
- **Findings.** Aquatic and terrestrial food availability during the decline window was comparable to previous years. Juvenile WCT condition in August 2019 was comparable to observations in years prior to the decline window. Juvenile WCT condition data were spatially limited in late summer 2018, and they were very sparse for adult WCT during the whole decline window. The strength of evidence for food availability being the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as negligible to moderate, with moderate to high confidence.
- **Life Stages.** Diets of juveniles and adults strongly overlap, although adults can consume larger prey. Findings applied to both juvenile and adult life stages of WCT.
- **Interactions.** Despite adequate food availability, metabolic deficits can occur if the energy expended exceeds the energy assimilated from food and available as stored body fat. Potential interactions include any stressors that may have impaired the efficiency of acquiring/assimilating food or increased the energy expended during 2018 and the winter of 2019 (i.e., the portion of the decline window that has sparse fish condition data).

Fish passage (FP)

- **Methods.** The broader context of watershed development and effects on channel geomorphology are presented in Chapter 2. The fish passage analyses focused on potential restrictions to fish movement during the fall migration period, and they were evaluated in three ways:
    - Using the critical riffle analysis (CRA) method to determine likely passability of riffles during the fall migration period from 1997 to 2019.
    - Using passive integrated transponder (PIT) tag data to assess fish movements from 2017 to 2020 at PIT arrays at the multi-plate culvert and Henretta weirs.
    - Analyzing telemetry data to estimate the proportion of fish that could be affected by hypothetical barriers. Available data are only for fish > 200 mm.
- **Findings.** Results of the CRA indicated the potential for fish passage to have been impeded within the fall migration periods in both 2017 and 2018 within the decline window and, likely, in some years prior to the window. Data from PIT tags showed high activity levels in juveniles during August, indicating possible movements before the assumed fall migration period. These PIT tag data also indicated that the decline likely occurred during the second year of the decline window. The available telemetry data suggest that across all fish and all periods, the movement of ~25% of the fish population would have been restricted in some way, if the southern drying reach became and remained fully impassable (this percentage would have been lower if the barrier were seasonal). Therefore, up to 25% of the population could conceivably have interacted with a hypothetical barrier at either the southern drying reach or the multi-plate culvert. The strength of evidence for fish passage being the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as moderate, with moderate confidence.
- **Life Stages.**
    - The CRA method provided separate criteria and results for juveniles and adults; the results were considered most relevant for adults seeking to move to overwintering habitats.
    - Available PIT tag data are primarily for juveniles.
    - Available radiotelemetry data are only for fish > 200 mm. Broad movement and timing patterns, therefore, are well studied for adults but are not well known for juveniles.
- **Interactions.** Migration restrictions alone would not lead to mortality, so this stressor would need to interact with other stressors to cause or contribute to the population decline. Partial or complete restriction of fish passage was rejected as a sole or partial

direct cause of the decline, because interaction with other stressors is required to cause mortality. Results indicated restrictions to fish passage existed at some times and locations, and these may have contributed to the decline by restricting fish to non-preferred overwintering habitats. The interaction with extreme ice and cold (ICE) was emphasized in the stressor evaluations as especially important, although interactions with other stressor pathways may occur. A potential interaction was also identified with habitat rehabilitation construction activities that occurred in late summer and fall of 2018. Activities during construction may have influenced fish behaviour and fish migrations.

Groundwater (GRW)

- **Methods.** Conceptual Hydrogeological Models for the Segment S6 Study Area[19], Segment S8 Study Area and Segment S10 Study Area were developed based on existing information to assess potential hydrogeological stressors. Historical groundwater elevation and quality data were reviewed to understand whether any significant changes in the groundwater flow regime or groundwater quality could have contributed to surface water quantity or quality effects. Available groundwater data spanned 2012–2019 for the Segment S6 Study Area, 2017–2019 for the Segment S8 Study Area and 2015–2019 for the Segment S10 Study Area. For surface water, a larger data set was available, and a subset was selected for the analysis.
- **Findings.**
    - No anomalous changes were observed in upgradient groundwater flows during and before the decline window for the Segments S6 or S10 Study Areas. This indicates that downgradient surface water flows were not significantly altered by groundwater during the decline window. The dataset from monitoring wells in the Segment S8 Study Area was insufficient to determine whether conditions were unique to the decline window. However, the cumulative effects of water withdrawals and pit development on groundwater flows and downgradient surface water flows are a key uncertainty.
    - No anomalous changes were observed in upgradient groundwater quality during and before the decline window in the Segment S6 Study Area. This suggests downgradient surface water quality was not significantly altered by groundwater during the decline window. The conceptual model for the Segment S6 Study Area suggests there are some discharge zones where mine-influenced groundwater is locally affecting surface water quality during low flows; however, the water quality in these discharge zones is considered unlikely to have affected the WCT

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[19] Study Areas are as described in Henry and Humphries (2021).

population during the decline window. Although historical groundwater quality data in the Segment S8 Study Area were limited, surface water quality was not significantly altered by groundwater and, therefore, we inferred that it would not have affected surface water quality during the decline window. Similarly, at a broad scale, downgradient surface water quality in the Segment S10 Study Area was not significantly altered by groundwater that discharged to Henretta Lake during the decline window. However, the water quality at depth in Henretta Lake, where mine-influenced groundwater may be discharging, is a data gap.

  - Overall, the strength of evidence that groundwater was the sole cause of the decline was classified as weak/none and the estimated contribution to the decline was classified as minor/negligible, with high confidence.
- **Life Stages.** Relevant to all life stages.
- **Interactions.** Groundwater-surface water interactions are significant throughout the UFR. Where groundwater is recharged by infiltration of surface water, impacts may be exacerbated by changes in surface flows and water quality in these recharge areas; however, due to the longer time groundwater takes to travel and the dispersion/mixing that occurs in groundwater, these changes may be muted in downgradient surface water discharge areas.

Habitat availability (HAB)

- **Methods.** Availability of hydraulically suitable fish habitat was calculated by applying habitat-flow relationships (for overwintering, spawning and summer rearing periods) to hydrology records in the UFR. The ability to calculate habitat availability during some portions of the decline window is limited due to scarcity of flow data during winter.
- **Findings.** Habitat availability for overwintering and spawning during the decline window was similar to availability before the decline window. Availability of summer rearing habitat was slightly lower in the decline window, but it was not low enough to be considered a sole cause of the decline, and the estimated contribution to the decline was minor/negligible, with moderate confidence.
- **Life Stages.** Time series analysis was performed for juveniles and adult habitats during the summer rearing period (15 July through 30 September), for adults during the overwintering period (15 October through 31 March) and for adults during the spawning period (15 May through 15 July). Results did not indicate notable differences in habitat availability for the different life stages during and prior to the decline window.
- **Interactions.** Habitat availability could conceivably interact with other stressors and conditions (e.g., water quality, calcite, general population biology); however, the

observed effects seemed to be minor/negligible and, therefore, substantive interactions are not expected.

Fish handling (HAN)

- **Methods.** Korman and Branton (2021) refined the population mortality rate reported in Cope (2020b). Four adjustments were made in the calculations, including (1) per capita mortality rates specific to the type of handling were used to calculate mortalities; (2) mortality, which was calculated sequentially; (3) the population mortality rate, where revisions were made to how mortality rates were combined and how mortality related to salvage inefficiency was treated; and, (4) the proportion of population handled, which was calculated using handling and population data from the same year.
- **Findings.** The maximum population mortality rates calculated using the adjusted approach with paired data was 2.4% for 2017 and 6.5% for 2019 (Table 2 in Korman & Branton, 2021). The population mortality rate in 2018 was 3.0%, which was based on 2018 captures and 2017 abundance. For the population mortality rate for 2018, we used the 2017 rather than 2019 abundance, because there is evidence that the decline happened in the winter of 2018/2019. Considering the estimated mortality rate ranges from 6.5 to 13.8% (largely for juveniles, see below), fish handling would not be the sole cause of the WCT decline, but it could have made a minor contribution.
- **Life Stages.** Most of the fish handled during fish salvage and monitoring are juveniles, so any mortality associated with handling would not be expected to cause the significant decline observed in the adult population.
- **Interactions**. Fish may be more susceptible to handling-related effects if they are already affected by other stressors. This could lead to a higher-than-expected per capita mortality rate from handling and, therefore, to a greater effect on the population.

Extreme cold and ice (ICE)

- **Methods**. Possible effects to fish from ice and prolonged, extreme cold were considered. These included entombment in ice, either within the water column or within the substrate; exclusion or displacement from preferred overwintering habitats; and direct physiological effects from cold or frazil ice, such as injury, energy deficits or freezing of tissue.
- **Findings.**
  - Air and water temperatures shifted from abnormally warm in January 2019 to abnormally cold in February through early March 2019. The temperature shift occurred during a time with a below-average snowpack, and, therefore, only thin snow and ice cover was present to buffer swings in temperature. Water temperature

    and water level/discharge readings at multiple locations in the watershed indicate the occurrence of ice and ice jams in the system at the onset of the cold period. The findings indicate that ice formation may have been abnormally severe and may have occurred suddenly, possibly leading to changes in the amount and characteristics of overwintering habitats and changes in physiological stresses. Evidence from game cameras and anecdotal reports support this conclusion; however, it is difficult to determine to what degree WCT were affected by ice formation, because there were no direct observations of fish during this period.
  - Spatial and temporal trends in air and water temperatures met requisite conditions to attribute this stressor pathway as a substantive component of the decline, although it is unlikely to have been a sole cause.
- **Life Stages.** Juvenile and adult life stages of WCT were not considered separately in the analysis, but this stressor pathway is considered applicable to both.
- **Interactions.** Extreme cold and ice may interact with several other stressor pathways, but an interaction with fish passage (FP) was emphasized as especially important if fish were unable to reach appropriate shelter in deep habitat that was well-buffered against temperature swings and intrusion from surface ice or frazil ice. Such intrusions may occur even in deeper portions of the river, and may have been exacerbated by other conditions such as seasonal low flows. Factors that affect WCT physiological condition during winter cold periods, such as water quality issues, could also play a role.

Industrial chemicals (IND)

- **Methods.** The evaluation of industrial chemicals followed a two-step process. First, a screening approach was used to identify chemicals that warranted further investigation. This screening step considered exposure potential (the likelihood of WCT being exposure to each spill) and hazard (toxicity of a substance to rainbow trout, which was used as a surrogate for WCT). Exposure potential was rated according to available information on each industrial chemical’s intended or approved use, storage and potential release mechanism. Second, for chemicals carried forward for further investigation, available information was summarized relevant to use, monitoring, transport, fate and the potential for acute or chronic effects. This information was used to evaluate the possibility that one or more industrial chemicals may have contributed to or caused the decline.
- **Findings.**
  - All industrial chemicals (except methyl isobutyl carbinol [MIBC], kerosene, antiscalant and flocculant, which are discussed below) were used and stored in a manner that prevented them from being released to the environment (e.g., no

discharge to fish-accessible waters, secondary containment, stored far away from any watercourse), and no releases were documented. These chemicals had a negligible likelihood of reaching a watercourse where WCT could be exposed.

- Kerosene and MIBC used in coal processing are discharged in wet tailings slurry into tailings ponds, and release from the tailings ponds to the receiving environment would only occur if there was infiltration to downgradient watercourses. However, both chemicals are reported to be biodegradable, and sampling conducted at other mine operations measured relatively low concentrations of MIBC in source applications and did not detect concentrations of kerosene downstream of the source application. Taken together, the available information on persistence and monitoring data indicated that these chemicals had a low likelihood of reaching a watercourse where WCT could be exposed.
- Antiscalants and flocculants were evaluated in detail because their intended and approved uses result in their being directly released to creeks or settling ponds. As a result, there is a high likelihood of exposure for WCT under certain circumstances.
    - Concentrations of antiscalant were below acute and chronic toxicity values at GHO, and antiscalant was not used at FRO during the decline window. Therefore, antiscalant was not expected to have contributed to or caused the WCT population decline.
    - Maximum dosage concentrations of liquid flocculant and estimated concentrations dissolved from floc blocks used at FRO were less than acute toxicity values, except for those on April 30, 2018 when cationic liquid flocculant was dosed into a sedimentation pond at a concentration above the associated acute toxicity value. No acute toxicity was observed in water samples collected from the sediment pond discharge location during flocculant use, which confirmed the expectation of no acute toxicity. Therefore, flocculants were not expected to have caused acute effects to WCT.
    - It is unknown if flocculants may have contributed to chronic effects, because no chronic toxicity information is available for these products. However, concentrations of residual flocculant in the receiving environment are expected to have been low, if at all present, because of flocculant interaction with total suspended solids (TSS), settling in the ponds and subsequent dilution downstream.
- The strength of evidence that this stressor was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as negligible, with moderate confidence for flocculant, which could not be ruled out as

potential contributor, and high confidence for all other chemicals, including antiscalant.

- **Life stages.** Where information was available, the evaluation considered potential effects to early life stages (embryos and alevins) or to juveniles and adults, i.e., the evaluation considered life-stage-specific toxicity data and presence of life stages in the area and at the time the industrial chemicals were used.
- **Interactions.** Given that requisite conditions were not met for industrial chemicals to have contributed to the population decline — even though evidence is uncertain for flocculant because there are no chronic toxicity data — potential interactions with other stressor pathways are thought to be minimal. Antiscalant has a positive interaction with calcite by preventing further precipitation downstream from where it is applied. Flocculant has a positive interaction with TSS by enhancing settling in ponds.

Infectious disease (INF)

- **Methods.** As there were no dead fish to examine or necropsy reports to review, the assessment was based on a review of the literature of trout pathogens that have been reported to cause die-offs and population declines in wild fish. Specific etiologies were discussed, based on their being perceived as having the highest potential for being the sole cause, or a contributing cause, of the population decline. The pathology, clinical signs and epidemiology of the diseases were reviewed and then compared with what is known about the UFR WCT population and the population's decline. As well, five fish that died of entrapment during the spring of 2020 were necropsied to look for underlying disease.
- **Findings.** Infectious disease was not considered a likely sole cause of the population decline. No large die-off event was detected, and the decline was characterized not only by affecting predominately adult fish but also by the absence of typical clinical signs, seasonality, the age classes being affected and expected lesions. The strength of the evidence that infectious disease was the sole cause of the WCT decline was classified as weak/none. The estimated contribution to the decline was classified as negligible to minor, with moderate to high confidence.
- **Life stages.** Older age classes of fish are typically most resistant to infectious disease.
- **Interactions.** Infectious agents cannot be ruled out as the direct cause of some mortalities in circumstances where fish are immunosuppressed due to other stressors.

Macrophytes (MAC)

- **Methods.** Data from field notes and underwater videos were available, but macrophyte survey data were not available.

- **Findings.**
    - Macrophytes and bryophytes have redeveloped since the 2013 flood. Aquatic macrophytes benefit from and facilitate the deposition of fines in low flow reaches.
    - Macrophyte decomposition could only affect dissolved oxygen regimes when stable low flows in summer and fall are followed by an extremely cold winter that interrupts oxygen influxes. The strength of evidence that macrophytes were the sole cause of the WCT decline via low oxygen stress associated with decomposition was classified as indeterminant due to data limitations, and the estimated contribution to the decline was negligible to moderate with low confidence.
    - Macrophytes interact with sediment constituents; however, there was no evidence of increased WCT exposure to constituents of concern via food during the decline window. The strength of evidence that macrophytes were the sole cause of the WCT decline via sediment constituents in the food chain was classified as weak/none, and the estimate contribution to the decline was negligible.
- **Life Stages.** Fluctuating levels of dissolved oxygen in depositional areas during winter low flows could affect overwintering juvenile and adult WCT.
- **Interactions.** A composite of extreme cold winter conditions in 2019 and organic decomposition may have reduced dissolved oxygen below the tolerance of overwintering WCT in low flow portions of lower Segment S6 (See Appendix D). Without the extreme cold winter, macrophyte decomposition alone could not instigate low dissolved oxygen conditions.

Stranding — Mainstem dewatering events (MST)

- **Methods.** This analysis addressed risks to fish from dewatering in the UFR mainstem and side channels that are not directly influenced by mine operations. A literature review was completed to provide general context, and available observations of drying and stranding were compiled. There are good estimates of the physical extent and timing of drying within the decline window (but not prior to it), and there are direct observations of stranding mortality. However, we have only indirect estimates of the total number of fish stranded. Seasonal declines in water level from the spring spawning period to the end of the incubation period were assessed to estimate potential for redd dewatering.
- **Findings.** Stranding mortality caused by drying is an ongoing seasonal influence in the UFR, as it is in other streams with drying reaches. Seasonal dewatering in the drying

reaches can cause stranding of fish and can lead to some mortalities, particularly when drying occurs earlier in the year than usual. Nevertheless, dewatering in the UFR mainstem did not satisfy a key, requisite condition for the spatial extent of the dewatering, and dewatering is therefore unlikely to have been the primary cause of the WCT population decline. Since dewatering occurred during the WCT summer rearing period in 2018, it is possible that stranding mortality from drying was greater during that period and, therefore, contributed to the WCT decline for both adults and juveniles. Potential for redd dewatering was present, but this effect was found to be fairly consistent among years and did not explain the decline.

- **Life Stages.** Juveniles are typically more sensitive to stranding from dewatering events than adults, because they tend to occupy shallow habitats that are more likely to dewater as flows recede. Higher sensitivity of juveniles is consistent with observations in the UFR of stranding occurring more often with juveniles than adults.
- **Interactions.** Drying may also influence fish migration, and this effect is assessed under fish passage (FP), where it is noted that effects on fish distribution may influence their exposure to other stressors.

Noise (NOI)

- **Methods.** The records of mine-related blasting were reviewed to determine its proximity to the UFR and the size and frequencies of the blasts. In addition, relevant literature on the effects on fish of noise and shock waves, transmitted in ground, air and water, were reviewed.
- **Findings.** Using data provided by Teck Coal on charge size and the Canadian guideline of an overpressure threshold of 100 kPa to prevent swim bladder damage, the minimum setback from the river was determined to be 123 m. The minimum distance of mine-related blasting to the UFR was 400 m, and most of the detonation occurred at much larger distances, up to 4 km. Relative to before the decline window, there were no changes to blasting location and occurrence. The strength of evidence that noise was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as negligible, with moderate to high confidence.
- **Life stages.** All life stages could potentially be affected by noise or shock waves.
- **Interactions.** No interactions of noise with other stressors were considered likely. Fish avoiding areas or changing behaviour in other ways due to sublethal shock waves and noise has been reported in the literature, but there is no direct evidence this occurs on the UFR. Noise is, therefore, not considered to be an indirect contributor to the population decline.

Nutrient enrichment (NUT)

- **Methods.** Total phosphorus (TP) was compared to trophic status categories and to screening values for assessing productivity.
- **Findings.** Trophic status was similar to or lower than previous conditions, except for one station (Fording River mainstem station LC_FRUS in 2019). Data for TP and site-specific relationships between TP and productivity indicated little to no evidence of nutrient enrichment effects. Nutrient enrichment did not meet the requisite conditions to contribute to or cause the WCT decline. The strength of evidence that this stressor was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as negligible with high confidence.
- **Life stages.** The analysis did not separate the different life stages of WCT, but the findings are considered relevant to all life stages.
- **Interactions.** Given that requisite conditions were not met for nutrient enrichment to have contributed to the decline, potential interactions with other stressor pathways are thought to be minimal.

Periphyton (PER)

- **Methods.** Data to evaluate periphyton and its potential effects during the decline window were not available. Instead, data from surveys in 2015 and 2013 were augmented by winter 2020 samples.
- **Findings.** Fine sediments and calcite particles trapped by periphyton can affect benthic invertebrate foraging. However, invertebrate densities showed little change during the decline window compared to previous years (see FAV: Food Availability). *Didymosphenia geminata* (Didymo) was detected in 2013 and 2015 periphyton surveys. Dense Didymo mats developed in at least one location of UFR mainstem in fall 2019, likely triggered by stable low flows with low TSS. Low summer/fall flows also occurred in the 2018 growing season, suggesting Didymo growth may also have been significant then. Fall flushing flows did not occur in 2018, so periphyton material that built up over the preceding growing season would have decayed over the winter. Organic decay is known to increase oxygen demand, lower hyporheic exchange and alter redox conditions in slow-flowing areas. Overall, the strength of evidence that periphyton was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as negligible to minor, with moderate confidence.
- **Life Stages.** Periphyton decomposition in depositional areas could contribute to biochemical oxygen demand and potentially affect overwintering juvenile and adult WCT.

- **Interactions.** Depending on their intensity, changes in dissolved oxygen and water chemistry instigated by periphyton decay can collectively apply stress to overwintering WCT during periods of severe winter conditions.

Poaching (POA)

- **Methods.** Information was compiled and reviewed. It included:
    - Enquiries with Teck personnel and contractors who may be aware of poaching activities poaching
    - A review of Teck Coal's trail camera data for evidence of poaching activities
    - Enquiries with the British Columbia Conservation Officer Services (BCCOS) on documented poaching violations
    - Literature reviews of fish studies completed on the UFR to better understand historic fish occurrence and distribution, along with anecdotal evidence of illegal fishing activity along the UFR, and
    - A review of fish capture methods that may be used in poaching activities and an evaluation of the plausibility that they could be used to explain the UFR fish population decline.
- **Findings.** Limited information was found on anecdotal occurrences of illegal fishing activities; the BCCOS did not have any documented violations during the decline window. Historic fish congregations occurred on portions of the UFR that are proximate to mine properties, which should prevent public access to these areas, thereby preventing poaching activities. The plausibility that either angling or gill netting could explain the UFR population decline was refuted.
- **Life Stages.** Adult and juvenile fish are potentially impacted by poaching activities.
- **Interactions.** Poaching activities may interact with other stressors that could cause fish to congregate in areas that may be accessible for poaching by the general public. However, there is insufficient evidence that poaching activity during the decline window was a contributor to the overall UFR fish population decline, and the estimated contribution to the decline was classified as negligible.

Predation (PRD)

- **Methods.** Two representative wildlife predators were selected, river otter and American mink. Data queries from both Teck Coal and government databases were made for the occurrence and distribution of predator species. Information reviewed included: literature reviews that summarized predator ecology, a theoretical feed consumption calculation to demonstrate potential foraging impacts by predators, discussions with other Subject Matter Experts on predator ecology and foraging behaviour and a winter track survey to better understand predator species occurrence and distribution along the UFR during the winter period.

- **Findings.** Both river otter and mink occur in the UFR. River otter is considered to be a specialist predator (foraging on fish), while American mink is a generalist predator. Theoretical feed consumption calculations identified that river otter can potentially impact the UFR fish population based on their foraging ecology, and based on various assumptions, while American mink likely do not have a profound effect on a fish population based on their foraging ecology. However, there is no empirical evidence on predator abundance and occupancy rates in the UFR during the decline window, thereby creating a high level of uncertainty that predation by river otter could have caused the fish population decline. The lack of understanding of predator abundance and occupancy rates makes the impact hypothesis that predators caused the UFR population decline indeterminant. The estimated contribution of predation to the decline was classified as minor/negligible, with moderate confidence. This is further supported by literature on river otter foraging ecology. River otter and other wildlife predators were known to occur in the UFR prior to the decline window, and their measured overall mortality rate on fish due to predation ranged from 9%–14%; there is no empirical evidence to suggest the annual predation rate increased 6–10 times during the decline window.
- **Life Stages.** Wildlife predation has the potential to impact all life stages of the WCT population. The representative wildlife predators selected are known to prey on both adult and juvenile fish.
- **Interactions.** Wildlife predation could interact with other stressors to impact fish. Wildlife predators could perform a targeted predation event on fish with decreased fitness caused by natural causes (e.g., spawning event, overwintering period), by being trapped by a barrier to fish passage, or by another stressor event that makes fish more susceptible to predation. For a predation event to occur, fish would likely need to be congregated and unable to avoid a predator or escape from them.

Stranding — Ramping (RMP)

- **Methods.** Ramping rates were examined at hydrometric gauges and temporary water level loggers that were installed in the UFR to support ongoing instream flow and ramping studies. The frequency, magnitude, wetted history and distribution of ramping events that exceeded generic criteria of -2.5 cm/h (fry-present) and -5.0 cm/h (fry-not-present) were used to assess the potential effect.
- **Findings.** Few ramping events exceeded the established criteria, and they were all assessed to result in low stranding risk to fish. According to those criteria, ramping

would not have caused sufficient mortality to be the single cause of the decline or even to have been a substantive contributing factor.

- **Life Stages.** Juveniles are typically more sensitive to stranding from ramping events than adults, because they tend to occupy shallow habitats that are more likely to dewater as flows recede. Criteria were evaluated separately for the fry-present period and the fry-not-present period. Results did not indicate a substantive effect for either life stage.
- **Interactions.** Interactions with other stressors are unlikely.

Metals and PAHs in sediment (SED)

- **Methods.** Sediment quality was evaluated using three methods: (1) screening metal and polycyclic aromatic hydrocarbon (PAH) concentrations against sediment quality guidelines (SQGs) to conservatively assess potential for sediment toxicity, (2) comparing concentrations of metals and PAHs between the historical and the decline window time periods and, (3) assessing the spatial distribution of exceedances of SQGs and/or historical concentrations of constituents in sediment during the decline window. These three lines of evidence were used together to identify constituents of concern that were then assessed in more detail with respect to their bioavailability and the nature of potential adverse effects associated with metals and PAHs.
- **Findings.** Site-specific sediment data indicate changes in sediment quality in the middle and lower reaches of the UFR. Site-specific studies and published literature indicate that the bioavailability of metals and PAHs from sediment in the UFR is limited. Low bioavailability suggests that aquatic organisms' exposure to metals and PAHs in sediment is low relative to the bulk sediment concentrations measured and, in turn, the potential for adverse effects indicated by SQGs exceedances may be lower than indicated by the SQG screen. It is not possible to preclude the possibility that sublethal effects could have occurred in the UFR where constituent concentrations were both elevated in sediment and bioavailable. However, even though those effects, such as reduced energetic fitness or developmental abnormalities, may cause individual mortalities, particularly in early life stages, they would be unlikely to cause the population level mortality of juveniles and adults observed in the population decline. Overall, the strength of evidence that metals or PAHs in sediment were the sole cause of the decline was classified as weak/none, and the estimated contribution to the WCT decline was classified as negligible, with high confidence.
- **Life Stages.** Early life stages are more sensitive to toxicity from metals and PAHs than adults.

- **Interactions.** If there were sublethal effects from metals and PAHs that reduced individual fitness, they could have made WCT more susceptible to other stressors.

Total suspended solids (TSS)

- **Methods.** Records of TSS from routine and event-based sampling in the UFR since 2012 were analyzed for all life stages using the severity of ill effects (SEV) models. Spatial and temporal data coverage was, however, discontinuous, which means that some anomalous TSS events may have been missed.
- **Findings.** Results of SEV models for the decline window were similar to or better than results before the decline window. Thus, requisite conditions for TSS being the sole cause were not satisfied; however, some effects were noted within and prior to the decline window, so contribution to the decline was not ruled out, and the estimated contribution to the decline was classified as minor/negligible, with moderate to high confidence.
- **Life Stages.** The SEV models for eggs/alevins, juveniles and adults used in the assessment showed that earlier life stages are more sensitive to TSS. Results did not indicate a differential effect by life stage with respect to meeting the requisite conditions or concluding there was an overall effect on the decline.
- **Interactions.** Interactions with other stressors are possible if physiological harm makes individuals more susceptible to other stressors. However, such interactions could not be evaluated.

Water quality (WQ)

- **Methods.** The assessment considered existing surface water quality data in combination with tissue chemistry and acute and chronic toxicity testing data to characterize the conditions to which WCT were exposed in the decline window and how these may have changed relative to prior conditions. These site-specific data were interpreted within the context of relevant and reliable toxicology information, and they were combined with available information on WCT movement and habitat use in the UFR watershed. The magnitude of potential chronic effects was characterized as:
  - Negligible potential for effects to aquatic life (below water quality guidelines)
  - No chronic effects to fish (below level 1 screening values)
  - Potential low-level effects (between level 1 and level 2 screening values)
  - Potential moderate-level effects (between level 2 and level 3 screening values), or
  - Potential high-level effects (above level 3 screening values)
- **Findings.**

- *Acute effects:* Water quality data and acute toxicity testing with rainbow trout provided little to no indication of potential acute effects to WCT. Potential acute effects of low dissolved oxygen were identified for one sample from Turn Creek (November 2018), one sample from Fording River station FR_FRCP1 (December 2018) and three samples from Fording River station RG_UFR1 upstream of mining (February 2019). In these five samples, potential acute effects of dissolved oxygen met the requisite conditions to contribute to the WCT decline via effects to juveniles and adults but did not meet the requisite conditions to be the sole cause. For early life stages (embryos and alevins), which are present from mid-May to late August, the effects did not meet the requisite conditions to contribute to the decline.
- *Chronic effects:* Seven constituents were identified as potential chronic stressors in one or more samples collected during the decline window: nitrate, selenium, sulphate, TDS, nitrite, lithium and dissolved oxygen.
    - Water quality in most areas indicated either no chronic effects (although there may be different constituents in different seasons) or the potential for up to low-level effects of a single constituent possibly contributing to the WCT decline. These same areas had some of the greatest recorded use by fish in each season (65 to 97%).
    - In other, localized, areas, notably some mine-affected tributaries and Fording River mainstem station FR_FRCP1 in fall and winter, water quality indicated potential for up to high-level effects of multiple constituents. At FR_FRCP1 this was supported by chronic toxicity test results for early life stages of fish. The available information from telemetry studies and the localized spatial extent of these areas generally indicated that a small proportion of the population could have overlapped with these conditions (see Section 8.5.3).
    - Chronic effects of water quality met the requisite conditions to contribute to the WCT decline via potential effects to all life stages but not to be the sole cause.
- For releases of mine-influenced water (WQ1), the strength of evidence that water quality was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as negligible with moderate to high confidence.
- For fish-accessible waters (WQ2), the strength of evidence that water quality was the sole cause of the decline was classified as weak/none. The estimated contribution to the decline was classified as minor in most areas and seasons, and moderate under localized conditions, especially in winter. Uncertainty for the moderate rating is associated with the proportion of fish that were exposed to

FR_FRCP1 conditions (see Section 8.5.3). A confidence rating of moderate to high was applied.

- **Life stages.** Where information was available, as described in the preceding bullets, the evaluation considered potential effects to early life stages (embryos and alevins) and to juveniles and adults.
- **Interactions.** Potential interactions among constituents measured for the water quality assessment and other stressor pathways are discussed below. They are discussed from a qualitative perspective because most combinations of stressors lack site-specific or literature data that would be needed to conduct a quantitative assessment. Interactions that could be negative (net increase in stress) are emphasized, although examples of interactions that could be positive (net decrease in stress) are also provided.
  - In the surface water quality report, qualitative consideration was given to the number of constituents with concentrations above screening values and to the potential for those constituents to interact.
    - Combined effects of constituents are not expected for most locations and seasons. The potential for combined effects was identified most commonly in mine-affected tributaries (all life stages), with occasional occurrences at mainstem stations for juveniles and adults (FR_FRCP1 in winter 2017 and 2018) and early life stages (FR_FRCP1 in summer-fall 2018 and FR_FRACBH in summer-fall 2017).
    - Of the constituents identified as potential chronic stressors, dissolved oxygen was identified as a constituent that could result in enhanced effects if fish were exposed to both low oxygen concentrations and other water quality stressors. This is because, when fish are exposed to low oxygen, they increase their respiration rate, and this is expected to increase uptake of ions across their gills.
  - An interaction between water quality and fish passage (FP) was emphasized in the water quality report as potentially important if migrating fish were trapped near mainstem station FR_FRCP1 when water quality indicated a potential for high-level effects. However, there may be interactions with several other stressor pathways (see following bullets).
  - There may be interactions between water quality and temperature. Interactions could be negative (net increase in stress) or positive (net decrease in stress) depending on the water quality constituent and the direction of temperature change (becoming warmer or colder). One example is ammonia toxicity, which decreases as temperature decreases. Another is the inverse relationship between the amount of oxygen that can be dissolved in water and temperature, which makes hypoxia more common in the summer (see Bollinger, 2021a, for more details).

- Laboratory studies indicate that excess dietary and bioaccumulated selenium can affect energy metabolism, behaviour and neuromuscular systems across all life stages of fish. Because implications for fish survival in the wild, in the context of other stressors, are not well studied (Bollinger, 2021a), potential effects cannot be ruled out. Potential interactions of selenium with other conditions such as low dissolved oxygen or low temperatures during the decline window are discussed in Section 8.7.
- There may be interactions between water quality and spills. The extent to which spills could increase surface water concentrations depends on the nature of the spill (e.g., volume, whether the spill is on ground or to surface water, distance to fish-accessible waters) and the properties of the spilled material (e.g., biodegradation, mobility). The interaction between water quality and spills is expected to be most relevant for the spills to fish-accessible surface waters or to waters with a surface connection to fish-accessible waters[20]. To the extent that water chemistry samples were collected at times and locations relevant to spills, this information was assessed in the spills report (Van Geest et al., 2021) and/or the surface water quality report (Costa & de Bruyn, 2021).

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[20] As discussed in Van Geest et al. (2021), most recorded spills in the decline window were to ground surface, several hundred metres from the nearest watercourse, and they were contained or cleaned up, which limited the time the spill had to potentially penetrate the ground surface. This, in addition to available information on mobility and degradation of the spilled materials, indicated that most spills had a negligible or low likelihood of reaching a watercourse where WCT could have been exposed. For these spills, interactions are interpreted to be unlikely.

8. Integrated Findings

8.1. INTRODUCTION

This chapter draws on results for individual impact hypotheses in the previous chapter and integrates the findings to identify the most likely contributors to the observed decline in the WCT population during the decline window. The decline in WCT appears to have been caused by extreme winter conditions and associated ice formation, combined with natural conditions and ongoing effects of development in the UFR. In this chapter we propose an integrated hypothesis that identifies the most likely combination of stressors and conditions that led to the decline.

To integrate the findings of the individual impact hypotheses with the broader context of conditions in the watershed, three periods are distinguished:

- Pre-development (before 1950s)
- Development period (after 1950s)
- Decline window (September 2017 to September 2019)

Conditions in the pre-development period are reviewed primarily in Chapter 2 (environmental setting and habitat) and Chapter 3 (WCT in the UFR). Stressors associated with development activities in the watershed before and during the decline window have been evaluated in the supporting SME reports (Appendix A), and results of those evaluations are summarized in Chapter 7. Evaluating individual impact hypotheses relied partly on considering whether a particular stressor could have affected one or more life stages of WCT at the right time and at the required spatial scale to have contributed to the observed decline. Key results regarding the life stages, timing and spatial scale of the decline are as follows (from Chapter 4):

- **Life stages.** The observed decline occurred in both adults and juveniles, although confidence about the magnitude of decline is lower for juveniles. Analyses of population monitoring results suggest that the observed decline in adults was not caused by lower survival rates for juveniles, and that the observed decline in juveniles was not caused by lower abundance of spawners associated with elevated mortality of adults. As such, it is most likely that both life stages were affected directly. This finding may suggest that the same stressors affected both juveniles and adults directly; nevertheless, it is possible that individual stressors acted more on one life stage than another.

- **Timing.** The decline in adults and juveniles most likely occurred in the second year of the decline window (2018–2019) rather than the first, most likely the winter of 2018/2019.
- **Spatial patterns.** Although the distribution of fish during winter 2018/2019 is uncertain, the magnitude of the decline indicates that the spatial impact of the contributing stressors and conditions was widespread. The greatest declines in abundance appear to have occurred in Segments S7 to S9 (segments most impacted by land use within Fording River Operations (FRO) property) and Segments S5 to S6 (immediately downstream of FRO).

Given this understanding of the decline, stressors of particular interest in the Evaluation of Cause are those that may have impacted adults and juveniles in the winter of 2018/2019 across most or all of the UFR.

This chapter is structured as follows:

- Section 8.2 provides a brief overview of the integrated hypothesis for the decline. It focuses on the stressors and conditions believed to have been most influential in the decline, while acknowledging the potential contributions of several others.
- Section 8.3 reviews the intrinsic conditions in the watershed prior to development in the area, with focus on conditions believed to have had most influence on the decline.
- Section 8.4 reviews changes in the watershed that occurred during development in the area, with focus on changes believed to have had most influence on the decline.
- Section 8.5 reviews the conditions and events that were anomalous or notable during the decline window.
- Section 8.6 details the integrated hypothesis for the decline and expands on the overview provided in Section 8.2.

A great deal of information and data have been used to evaluate the individual impact hypotheses and to build the integrated hypothesis for the decline. Considering all available information about the decline and the potential stressors, the Evaluation of Cause Team believes that the integrated hypothesis presented here is the most likely explanation for the decline, while acknowledging there are insufficient data to draw highly confident conclusions.

8.2. OVERVIEW: AN INTEGRATED HYPOTHESIS FOR THE DECLINE

The Evaluation of Cause Team hypothesizes that the decline in abundance of WCT during winter 2018/2019 was caused by extreme winter conditions in 2019 associated with ice formation, natural conditions in the watershed, and ongoing effects of development in the

UFR. Although all segments appear to have experienced substantial losses, the decline appears to have been most severe in Segments S5 through S9, within and immediately downstream of FRO property. The core hypothesis is described below.

8.2.1. Overwintering Migration (Fish Passage)

Fish are believed to have experienced challenges migrating to overwintering areas before winter 2018/2019. Overwintering areas are sparse in the UFR and they are spatially separate from some summer rearing areas. Abundance and distribution of overwintering areas, as well as access to them, have been affected by channel widening and aggradation, by water use and by loss of tributary habitats, particularly in Segments S7 to S9 where mining-related changes to the stream channel have been most pronounced. In essence, mining development has made passage to overwintering areas more challenging for fish.

Specific to the decline window, flows were low in late summer 2018, which, combined with water use and earlier drying in the drying reaches, likely made the fish's passage to their preferred overwintering areas more challenging than usual. These challenges may have occurred at multiple locations and may have influenced a substantial portion of the population. For example, the available telemetry data across all fish and all periods suggest that the movement of up to 25% of the population may have been restricted in some way if the southern drying reach became and remained fully impassable. If the barrier was intermittent, the percentage of affected fish would have been lower. However, the actual number of fish affected and the outcome of this interaction are unknown.

8.2.2. Winter Conditions and Low Flows

Extreme cold air temperatures in February through early March 2019, combined with warm preceding conditions, a lower than normal snowpack and seasonal low flows in winter, led to extreme ice conditions. The extreme weather occurred throughout the UFR, but its effects would have varied spatially depending on river width and depth and ice formation processes specific to the site. Nonetheless, data show that ice formed abundantly throughout the UFR. Fish that were confined to relatively shallow overwintering habitats in winter 2018/2019 would likely have been more susceptible to the potential, direct and indirect effects of ice and low flows than fish that occupied deeper, low velocity water. However, even fish that successfully reached preferred, deeper, overwintering lotic areas may have been displaced, because low flows and ice reduced the amount of usable habitat and, in doing so, concentrated the fish in smaller volumes of water. Water use may have exacerbated these conditions.

8.2.3. Potential Mechanisms of Mortality

Considering the combined effect of the challenges the fish experienced with overwintering migration, extreme winter conditions and low winter flows, mortality could have occurred in several ways. Ice could have caused mortality directly by entombing the fish, or by injuring or suffocating them due to frazil ice forming. These ice effects would have been more likely to affect fish that were unable to reach preferred, deeper overwintering areas. In addition, other related causes or contributors are possible, either alone or in combination. These include:

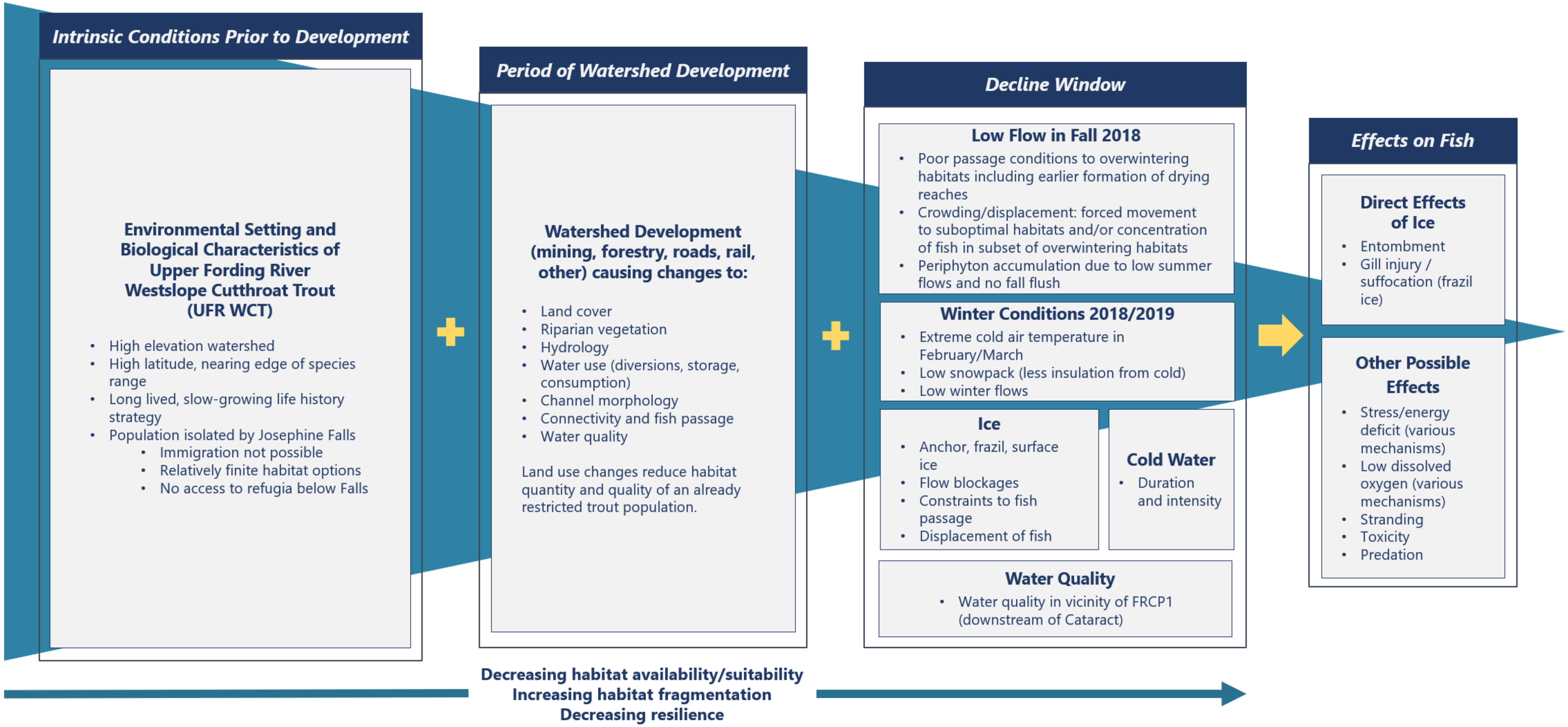
- Fish stress and energy deficits associated with winter conditions and the preceding fall migration.
    - Examples of stress and energy deficits associated with winter conditions include cold, movements to avoid ice conditions, crowding due to ice conditions, or challenges in accessing food.
    - Examples of stress and energy deficits associated with the preceding fall migration include higher energy demands associated with challenges in accessing overwintering areas, or reduced foraging time or efficiency, resulting in lower energy storage going into winter.
- Shortages of dissolved oxygen due to flow blockages or other mechanisms
- Stranding
- Ongoing stress attributed to mining-related water quality constituents, and
- Predation

The stressors and conditions underlying the integrated hypothesis could affect both adults and juvenile fish; however, the magnitude of mortality for different life stages would likely differ.

8.2.4. Relative Contribution of Stressors and Conditions to the Fish Decline

It is difficult to characterize the relative contributions of various stressors and conditions to the decline in isolation because the stressors and conditions are interdependent. The Evaluation of Cause Team believes that of all the stressors, the extreme winter (cold/ice) was the most unique element during the decline window compared to previous years. However, it is not possible to estimate the effect of the extreme winter alone, because its effect depended on interactions with other stressors.

Natural and anthropogenic conditions and stressors are likely to affect resilience of the UFR population (see Chapter 3), including its ability to resist disturbance of any kind. Important conditions and stressors that were present prior to and during development in the area, as well as the notable changes and events during the decline window, are summarized in Figure 8-1 and discussed in the following sections.



Intrinsic Conditions Prior to Development

Environmental Setting and Biological Characteristics of Upper Fording River Westslope Cutthroat Trout (UFR WCT)

- High elevation watershed
- High latitude, nearing edge of species range
- Long lived, slow-growing life history strategy
- Population isolated by Josephine Falls
    - Immigration not possible
    - Relatively finite habitat options
    - No access to refugia below Falls

+

Period of Watershed Development

Watershed Development (mining, forestry, roads, rail, other) causing changes to:

- Land cover
- Riparian vegetation
- Hydrology
- Water use (diversions, storage, consumption)
- Channel morphology
- Connectivity and fish passage
- Water quality

Land use changes reduce habitat quantity and quality of an already restricted trout population.

+

Decline Window

Low Flow in Fall 2018

- Poor passage conditions to overwintering habitats including earlier formation of drying reaches
- Crowding/displacement: forced movement to suboptimal habitats and/or concentration of fish in subset of overwintering habitats
- Periphyton accumulation due to low summer flows and no fall flush

Winter Conditions 2018/2019

- Extreme cold air temperature in February/March
- Low snowpack (less insulation from cold)
- Low winter flows

Ice

- Anchor, frazil, surface ice
- Flow blockages
- Constraints to fish passage
- Displacement of fish

Cold Water

- Duration and intensity

Water Quality

- Water quality in vicinity of FRCP1 (downstream of Cataract)

Effects on Fish

Direct Effects of Ice

- Entombment
- Gill injury / suffocation (frazil ice)

Other Possible Effects

- Stress/energy deficit (various mechanisms)
- Low dissolved oxygen (various mechanisms)
- Stranding
- Toxicity
- Predation

Decreasing habitat availability/suitability
Increasing habitat fragmentation
Decreasing resilience

Figure 8-1. Stressors and conditions present in the upper Fording River prior to development, during development and specific to the decline window that are believed to have contributed to the observed decline in abundance of Westslope Cutthroat Trout in the upper Fording River.

8.3. INTRINSIC CONDITIONS IN THE UFR PRIOR TO DEVELOPMENT

When considering the decline, several characteristics of the upper Fording watershed and the WCT population are relevant.

Edge of range. The WCT population in the UFR is near the edge of its latitudinal and elevational range. While acknowledging that post-glacial dispersal barriers also influenced current distribution, the fact that few WCT populations occur farther north suggests the UFR is near where habitat transitions from being suitable for supporting WCT populations in the long term to habitats that are less suitable.

The UFR watershed is at high elevation, > 1,400 m above sea level. This is an environment with low nutrient concentrations (Minnow Environmental Inc., 2020), habitat limitations (e.g., ephemeral, or temporary conditions) and short growing seasons that may limit fish productivity (i.e., growth rate), like neighbouring systems. Robinson (2007) showed an inverse relationship between WCT growth rate (productivity) and elevation in the neighbouring system in Oldman River, AB. However, fish productivity and density are not fully comparable because systems with lower productivity can still have high fish densities, as seen in some UFR sites. Westslope Cutthroat Trout are adapted to cold, unproductive environments and have a long-lived, slow-growing life history strategy, as described in Chapter 3, (Behnke, 1992; McPhail, 2007). Nonetheless, even though WCT are adapted to local conditions in the Elk River watershed, conditions may occur in relatively small streams in the UFR watershed that are near or beyond an individual fish’s tolerances, affecting its physiological performance (e.g., growth, fecundity and survival) and potentially affecting the population’s abundance and distribution. The geographic limits of a species are typically marked by conditions approaching the limits of suitability, although other ecological interactions, especially inter-specific competition (competition among species), play an important role in species distributions.

Restricted distribution. The UFR population is isolated by Josephine Falls, which prevents other fish from immigrating. The population’s distribution is therefore restricted. This makes the population vulnerable, because small, isolated populations are inherently at risk of extirpation (becoming locally extinct) as a result of fluctuations in abundance, lack of rescue (immigration) from adjacent populations and potential loss of genetic diversity over the long term (Frankham, 1995; McElhany et al., 2000; Reed et al., 2003; COSEWIC, 2019).

Josephine Falls restricts the distribution of the UFR population to a relatively small area (~55 km of mainstem) compared to other notable WCT populations in the upper Kootenay River sub-basin. This not only restricts distribution but also limits availability of suitable habitats for the population. For example, fish that seek habitats for a specific purpose (say rearing or refuge) have limited options, which means that negative effects from either local or regional influences may affect a larger portion of the population than would be the case in a population that occupies a larger area.

Overwintering habitat. Overwintering habitat appears to be particularly limiting in the UFR. Several overwintering locations that support approximately 90% of the overwintering population were identified by Cope et al. (2016): Henretta Pit Lake (62.9 rkm), Clode Flats (58.4 rkm to 61.6 rkm), the multi-plate culvert plunge pool (57.5 rkm), the S6 pools (42 rkm to 48 rkm) and the log jams and bedrock pools near GHO (24.2 rkm through 30.5 rkm). Two of the five overwintering areas (Henretta Lake and the multi-plate culvert plunge pool) are artificial and did not exist prior to mining. This limitation in overwintering habitat is inherent in the UFR, to some extent, because of the small size of the watershed above Josephine Falls. In addition, while the availability of overwintering habitat — quantity and distribution — has been affected by development in the core mining areas (see Section 8.5.2), it is not clear to what extent the limited overwintering habitat throughout the watershed is natural. However, factors like large flood events and low streamflow are known to play a role in altering channel morphology and constraining habitat, respectively.

With limited areas of high-quality overwintering habitat, much of the population can be found in only a few, relatively small portions of the total river area, which puts a large proportion of the population at risk when one or more overwintering areas are affected by adverse conditions. Abundant and diverse habitat options would theoretically produce greater demographic resilience by increasing the likelihood that a substantial portion of the population survives a stochastic (random) event.

Not only are overwintering areas limited, but fish access to those areas is also known to be challenging at some locations under some flow conditions, and it is possible that rearing and overwintering habitats were not always well connected prior to development in the area (Hocking et al., 2021a). Seasonal drying reaches and shallow riffles occur at several locations in the UFR, and a portion of the fish population typically transits these areas between summer rearing and overwintering periods. Depending on the time of year and flow in the river, these drying reaches and shallow riffles may be impassible (Harwood et al., 2021).

Drying sections. There are two, large (i.e., > 1 km) sections of the Fording River that undergo seasonal drying (Zathey & Robinson, 2021; Hocking et al., 2021a). The southern section is located at the downstream end of Segment S7 immediately upstream from the overwintering habitat in Segment S6, and the northern drying section is located within Segment S9. These two sections essentially bracket habitat within the FRO property. Within this stretch of river, the multi-plate outlet pool is identified as one of the only higher-use overwintering habitats (Cope et al., 2016). Seasonal drying was reported as early as the

1970s both in the mainstem and some tributaries (e.g., Kilmarnock Creek), indicating that seasonal low flows and drying would have been a persistent influence on the ability of fish to move between areas of the watershed for rearing and overwintering. A variety of natural and anthropogenic factors contribute to stream drying (see Section 2.3.3), and it is unclear to what extent drying reaches in the UFR are natural and to what extent the patterns of drying have been influenced by development.

Drying sections also have the potential to cause mortality by stranding the fish. Stream salmonids are adapted to seasonal, periodic changes in stream drying, and they behave in a manner that limits their exposure to harmful environmental conditions. For example, they often start moving to overwintering habitats in fall, as the water temperature declines. However, anomalous timing and extent of drying have the potential to negatively impact individuals and populations.

Credit: Ecofish Research

8.4. DEVELOPMENT PERIOD — WHAT CHANGED?

8.4.1. Habitat Loss, Alteration and Connectivity

Open pit mining and forestry have modified the UFR watershed, as described in Chapter 2. The elevational profile of the watershed has been altered, along with drainage networks and connectivity within the watershed. Natural drainage patterns have been altered as some surface watercourses have been excavated, buried or redirected. In the early 1950s, approximately 990 linear kilometres of fish habitat were present upstream of Josephine Falls. Of the 990 km in 1950, WCT would have occupied approximately 45 km of mainstem and 180 km of tributary habitat. This demonstrates the limits of mainstem habitat this population would have been able to occupy. Overall, approximately 11% of the total stream length has been lost, with 878 km remaining in 2019, primarily due to losses in tributary habitat. Substantial tributary areas (~45%) were also disconnected from the mainstem (see Section 2.5.2). Much of the loss is from areas upstream from where the fish are distributed, such as steep slopes where ephemeral, high-elevation streams have been lost (see Section 2.5.2). However, habitat that fish used to occupy has also been lost, notably in Clode Creek, Lake Mountain Creek, Brownie Creek and Kilmarnock Creek. In addition to tributary losses, some Fording River mainstem habitat was lost or altered while FRO was being developed (see Section 2.5.2). Some habitat in the UFR has been gained. Examples include Fish Pond Creek, Henretta Lake and other channel rehabilitation projects (see Section 2.5.3).

Currently, portions of UFR and tributaries flow through an active mining landscape where the riparian forest has been impacted (altered or removed). Impacted riparian forest is present along portions of tributaries and the mainstem and is most pronounced in Segments S8 and S9, which flow through FRO (see Section 2.5.2). In much of this area, riparian vegetation is entirely lacking. Overall, approximately 18% of riparian habitat in the UFR watershed has been lost and another 13% has been altered (see Section 2.5.2).

Riparian areas are recognized as a component of critical fish habitat (Richardson et al., 2010). Their functions include: (1) providing large woody debris, (2) containing or filtering sediments, (3) maintaining aquatic thermal regimes, (4) assisting to stabilize banks and (5) contributing food and nutrients to the aquatic system (Hoover et al., 2007; Naiman et al., 2000; Richardson et al., 2005; Chilibeck et al., 1992). Loss or degradation of riparian function can therefore have negative influences on fish habitat. This influence is particularly evident in Segments S7, S8 and S10 where large woody debris was entirely absent before rehabilitation (Cope et al., 2016). The 2013 flood exacerbated bank erosion and channel aggradation, which contributed to channel widening for parts of the river through the FRO property (Teck Coal, 2016). Channel overwidening and loss of repeating riffle, pool, glide sequences are systemic issues that contribute to challenges to fish passage and other issues in the UFR (see Section 2.5.2). They are targeted for habitat rehabilitation efforts (e.g., Robinson et al., 2019).

Chapter 2 discusses uncertainty about the amount and condition of fish habitat present in the mainstem before mining began. However, through review of a combination of aerial imagery and present-day habitat conditions, it appears likely that channel widening and aggradation have reduced overwintering potential in certain reaches of the Fording River (see Section 2.5.2). Further losses may also have occurred through loss of river meanders and related habitat when the North and South Tailings Ponds were constructed. In addition, the loss of tributaries such as Kilmarnock Creek has resulted in direct loss of overwintering habitat (Norecol, 1983). Gains have also accrued. For example, Teck Coal created overwintering habitat in Henretta Lake and Fish Pond Creek and is improving overwintering habitat through rehabilitation projects along the Fording River mainstem (see Section 2.5.3). Henretta Lake provides high-use overwintering habitat, whereas more recent rehabilitation projects still require time for habitat to mature and be fully usable (Robinson et al., 2019).

The WCT of the UFR must be able to move longitudinally in the river to access spawning, rearing and overwintering areas (e.g., Sheer & Steel, 2006; COSEWIC, 2016). These fish may have experienced challenges to movement in the period before development in the area (Section 8.3), but these challenges are thought to have been exacerbated during development. In some instances, aggradation may have exacerbated the extent and duration of seasonal drying sections and shallow riffles. Habitat connectivity has also been altered through numerous works and activities. Examples include building road crossings (culverts) for mining and forestry, which have potential for disrupting connectivity. These conditions and stressors influence the WCT's ability to move from the middle segments of the UFR to overwintering areas upstream in Henretta Lake and downstream in Segment S6. For example, tributary streams such as Kilmarnock Creek that have documented overwintering use, have been fragmented from the Fording River mainstem (Norecol, 1983). If fish are unable to reach optimal overwintering habitats, they may be more susceptible to winter stresses (Harwood et al., 2021).

8.4.2. Water Quality

When Costa and de Bruyn (2021) evaluated the role of surface water quality in the WCT decline, they considered existing surface water quality data together with data for tissue chemistry and acute and chronic toxicity testing. Findings that were anomalous or notable during the decline window are discussed in Section 8.5.3.

Ongoing water quality conditions that are associated with development but are not specific to the decline window suggest that:

- Water quality in some areas indicates no potential for effects on fish because concentrations are below long-term water quality guidelines and/or below screening values for fish.
- Water quality in some areas indicates a potential for low-level chronic effects due to concentrations of one or more constituents (in most areas for a single constituent) exceeding a water quality guideline and/or screening value.
- Water quality in some tributaries and in a section of the Fording River downstream of Cataract Creek under seasonal dry conditions (when fish access to this area is restricted by dry reaches) had concentrations of one or more constituents exceeding screening values that indicate a potential for higher-level effects.

Fish distribution information indicates that most of the WCT population resides in areas of the UFR watershed where water quality indicates no chronic effects or potential for up to low-level effects on chronic endpoints. Nevertheless, it is recognized that the combined stress of elevated water quality constituents or combinations of multiple constituents could have subtle effects on the health of fish and their ability to withstand other stressors or events. Unfortunately, the links between subtle water quality changes and fish survival, reproduction and growth are often not well characterized in the scientific literature for single constituents, let alone for mixtures. Chronic toxicity tests are unlikely to detect subtle long-term effects that stress fish but do not alone cause detectable changes to growth, reproduction or survival.

Selenium is of particular public interest in the UFR. Early life stages of WCT are more sensitive to selenium than older life stages (reviewed in Bollinger, 2021a). Nevertheless, laboratory studies indicate that excess dietary and bioaccumulated selenium can affect energy metabolism, behaviour and neuromuscular systems across all life stages of fish. And because implications for fish survival in the wild in the context of other stressors are not well studied (Bollinger, 2021a), potential effects cannot be ruled out. Potential interactions of selenium with other conditions such as low dissolved oxygen or low temperatures during the decline window are discussed in Section 8.7. Finally, it is important to keep in mind that any potential effects on WCT in early life stages, including from selenium exposure, did not lead to the observed decline in adult abundance between 2017 and 2019 (see Section 8.1 and Chapter 4).

8.4.3. Changes to Hydrologic Function and Water Quantity

Mountain top coal mining affects the way water moves throughout a watershed into streams and rivers, with effects occurring at multiple spatial and temporal scales (Jaeger, 2015). The effects of mining on watershed-scale hydrology occur because mine development alters topography, drainage networks, surface and subsurface flow paths, soil conditions and vegetation conditions within the watershed. These structural changes ultimately change the water budget, where changes in streamflow are driven by the way new features are organized on the landscape (e.g., flooded pits, spoil piles and road networks). A meta-analysis of studies in the United States suggested there is considerable variability in watershed-specific hydrologic response to mining (Miller & Zegre, 2014). For example, studies have shown that while spoil piles dampen peak flow and augment baseflow due to higher recharge rates (Villeneuve et al., 2017), compacted surfaces run off quicker and infiltrate less water, resulting in significant variability in hydrologic conditions (Miller & Zegre, 2014). While the variability in hydrologic response makes it difficult to generalize changes in the streamflow regime (pattern) in the UFR over time, these studies suggest watershed-scale hydrologic conditions may have changed in a meaningful way.

In addition to watershed-scale changes, local effects on hydrologic conditions result from water use and water management. Water diversion, storage and consumption have the potential to influence instream flows, and when flow conditions are lowest, habitat limitations tend to be greatest (Bradford & Heinonen, 2008; Rosenfeld, 2017). Water use during these low flow periods potentially has the greatest ecological effect. Use is subject to water licence Instream Flow Requirements (IFRs) and maximum use restrictions that are intended to limit effects. The current IFRs were issued as part of a 5-year order, and longer-term IFRs will be set as part of a water licence review process based on results from ongoing monitoring activities.

In the UFR, water use varies temporally and spatially as a proportion of observed surface water flow. Water use records were sufficient to tally water use according to the WCT's activity period, from 2015 through most of 2019. Upstream of the hydrometric station FR_FRNTP, water use was lower during the decline window than in previous years, when withdrawals from Shandley Pit, Eagle Pond and Eagle Pit 4 were excluded, but they were higher during the decline window when these stored water sources were included. Comparing water use during the decline window and prior to the decline window thus depends critically on the assumed hydraulic connectivity of these stored water sources (Wright et al., 2021). Some analysis of hydraulic connectivity has been completed (e.g., O'Neill, 2020), but more analysis would be useful (see recommendations in Chapter 9). Quantifying the influence of water use on surface flow in the Fording River would require a detailed hydrology model that was not available for the Evaluation of Cause analyses; therefore, Wright et al. (2021) undertook analyses that compared Fording River streamflow over time to provide insights on the potential role of flow in the WCT decline. Changes in stream flows and their role in the WCT decline were assessed through detailed analysis of several impact pathways, including habitat availability (Healey et al., 2021), ice (Hatfield & Whelan, 2021), fish passage (Harwood et al., 2021), stranding (Faulkner et al., 2021; Hatfield et al., 2021; Hocking et al., 2021) and water quality (Costa & de Bruyn, 2021).

8.5. DECLINE WINDOW — WHAT WAS ANOMALOUS OR NOTABLE?

8.5.1. Extreme Weather and Ice Formation

The UFR experienced an anomalous cold period in February and March 2019. This cold period, combined with warm preceding conditions, a low snowpack and seasonally low river flows, is hypothesized to have led to extreme ice conditions. Winter of 2018/2019 began mild, with air temperatures near or above historic median values. Then, from February 2 to 3, 2019, the average air temperature dropped from 0 ºC to -22 ºC (or daily maximum of 2 ºC to daily minimum -25 ºC) (Hatfield & Whelan, 2021), and it remained low for the next several weeks. February's mean air temperature in 2019 of -16.6 °C was 9 °C colder than the long-term mean from 1970 (-7.7 °C), a difference that was statistically significant (Hatfield & Whelan, 2021). Not only was it colder but it was consistently colder. During 19 of 28 days in February 2019, the minimum daily temperature was below -20 °C (Hatfield & Whelan, 2021). By comparison, February 2018 had similar cold air temperatures, but these occurred for days rather than weeks, and warmer temperatures — around the long-term median — returned between the intense cold periods. In 2019, air temperatures did not return to the long-term median until after early March, resulting in February's average air temperature being a 1 in 50-year event and the coldest February on record at the long-term Environment Canada weather station at Sparwood.

In addition to winter 2018/2019 having an unusually cold period, snow accumulation was less than normal. Total snowfall was only two-thirds of the 2014–2018 average, but most importantly, at the time of the temperature drop the snow water equivalent was well below the 25th percentile of the long-term record, and it remained below for the rest of the winter (Hatfield & Whelan, 2021). A combination of atmospheric cold and a shallow blanket of insulating snow can cause both land and water to cool rapidly through heat loss to the atmosphere, and this combination sets up conditions for extensive ice formation.

Water temperature and water level trends in the UFR also differed from previous years during the 2018/2019 winter. At the beginning of winter, relatively warm, mild water temperatures were observed at two of the monitoring locations (FR_HC1 and FR_FRNTP). Water temperatures then dropped rapidly during the February air temperature drop, going below 0 °C and reaching -4 °C at FR_FRNTP (Hatfield & Whelan, 2021). Water temperature at FR_FRABCHF was notably variable from mid-November until early January, with regular swings from 3 °C to 0.5 °C; however, during February and until early March 2019, the water temperature dropped to zero for roughly half the days. Hatfield and Whelan (2021) speculated that the unusually cold period led to rapid and extreme variations in water level during February 2019, due to the effects of ice formation (through discharge depression or reduced flows). Rapid variations in water level were further interpreted as ice jam formation and release, suggesting that water levels and hydraulic conditions were highly unstable (Hatfield & Whelan, 2021).

Overall, based on weather and hydrometric data supported by limited field observations, Hatfield and Whelan (2021) concluded that the timing, duration and intensity of ice formation in the UFR were abnormal and were likely severe for overwintering WCT. The extreme weather occurred throughout the UFR, but effects would have varied spatially depending on the morphological characteristics of the river (e.g., wetted width, depth and velocity) and the ice formation processes, such as the generation of surface, frazil and anchor ice.

8.5.2. Low Flows and Fish Passage

Hydrologic conditions in late 2018 during the decline window were low in all reaches of the Fording River, but they were not the lowest on record. Mean stream flows in August, September and October were below the 25th percentile of records from 1970–2018; and baseflow during winter 2018–2019 was also lower than average (Wright et al., 2021). Average flow in the Fording River in February 2019 was at the 37th percentile (Fording River at the mouth, WSC 08NK018; available data from 1970–2019). These flows alone are not extreme or abnormal; however, when coupled with an extreme cold event and extensive ice formation, conditions were likely severe for overwintering WCT in many locations of the UFR. Areas of deep water like Henretta Lake are expected to have been more protected than shallow areas.

The conditions of February and early March 2019 likely reduced availability of suitable overwintering habitat. This could have occurred through water being depleted as ice formed, habitat being consumed from ice intruding into usable habitats like stream margins and, probably, from habitat being disrupted by the presence of frazil and anchor ice (Hatfield & Whelan, 2021). Hydrologic conditions combined with channel conditions at some locations are suspected to have led to the restricted habitat connectivity (i.e., restricted fish passage) that existed before the extreme cold event, and thereby exacerbated the consequences of the extreme cold in February 2019. Notably, restrictions to fish passage in fall 2018 may have prevented some fish from reaching preferred overwintering habitat (Harwood et al., 2021) and either required them to use less suitable habitats or increased their density in the areas they did choose. Ongoing fish passage restrictions through winter may also have precluded fish from moving to alternate overwintering habitats during the extreme weather. Although restrictions to fish passage are believed to have existed before the decline window, the consequences of poor fish passage conditions seem to have been greater during the decline window.

Historical information, recent monitoring and modelling suggest that drying in the southern drying section occurred considerably earlier in 2018 compared to December in 2017 and January in 2020, with dry conditions first reported in early September (Hocking et al., 2021). Monthly surveys of the northern section were not initiated until fall 2019, but in both 2019 and 2020 dry conditions were reported in the northern section approximately one month earlier than in the south (Zathey & Robinson, 2021). Dry, impassable conditions in the north may, therefore, have occurred in early August, well before fish migrations to overwinter habitats are assumed to occur. The timing of the northern drying section is important because it may have prevented fish from migrating upstream to overwinter in Henretta Lake, a movement that a large percentage of the UFR population generally undertakes (Cope et al., 2016; Akaoka & Hatfield, 2021). Drying of the southern section may also have created a migration barrier, depending on the timing of the drying and the timing of fish movement. Akaoka and Hatfield (2021) examined the telemetry data from Cope et al. (2016) and found that fish that overwinter in Segments S5 to S6 would have been most affected, although some fish that overwinter in Segments S8 to S11 and Henretta Lake would also have had to transit this drying reach. The available telemetry data suggest that, across all fish and all periods, movement of ~25% of the fish population would have been restricted in some way if the southern drying reach became and remained fully impassable (the percentage of affected fish would have been lower if the barrier was seasonal).

Relationships between hydrologic conditions, channel condition and passage are not constant. During much of the decline window, flows at the Water Survey of Canada station, Fording at the mouth (see Section 2.3.3) were below the 25th percentile, but this has occurred at least seven other times since 1970. And overall, average flow in February 2019 was at the 37th percentile, which is not considered extreme or abnormal. Although the UFR WCT population was not monitored intensively before 2012, clearly, the population persisted despite previous low flow periods. We cannot accurately predict fish passage on hydrologic time series alone, because changes in morphology of the channels affect the ability to pass through them, and such changes often occur from one year to the next. Most importantly, the consequences of impeded fish passage likely differ substantially between years, depending on the number of migrating fish affected and the subsequent conditions experienced by fish that are forced to use non-preferred overwintering habitats.

The effect that restricted fish passage would have had on the population, therefore, depends critically on interactions with other stressors during the decline window.

8.5.3. Other Anomalous or Notable Conditions

In this section, we discuss other anomalous or notable conditions that occurred in the UFR during the decline window that were not associated with extreme winter conditions and below-average streamflow.

Water quality

For most areas, a review of water quality during the decline window indicated there was either no potential for effects to fish, or potential for low-level effects from a single constituent exceeding a water quality guideline and/or screening value (Costa & de Bruyn, 2021). In localized areas where water quality indicated potential higher-level effects from multiple constituents, interpreting the extent to which surface water quality may have contributed to the WCT decline depended on how many fish may have overlapped with these conditions. The available telemetry information and the localized spatial extent of the conditions generally indicated that a low proportion of the WCT population may have been affected by water quality in mine-affected tributaries. Portions of the mine-affected tributaries that are accessible to fish and had water quality that indicated potential high-level effects accounted for a small fraction of habitat in the UFR watershed, and generally these portions have lower-quality habitat than other areas. However, the particular conditions in the reach of the Fording River downstream of Cataract Creek, associated with water quality at FR_FRCP1, warrant discussion.

Water quality at FR_FRCP1 indicated potential high-level effects of sulphate and total dissolved solids in fall 2018, winter 2018 and winter 2019, and it indicated potential acute effects of dissolved oxygen in December 2018. These findings represented a change from conditions before the decline window (Costa & de Bruyn, 2021). Concentrations of sulphate and/or total dissolved solids (TDS) indicating potential high-magnitude effects occurred from October 2018 to March 2019. The magnitude of the elevated concentrations during this period was higher than previous years, the length of time they lasted was longer and their onset occurred earlier.

This reach of the Fording River downstream of Cataract Creek has uncertain fish access in winter due to seasonal drying. When the reach is dry, movement from S6 or downstream segments would be inhibited. However, telemetry data indicate that fish may reside in Segments S6 to S8 in winter, and fish have been recorded moving past FR_FRCP1 in fall and winter (Akaoka & Hatfield, 2021). These data indicate that Segment S7 represented a relatively small proportion of use by fish in the UFR watershed in the seasons when potential high-level effects were identified. Specifically, less than 3% of radio-tagged WCT were recorded in Segment S7 in winter (see Appendix C), and it is expected that at least some of these fish resided in the portion of Segment S7 upstream of Cataract Creek, where water quality indicated no chronic effects or a potential for low-level effects. A greater percentage (10%) of tagged WCT were recorded in Segment S7 in summer and fall (see Appendix C). Akaoka and Hatfield's (2021) analysis indicated that some tagged fish may have passed through the location of FR_FRCP1 in winter (9.7%) and in summer and fall (8.1%) during the period of the telemetry study. However, timing and the extent of movements during the decline window may have differed due to inter-annual differences in the extent and timing of seasonal drying or other factors.[21] Combined with the fish estimated to reside in Segment 7 (2.7% in winter; 10% in summer and fall), these estimates indicate that up to 12.4% of WCT in winter and up to 18.1% of WCT in summer and fall could potentially have been exposed to conditions at FR_FRCP1 for some period of time and, therefore, that they may have experienced potential effects of sulphate and TDS. These percentages are expected to be biased high because spatial resolution of the data is too coarse to confidently ascertain movement within the river zones defined for the analysis. Because of the uncertainty about how many fish were exposed to these conditions, the extent to which these conditions may have contributed to the decline is uncertain.

Accumulation of periphyton and macrophytes

Flows in the UFR were stable in the 2018 growing season and favoured periphyton and macrophyte growth. That growing season was followed by a fall with stable low flows (no usual fall flush), which could have led to higher than usual biomass going into winter 2018/2019. Furthermore, the UFR may be susceptible to accumulation of periphyton in some areas, particularly tributaries, because periphyton physically attaches to calcite. Potential effects of periphyton and macrophyte decomposition on dissolved oxygen levels are considered below.

8.6. PUTTING IT ALL TOGETHER — AN INTEGRATED HYPOTHESIS

Based on information in Sections 8.3 to 8.5 above, extreme winter conditions — driven primarily but not only by cold air temperatures — combined with limited overwintering habitat and constraints on fish passage, are believed to have had a strong influence on the 2017–2019 decline of WCT in the UFR. Winter conditions are thought to strongly affect fish survival in interior continental watersheds (Alexiades et al., 2012), and during extreme winters substantial fish losses can occur (Templeman, 1965). For example, Hoffsten (2003) reported a 77% reduction in trout density and marked reductions in abundance and species richness of macroinvertebrates, after an extremely cold winter with low snowfall in nine, medium-sized streams in central Sweden. Through telemetry studies and tag recovery, Cope et al. (2016) noted 10 of 55 identified mortalities in the UFR were associated with ice or winter conditions in years that did not have noteworthy climatic anomalies. Stochastic (random) events play a role in determining population distribution and abundance, whether through higher-than-normal freshets (Robinson & McPherson, 2014), mid-winter floods (e.g., Cunjak et al., 1998; Erman et al., 1988; Maciolek & Needham, 1951) or ice-related

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[21] Due to the spatial coarseness of the telemetry data, this analysis considered telemetry data in terms of zones (the combination of multiple segments), rather than individual segments. It did not consider that movement may have been impeded by drying reaches or impassible riffles in the decline window and, therefore, that movement may have been less than was recorded in the telemetry study.

conditions such as anchor and intruding ice (e.g., Brown & Hubert, 2011) or ice break-up (e.g., Scrimgeour et al., 1994). Temperate fish are broadly adapted to seasonal disturbance, but occasional, unpredictable, extreme events can have large demographic consequences, at least in the short term (Hocking et al., 2021).

The next section explores how fish mortality could have occurred (see Figure 8-1, right-side box). We do not know exactly how fish died because no carcasses were observed in the winter of 2019 (or at any time in substantial numbers). The integrated hypothesis considers that extreme ice conditions were unique to the decline window and that the combination of those conditions with limited overwintering habitat and fish passage constraints led to substantial mortality. However, specific mechanisms of fish mortality may have involved other stressors and conditions, and these are also discussed.

8.7. POTENTIAL MECHANISMS OF MORTALITY

Ice

Fish mortality could have occurred from direct physical effects of ice. First, ice could have physically entombed fish. This seems less likely for adults, because it would require the entire water column to freeze, but is more plausible for smaller fish that are buried in the substrate. Fish in suboptimal habitats, particularly shallow areas, are more likely to have been subjected to entombment. Water temperature records indicate that the cold event of February 2019 was likely extreme enough to freeze significant portions (cross-sections) of the preferred overwintering areas in Segments S2 and S6. Second, fish could have been injured directly and could have suffocated due to frazil ice. Cunjak et al. (1998) give examples of frazil and surface ice intruding into as much as 80% of a stream cross-section or a deep pool. If fish cannot avoid frazil ice, there is speculation that suspended ice crystals may impede respiration by physically obstructing the oral cavity and/or gills, or it could abrade the gill epithelium causing hemorrhage and lesions. Direct evidence for these effects causing stress or mortality is limited, and a more likely effect of frazil ice may be that it displaces fish (Bollinger, 2021a), as discussed below.

Beyond the direct physical impacts of ice to fish, another plausible cause of fish mortality could have been stress and energy deficits, which could have occurred by various mechanisms. Ice accumulation can reduce habitat space and suitability in overwintering pools (Cunjak, 1996; Brown & Hubert, 2011) and lead to fish crowding into fewer areas. This is believed to have occurred in the UFR in the winter of 2019, particularly due to lower than average winter flows (Wright et al., 2021; Hatfield & Whelan, 2021). One implication of ice intrusion is displacement, because fish are known to move in response to ice intruding into their overwintering location (e.g., Roussell et al., 2004; Whalen et al., 1999). Another is that movement responses could potentially also occur in response to crowding. Whether movement occurs in response to ice or crowding or both, the energy the fish would expend would occur at a time when they are trying to limit energy expenditure, or when they are weaker and more susceptible to other stressors.

Stress and energy deficits

Stress and energy deficits may also occur in response to extremely cold water, which causes changes in behaviour, physiology and enzymatic function. Although WCT at high elevations are undoubtedly adapted to low water temperatures in winter, if water temperatures fell below the species-specific preferred temperature (Shuter et al., 2012), physiological stress could have contributed to, or even caused, mortality. Fish are subject to increasing osmotic stress as they approach their tolerance limits for low water temperatures, and extreme low temperatures will cause mortality if osmoregulation cannot prevent plasma from freezing (Bollinger, 2021a). At extremely low water temperatures, we can, at the least, expect that fish will be subject to increased stress.

Food availability

Benthic invertebrate abundances in the UFR indicated adequate food availability for WCT during the decline window (Orr & Ings, 2021). However, the state of fish energy (lipid) reserves entering the winter of 2019 is uncertain, because body condition data were spatially limited in the summer/fall of 2018 (Orr & Ings, 2021) and body condition is not always a reliable indicator of lipid reserves (Handy, 1997; Simpkins et al., 2000, 2003; Robinson, 2010). Also, compared to other years for which we have data, low flows and early onset of drying in the UFR in the fall of 2018 may have reduced access to food or increased energy expenditures (e.g., greater physiological stress from hampered passage, less time foraging and/or increased travel distance to food). Fish energy depletion is greatest during the fall period of rapid water temperature (and photoperiod) decline, compared to later in the winter when low temperatures have stabilized (Cunjak et al., 1987; Metcalfe & Thorpe, 1992; Handy, 1997; Koljonen et al., 2012). Salmonids continue to feed in winter, but food acquisition and digestion efficiencies are reduced in cold water (Cunjak et al., 1987; Elliot, 1991; Finstad et al., 2004; Watz & Piccolo, 2011). Also, reduced habitat availability associated with winter low flows and ice formation (see above) could reduce access to food or increase competition for it. Therefore, the low flows of fall 2018, followed by the extreme cold period in February 2019 may have contributed to winter energy deficits, in spite of adequate food availability.

Stranding

Another potential cause of mortality is stranding. Fish could have become stranded during the fall 2018 migration period when the timing of drying in ephemeral reaches was earlier than observed in other recent years (Hocking et al., 2021), and we know that some fish, especially juveniles, were stranded in this period of time within a side-channel. Additionally, stranding during winter could have occurred if fish in suboptimal winter habitats were moving to escape ice formation and winter low flow conditions. However, it is unlikely that stranding was a significant contributor to the decline of either adults or juveniles.

Water quality

Water quality could have contributed to stress through ongoing, subtle effects of constituents related to mining, as discussed in Section 8.4.2. If fish are stressed due to the quality of the water, they may be more susceptible to other stressors, and water quality cannot, therefore, be ruled out as a contributor to the decline. Single constituents or multiple, interacting constituents could contribute to such stress, and it has been speculated that such stress may be exacerbated by the stress of low temperatures. Selenium is of particular public interest in the UFR. Its potential effects via oxidative stress (by causing damage to membrane lipids) may combine with similar effects of low dissolved oxygen and ammonia (reviewed in Bollinger, 2021a). In addition, elevated levels of selenium can alter glycogen and triglyceride metabolic pathways, which may be significant during cold conditions when fish are mobilizing fat stores and responding to varying energy demands. The result could be energy deficits which, if extreme, could lead to mortality. Further potential effects of selenium are detailed in Bollinger (2021a).

Beyond causing ongoing stress, water could also have caused toxicity directly, if there were specific events or changes in quality during the decline window, or if there were changes in the distribution of fish that exposed them to conditions they were not exposed to before the decline window. There were anomalous or notable conditions in some locations, in particular at FR_FRCP1, but relatively few fish are estimated to have been exposed to those conditions (see Section 8.5.3). In terms of fish distribution, the available information suggests that a low proportion of the WCT population may have been affected by water quality in mine-affected tributaries where there was potential for high-level effects (see Section 8.5.3, and Costa & de Bruyn, 2021).

Dissolved oxygen

As the SMEs worked on integrating the stressors, the question of whether dissolved oxygen (DO) could have had a role in the fish decline kept arising from different impact hypotheses. Therefore, a subset of SMEs looked at this question, together, and summarized key findings (Appendix D). The measured DO sag (drop) at Segment S6 during winter 2019 was part of a declining DO trend in this reach that was anomalous during the decline window. However, the sag did not reach critical thresholds for juvenile or adult WCT survival, a finding that was supported by screening and analysis of field-collected DO data (Costa &de Bruyn, 2021).

Theoretically, sediment oxygen demand could be responsible for localized DO consumption that results in adverse oxygen concentrations (<3–5 mg/L) when a series of conditions occurs: (1) a growing season with stable low flows producing a large periphyton and macrophyte crop, together with embedded sediment; (2) no fall flushing flows to remove this material; and (3) prolonged, very cold winter conditions and seasonally low winter flows that lead to persistent ice formations/blockages and deep frost. This series of conditions occurred at the lower Segment S6 overwintering site in February 2019 (Larratt & Self, 2021; Appendix D). The sum of biological, chemical and sediment oxygen demands may reduce oxygen to the point that fish become stressed, consume their excess energy stores (reviewed in Bollinger, 2021a), are displaced due to searching for better oxygenated waters and/or die due to hypoxia. Trout mortality caused by winterkill when anoxic conditions develop under ice cover in shallow lakes is well known, and it is also recorded in river systems (Cunjak et al., 1998; Ramsey, 2020). However, in Henretta Lake, its large size, depth to volume ratio and inflows could prevent winterkill from occurring, despite annual winter-long ice cover. Similarly, winterkill is unlikely in the upstream half of the Segment S6 overwintering area, due to a large inflow of oxygen-bearing groundwater.

At lower Segment S6, the locations and frequency of monitoring may not have detected localized or short-term low DO conditions (see Appendix D) that may have occurred in overwintering habitats during the weeks of anomalous ice conditions in 2019. The mechanisms above are all plausible at lower Segment S6 and are difficult to confirm or refute based on the monitoring data.

Other Stressors

Finally, other stressors such as predation could have played a role in the decline, if fish were more susceptible in constricted areas due to the physical constraints of ice and low flows, or if they simply lacked the energy reserves to avoid predators. Although predation seems unlikely to have resulted in a 90% decline in the population, in the absence of data it cannot be ruled out as a contributor.

8.8. CONCLUSION

A widespread decline in WCT abundance from 2017 to 2019 was observed in the UFR. The decline appears to have been most severe in Segments S5 through S9, within and immediately downstream of Fording River Operations property, although all river segments appear to have experienced substantial losses. The Evaluation of Cause Team hypothesizes that the occurred in February–March 2019 and was caused by the interaction of extreme ice conditions (due to extreme prolonged cold air temperatures, seasonal winter low flows and low winter snowpack), sparse overwintering habitats and restrictive fish passage conditions during the preceding migration period in fall 2018. While some stressors such as cold weather are natural, mining development has altered the availability of overwintering habitats in portions of the river and exacerbated the challenges to fish passage through water use, channel widening and aggradation.

The Evaluation of Cause Team believes that, among all of the stressors, the extreme winter (cold/ice) was the most unique element during the decline window compared to previous years. However, we cannot estimate the effect of the extreme winter alone, since its effect depended on interactions with other stressors.

The specific mechanisms of fish mortality are not known, but they may include one or more of the following:

- Direct physical effects of ice on fish (e.g., entombment, or gill injury or suffocation due to frazil ice)
- Stress and energy deficits associated with cold stress, movements to avoid ice conditions or crowding, or challenges in accessing food
- Shortages of dissolved oxygen due to flow blockages or other mechanisms
- Stranding
- Ongoing stress attributed to water quality constituents, or
- Predation.

Credit: Minnow Environmental

9.

The Way Forward

9.1. PREFACE

The purpose of this chapter is to provide a bridge from the findings of the Evaluation of Cause to next steps that will support recovery of the WCT population in the UFR. Based on the Evaluation of Cause Team's interactions with Teck Coal, the Ktunaxa Nation Council (KNC) and the regulatory agencies, we recognize that population recovery efforts are already underway and will continue to be developed. These include taking operational actions to manage water usage, assessing opportunities to expand or improve fish habitat and conducting environmental monitoring and research and development.

There is ongoing work by Teck Coal, as described in the Elk Valley Water Quality Plan (2014), to stabilize and reverse trends in water quality constituents. Based on the findings presented in Chapter 8, the Evaluation of Cause Team recommends that Teck Coal continue their efforts under the Plan and recent updates to it (Implementation Plan Adjustment; IPA), which will improve water quality. These improvements will benefit the habitats of this important fish species and likely increase the resilience of the population going forward (see Section 9.2). Given that the Elk Valley Water Quality Plan and IPA are already being implemented, the focus of these recommendations (Section 9.3) is on other aspects of the fish decline that could be addressed through recovery efforts — water quantity and habitat quality.

In addition, Teck Coal is working with the KNC and regulatory agencies to revisit their approach to understanding and monitoring WCT population abundance in the UFR. The Evaluation of Cause Team supports this effort to establish and commit to a long-term monitoring framework for population abundance of UFR WCT.

We understand that the Evaluation of Cause is being published concurrent with WCT recovery plans that are being prepared in 2021 by regulatory agencies, the KNC and Teck Coal. Consistent with our mandate and findings, these recommendations emphasize the importance of resilience (Section 9.2) and are based on a watershed approach (Section 9.3).

The Evaluation of Cause focused on the question of what happened to the UFR WCT. During that work, the team identified concrete early actions that have been acted on, for example, installing instrumentation to monitor ongoing water quality (temperature and oxygen) and installing an additional PIT tag detection array. The Evaluation of Cause's recommendations are meant to complement and inform other, ongoing initiatives to support recovery of this population.

9.2. CONCEPT OF RESILIENCE

Resilience *is a measure of the persistence of systems and their ability to absorb change and disturbance (Holling, 1973) without fundamental changes in function or structure (Wenning et al., 2017). Resistance and recovery are the two key components of demographic resilience.*

Resistance *is the capacity to withstand disturbance and can be represented by the magnitude of decline in abundance following disturbance.*

Recovery *represents the magnitude or rate of population increase after the disturbance lessens. Resilience maintains capacity for renewal and provides an ecological buffer that protects the system (Gunderson, 2000).*

As detailed in Chapter 8, the Evaluation of Cause Team hypothesizes that the decline in abundance of WCT in the UFR was caused by the interaction of extreme temperature and ice conditions in February–March 2019, sparse overwintering habitats and restrictive fish passage conditions during the preceding migration period in fall 2018. Some of these stressors are natural, such as extreme weather, but mining development has contributed to the loss of overwintering habitats in portions of the river and has exacerbated the challenges to fish passage, through water use and alteration of channel morphology. Taken together, these natural and anthropogenic stressors and conditions likely affected the resilience of the UFR population.

The upper Fording River watershed and its WCT population have been subjected to disturbances over its history, both natural and anthropogenic. The WCT population has been resilient enough to withstand and recover from previous disturbances.

The Province and KNC's recovery planning (with input from others, including Teck Coal) for this population underlines the importance of resiliency as part of population recovery. The goal of this Conservation Action Plan[22] is to "*restore and maintain a viable self-sustaining population of WCT in the UFR which is robust enough to support beneficial use. A viable population is one that can be expected to sustain itself over a 100 years or longer time span and be resilient to environmental changes and ongoing mining stressors. This is in line with Ktunaxa conservation principles to plan for seven generations in the future and the importance to Ktunaxa citizens to have a sustainable harvest fishery for the sustenance of Ktunaxa people.*"

9.3. RECOMMENDATIONS

Building on the goal of restoring and maintaining a viable self-sustaining population, our recommendations leverage the findings of the Evaluation of Cause and recognize current knowledge gaps discussed in the SME reports. Recovery will involve: (1) identifying the habitat features and stressors that limit the population at key life stages and, where possible, (2) restoring habitat and (3) mitigating and/or eliminating those stressors that affect fish vital rates (like recruitment and survival). We acknowledge that work is already underway in relation to these recommendations, so future work should augment and build on that foundation.

Recommendation 1

Consider developing a watershed-scale hydrological model to better understand surface water levels as influenced by landscape changes, groundwater interactions, consumptive water use, water diversion and water storage. Use this information, where appropriate, to understand historical effects and to assess effects of proposed restoration or development.

Surface water levels and flows affect multiple ecological factors, such as fish passage, habitat availability, water quality and other parameters. Understanding the effects of historical and potential future mining actions (both development and restoration) requires improved understanding of the hydrological response to mining. Development of a detailed hydrology model was not feasible for the Evaluation of Cause, but such a model would help plan and prioritize future actions in the upper Fording watershed. A watershed-scale hydrological model (i.e., integrated across the watershed and considering surface

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[22] Work in progress, information obtained from Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

water and groundwater) could be useful to identify drivers (e.g., water diversion, storage, consumption) and physical sensitivities (e.g., where and when the system is vulnerable to further changes to surface water levels, increased risks of issues related to fish passage, stranding and/or exacerbated drying conditions). Development of such a model will take time, and the parties involved (Teck Coal, KNC and agencies) should not wait for this model to be developed before initiating measures to improve water management and access to habitats.

Recommendation 2

In the ongoing development of the WCT Recovery Plan[23] and future implementation, consider key aspects of WCT habitat requirements (water quality, water quantity, physical habitat) in the UFR.

Assemble existing information and conduct a gap analysis to characterize habitat requirements for this species relative to current habitat in the watershed with a focus on identifying and describing: (1) key habitats that sustain and limit population abundance (e.g., overwintering), (2) impacts to mainstem habitats (particularly channel widening, aggradation and loss of connectivity) and impacts to tributaries. Where gaps are prioritized for their role in informing fish recovery, design and implement the work necessary to address the information gaps, and learn from the performance of previous habitat restoration projects conducted in this watershed.

The WCT Recovery Plan and its implementation should build on existing habitat to restore and enhance fish habitat, with the goal of increasing resilience. This plan should consider actions that could be taken within Segments S6 to S9, which have limited rearing and holding habitat but are a migration corridor for WCT. In addition, to improve understanding of the population to stressors, the recovery planning process could leverage the WCT population model that is being developed for the upper Fording River.

Specific restoration projects should be prioritized, using criteria agreed with the parties involved (e.g., potential benefit to fish population, timing of anticipated response [time is of the essence], and technical feasibility). This plan should be integrated with the vision for the UFR in the context of longer-term mine closure.

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[23] A Recovery Plan is being developed for the upper Fording River WCT population that will lay out strategy, objectives and actions to recover fish populations, including enhancing fish habitat and population resilience.

9.4. CLOSURE

We conclude by acknowledging that the upper Fording River is a dynamic system, and that building the resilience of the UFR WCT population will require an adaptive management approach. This approach will need to carefully explore, test and monitor management actions to learn which actions best support the restoration objectives of recovery planning.

Glossary

Term	Description
adfluvial-migratory	WCT populations that migrate between spawning/rearing tributaries and adult-rearing lakes
acute toxicity	the adverse effects of a substance on an organism that results from either a single exposure or from multiple exposures in a short period of time
age-length data	data on the relationship between the age and length of fish
aggradation	the deposition of material by a river, stream or current
alevin	a newly spawned salmon or trout still carrying the yolk
alluvial	relating to or composed of clay, silt, sand, gravel etc., deposited by running water
aquatic organisms/ aquatic life	animals (invertebrates, amphibians, fish, birds, etc.) that live in or depend on an aquatic environment
ammonia	chemical compound made of nitrogen (N) and hydrogen (H) with the formula NH_3
anchor ice	ice attached to the beds of streams, lakes and shallow seas,
anoxic	greatly deficient in oxygen
anthropogenic	of, relating to, or resulting from the influence of human beings on nature
antiscalant	material preventing or slowing the build-up of minerals (scaling) on a surface that can occur when water has a high mineral content
aquitard	a geologic formation that lies adjacent to a water-bearing stratum of permeable rock, sand or gravel (aquifer) and that allows only a small amount of liquid to pass
autolysis	the process in which cells break themselves down
bar	a ridge or mound of boulders, gravel, sand and mud found along or in a stream channel at places where decrease in velocity causes deposition of sediment

Term	Description
barotrauma	injury caused by a change in air pressure, affecting typically the ear or the lung
baseline	current or existing conditions that serve as a reference point for comparing future conditions
basibranchial teeth	teeth behind the tongue
benchmark	a standard or point of reference against which things may be compared or evaluated
benthic invertebrates	small organisms that lack backbones and live in or on the bottom of sediments of rivers, streams and lakes; these include the larvae of aquatic insects, as well as clams, snails, mussels, crayfish and various other kinds of aquatic worms
bioaccumulation	the build-up of substances, both toxic and benign, within the body tissues of an organism
bioconcentration	the process by which a chemical concentration in an aquatic organism exceeds that in water, as a result of exposure to a waterborne chemical
biogenic calcite	calcite produced by living organisms
bio-clogging	clogging of pore space in soil by microbial biomass
biological oxygen demand	the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature
biomagnification	concentration of toxins, such as pesticides, in the tissues of tolerant organisms at successively higher levels in a food chain
bioreactor	a vessel in which a biological reaction or change takes place
braided channel	a network of river channels separated by small, often temporary, islands
bryophytes	small, non-vascular plants, such as mosses, liverworts and hornworts
calcite	a hard mineral that can form on streambeds and is the same as the build-up that forms in tea kettles or water heaters in homes with hard water Calcite occurs naturally, but its formation can be accelerated by runoff water from mines. It is not a human health concern, but excessive

Term	Description
	calcite build-up can change the characteristics of streambeds by cementing rocks together and affecting habitat for fish and invertebrates.
calcite concretion	a hard, compact mass of calcite formed by the precipitation of mineral cement within the spaces between particles, and is found in sedimentary rock or soil Calcite concretion occurs naturally, but its formation can be accelerated by runoff water from mines.
calcite index	a numeric expression of the extent and degree of calcite formation; typically given as a range from 0 to 3
carrying capacity	the maximum population that an area will support without undergoing deterioration
cascade	a steep, usually small fall of water
causal pathway	pathway of effect that could be the cause of the observed effect
channel	the bed where a natural stream of water runs
chronic toxicity	the adverse effects of a substance on an organism that result from long-term exposure
coal seam	a bed of coal occurring between layers of rock
compliance point	a water monitoring station that is immediately downstream from a Teck Coal mine operation in the Elk Valley
condition factor	a measure of overall fish condition usually based on general shape of the fish and length and weight.
conditions (in the context of stressors and conditions)	entities that can be identified as contributing to an adverse response but can be either natural or mine related
confidence interval	the probability that a population parameter will fall between a set of values for a certain proportion of times
Continental Divide	the watershed of North America comprising the line of highest points of land separating the waters flowing west from those flowing north or east, coinciding with various ranges of the Rockies and extending south-southeast from northwestern Canada to northwestern South America
constituent	an element or ionic compound that may pose a threat to ecological or

Term	Description
	human health when present at sufficient concentrations
culvert	a transverse drain
cumulative effects	changes to the environment that are caused by combinations of stressors with other past, present and future human actions (see also stressor interaction)
cyanobacteria	a division of microorganisms related to bacteria but capable of photosynthesis
cyanotoxins	toxins produced by cyanobacteria
decline window	period between September 2017 and September 2019 when the population of UFR WCT declined (note that the decline window is refined in the Evaluation of Cause, but this term typically refers to the entire two-year time period until Chapter 8)
demographics	the study of a population based on factors such as age and sex
denitrification	the microbial reduction of nitrate or nitrite coupled to electron transport phosphorylation, resulting in gaseous N either as molecular N_2 or as an oxide of N
dewater	to remove water from
didymo	*Didymosphenia geminata* or "rock snot" is a brownish alga that can form thick mats on river bottoms and shorelines
discharge depression	a reduction in stream discharge
dissolution	the act or process of dissolving
dissolved oxygen	the amount of oxygen that is present in water
dragline	an excavating machine in which the bucket is attached by cables and operates by being drawn toward the machine
drying section (or drying reach)	section of the upper Fording River that goes dry seasonally
ecosystem	the complex of a community of organisms and its environment functioning as an ecological unit
electrofishing (also electro-shocking)	a common scientific survey method used to sample fish populations by using a direct electric current to temporarily immobilize fish

Term	Description
Elk River watershed	the area that includes the Elk River and all of its tributaries
endemic	an organism that is restricted or peculiar to a locality or region
ephemeral stream	a temporary stream that only flows for a brief period as a direct result of precipitation
epithelium	a membranous cellular tissue that covers a free surface or lines a tube or cavity of an animal body and serves especially to enclose and protect the other parts of the body
etiologies	the causes of diseases or abnormal conditions
eutrophication	the process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen
evaporation	the process of becoming vapour
fault(ed)	planar or gently curved fracture in the rocks of Earth's crust, where compressional or tensional forces cause relative displacement of the rocks on the opposite sides of the fracture
fecundity	number of eggs a female produces
filamentous algae	colonies of algae that link together to form threads or mesh-like filaments
fish-accessible waters	waters that are fish bearing at some time of the year (or that have not been proven to be non-fish bearing)
fish use	describes occupancy by fish in river segments of the UFR during key activity periods such as overwintering, spawning, incubation, rearing and migration; typically confirmed through field observations, captures or radio-tagging studies
flocculant	a chemical product which helps to remove suspended solids from water by aggregating the material into flakes or "flocs" that float to the surface of the water or settle at the bottom
floodplain	level land that may be submerged by floodwaters
Floy tag	a visual marking tag used for fish research
fluvial-resident	headwater stream WCT populations living above barriers that complete their life cycle within a very restricted distribution and remain relatively

Term	Description
	small (i.e., < 200 mm long) due to the cold, nutrient-poor nature of these small streams
fluvial-migratory	migratory WCT populations that move between small spawning/rearing tributaries and larger, more productive adult-rearing rivers
fold(ed)	in geology, undulation or waves in the stratified rocks of Earth's crust Stratified rocks were originally formed from sediments deposited in flat horizontal sheets, but in some places the strata are no longer horizontal and have been warped in folds
fragmented population	a population of Westslope Cutthroat Trout for which downstream movement is possible, but upstream movement is not possible for any life stage or at any flow
frazil ice	soft or amorphous ice formed by the accumulation of ice crystals in water that is too turbulent to freeze solid
freshet	the flood of a river caused by heavy rain or melted snow, typically in spring
fry	juvenile fish stage capable of feeding itself but that has not yet developed scales or fully-formed fins
gaining reach	a reach that receives water from groundwater that adds to its overall surface flow
genera	singular: genus — a group of animals or plants that share some characteristics in a larger biological group
genetically pure	without hybridization (see definition for hybridize)
glacial	of, relating to, or produced by glaciers
glide	a river/stream habitat type where the flow is characterized by slow-moving, nonturbulent flow
groundwater	water that flows beneath the water table, in soils and geologic formations
hanging valleys	a tributary valley whose mouth is set above the floor of the main valley, usually as a result of differences in glacial erosion
headwaters	the source of a stream

Term	Description
hemorrhage	a copious or heavy discharge of blood from the blood vessels
hybridize	(of an animal or plant) breed with an individual of another species or variety
hydraulic	of or relating to water or other liquid in motion
hydrophobicity	lacking affinity for water
hyporheic	denoting an area or ecosystem beneath the bed of a river or stream that is saturated with water and that supports invertebrate fauna that play a role in the larger ecosystem
hyporheic exchange	the mixing of surface and shallow subsurface water through porous sediment surrounding a river
hypoxia	a condition in which the body or a region of the body is deprived of adequate oxygen supply at the tissue level
impact hypothesis	an overarching way to describe how a stressor may have influenced the WCT population
impeded population/ impeded passage	a population of Westslope Cutthroat Trout where there is some bi-directional movement, but potential, seasonal/flow or life stage barriers exist
incubation	the process of maintaining an embryo under conditions favourable for hatching
index of abundance	measurement of relative abundance, often per unit effort
industrial chemical	chemicals developed or manufactured for use in industrial operations or research by industry, government or academia
infectious agent	organisms capable of producing infection or infectious disease, including bacteria, fungi, viruses and parasites
insectivorous	an animal or plant that eats insects
interbreed	(with reference to an animal) breed or cause to breed with another of a different species
interstitial	(of minute animals) living in the spaces between individual sand grains in the soil or aquatic sediments
introgression	transfer of genetic information from one species to another

Term	Description
instream flow	water flows and levels in a stream or other waterbody
Last Glacial Maxima	the period of time when the continental ice sheets reached their maximum total mass during the last ice age
latent mortality	a term for harm caused when an animal survives one event or circumstance but incurs damage that only shows up much later
large woody debris	refers to the fallen trees, logs and stumps, root wads and piles of branches along the edges of streams/rivers, which provide habitat to fish and other organisms
lentic	of, relating to, or living in still waters (such as lakes, ponds or swamps)
lesions	an abnormal change in structure of an organ or part due to injury or disease
lithium	the chemical element of atomic number 3, a soft silver-white metal
losing reach	a reach that loses water as it flows downstream The water infiltrates into the ground, recharging the local groundwater, because the water table is below the bottom of the stream channel.
lotic	of, relating to, or living in actively moving water
macroinvertebrate	any animal lacking a backbone and large enough to see without the aid of a microscope
macrophyte	a plant, especially an aquatic plant, large enough to be seen by the naked eye
mainstem	the main course of a river or stream
mark-recapture	a technique used to estimate the size of a population
meltwater	water derived from the melting of ice and snow
membrane lipid	a molecule, structurally similar to fat or oil, which forms the double-layered surface of a cell (called the lipid-bilayer)
meso-habitat	a medium-sized habitat
Mist Mountain Formation	a geologic formation present in the southern and central Canadian Rockies
moraine	any accumulation of unconsolidated debris (e.g., rock) that occurs in

Term	Description
	both currently and formerly glaciated regions, and that has been previously carried along by a glacier or ice sheet
moraine-dammed lakes	occurs when the terminal moraine has prevented some meltwater from leaving the valley
morphology	the external structure of rocks in relation to the development of erosional forms or topographic features
neuromuscular system	all the muscles in the body and the nerves serving them
neutral reach	a reach with a lack of a gain or loss of streamflow
nitrate	a chemical with the formula NO_3, that helps plants grow
nitrite	a chemical with the formula NO_2-
nitrification	the biological oxidation of ammonia to nitrite followed by the oxidation of the nitrite to nitrate
nival	of or relating to a region of perennial snow
Non-random sampling	Under a non-random sampling approach, there is not an equal probability of each sample being chosen. A sample chosen randomly is meant to be an unbiased representation of the total population, so non-random sampling may bias sampling
North American Plate	a major tectonic division of the Earth's crust
observer efficiency	the ratio of the number of tags observed to the number of tags present in the survey area, used to estimate the proportion of fish the snorkel team observed
offsetting	a means to reduce or compensate for impacts to fish productivity, habitat loss or other ecosystem function; offsets are used after steps to avoid or mitigate impact
oomycete	a subclass of parasitic fungi
open pit mining	a surface mining technique that extracts minerals from an open pit in the ground
oral cavity	the part of the mouth behind the gums and teeth
osmotic	of, relating to, caused by, or having the properties of osmosis

Term	Description
osmotic stress	a change in osmotic pressure causing a rapid passage of water or other solvent across a membrane by osmosis; in living cells this may result in rupture of the cell membrane and lysis of the cell
osmosis	movement of a solvent (such as water) through a semipermeable membrane (as of a living cell) into a solution of higher solute concentration that tends to equalize the concentrations of solute on the two sides of the membrane
osmoregulation	regulation of osmotic pressure especially in the body of a living organism
overburden	materials overlying the coal resource
overwintering	the process by which some organisms pass through or wait out the winter season, or pass through that period of the year when "winter" conditions (cold or sub-zero temperatures, ice, snow, limited food supplies) make normal activity, or even survival, difficult or near impossible
oxbow	an arc or crescent-shaped body of water located in an abandoned river channel
oxidative stress	physiological stress on the body that is caused by the cumulative damage done by free radicals (which are especially reactive atoms that have one or more unpaired electrons)
oxygen demand	the amount of oxygen that can be consumed by chemical reactions in a measured solution
passability	the state of being passable (by fish)
periodicity	the quality, state, or fact of being regularly recurrent or having periods
periphyton	freshwater organisms such as algae and bacteria that attach to rocks, plants, suspended particles and other objects in the water
permanently fragmented population	a population of Westslope Cutthroat Trout where both upstream and downstream migration is fully cut off for all months and flows
phosphorus	a nonmetallic element with atomic number 15 that is essential for life in all known organisms; often found in combination with other elements as phosphates
pit dewatering	the movement of water from pits to support mine operations

Term	Description
PIT tag	Passive Integrated Transponder, an electronic microchip encased in biocompatible glass that protects the electronic components and prevents tissue irritation PIT tags serve as a permanent coded marker for identifying an individual animal
plasma	the fluid part of blood that carries suspended material (e.g., blood cells)
points of release for mine-influenced water/ release locations	locations where Teck Coal is permitted to release water
polycyclic aromatic hydrocarbon	any of a class of hydrocarbon molecules that have multiple carbon rings; a class of chemicals that occur naturally in coal, crude oil and gasoline
pool	an area of the stream characterized by deep depths and slow current
primary productivity	term used to describe the rate at which plants and other photosynthetic organisms produce organic compounds in an ecosystem
process error	true variation in animal population abundance caused by variation in processes like recruitment and survival
proliferative kidney disease	one of the most serious parasitic diseases of salmonid populations in Europe and North America
proximate cause	the immediate cause that precipitates a condition
Quaternary	the geologic period of time that encompasses the most recent 2.6 million years — including the present day
radio tag	a tag used in telemetry studies
ramping	rapid changes in water level or flow in streams that can result in stranding and mortality of fish
reach	a section of a stream that is typically 100 metres long or more
rearing	the times of year when fish are most likely to be feeding and growing (accumulating somatic or reproductive tissue) During the rearing period, fish may be undertaking life history activities such as reproduction, migration and maintenance of territories. This period is in contrast to the overwintering period when such activities

Term	Description
	are limited or absent.
recruitment	the increase in a natural population as progeny grow and immigrants arrive
redox	a process in which one substance or molecule is reduced (loses an electron) and another is oxidized (gains an electron)
redd	the spawning ground or nest of various fishes
reference (stream, area, tributary)	a watercourse that has not been affected by mining activity; typically located upstream of mine operations
removal-depletion	an electrofishing method where a section of stream is sampled repeatedly and the fish captured are temporarily removed Because each sampling pass should remove fewer fish, the total population can be estimated by extrapolating the decreasing number to 0.
resistance	represents the magnitude of abundance decline following disturbance
resilience	a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables[24]
recovery	the magnitude or rate of population increase after the disturbance abates
requisite condition	the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT
riffle	an area of stream characterized by shallow depths with fast, turbulent water
riparian zone	the area of terrestrial habitat adjacent to and most directly influenced by a river or stream
Rocky Mountain Trench	a long and deep valley extending approximately 1,500 km from the northwest Montana through British Columbia to just south of the Yukon Territory
Rocky Mountain Foreland Belt	one of the five morphogeological belts that ultimately define the geologic setting in British Columbia from east to west

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[24] Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics. 4: 1–23

Term	Description
	The Foreland Belt consists of sedimentary rock.
run	an area of stream characterized by moderate current, continuous surface and depths greater than riffles
runoff	releases of mine-influenced water that are not written into a permit with a specified location; and/or water that flows over land due to gravity
Salmonidae	a family of fish that includes salmon, trout, chars, freshwater whitefishes and graylings, which collectively are known as the salmonids
salvage	a fish salvage involves collecting fish from an isolated/unsuitable area and relocating them
screening value	a benchmark or numeric value used to identify constituents or other stressors that merit further evaluation
secondary productivity	the generation of biomass of consumer organisms in a system
sedimentary rock	rock formed through deposition and solidification of sediment, like the sediment transported by water or ice
sediment oxygen demand	the rate at which dissolved oxygen is removed from the water column during the decomposition of organic matter in streambed or lakebed sediments
selenium	the chemical element of atomic number 34 and a constituent (see definition) in the upper Fording River
sexual dimorphism	distinct difference in size or appearance between the sexes of an animal, in addition to difference between the sexual organs themselves
side-channel	a channel that branches from a main channel of a river
snow water equivalent	the amount of water in the snowpack if you melted the snow
solute	the minor component in a solution, dissolved in the solvent
spawn/spawning	to produce or deposit (eggs) — used of an aquatic animal
Special Concern (COSEWIC)	a wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats
spoil/spoiling	the overlying material that is removed during mining in order to access

Term	Description
	the desired material below/the placement of spoils on land
sportfish	a type of fish prized for the sport it gives the angler
snorkel survey	a technique used for the underwater observation and study of fish in flowing waters
stranding	when fish become trapped due to a sudden decrease in water levels caused by natural or anthropogenic events
stressor	any physical, chemical or biological entity that can induce an adverse response; in the Evaluation of Cause, stressors are potential causal factors that were considered by the Evaluation of Cause to determine causal links to the decline of WCT
stressor interactions	the outcome of stressors working in an additive, synergistic and/or antagonistic manner
subfamily	a category in biological classification
sublethal	an effect that is less than lethal, such as effects on growth and reproduction
sublimation	the process of passing directly from the solid to the vapour state
suboxic	a zone of water in which the concentration of oxygen is very low
subspecies	a category in biological classification that designates a population of a particular geographic region that is genetically distinguishable from other populations of the same species
sulphate	Sulphate in water (aqueous phase) is a negatively charged ion that is composed of one sulphur atom with four oxygen atoms surrounding it
sulphur reducing bacteria	bacteria that convert sulphate (SO_4^{2-}) to hydrogen sulphide (H_2S).
sump	A pit or hollow in which liquid collects, often in the floor or a building or in an area where hydraulic control is desired
swale	a depression in elevation relative to surrounding land; similar to a ditch, but may be less defined
tailings	the waste materials remaining after the target mineral or product is extracted or separated from ore
telemetry	the science or process of collecting information about objects that are

Term	Description
	far away and sending the information somewhere electronically
till	glacial debris
tributary	a river, stream or creek flowing into a larger river or lake
topography	the physical appearance of the natural features of an area of land, especially the shape of its surface
total suspended solids	particles larger than 2 microns and found in the water column
total dissolved solids	the amount of material, such as metals, minerals and ions, dissolved in a particular volume of water (typically measured in milligrams per litre)
transpiration	the process of water moving through a plant and evaporating from aerial parts, such as leaves, stems and flowers
trophic status	trophic relates to nutrients/nutrition, so trophic status refers to a classification based on the amount of available nutrients in a system
U-shaped valley	valleys formed by the process of glaciation with steep, straight sides and a flat or rounded bottom (like a "U")
upgradient	a location that is the source groundwater for another location; similar to upstream
upwelling	An upward movement from a lower source
water quality guideline	generic values intended to identify constituents that could contribute to acute (short-term) or chronic (long-term) stress to aquatic life
watershed	the area that drains to a single stream or river; frequently referred to as a river basin
waste rock	the rock excavated during mining to expose the coal seams (also referred to as spoil)
whirling disease	a disease caused by *Myxobolus cerebralis*, a microscopic parasite that affects salmonid fish such as trout, salmon and whitefish

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Appendices

Appendix A: Subject Matter Expert Report and Stressor List

Table A-1. Subject Matter Expert report and stressor list

Focus	Citation for Subject Matter Expert Reports
Climate, temperature, and streamflow	Wright, N., Greenacre, D., & Hatfield, T. (2021). *Subject Matter Expert Report: Climate, water temperature, streamflow and water use trends. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Ice	Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Habitat availability (instream flow)	Healey, K., Little, P., & Hatfield, T. (2021). *Subject Matter Expert Report: Habitat availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Stranding – ramping	Faulkner, S., Carter, J., Sparling, M., Hatfield, T., & Nicholl, S. (2021). *Subject Matter Expert Report: Ramping and stranding. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Stranding – channel dewatering	Hatfield, T., Ammerlaan, J., Regehr, H., Carter, J., & Faulkner, S. (2021). *Subject Matter Expert Report: Channel dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Stranding – mainstem dewatering	Hocking M., Ammerlaan, J., Healey, K., Akaoka, K., & Hatfield T. (2021). *Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd. Zathey, N., & Robinson, M.D. (2021). *Summary of ephemeral conditions in the upper Fording River Watershed. In Hocking et al. (2021). Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.

Focus	Citation for Subject Matter Expert Reports
Calcite	Hocking, M., Tamminga, A., Arnett, T., Robinson M., Larratt, H., & Hatfield, T. (2021). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd.
Total suspended solids	Durston, D., Greenacre, D., Ganshorn, K & Hatfield, T. (2021). *Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Fish passage (habitat connectivity)	Harwood, A., Suzanne, C., Whelan, C., & Hatfield, T. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. Akaoka, K., & Hatfield, T. (2021). Telemetry Movement Analysis. In Harwood et al. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.
Cyanobacteria	Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes.* *Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Larratt Aquatic Consulting Ltd.
Algae / macrophytes	

Focus	Citation for Subject Matter Expert Reports
Water quality (for all parameters except water temperature and TSS [which were assessed by Ecofish Research])	Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd. Healey, K., & Hatfield, T. (2021). *Calculator to assess potential for cryoconcentration in upper Fording River.* In Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.
Industrial chemicals, spills and unauthorized releases	Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd. Branton, M., & Power, B. (2021). *Stressor Evaluation – Sewage.* In Van Geest et al. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.
Wildlife predators	Dean, D. (2021). *Subject Matter Expert Report: Wildlife predation. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by VAST Resource Solutions Inc.
Poaching	Dean, D. (2021). *Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by VAST Resource Solutions Inc.
Food availability	Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Minnow Environmental Inc.

Focus	Citation for Subject Matter Expert Reports
Fish handling	Cope, S. (2020). *Subject Matter Expert Report: Fish handling. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Westslope Fisheries Ltd.
	Korman, J., & Branton, M. (2021). *Effects of capture and handling on Westslope Cutthroat Trout in the upper Fording River: A brief review of Cope (2020) and additional calculations.* Report prepared for Teck Coal Ltd. by Ecometric Research and Azimuth Consulting Group.
Infectious disease	Bollinger, T. (2021). *Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by TKB Ecosystem Health Services Ltd.
Pathophysiology	Bollinger, T. (2021). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by TKB Ecosystem Health Services Ltd.
Coal dust and sediment quality	DiMauro, M., Branton, M., & Franz, E. (2021). *Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Azimuth Consulting Group Inc.
Groundwater quality and quantity	Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population.* Report Prepared for Teck Coal Ltd. by SNC-Lavalin Inc.

Table A-2. Evaluation of Cause Team for the upper Fording Westslope Cutthroat Trout population decline.

Name	Affiliation	University Degree(s)	Professional Designation(s)	Years of Professional Experience (since last degree)	General Area of Practice
Trent Bollinger	TKB Ecosystem Health Services	HBSc DVM DVSc	Professor	28+	Epidemiology and fish pathology
Maggie Branton	Azimuth Consulting Group (Associate) & Branton Environmental Consulting	BSc MES PhD	PAg	16+	Ecological risk and impact assessment
Scott Cope	Westslope Fisheries	MSc	RPBio	25+	Freshwater fisheries
Emily-Jane Costa	Golder Associates	HBSc MSc		7+	Aquatic Health
Adrian de Bruyn	Golder Associates	BSc MSc PhD	RPBio Adjunct Professor	19+	Environmental Toxicology
Denis Dean	VAST Resource Solutions	BSc	RPBio P Biol	17+	Wildlife Biology
Todd Hatfield	Ecofish Research	PhD	RPBio	24+	Aquatic ecology
Ryan Hill	Azimuth Consulting Group	BSc MRM	RPBio	25+	Applied Ecology
Stefan Humphries	SNC-Lavalin	MSc	PGeo	17+	Hydrogeology
Kyle Knopff	Golder Associates	MA PhD	RPBio	15+	Wildlife biology and impact assessment
Josh Korman	Ecometric Research	MSc PhD	Adjunct Professor	28+	Fisheries ecology and modelling
Heather Larratt	Larratt Aquatic Consulting Ltd.	HBSc	RPBio	42+	Periphyton Biofilms, Bioreactors
Karsten Liber	University of Saskatchewan	BSc PhD	Professor	30+	Aquatic ecotoxicology

Name	Affiliation	University Degree(s)	Professional Designation(s)	Years of Professional Experience (since last degree)	General Area of Practice
Ryan MacDonald	MacHydro	PhD	PAg Assistant Professor	8+	Hydrology and cumulative effects
Carol Murray	ESSA	BSc MSc	RPBio	32+	Adaptive Management
Patti Orr	Minnow Environmental Inc.	BSc MSc		30+	Aquatic science
Beth Power	Azimuth Consulting Group	BSc MSc	RPBio P Biol CSAP^{RISK}	32+	Ecological Risk Assessment
Mike Robinson	Lotic Environmental	MSc	RPBio	15+	Aquatic science

Appendix B: Evaluation of Cause Framework Table

EVALUATION OF CAUSE: FRAMEWORK FOR OVERARCHING HYPOTHESIS #1

This Framework is a systematic approach that Subject Matter Experts (SMEs) used to synthesize their findings with respect to individual stressors (under Overarching Hypothesis #1) and the degree to which they may have contributed to the decline in Upper Fording River Westslope Cutthroat Trout (UFR WCT). The approach to evaluate Overarching Hypotheses #2 is descriped in the Evaluation of Cause Team, (2021)*.

***Evaluation of Cause Team, (2021). Evaluation of Cause — Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited by Evaluation of Cause Team.**

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	**SME**	**Citation for SME's Analysis**	**Stressor**	**Potential Causal Pathways** (= pathway of effect that could be the cause of the observed effect)	**Impact Hypotheses** (= an overarching way to describe how a stressor may have influenced the WCT population)	**Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)**	**Endpoints** (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	**What are the "requisite conditions" for this impact hypothesis to be explanatory?** (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	**Are the requisite conditions for this impact hypothesis met?** (Based on information the SME has and professional judgement)	**Uncertainties or Data Gaps** (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	**Summary of Findings**	**What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)?** (strong, possible, weak/none, indeterminant)	**If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?**	**If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline?** (major, moderate, minor/negligible)	**If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?**
RMP	**Todd Hatfield (Ecofish Research)**	Faulkner, S., M. Sparling, S. Nicholl, J. Carter, and T. Hatfield. 2021. Subject Matter Expert Report: Ramping and Stranding. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited by Ecofish Research Ltd.	Ramping	Rapid change in water level -> stranding of fish -> increase in mortality -> lower fish abundance	Did ramping within the UFR cause or contribute to the observed WCT population decline?	More relevant to younger life stages because shallow habitats are more susceptible to dewatering and are preferred habitat for fry and juveniles, but adult stranding can also occur; August through October is most likely time for stranding to occur because this is the period when fry are present, water use is highest, and streams have low flows	Ramping rates were examined at hydrometric gauges and temporary water level loggers that were installed in the UFR to support on-going instream flow and ramping studies. The frequency, magnitude, wetted history and distribution of events exceeding DFO generic criteria were used to assess the level of potential effect.	Spatial extent: Ramping exceedance events occurred in a relatively large portion of the UFR (therefore assumed to affect a large portion of the population) Duration: Ramping exceedance events were of a duration great enough to cause fish mortality Location: Ramping exceedance events occurred within the UFR where habitat is sensitive to stranding and fish are present. Timing: Ramping exceedance events occurred during the Decline Window when fish are present (adults are present throughout the year; fry are present from August through October) Intensity: Exceedances of ramping rate criteria were large enough to isolate or strand substantial numbers of fish or were frequent enough to cause substantial mortality over time	Spatial extent: No. Based on data examined there was not a large spatial extent of ramping events. Duration: Yes. Duration of ramping events was sufficient to be able to cause fish mortality Location: Yes. Ramping events occurred in the UFR where habitat is sensitive to stranding and fish may be present Timing: Yes. Ramping events occurred during the Decline Window in both the fry present and fry-not present periods Intensity: No. Ramping events with a moderate or high stranding risk occured infrequently, and the magnitude of the ramping events was concluded that they were unlikely to pose a stranding risk to adults.	Low uncertainty. Gauging issues due to autobubbler hydrometric stations have led to erroneous ramping events and data. This has been verified for 2019 ramping events through evaluation of level logger data. There is some uncertainty associated with the application of the generic DFO ramping criteria to the UFR without having site specific ramping response information; however, stage change data recorded at hydrometric stations is conservative given the confined channel units in which gauges are usually located. Little uncertainty was associated with the categorization of fish stranding risk because this was based on quantitative and qualitative considerations as well as extensive professional experience.	There were few ramping exceedance events and none were of sufficent magnitude to pose stranding risk to adult fish, and were limited in spatial and temporal extent; according to established criteria, ramping would not have caused sufficient mortality to be the single cause or even a substantive contributing factor.	Weak/none. Unlikely to be a single or primary cause.	Yes, but unlikely to be a large effect.	Minor/negligible.	Based on frequency of ramping exceedance events and their intensity, the ramping events identified may result in low levels of mortality; however, it is unlikely that ramping would interact with other stressors, except as a contribution to cumulative mortality.
CHN	**Todd Hatfield (Ecofish Research)**	Hatfield, T., J. Ammerlaan, H. Regehr, J. Carter, S. Faulkner. 2021. Subject Matter Expert Report: Channel Dewatering. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited by Ecofish Research Ltd.	Channel Dewatering Events	channel dewatering -> stranding of fish -> increase in mortality -> lower fish abundance	Did dewatering of natural and constructed channels cause or contribute to WCT population decline?	Relevant to all life stages: spawning, incubation, and rearing; potential for effect is related to channel characteristics (channels differ in the quality of habitat for fish and in their sensitivity to stranding)	Potential stranding risk was assessed for each channel through examination of fish presence, habitat quality, habitat sensitivity to stranding, habitat quantity (relative to available habitat in the UFR), and evidence of dewatering	Spatial extent: The dewatering event affected a relatively large portion of accessible fish habitat relative to that available in the UFR (therefore assumed to affect a large portion of the population) Duration: The dewatering event was of a duration great enough to cause fish mortality Location: The dewatering event occurred in the channel in a location where fish are present (accessible to fish and suitable for fish) and where habitat is sensitive to stranding Timing: The dewatering event occurred during the Decline Window when fish were present (adults are present throughout the year, fry are present from August through October) Intensity: Flow during the dewatering event was reduced sufficiently to isolate or strand fish	Spatial extent: No. Amount of habitat affected by channel dewatering for channels with high potential stranding risk is small relative to the habitat in the UFR (0.91%) Duration: Duration of dewatering events could not be determined with available hydrological data (mostly spot measurements) Location: Yes for three channels that were assessed to have had high potential stranding risk: Kilmarnock Phase 1 Channel, Fording River Side Channel, and Kilmarnock Phase 2 Channel Timing: Yes for the three channels that were assessed to have had high potential stranding risk: dewatering events occurred during the Decline Window when adults or fry may be present Intensity: Yes for the three channels that were assessed to have had high potential stranding risk: channels were complete dewatered (zero flow)	Uncertainties include: Hydrological data limitations: assessment of dewatering was based largely on spot measurements which are less likely to capture variability or extreme flow events; data gaps exist for months within years and time periods; hydrological data were not available for some channels or portions of channels; rates of flow change, duration of dewatering events, and fine-scale wetted history could not be determined; assessment of dewatering did not consider flow in the UFR (flows in the UFR can backwater channels reducing dewatering potential) Assumptions regarding consequences of low flows: it was assumed that any flow (i.e., > 0 m^3/s) will sustain fish and that a cessation of flow (i.e., 0 m^3/s) would cause stranding of fish; however, data on site-specific habitat characteristics were not available to evaluate what flows would be required to sustain fish Comparison between periods (Decline Window and historical period): confident comparison is limited by the quality of the hydrological data Assumptions related to Spatial Extent: area calculations did not include the Fording River Side Channel or other similar side channels; spatial distribution of the WCT population within accessible habitat was not considered in the assessment (assumed to be represented by area)	A requisite condition to cause the WCT population decline was not satisfied because a low proportion of habitat (0.91%) relative to habitat in the UFR was assessed to have had a high potential stranding risk and because dewatering events similar to those documented for the Decline Window were also documented during the historical period. A requisite condition to contribute to the WCT population decline was satisfied because there was a high potential stranding risk identified for a low portion of the UFR fish population during the Decline Window.	Weak/none. Requisite condition to cause the WCT population decline was not satisfied (a low proportion of habitat had high potential stranding risk and dewatering events were similar in the Decline Window and the historical period) and numerous uncertainties were identified, especially in relation to the limitations of hydrological data used to characterize dewatering events and assess the potential for fish stranding.	Yes. The requisite condition to contribute to the WCT population decline was satisfied because channel dewatering had the potential to cause high stranding risk for a low portion of the UFR population during the Decline Window	Moderate: Channel dewatering may have contributed to the WCT decline in the UFR because dewatering was documented for channels that were accessible to fish and sensitive to stranding but dewatering events similar to those documented for the Decline Window were also documented during the historical period (using similar methods and assumptions)	The channel dewatering stressor may interact with the UFR ramping stressor, the ice formation stressor, and the habitat availability stressor (impact hypotheses to be listed once all reports complete)
MST	**Todd Hatfield (Ecofish Research)**	Hocking M., J. Ammerlaan, K. Healey, K. Akaoka, and T. Hatfield. Subject Matter Expert Report: Mainstem Dewatering. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.	Mainstem Dewatering Events	Mainstem dewatering -> stranding of fish -> increase in mortality -> lower fish abundance	Did dewatering of the UFR mainstem habitats cause or contribute to the observed WCT population decline?	Relevant to all life stages: spawning, incubation, and rearing; potential for effect is related to the timing and location of drying within the UFR mainstem	Potential stranding risk was assessed used information from several sources: a literature review of dewatering effects on fish stranding and mortality, information on fish stranding events in the UFR, and the timing and extent of dewatering events in the UFR. The potential effect of stranding was estimated using fish use (telemetry) information.	Spatial extent: The dewatering event affected a relatively large portion of accessible fish habitat relative to that available in the UFR (therefore assumed to affect a large portion of the population) Duration: The dewatering event was of a duration great enough to cause fish mortality Location: The dewatering event occurred in the mainstem UFR in a location where fish are present (accessible to fish and suitable for fish) and where habitat is sensitive to stranding Timing: The dewatering event occurred during the Decline Window when fish were present Intensity: The dewatering event led to stranding of a sufficent number of fish to cause or play a role in the decline.	Spatial extent: No.A potential maximum estimate for mortality from stranding was limited to up to 7.0 % of the population based on proportion of mainstem length Duration: Yes. Dewatering of the mainstem was of sufficent length to cause fish mortality. Location: Yes. Timing: Yes. Intensity: No. A maximum estimate for mortality from stranding was limited to 2.5% of the population based on the relative fish use estimates.	Uncertainties include: Limited data on actual WCT mortalities from stranding in the Decline Window and therefore uncertainty on the intensity of stranding that may have occured The relative fish use was estimated using data collected in 2012 to 2015 and are only estimates of actual fish distribution during the Decline Window The dewatering observations in the drying reaches are limited to 2017 to 2020 and do not allow for an assement of conditions prior to the Decline Window. There are data gaps in the flow and stage data during and prior to the Decline Window due to icing and other effects. The scenarios used to estimate potential mortality from stranding do not account for fish movement away from dewatered areas in response to stage declines.	We conclude that drying in the UFR mainstem causing stranding mortality is unlikely to have been the primary cause of the WCT population decline. However, because dewatering occurred during the WCT summer rearing period in fall 2018 and because the extent of drying was largest in 2018/2019, it is possible that stranding mortality from drying was greater in 2018/2019 and therefore a contributing cause for WCT decline for both adults and juveniles.	Weak/None - there are good estimates of physical extent and timing of drying within the Decline Window, and direct observations of stranding mortality. However, we have only indirect estimates of total number of fish stranded. Estimates of maximum effect are likely greater than actual stranding, and maximum predicted effect is lower than total decline.	Yes	Moderate	Stranding is not expected to interact with other stressors. However, mainstem dewatering (drying reach) may influence effects of other stressors due to the potential for drying to limit fish migration.This latter effect is discussed in the Fish Passage report, where it is noted that effects on fish distribution may influence exposure to other stressors like water quality or extreme weather.
HAB	**Todd Hatfield (Ecofish Research)**	Healey, K., P. Little and T. Hatfield. 2021. Subject Matter Expert Report: Habitat Availability. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited by Ecofish Research Ltd.	Habitat Availability	water levels in streams > restricted distribution and amount of suitable habitat > confinement of fish to subset of habitats > increased competition (lower carrying capacity) OR increased exposure to predation/spill/stranding/other factors > decline in growth or increase in mortality > lower fish abundance	Habitat Availability: Did low availability of habitat lead to severe reduction in fish abundance, or to increased exposure to acute stressor?	Relevant to multiple life stages - evaluation focussed on spawning, summer rearing, and overwintering	Evaluate available habitat with suitable hydraulic characteristics via habitat time series analysis. Habitat calculated by applying habitat-flow relationships developed for important overwintering, spawning, and summer rearing locations (Cope et al 2016) to hydrology records in UFR . Habitat quantity during life stage periods compared between years to assess whether habitat was lower during the Decline Window.	For this impact hypothesis to be explanatory, the following would need to be met: 1. habitat needs to be the primary limiting factor for adults and juveniles (i.e., not factors unrelated to habitat quantity and quality) Spatial extent: Suitable habitat availability is reduced over much or most of the UFR Duration: Suitable habitat availability is reduced for a prolonged period (substantive proportion of time) within critical WCT life history periods Location: Suitable habitat availability is reduced in locations that are important for WCT within the UFR. Timing: Reduction in suitable habitat availability occurred during the Decline Window (i.e., is temporally consistent with the observed decline) and during critical time periods for WCT Intensity: Suitable habitat availability is substantively reduced during the Decline Window relative to previous time periods	Requisite condition to cause: No Requisite condition to contribute: Yes	Incomplete flow data record limits ability to complete Evaluation of Cause for the entire Decline Window. In particular, missing data during the winter limits ability to calculate habitat during substantial portion of this time. Also some missing data in September 2017 limit ability to assess duration of reduced flow/habitat in Fording River. Uncertainty in habitat-flow relationships primarily due to Habitat Suitability Criteria, and relationships between flow at transect locations and hydrometric gauges available for time series analysis. Uncertainty can be reduced by reviewing the data gaps and assessing whether flow during missing periods is likely to be anomalous.	For overwintering and spawning, habitat availability during the Decline Window was typical throughout the UFR. For summer rearing, average Henretta Creek habitat in 2017 was 25% less than the average habitat across all years. Fording River habitat availability in late September 2017 was also less than other years (quantitative estimates are not possible because of missing data).	Weak/none. Although there is evidence that less suitable summer rearing habitat was available in 2017, the magnitude of the reduction was fairly small, and a reduction in rearing habitat would not likely result in mortality on its own; thus, this pathway cannot be the sole explanation for the observed decline.	Yes, a requisite condition to contribute to the population decline was satisfied because there was less summer rearing habitat in September 2017 throughout UFR.	Minor/Negligible; other factors needed to account for the large decline observed.	This pathway could conceivably interact with many other pathways (e.g., water quality, calcite, general population biology); however, the observed effects seem to be minor/negligible.

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	**SME**	**Citation for SME's Analysis**	**Stressor**	**Potential Causal Pathways** (= pathway of effect that could be the cause of the observed effect)	**Impact Hypotheses** (= an overarching way to describe how a stressor may have influenced the WCT population)	**Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)**	**Endpoints** (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	**What are the "requisite conditions" for this impact hypothesis to be explanatory?** (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	**Are the requisite conditions for this impact hypothesis met?** (Based on information the SME has and professional judgement)	**Uncertainties or Data Gaps** (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	**Summary of Findings**	**What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)?** (strong, possible, weak/none, indeterminant)	**If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?**	**If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline?** (major, moderate, minor/negligible)	**If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?**
TSS	**Todd Hatfield (Ecofish Research)**	Durston, D., D. Greenacre, Ganshorn, K and T. Hatfield. 2021. Subject Matter Expert Report: Total Suspended Solids. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd., 2021.	Total Suspended Solids (TSS)	Release or runoff of sediment laden water -> exposure to elevated TSS -> behavioural, physiological, habitat effects -> decline in growth or increase in mortality -> lower fish abundance Release or runoff of sediment laden water -> exposure to elevated TSS -> behavioural, physiological, habitat effects -> decline in growth or increase in mortality -> lower fish abundance	Did exposure to TSS in the UFR and its tributaries cause or contribute to the observed WCT population decline?	Evaluate all life-stages: adult, juvenile, and eggs and larvae. TSS data were collected during routine water quality monitoring in the mainstem of the UFR, tributaries and at additional release locations in accordance with regulatory permit conditions. TSS data from event-based monitoring were collected for un-licensed releases or when TSS exceeded the concentration specified by license. Data were supplied for the Janary 2012 to December 2019 period and analyzed during the Decline Window (September 2017 to September 2019) and prior years.	TSS records from discontinuous sampling in the UFR since 2012 have been analyzed using Severity of ill effects (SEV) models for fish life-stages (developed by Newcombe and Jensen, 1996). The potential effects of TSS were evaluated by assuming chronic (30-day) exposure from samples collected during routine monitoring (i.e., the UFR, its tributaries, and authorized discharge points) and acute (96-hour) exposure for routine monitoring results and unauthorized discharges. TSS concentrations and SEV index scores for all life stages were assessed to evaluate spatial and temporal trends in the UFR and tributaries.	A requisite condition to cause was identified when TSS concentrations had the potential for high or very high magnitude effects during the Decline Window relative to the historical period and occurred over a wide area where fish were present. This may occur through multiple high magnitude events (0 – 20% mortality) or as few as one very high magnitude event (40 – 100% mortality). Meeting these conditions could result in a population-level effect consistent with the observed WCT population decline. A requisite condition to contribute was identified when SEV data had the potential for localized high or very high magnitude effects and/or widespread moderate magnitude effects during the Decline Window relative to the historical period. Localized effects could result in mortality but at a limited spatial scale that is insufficient to explain the mortality levels associated with the WCT decline; whereas, widespread moderate magnitude effects do not directly cause mortality but are associated with reductions in feeding and increased stress, which can reduce fish health and may result in mortality when combined with other effects.	Requisite condition to <u>cause</u>: No Requisite condition to <u>contribute</u>: Yes	• All TSS data were obtained from spot samples, which were generally taken at weekly or monthly intervals, meaning that potential effects may have occurred between samples. The temporal assumptions made when analyzing the data (i.e., spot measurements are representative for the entire 96-hour or 30-day period) may not be valid, so greater or lesser acute or chronic effects may have occurred. • Samples are assumed to be representative of the average TSS conditions for the corresponding habitat area. This is deemed to be a reasonable assumption but the influence of the assumption is likely to vary depending on the characteristics of localized sediment sources upstream or downstream of the sample location. • Predictions of harm from TSS are based on general SEV models that are not specific to WCT and derived from limited data, such that the actual effects could be less or greater.	For both chronic and acute effects, a requisite condition to cause the WCT population decline was not satisfied for any life stage because area-weighted average SEV results for routine monitoring were similar or better during the Decline Window than prior to Sep 2017, while SEV results for event-based monitoring showed no events of sufficient magnitude that were widely coincident with WCT distribution. For both chronic and acute effects, a requisite condition to contribute to the WCT population decline was satisfied. For chronic effects, the assessment identified: moderate magnitude chronic effects to adult and juvenile salmonids; and high or very high magnitude chronic effects to eggs and larvae. For acute effects, the assessment identified: moderate to very high magnitude acute effects to adults; moderate to high magnitude acute effects to juveniles; and moderate, high, or very high magnitude acute effects to eggs and larvae.	Weak/none. Requisite condition to cause the decline was not satisfied for any life stage because area-weighted SEV model results were similar to or better than pre-Sep 2017. Uncertainty exists about TSS events that may not have been detected due to spatial and temporal gaps in data coverage.	Yes. For all life stages, the requisite condition to contribute to the decline was satisfied because SEV model results showed that TSS concentrations had the potential to cause chronic or acute effects between Sep 2017 and Sep 2019; however, there was no marked change in predicted effects coincident with timing of the population decline.	Overall, this assessment indicates that TSS stressors may have contributed to the WCT decline in the UFR, but more detailed TSS records are needed to validate the results of the available data.	TSS analysis does not provide context for other impact hypotheses, but TSS effects may be additive to other stressors.
C&H	**Todd Hatfield (Ecofish Research)**	Wright, N., D. Greenacre, and T. Hatfield. 2021. Subject Matter Expert Report: Climate, Water Temperature, Streamflow and Water Use Trends. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd.	Climate and Hydrology	a) Mortality from extreme weather (climate) and flow	Is there evidence for anomalies in climatic factors, water temperature, streamflow, or water use during the Decline Window, in comparison to previous years, which could have interacted with other stressors evaluated for the EoC of the WCT population decline?	Relevant to all life stages.	Hydrometric and climate station data, water temperature data, operational water use records, WCT periodicity. All data were reviewed for gaps. The most reliable data were reviewed to identify trends and anomalies in the Decline Window (from September 2017 to September 2019), relative to historical data. Analysis of daily climate data involved computing summary statistics for each station, for each month and year. Ecologically relevant statistics were used to describe trends and anomalies in daily water temperature, streamflow, and water use data for each WCT life stage.	Climatic factors and flow are expected to play an influencing role, interacting with other potential WCT stressors, rather than directly causing fish mortality. Requisite conditions were defined to help identify anomalous climate (weather) and hydrology events that may have played a substantive role in the WCT population decline. The results of our climate and streamflow data analysis are meant to support the evaluation of cause for other stressors, rather than testing directly for climate and hydrology effects. Spatial extent: The anomlous event affected broad areas in the UFR mainstem and tributaries. Duration:Not specified; judged in combination with intensity Location:The anomalous event occurred throughout much or all of the UFR. Timing: The anomalous event occurred during the Decline Window and exceeded guidelines (in the case of water temperature) during any of the key WCT life stage periods Intensity: Identify anomalous events relative to historic; exceedance of thresholds for water temperature.	Most data during the Decline Window were not anomalous. Climate, hydrology, and water use were determined to be similar between the Decline Window and the historical period, with the exception of air temperatures in February 2019, water use (expressed as a percentage of flow) during the over-wintering migration period in 2017, and the overwintering period in 2017-2018, and water temperature during the spawning migration period during the Decline Window. The results of our climate and streamflow data analysis are meant to support the evaluation of cause for other stressors, rather than testing directly for climate and hydrology effects.	Discontinuous spatial and temporal data coverage, including data gaps in winter due to ice, mean that there is uncertainty in the water temperature and streamflow analysis	Air temperatures in February 2019 were the coldest temperatures of any February at stations with records dating back to 2001, and below the 25th percentile of any February in the longer-term (50 year) data record. Total snowfall was less during the winter of 2018-2019, which is reflected in the longer-term snow pillow record (50-years), which showed snow water equivalent was below 25th percentile from mid-January 2019 onward. Water temperature and/or streamflow were lower, and water use was higher, during some WCT life stages during the Decline Window compared to previous years; however, there is moderate uncertainty due to temporal gaps and results were not consistent across data stations.	Most data during the Decline Window were not anomalous. Climate, hydrology, and water use were determined to be similar between the Decline Window and the historical period, with the exception of air temperatures in February 2019, water use (expressed as a percentage of flow) during the over-wintering migration period in 2017, and the overwintering period in 2017-2018, and water temperature during the spawning migration period during the Decline Window. The results of our climate and streamflow data analysis are meant to support the evaluation of cause for other stressors, rather than testing directly for climate and hydrology effects.	Yes	Moderate; however, other factors (e.g., interactions with other stressors like ice) are needed to account for the large decline observed.	Climate and streamflow data analysis are meant to support the evaluation of other stressors. Even if air and water temperature (climate) were considerably lower and/or streamflow considerably less during key life stages, the magnitude and duration were not clearly sufficient in and of themselves to account for the large decline observed; other factors would need to have interacted with the climate stressors.
ICE	**Todd Hatfield (Ecofish Research)**	Hatfield T. and C. Whelan. 2021. Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. Report Prepared by Ecofish Research Ltd.	Extreme Cold and Ice	a) Direct mortality from freezing of occupied habitat, b) Mortality due to exclusion of fish from preferred overwintering habitat caused by the formation of anchor, frazil or surface ice, and c) Mortality due to the physiological effects on WCT from adverse overwintering conditions.	Did ice formation cause or contribute to the observed WCT population decline?	Relevant to multiple life stages; however, the available information does not allow separate evaluations for each life stage.	We compiled and summarized available records of air and water temperature, snowpack, and discharge for the Decline Window and the period prior to the Decline Window from several sources. Data on ice extent, thickness and duration are very limited, but were also evaluated.	Spatial extent: Detrimental ice conditions occurred over an area large enough to affect a large proportion of the fish population Duration: Presence of frazil ice, anchor ice or surface ice was of sufficient duration to result in fish mortality Location: Areas in the UFR occupied by fish were affected by detrimental ice conditions Timing: Ice conditions and overwintering habitat availability were more severe during the Decline Window than before Intensity: Ice conditions were more detrimental during the Decline Window than before, or acted in combination with other factors to cause higher mortality during the Decline Window	Yes	Uncertainty due to lack of direct observations, and likelihood of variable spatial and temporal effects of ice formation	Air and water temperatures in winter 2019 shift from abnormally warm to abnormally cold. This is combined with a below average snowpack. Water temperature and stage/discharge readings indicate the presence of ice in the system. Findings suggest that ice formation could have been abnormally high, and occurred very suddenly. Evidence from game cameras and anecdotal reports support this conclusion; however, there were no direct observations to determine to what degree WCT were affected by ice formation.	Possible - Conditions for severe ice formation were present in Feb 2019, and alone could cause WCT mortality.	The temperature shift in February 2019, together with antecedant conditions could have caused unusually high ice formation which could directly and indirectly affect WCT survival. The effects of this cause would be exacerbated by interactions with other pathways, such as if connectivity was concurrently decreased.	This impact pathway is likely to have contributed to WCT population decline	Stream connectivity could play a role in whether WCT were able to reach stable overwintering habitat in winters of 2018/19, although this would only have affected a portion of the fish. Factors that affect WCT condition during winter cold periods could also play a role (e.g., water quality)
FP	**Todd Hatfield (Ecofish)**	Harwood, A., C. Suzanne, C. Whelan, and T. Hatfield. 2021. Subject Matter Expert Report: Fish Passage. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. January 2021.	Fish Passage	Low water levels in streams -> Limited access to overwintering habitat -> Confinement of fish to suboptimal overwintering habitats -> Increased mortality in winter -> Lower fish abundance	Fish Passage: Did restricted fish passage within the UFR during the fall migration period contribute to the observed WCT population decline?	Relevant to mobile life stages fry, juveniles, adults; assessed critical riffles and areas subject to shallowing/drying during low flows that may impede fish migration within the UFR mainstem (confluence of Chauncey Creek to confluence of Henretta Creek); focused on the fall migration window from September 1 to October 15, but evaluated conditions from August 1 to October 30 to get a better understanding of variability in conditions among years; evaluated conditions at potential riffle barriers on the UFR mainstem during this period in different years	Evaluation of potential restrictions to fish movement during the fall WCT migration period focused on a critical riffle analysis (CRA) that involves examination of conditions at riffles that may act as barriers to movement at low flows. The evaluation was supported by summarizing passive integrated transponder (PIT) data collected at two arrays in the UFR installed at the Multi-plate and Henretta culverts, completing additional analyses on radio telemetry data collected by Cope et al. (2016), documenting the recent habitat rehabilitation work that has occurred on the Fording River mainstem and the potential for impacts on migration during construction, and evaluating the occurrence of large log jams on the upper Fording River mainstem. For the CRA, we assessed 2018 results from non-linear transects and passability of riffles according to Criterion 2 (contiguous wetted width). The analysis was extended to evaluate likely passage conditions at critical riffles using available flow data from other years when available (1997-2019).	Loss of connectivity to preferred overwintering habitats is expected to play an influencing role, interacting with other potential WCT stressors and factors (e.g., climate, predation, water quality), rather than directly causing fish mortality. Accordingly, we used results of the CRA to assess whether requisite conditions to contribute to the decline of WCT were met. Requisite conditions were based on spatial (extent and location) and temporal (timing and duration) aspects of low water levels and connectivity loss and on the intensity (magnitude) of the water depth reductions relative to passability criteria for fish.	Requisite conditions to <u>cause</u> were not met. Requisite conditions to <u>contribute</u> were met.	Key uncertainties: 1. There may have been morphological changes at critical riffles between 2018 when empirical measurements were taken and the other years assessed. Based on freshet flows, this is more likely between the 2017 and 2018 fall migration periods, than the 2018 and 2019 fall migration periods. 2. Given the distance between the critical riffles and the hydrometric gauges at Measuring Points B and C, and the small range of variability in flows during the period when loggers were installed at the riffles in 2018, it was not possible to develop accurate stage-discharge relationships relating stage at the critical riffles to discharge at the hydrometric gauges. If inflow conditions and/or operational water use between the critical riffles and the hydrometric gauges at Measuring Points B and C were different in 2018 than the other years being assessed, then passage conditions at the critical riffles may have been different even if Measuring Point discharge was the same. 3. Passage impedances at critical riffles are based on depth criteria and wetted width thresholds for passage, rather than direct observations of fish passage.	Results of the critical riffle analysis indicate potential fish passage impedance within the fall migration period of September 1 to October 15 in 2017 (FRD-CRA04 and 05) and 2018 (FRD-CRA02, 03, 05). In 2018, migration past the three riffles noted above was impeded for approximately two thirds or more of the 45-day migration period. Results of the PIT tag analysis showed detections in the summer of 2017 and the summer of 2018 are comparable, whereas detections in the summer of 2019 are much lower, providing some evidence that the decline occurred between the summers of 2018 and 2019. There is also evidence that the Henretta culvert or associated weirs act as a partial barrier to migration.	Weak/none. Although there is evidence that passage may have been impeded at certain riffle barriers, the failure to reach preferred overwintering habitat would not directly result in fish mortality; thus, this pathway cannot be the sole explanation for the observed decline.	Yes. Given that potential fish passage impedances were identified at certain riffle barriers during the fall migration period within the Decline Window, some of the requisite conditions to contribute to the decline (Duration, Location, Timing, Intensity) were met. However, requisite conditions for Spatial Extent could not be confidently assessed because passage impedances were identified only at some locations and the influence of impedance at these locations will depend on the life-history strategy of WCT (migrant or resident) and the location of rearing habitat relative to overwintering habitat for different individuals.	Moderate. There is evidence that movement to optimal overwintering habitat was impeded. To result in mortality other stressors would need to interact with the lack of connectivity and resulting confinement of fish to sub-optimal habitats.	The impedance of migration at critical riffles could have contributed to the observed WCT decline in combination with other stressors such as climate (e.g., extreme cold event in February 2019 and associated icing and dewatering), predation, and water quality.
							cont'd: The PIT tag analysis utilized existing data from two PIT tag detection arrays that were installed at the Multi-plate and Henretta culverts in 2017. Data were evaluated to ascertain the number and timing of fish movements from 2017 to 2020 and used to provide insight into the timing of the WCT population decline. Additional analysis of the radio telemetry data collected by Cope et al. (2016) between 2012 and 2015 (Appendix B) assessed key trends in WCT movement in the upper Fording River including the distance and timing of movement, and the potential implications of passage barriers. Rehabilitation work that has occurred on the Fording River mainstem between 2016 and 2018 was documented to allow a qualitative assessment of the potential for behavioral avoidance of construction works. Additionally, we used orthophotos from 2007, 2012, 2013, 2016, 2017, 2018 and 2019 to assess the potential for log jam formation to interrupt WCT migration behaviour in the UFR.	cont'd: <u>Spatial Extent:</u> Loss of connectivity prevented access to preferred overwintering habitat within much of the UFR mainstem (confluence of Chauncey Creek to confluence with Henretta Creek [S6 through S9]) <u>Duration:</u> Loss of connectivity was maintained for long enough to prevent access to preferred overwintering habitat (e.g., weeks) <u>Location:</u> Low water levels occurred in locations sensitive to loss of connectivity (riffles located in S6, S7, S8 and S9) <u>Timing:</u> Loss of connectivity occurred during the Decline Window during the fall migration period (September 1 to October 15) <u>Intensity:</u> Water depth in critical connectivity locations (e.g., riffles) was shallow enough to restrict fish movement (assessed in relation to minimum depth criterion for fish passability)		cont'd: 4. There is the potential that migration impedance may put a substantial portion of the UFR WCT population at increased risk of overwintering mortality; however, the extent to which resident fish may be affected by lost connectivity is uncertain as this evaluation focussed on fish that migrate to overwintering habitat. 5. PIT tag analyses were largely restricted to the Decline Window as there were no accessible historical data. Further, the relationship between culvert passage and UFR flow has not been assessed; thus, culvert passage could not be evaluated in comparison to previous years when WCT abundance had not yet decreased.					
										cont'd: 6. The analysis used assumptions regarding the timing of migration to overwintering areas based on previous work, and the PIT tag analysis and aspects of the telemetry analysis indicated higher levels of activity and movement in the summer rearing period compared to the fall migration period. However, evaluation of movement trends using telemetry data found general alignment with the assumed fall migration period of September 1 to October 15. Nevertheless, if migratory patterns differ from the assumed timing, this could affect potential consequences of identified barriers and interactions with seasonal flow and water level changes. 7. If fish are impeded from migrating past critical riffles or through culverts, there is uncertainty as to the fate of these fish, the quality of the overwintering habitat they need to occupy and the extent to which they are more susceptible to other stressors during the overwintering period.					

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	SME	Citation for SME's Analysis	Stressor	Potential Causal Pathways (= pathway of effect that could be the cause of the observed effect)	Impact Hypotheses (= an overarching way to describe how a stressor may have influenced the WCT population)	Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)	Endpoints (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	What are the "requisite conditions" for this impact hypothesis to be explanatory? (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	Are the requisite conditions for this impact hypothesis met? (Based on information the SME has and professional judgement)	Uncertainties or Data Gaps (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	Summary of Findings	What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)? (strong, possible, weak/none, indeterminant)	If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?	If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline? (major, moderate, minor/negligible)	If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?
CAL	**Todd Hatfield (Ecofish Research)** **Mike Robinson (Lotic Environmental)** **Heather Larratt (Larratt Aquatic Consulting)**	Hocking, M., A. Tamminga, T. Arnett, M. Robinson, H. Larratt, and T. Hatfield. 2021. Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd.	Calcite	a) Recruitment failure from reduced spawning success	Calcite (a): Did increased calcite presence/concretion over time result in the observed decline in fish population via decrease in recruitment and spawning success?	Relevant to spawning and spawning success. Limited to spawning habitats and fry production throughout UFR.	Calcite index, presence, concretion data (2013-2019) for UFR mainstem and tributary segments were assessed by reach and over time. Corresponding fish data were evaluated by stream segment and compared to calcite data. Review of dose-response relationships between spawning suitability and calcite developed in the Calcite effects to spawning suitability study (Hocking et al. 2020).	Spatial extent: Widespread calcite in mainstem and tributary areas of the UFR that support WCT. Duration: Calcite reduces spawning habitat suitability during WCT decline window. Location: Widespread calcite in UFR mainstem and tributary WCT spawning habitat. Timing: Calcite index and concretion would have to change between the pre-window and decline window to explain the observed decline. Intensity: Moderate to high calcite index and/or concretion scores would be needed.	Spatial extent: Yes, calcite growth from mine-related influence is present in all reaches of the UFR and many tributaries. Duration: No, there is no significant change in calcite conditions and trends in spawning suitability in pre- window versus decline window periods, apart from an isloated increase in calcite in the FORD9 unit of the UFR mainstem. Location: Yes, calcite is present in UFR and mine affected tributaries, but calcite concretion levels remain low. Timing: No distinct change observed in calcite between pre-window and decline window periods. A gradual increase in calcite index in UFR mainstem observed from 2013-2019. Intensity: No, average calcite index of ~0.8 in UFR mainstem; average concretion scores = ~0.06 throughout UFR fish bearing reaches during decline window.	Uncertainty in the application of the spawning suitability curve developed at the mesohabitat scale to the regional calcite data at the reach scale. Focus on trends rather than predicting absolute spawning suitability. Uncertainty of how calcite effects on spawning suitability may translate to population level effect. However, given that the decline was observed across age classes in one year there is not a clear effect pathway possible.	Calcite index and concretion did not change markedly between pre-window and decline window periods and remained relatively low intensity in WCT habitat. Average calcite concretion = 0.06. Current models predict that relatively low levels of concretion can have significant effects on spawning suitability; however, no major shifts in suitability were predicted between pre-window and decline window periods. Overall this pathway does not explain fish population declines across all age classes in one year. Effects would be expected to be seen in the fry age class, but not other age classes.	Weak/none. Relatively low calcite levels in most locations; some increase in calcite observed over time, but not to intensity levels that would be causal. Unlikely as primary cause. No effect pathway to WCT age classes other than fry.	Yes	Minor/Negligible	Calcite concretion can reduce spawning suitability, which may reduce WCT carrying capacity if good spawning habitat is limiting. However, evidence is weak that this could be a substantial contributing factor for declines across all age classes in the decline window. Interactions would be required across other effect pathways with calcite to elicit response across all age classes.
				b) Mortality from reduced rearing success due to effects availability of fish food	Calcite (b): Did increased calcite presence/concretion over time result in the observed decrease in fish population via declines in invertebrate production?	Relevant to juvenile and adult rearing and overall WCT productivity in UFR across age classes.	Calcite index, presence, concretion data (2013-2019) for UFR mainstem and tributary segments were assessed by reach and over time. Corresponding fish data were evaluated by stream segment and compared to calcite data. Review of available information related to Calcite effects to rearing habitat, including dose-response relationships between calcite and periphyton and invertebrates	Spatial extent: Widespread calcite in mainstem and tributary areas of the UFR that support WCT. Duration: Calcite reduces rearing habitat productivity during WCT decline window. Location: Widespread calcite in UFR mainstem and tributary WCT rearing habitat. Timing: Calcite index and concretion would have to change between the pre-window and decline window to explain the observed decline. Intensity: Moderate to high calcite index and/or concretion scores would be needed.	Spatial extent: Yes, calcite growth from mine-related influence is present in all reaches of the UFR and many tributaries. Duration: No, there is no significant change in calcite conditions and trends in spawning suitability in pre- window versus decline window periods, apart from an isloated increase in calcite in the FORD9 unit of the UFR mainstem. Location: Yes, calcite is present in UFR and mine affected tributaries, but calcite concretion levels remain low. Timing: No distinct change observed in calcite between pre-window and decline window periods. A gradual increase in calcite index in UFR mainstem observed from 2013-2019. Intensity: No, average calcite index of ~0.8 in UFR mainstem; average concretion scores = ~0.06 throughout UFR fish bearing reaches during decline window.	Uncertainty regarding magnitude and importance of this pathway due to lack of data on dose-response relationships. Pathway described via literature review but there is uncertainty about the relationships between calcite and toxicity and toxicity and WCT population effects.	Calcite index and concretion did not change markedly between pre-window and decline window periods and remained relatively low intensity in WCT habitat. Average calcite concretion = 0.06. Effect pathway consistent with effects across age classes but the calcite trend data do not support this as a sole cause for single year decline.	Weak/none. Relatively low calcite levels in most locations; some increase in calcite observed over time, but not to intensity levels that would be causal. Unlikely as primary cause.	Yes	Minor/Negligible	Evidence is weak for the importance of this pathway, even as a contributing factor. Even if rearing habitat was impeded, other factors would need to have contributed to account for the large decline observed in the decline window. The most possible interaction is with flow and climatic conditions during the growing season, followed by a severe winter.
				c) Mortality from releases of metal and cyanotoxins during the dissolution of calcite	Calcite (c): Did increased calcite presence/concretion over time result in the observed decrease in fish population via released toxins during calcite dissolution?	Relevant to all life stages of WCT throughout UFR downstream of calcite accumulations.	Calcite index, presence, concretion data (2013-2019) for UFR mainstem and tributary segments were assessed by reach and over time. Corresponding fish data were evaluated by stream segment and compared to calcite data. Review of available information in Elk Valley and literature related to presence ot toxins produced by native cyanobacteria, biogenic calcite precipitation pathway, including periphyton-calcite relationships, buildup and release of metal toxins and cyanotoxins, evidence for dissolution events during the Decline Window, and interactions with flow and temperature conditions in the decline window.	Spatial extent: Widespread calcite dissolution in mainstem and tributary areas of the UFR that support WCT. Duration: Biogenic calcite dissolution occurs from calcite accumualtions during the decline window. Location: Widespread calcite in and upstream of UFR mainstem and tributary WCT habitat. Timing: Biogenic calcite dissolution would have to change between the pre-window and decline window to explain the observed decline. Intensity: Moderate to high calcite index and/or concretion scores would be needed.	Spatial extent: Yes, calcite growth from mine-related influence is present in all reaches of the UFR and many tributaries. Duration: No, there is no significant change in calcite conditions and trends in spawning suitability in pre- window versus decline window periods, apart from an isloated increase in calcite in the FORD9 unit of the UFR mainstem. Location: Yes, calcite is present in UFR and mine affected tributaries, but calcite concretion levels remain low. Timing: No distinct change observed in calcite between pre-window and decline window periods. A gradual increase in calcite index in UFR mainstem observed from 2013-2019. Intensity: No, average calcite index of ~0.8 in UFR mainstem; average concretion scores = ~0.06 throughout UFR fish bearing reaches during decline window.	Uncertainty regarding effects of calcite on rearing fish due to lack of data on dose-response relationship for released cyanotoxins/metals. Data exists for calcite to periphyton and invertebrates but not calcite to rearing fish. For example, even if a dissolution event occurs it is unknown the levels of cyanotoxicity that WCT may be exposed and their population response.	Calcite index and concretion did not change markedly between pre-window and decline window periods and remained relatively low intensity in WCT habitat. Average calcite concretion = 0.06. Effect pathway consistent with effects across age classes but the calcite trend data do not support this as a sole cause for single year decline. Evaluation of the dissolution potential and flow data during the decline window suggest that a dissolution event would be rare but two did occur in the fording river downstream of LCO Dry Creek.	Weak/none. Relatively low calcite levels in most locations; some increase in calcite observed over time, but not to intensity levels that would be expected to be causal. Data suggests potential for two dissolution events to have occurred in the Decline Window downstream of LCO Dry Creek, although this appears to have been localized and could have affected only a minor propoortion of the overall WCT UFR population (10% or less). Unlikely as primary cause, although there is high uncertainty associated with this pathway due to the lack of dose-response relationships.	Yes	Minor/Negligible (although note high uncertainty)	Evidence is weak for the importance of this pathway, although there is high uncertainty and it is possibly a contributing factor. The most likely interaction is with flow and climatic conditions in fall (prevalence of fall flushing flows) and in winter (low flows).
				d) Recruitment failure from reduced incubation success	Calcite (d): Did increased calcite presence/concretion over time result in the observed decrease in fish population via decreases in incubation success?	Relevant to incubation success. Limited to spawning habitats and fry production throughout UFR.	Calcite index, presence, concretion data (2013-2019) for UFR mainstem and tributary segments were assessed by reach and over time. Corresponding fish data were evaluated by stream segment and compared to calcite data. Review of available information related to Calcite effects to incubation habitat, including dose-response relationships between calcite and dissolved oxygen and hyporheic flow in the substrate	Spatial extent: Widespread calcite in mainstem and tributary areas of the UFR that support WCT. Duration: Calcite reduces incubation habitat suitability during WCT spawning and incubation periods and during decline window. Location: Widespread calcite in UFR mainstem and tributary WCT spawning habitat. Timing: Calcite index and concretion would have to change between the pre-window and decline window to explain the observed decline. Intensity: Moderate to high calcite index and/or concretion scores would be needed.	Spatial extent: Yes, calcite growth from mine-related influence is present in all reaches of the UFR and many tributaries. Duration: No, there is no significant change in calcite conditions and trends in spawning suitability in pre- window versus decline window periods, apart from an isloated increase in calcite in the FORD9 unit of the UFR mainstem. Location: Yes, calcite is present in UFR and mine affected tributaries, but calcite concretion levels remain low. Timing: No distinct change observed in calcite between pre-window and decline window periods. A gradual increase in calcite index in UFR mainstem observed from 2013-2019. Intensity: No, average calcite index of ~0.8 in UFR mainstem; average concretion scores = ~0.06 throughout UFR fish bearing reaches during decline window.	Some uncertainty remains via the application of the current dose-response relationships between incubation conditions and calcite. However, uncertainty is reduced in this pathway compared to others.	Calcite index and concretion did not change markedly between pre-window and decline window periods and remained relatively low intensity in WCT habitat. Average calcite concretion = 0.06. Current models predict weak relationships between incubation conditions and calcite. Overall this pathway also does not explain fish population declines across all age classes in one year. Effects would be expected to be seen in the fry age class, but not other age classes.	Weak/none. Relatively low calcite levels in most locations; some increase in calcite observed over time, but not to intensity levels that would be causal. Unlikely as primary cause. No effect pathway to WCT age classes other than fry.	No	Minor/Negligible	Evidence is weak for the importance of this pathway, even as a contributing factor.
				e) Mortality from reduced rearing success due to effects on overwintering survival	Calcite (e): Did increased calcite presence/concretion over time result in the observed decrease in fish population via decreases in overwintering habitat?	Relevant to juvenile and to a lesser extent adult overwintering survival throughout the UFR.	Calcite index, presence, concretion data (2013-2019) for UFR mainstem and tributary segments were assessed by reach and over time. Corresponding fish data were evaluated by stream segment and compared to calcite data. Review of available information related to calcite effects to overwintering habitat, and relationships to overwintering conditions during the decline window.	Spatial extent: Widespread calcite in mainstem and tributary areas of the UFR that support WCT. Duration: Calcite reduces overwintering habitat quality during WCT decline window. Location: Widespread calcite in UFR mainstem and tributary WCT rearing habitat. Timing: Calcite index and concretion would have to change between the pre-window and decline window to explain the observed decline. Intensity: Moderate to high calcite index and/or concretion scores would be needed.	Spatial extent: Yes, calcite growth from mine-related influence is present in all reaches of the UFR and many tributaries. Duration: No, there is no significant change in calcite conditions and trends in spawning suitability in pre- window versus decline window periods, apart from an isloated increase in calcite in the FORD9 unit of the UFR mainstem. Location: Yes, calcite is present in UFR and mine affected tributaries, but calcite concretion levels remain low. Timing: No distinct change observed in calcite between pre-window and decline window periods. A gradual increase in calcite index in UFR mainstem observed from 2013-2019. Intensity: No, average calcite index of ~0.8 in UFR mainstem; average concretion scores = ~0.06 throughout UFR fish bearing reaches during decline window.	Uncertainty regarding effects of calcite on overwintering fish due to lack of data on dose-response relationship.	Calcite index and concretion did not change markedly between pre-window and decline window periods and remained relatively low intensity in WCT habitat. Average calcite concretion = 0.06. Effect pathway expected to be most prevalent with overwintering juveniles and therefore is not consistent with effects to WCT adults. Data do not support this pathway as sole cause for WCT declines.	Weak/none. Relatively low calcite levels in most locations; some increase in calcite observed over time, but not to intensity levels that would be causal. Unlikely as primary cause. Not a likely effect pathway to WCT adults.	Yes	Minor/Negligible	Evidence is weak for the importance of this pathway, even as a contributing factor, although there is some uncertainty. Even if overwintering habitat was impeded, other factors would need to have contributed to account for the large decline observed in the decline window. The most likely interaction is with flow and climatic conditions during winter of 2018/2019.

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	**SME**	**Citation for SME's Analysis**	**Stressor**	**Potential Causal Pathways** (= pathway of effect that could be the cause of the observed effect)	**Impact Hypotheses** (= an overarching way to describe how a stressor may have influenced the WCT population)	**Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)**	**Endpoints** (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	**What are the "requisite conditions" for this impact hypothesis to be explanatory?** (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	**Are the requisite conditions for this impact hypothesis met?** (Based on information the SME has and professional judgement)	**Uncertainties or Data Gaps** (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	**Summary of Findings**	**What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)?** (strong, possible, weak/none, indeterminant)	**If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?**	**If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline?** (major, moderate, minor/negligible)	**If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?**
WQ	**Emily-Jane Costa, Adrian de Bruyn (Golder Associates)**	Costa EJ., de Bruyn A. 2021. Subject Matter Expert Report: Water Quality. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.	Water quality (Release of Mine Influenced Water)	Direct lethal or sublethal effects	Did exposure to releases of mine-influenced water quality contribute to or cause the WCT decline?	Not restricted; depends on where water was discharged into fish-accessible waters in the upper Fording River watershed in the decline window.	1) Surface water quality at the point of discharge 2) Acute testing data for rainbow trout at discharge locations	To contribute: an indication of a potential acute or chronic effect at a point of release, per the definition provided in the report. To cause: an indication of a potential acute or high-level chronic effect that could have affected a large fraction of the WCT population, either by being widespread or by occurring at a time and location that overlapped with a large number of fish in time and in space.	To contribute: Yes To cause: No	1) Rainbow trout was used as a surrogate to evaluate potential effects to WCT. 2) Combined effects of multiple constituents. 3) Data gaps and false negatives.	Authorized discharge water was not acutely lethal to rainbow trout. Most constituents were below acute screening values for rainbow trout. Acute effects could not be ruled out for DO in Turn Creek (one sample collected in November 2018). 8 of 190 release locations had the potential for a chronic exposure.	Weak/none	None for most constituents Weak for dissolved oxygen because of a lack of documented fish use in Turn Creek.	Negligible.	Other stressors that overlapped with water quality stressors in time and in space.
			Water Quality (Fish Accessible Waters)	Direct lethal or sub-lethal effects	Did exposure to surface water quality in fish accessible waters contribute to or cause the WCT decline?	Not restricted; depends on where water quality was elevated relative to benchmarks and screening values and where WCT were located in time and in space.	1) Surface water quality in the upper Fording River watershed compared to WQGs and toxicological benchmarks and screening values for fish. 2) Tissue selenium data in the upper Fording River watershed compared to benchmarks for fish. 3) Chronic testing data for early life stages of fathead minnow and rainbow trout.	To contribute: a constituent or result that indicated a potential for effects to fish in the decline window. To cause: a constituent or finding that indicated a potential for high-level effects that could have affected a large fraction of the WCT population, either by being widespread or by occurring at a time and location that overlapped with a large number of fish in time and in space.	To contribute: Yes To cause: No	1) Combined effects of multiple constituents. 2) Incomplete spatiotemporal coverage of data. 3) Confidence in benchmarks and screening values. 4) Spatial summaries assume fish use in the decline window was similar to that measured in 2012 to 2015 telemetry studies. 5) Microbial interferences in chronic tests.	Negligible potential for effects for most constituents assessed. Potential chronic effects of seven constituents. In most places, up to low-level effects of a single constituent. In some places, up to high-level effects of multiple constituents. No constituents or findings met requisite conditions to cause the WCT population decline.	Weak/none Measured conditions across most of the upper Fording River watershed indicated no chronic effects, and most or all of the remaining habitat indicated a potential for localized and low-level chronic stress to early life stages of WCT. The potential for chronic water quality effects on adult fish is expected to be lower than for early life stages.	Yes Minor/uncertain in most segments and seasons, moderate under localized conditions, especially in winter.	Minor overall (moderate in specific localized areas) and Uncertain Localized conditions could have contributed if conditions in the decline window resulted in greater exposure of WCT to those conditions than were indicated by the telemetry studies.	Multiple water quality constituents. Other stressors that overlapped with chronic water quality stressors in time and in space. Factors that would increase number of fish exposed to potential high-level effects.
NUT1	**Emily-Jane Costa, Adrian de Bruyn (Golder Associates)**		Nutrient enrichment	Increased productivity, which can lead to several direct or indirect effects	Did nutrient enrichment contribute to or cause the WCT population decline?	Not restricted; depends on where TP was elevated relative to screening values and where WCT were located in time and in space.	1) TP in the upper Fording River watershed compared to trophic status categories. 2) TP in the upper Fording River watershed compared to level 1 screening value for productivity.	To contribute: localized trophic status change at TP concentrations associated with productivity changes. To cause: widespread trophic status changes at TP concentrations associated with productivity changes, or a finding that could have affected a large fraction of the WCT population, either by being widespread or by occurring at a time and location that overlapped with a large number of fish in time and in space.	To contribute: No To cause: No	1) Data gaps and false negatives. 2) Level 2 and 3 screening values could not be derived because limited site-specific productivity data associated with higher TP concentrations. 2) Spatial summaries assume fish use is proportional to habitat size (area-weighted) or fish distribution in the decline window was comparable to that measured in 2012 to 2015 telemetry studies (relative fish use).	Trophic status was similar or lower than previous conditions, except for one mainstem station (LC_FRUS). Comparison of TP concentrations to screening values and review of supporting information (historical concentrations, site-specific relationships with productivity, periphyton and macrophyte scores, secondary productivity) indicated a negligible potential for changes to primary productivity in the decline window.	Weak/none The evidence indicates a lack of nutrient enrichment	Not applicable (not identified as a potential contributor)	Not applicable (not identified as a potential contributor)	Not applicable (not identified as a potential contributor)
IND	**Emily-Jane Costa, Adrian de Bruyn (Golder Associates)**	Van Geest J., Hart V., Costa EJ., de Bruyn A. 2021. Subject Matter Expert Report: Industrial Chemicals, Spills and Unauthorized Releases. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.	Industrial chemicals	Direct lethal or sub-lethal effects	Did exposure to industrial chemicals contribute to or cause the WCT population decline?	Not restricted with respect to life stages, locations, or timing; depends on when and where industrial chemicals were used relative to where WCT were located in time and in space.	Depends on chemical, but generally included: 1) Hazard and likelihood of exposures (e.g., storage and potential release mechanisms). 2) Available information for each chemical regarding use, monitoring, toxicity testing, transport, and fate.	To contribute: a chemical with moderate or high potential for exposure that indicated a potential for acute or chronic effects. To cause: a chemical or finding that indicated a potential for acute or chronic effects in the majority of habitat (magnitude ratings of moderate to high in the majority of habitat).	To contribute: No for most chemicals /Uncertain for flocculant To cause: No for all chemicals	1) Assumes that all spills were accurately recorded. 2) Data gaps regarding storage containment and unknown product type. 3) Chronic toxicity information for flocculant.	Most industrial chemicals were used and stored in a manner that prevented release to the environment (e.g., no discharge to fish accessible waters, secondary containment, stored far away from any watercourse) and no releases were documented. MIBC and kerosene had low likelihood of reaching a watercourse where exposure of WCT could occur. Antiscalant concentrations were below acute and chronic toxicity values. Flocculant was not expected to be the cause of WCT decline but unknown if may have contributed to decline.	Weak/none	Not applicable (not identified as a potential contributor) for most industrial chemicals, including antiscalant. Uncertain for flocculant due to limited information on potential for chronic effects from residual flocculant.	Not applicable (not identified as a potential contributor) for most industrial chemicals, including antiscalant. Uncertain for flocculant due to limited information on potential for chronic effects from residual flocculant.	Not applicable (not identified as a potential contributor) for most industrial chemicals, including antiscalant. Uncertain for flocculant due to limited information on potential for chronic effects from residual flocculant.
DIS	**Emily-Jane Costa, Adrian de Bruyn (Golder Associates)**		Spills	Direct lethal or sub-lethal effects	Did exposure to spills contribute to or cause the WCT population decline?	Not restricted with respect to life stages, locations, or timing; depends on when and where spills occurred relative to where WCT were located in time and in space.	Depends on spill, but generally included: 1) Hazard and likelihood of exposure (e.g., details of event such as spill volume, distance to surface water, and cleanup actions). 2) Available information for each spill regarding material, transport, and fate.	To contribute: a spill with moderate or high potential for exposure that indicated a potential for acute or chronic effects. To cause: a spill or finding that indicated a potential for acute or chronic effects on a large fraction of the population (magnitude ratings of moderate to high in the majority of habitat).	To contribute: No for most spills /Possible for two spills (incidents 3778, 3787) To cause: No for all spills	1) Assumes that all spills were accurately recorded. 2) Data gaps regarding water chemistry samples of spilled material. 3) Exact product or composition of spilled material.	Most spills were to ground surface, several hundred metres from the nearest watercourse, and were contained or cleaned up. This information and environmental fate properties indicated that these substances had a negligible or low likelihood of reaching a watercourse where exposure of WCT could occur. Three spills with high likelihood of exposure (4383, 4658, 4670) were below short-term WQGs and/or acute screening values. Two spills with high likelihood of exposure (incidents 3778, 3787) could not be ruled out as contributors.	None	Not applicable (not identified as a potential contributor) for most spills. Weak for two spills (incidents 3778, 3778) because events occurred in the lower end of the watershed and at the end of the decline window.	Not applicable (not identified as a potential contributor) for most spills. Negligible to minor, with uncertainty because water chemistry samples were not collected for the spilled material.	Not applicable (not identified as a potential contributor) for most spills.
CTX	**Heather Larratt (Larratt Aquatic Consulting)**	Larratt H., Self J. 2021. Subject Matter Expert Report: Cyanobacteria, Periphyton and Aquatic Macrophytes. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd.	Cyanobacteria and cyanotoxins	Cyanobacteria and cyanotoxicity mediated impacts to WCT	A. Are cyanotoxins in the UFR at sufficient concentrations and durations to cause adverse effects to benthic invertebrates and fish in general, and specifically can they cause mortality in juvenile and adult life stages of WCT in the UFR during the decline window? B. Did fish mortalities increase because calcite dissolution in localized, depositional areas released embedded cyanotoxins during winter low flows particularly in the decline window?	CTX1 Cyanotoxins are a potential concern for all WCT age classes but especially to alevins/fry living/feeding at sites with high cyanobacteria counts (e.g. RG_MP1 Rkm 58.5; FOBSC Rkm 53.5, FOUEW Rkm 41) in summer (WCT summer rearing to overwintering migration). CTX2. Cyanobacteria and cyanotoxins stored in the sediments and calcite of depositional areas could affect invertebrates and overwintering WCT during very low flows at (RG_MP1, S6 reach etc.)	Presence of cyanobacteria known to produce cyanotoxins at UFR sites | Correlations between benthic invertebrate metrics and periphyton metrics or surrogates (sediment TOC) | invertebrate toxicological studies assessed for effects not explained by water chemistry | Grab samples from Dry Creek algae bloom assessed for cyanotoxicity potential | Literature on cyanotoxin biomagnification, persistence etc. | Assessed cyanobacteria proliferations in 2013, 2015, interlab study, winter 2020 samples | UGHC calcite metals project | annual calcite extent CI reports | distribution of *Phormidium autumnale* | Cause reports e.g., Goudey et al. 2009 | MacGregor and Day (SRK) 2011 | Lotic annual CI extent reports 2012 - 2019 | photography and field observations by FRO field staff and consultants | Teck staff calcite dissolution calculations	Spatial extent: Cyanobacteria must be found generally in UFR and/or in UFR depositional habitats pools, lentic areas, WCT overwintering areas both on substrates and embedded in calcite: Yes (based on 2013, 2015, 2020 samples and porous biogenic calcite observations) Duration: More than one month of cyanobacteria blooms in low flow periods in late summer that persist through winter with Aug 2018 - Apr 2019 low flows of particular interest Location: Cyanobacteria bloom would have to occur at sites that affect key WCT rearing/overwintering locations, particularly those that are difficult for WCT to leave Timing: A cyanobacteria bloom would have to occur during the summer-fall growing season and persist into the winter low flow period (WCT incubation-summer rearing period to overwintering), with Aug 2018-Apr 2019 low flows of particular interest Intensity: Would need cyanobacteria blooms in summer followed by extensive mat decomposition and/or cyanobacterial-calcite dissolution during winter low flows with no intervening flushing flow	Spatial extent: Yes (based on 2013, 2015, 2020 samples and biogenic calcite observations) Duration: No (no periphyton samples from 2017-2019 to confirm cyanobacteria densities and persistence; no data loggers 2018 – 2019 to confirm diurnal DO fluctuations indicative of a bloom) Location: Yes (probable based on available algae samples from WCT overwintering sites (S6, RG_MP1, etc. from previous years and on low flows, however no samples from 2017-2019 to determine cyanobacteria densities; and no sampling of hyporheic zone for surrogate parameters (e.g., TOC, BOD, exchange rate) Timing: Yes (probable based on available samples from other years outside the decline window and low flows in summer 2018 persisting into winter 2019) Intensity: No (Calcite dissolution calculations showed only localized dissolution was thermodynamically possible in mainstem river flows but was possible in Feb. 2019 at LC_FRDSDC (pH lowered 1 unit) and in localized areas of the periphyton mat experiencing low pH during decomposition, however, no cyanobacteria densities to directly address this, also no sampling of in-situ hyporheic exchange that could dilute cyanotoxins during low UFR flows)	The intermittent cyanobacteria research in UFR (Sept 2012/2013, Sept 2015, Feb 2020) did not cover the decline window (Sept 2017 – Sept 2019). A periphyton/cyanobacteria assessment during the decline window would have reduced uncertainty considerably. Acute cyanotoxicity to benthic invertebrates and WCT was not detected during 2015 when the most extensive periphyton data was collected and is expected to be low in the WCT decline window. However, it was not possible to determine if there have been chronic sub-lethal stress from cyanotoxins that could have reduced individual fitness and made them more susceptible to other stressors. Natural variability in cyanobacteria densities can change dramatically over a period of days to weeks, especially during low flow events, thus 2015 data cannot be used to determine cyanotoxicity (cyanobacteria density + timing + duration/persistence) in the decline window.	Like most rivers, cyanotoxins can be produced by numerous cyanobacteria taxa found in the UFR. Most benthic cyanobacteria occurring in rivers do not kill fish, but naturally occurring P. autumnale blooms have in other river systems. Phormidium autumnale grows on and in UFR biogenic calcite crusts, where dark conditions can enhance its cyanotoxin production. Chronic low-dose exposure to cyanotoxins during low flows can affect invertebrate and fish health, particularly alevin and juvenile WCT but only at sites with large cyanobacteria populations. Summer or winter cyanotoxin stress may lower overall fish health, potentially making them more susceptible to other stressors. Cyanobacteria presence and the possibility of chronic low-dose stress to WCT is both natural and long-standing in the UFR, thus low-dose stress is unlikely to account for the WCT decline. Overall, cyanotoxins would not account for the WCT decline because early WCT life stages are more susceptible to cyanotoxins with lesser consequences to older age classes, and this is not consistent with the observed WCT decline.	The strength of evidence for hypothesis 1A (CTX 1) and 1B (CTX 2) is indeterminant due to the limited periphyton sampling in the UFR and no sampling during the WCT decline window. Without samples from the Sept 2017 - Sept 2019 window, cyanotoxicity cannot be proved or disproved.	Yes.	Negligible under typical circumstances / Minor if a cyanobacteria bloom occurred	Cyanotoxins released during calcite dissolution during low winter flows can increase WCT exposure directly or through diet, potentially detracting from WCT fitness during the cold winter months. Cyanotoxins could co-occur with ice-affected conditions, and localized low DO / pH depression from cyanobacteria/periphyton decay. These stressors could affect overwintering juvenile/adult WCT, particularly if the fish could not move to evade the composite of undesirable winter conditions.

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	SME	Citation for SME's Analysis	Stressor	Potential Causal Pathways (= pathway of effect that could be the cause of the observed effect)	Impact Hypotheses (= an overarching way to describe how a stressor may have influenced the WCT population)	Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)	Endpoints (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	What are the "requisite conditions" for this impact hypothesis to be explanatory? (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	Are the requisite conditions for this impact hypothesis met? (Based on information the SME has and professional judgement)	Uncertainties or Data Gaps (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	Summary of Findings	What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)? (strong, possible, weak/none, indeterminant)	If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?	If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline? (major, moderate, minor/negligible)	If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?
PER	**Heather Larratt (Larratt Aquatic Consulting)**	Larratt H., Self J. 2021. Subject Matter Expert Report: Cyanobacteria, Periphyton and Aquatic Macrophytes. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd.	periphyton	Filamentous algae blooms mediate impacts to WCT	A. Did periphyton, particularly filamentous algae blooms, reduce hyporheic exchange to an unusual extent during the decline window? B. Did filamentous algae blooms, such as Didymo, provide poor forage and degrade physical habitat (altered DO, pH, redox) for benthic invertebrates and WCT particularly in low velocity (<~1m/s) UFR reaches during the decline window?	A. (PER1) Areas with harmful filamentous algae blooms can affect alevins and fry through the summer rearing stage by isolating the gravel from the water column with the periphyton mat and by inducing bio-clogging. B. (PER2) All age classes of WCT have a minimum requirement of ~ 3mg/L dissolved oxygen (DO) which may not be met when stable low flows occur through the growing season without a fall flushing flow. This allows filamentous algae blooms to develop and persist which can affect WCT at winter refugia such as sections of S6	Fall 2012 taxonomic analysis of 25 samples from 13 sites UFR | Fall 2015 - Extensive taxonomic and chl-a datasets from 23 UFR sites | Fall - visual field periphyton scores (1-5) Sept-Oct 2019 Photography and field observations | Feb 2020 10 samples + 2 duplicates periphyton grab samples through ice | SNC Lavalin drivepoint data; pH redox DO conductivity turbidity, ions, metals data from Dec 2019 to Feb 2020 | UFR discharge data -continuous | u/w drone video | Dry Creek 2018 grab samples of bloom and invertebrates, tissue analyses (Minnow) | SNC Lavalin drivepoint data; pH redox DO conductivity turbidity, ions, metals data from Dec 2019 to Feb 2020 | UFR discharge data -continuous | In-situ DO - FRO Temp/DO loggers deployed in winter 2020, retrieved prior to freshet by FRO | Algae data 2015 - reviewed for fines entrapment | Samples from February 2020 were examined and photographed for TSS/coal fines | Minnow, Golder, SNC Lavalin sediment data for metals and PAH from coal fines |	Spatial extent: Blooms would have to occur throughout UFR particularly in key WCT areas Duration: Increased filamentous periphyton blooms in the late growing season particularly in years between large freshets/floods, with the refined decline window (Feb-Mar 2019 of particular interest} Location: A filamentous algae bloom at key spawning/rearing/overwintering WCT locations including RG_MP1 (Rkm58.5), FR_FR2 (Rkm 56) through S6 to FR_FR5 (Rkm 36); sites important to WCT with mine-affected fines deposition such as FOUKI (Rkm 55.5) FOBKS (Rkm 54) FOBSC (Rkm 53.5) FRCP1 (Rkm 52) Timing: A filamentous algae bloom in summer that persisted into winter, with no intervening fall spate (>~2-5 m3/s at FRNTP), with the refined decline window (Feb-Mar 2019) of particular interest, thus a bloom in summer 2018 persisting into winter 2019 with no fall flushing flows Intensity: Filamentous algae blooms would have to be extensive and dense enough to induce habitat degradation, leading to a significant drop in benthic invertebrate density or quality OR a bloom of harmful filamentous algae (e.g. Didymo, Phormidium, heavy bloom of filamentous green or golden algae) large enough to directly affect some WCT life stages	Spatial extent: Yes. (blooms are probable, extrapolating from available anecdotal photography, sediment TOC, flow data and periphyton samples) Duration: Yes. (probable based on samples from other years showing abundant algae, but no algae samples from 2017-2019 to confirm, relied on sediment TOC samples) Location: No (bloom photography is limited and does not cover all key sites so extent of bloom is unconfirmed, and there are no periphyton samples from 2017-2019 to confirm) Timing: Yes (based on flow data, model averaging of periphyton data prior to the decline window and limited Winter 2020 periphyton samples) Intensity: No (no direct evidence based on periphyton samples, but indirect evidence based on studies showing no impact to benthic invertebrate community metrics but without algae samples from decline window, cannot be verified)	The biggest uncertainties from filamentous periphyton impacts arise from infrequent periphyton sampling, with the last systematic sampling in 2015. Natural variability is inherent in periphyton site sampling making between years extrapolation difficult. No UFR taxonomic samples were available from the decline window.	Proliferations of filamentous algae during late summer low flows are probable in most years since 2013 and in 2019, they exceeded observed extents in other regional rivers. Filamentous green algae blooms in Fish Pond Creek and a widespread but moderate Didymosphenia geminata (Didymo) bloom through the UFR mainstem were observed during stable low flows in early fall 2019. A similar bloom may have occurred in 2018 but data are limited. Sites with abundant Didymo in 2019/2020 also had some in 2015 sampling, indicating that it was not a recent introduction to these sites. Growing season conditions in the WCT Decline Window were conducive to an algae bloom due to stable low flows with low TSS. Based on fisheries research elsewhere, excessive filamentous Didymo growth is unlikely to account for the WCT decline, however its bloom phases could potentially stress juvenile WCT during their summer rearing stage. Similarly, a gradually reduced hyporheic exchange during late summer through localized substrate bioclogging is a common occurrence regionally, so is unlikely to account for or contribute to the WCT decline. However, without a fall flushing flow to remove it, the unusually large amount of organic material from a filamentous algae bloom would commence decay during the winter, affecting dissolved oxygen demand, hyporheic exchange, redox conditions, all with some potential to affect overwintering WCT. Lowering dissolved oxygen in slow-flowing reaches during prolonged ice cover appears to be the only mechanism by which periphyton could have contributed to the WCT decline, however data to support this mechanism is not available from the Decline Window.	The strength of evidence for Hypothesis 2A (PER1) is indeterminant and 2B (PER2) is weak due to limited periphyton sampling in the UFR and no sampling during the WCT decline window.	Yes.	Negligible under typical circumstances / Minor if a filamentous algae bloom occurred	Periphyton bioclogging can alter hyporheic exchange to river water on a localized scale and can co-occur with greater BOD/COD/SOD in winter months, particularly when there was no fall flushing flow to clear out periphyton material. Reduction in the feed quality of periphyton algae for invertebrates could co-occur with other stressors such as metal or cyanotoxin bioaccumulation, or biologically accelerated biogenic calcite formation. An altered benthic invertebrate communitiy can affect WCT feeding choices. Stress from winter low dissolved oxygen (DO) in Winter 2019 would be concurrent with low water temperature stress/frazil ice formation anchor and surface ice formation and deep frost, and would co-occur with calcite dissolution release of cyanotoxins and potential low DO.
PER		Larratt H., Self J. 2021. Subject Matter Expert Report: Cyanobacteria, Periphyton and Aquatic Macrophytes. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd.		Bioaccumulation and altered UFR bioreactor function exerts impacts on WCT	A. Does periphyton entrapment of TSS and calcite cause bio-clogging that restricts hyporheic exchange thus reducing the bioreactor function and habitat quality including dissolved oxygen, and was this process unusual in the decline window? B. Did periphyton metal bioaccumulation and SRB-mediated processes important to selenium or other metals cycling within the periphyton mat and the underlying hyporheic in the Upper Fording watershed have consequences to WCT during the decline window? C. Did nitrification and denitrification in the periphyton-influenced hyporheic zone affect UFR water quality or dissolved oxygen concentrations sufficiently to impact WCT?	A. (PER3) Bio-clogging mechanisms can alter WCT habitat values by limiting a suite of valuable bioreactor functions of the hyporheic exchange at depositional UFR sites. B. (PER4) Relevant when metals bioconcentrate from water into periphyton to macroinvertebrate tissues particularly at mine-influenced sites (not when metals adsorb onto periphyton surfaces), potentially affecting the WCT age classes that utilize benthic invertebrates. C. (PER5) Nitrification could contribute to adult WCT DO stress in slow-flowing UFR habitats during Feb 2019 (long ice cover/record low flows). Hyporheic nitrogen transformations could lead to nitrate exceedances in mainstem UFR, affecting YOY most.	Sediment PAHs, Se, other metals from the FRO collected from mine-influenced and reference sites in 2018 and 2019 | Benthic Invertebrate metrics Teck FRO LAEMP Minnow 2018 and 2019 | Tissue Se in benthic invertebrates and periphyton from Dry Creek 2018 | Full scan tissue metals in green algae bloom Line Creek 2016 |AFDW data 2015 | Minnow, Golder, SNC Lavalin sediment data for metals and PAH from coal fines | Minnow, 2019 Didymo tissue metals | Sept 2015 algae data at numerous UFR sites downstream of the spill e.g.FOUKI >>Rkm.55.5 | Feb 2020 12 algae grab samples to detect residual algae from summer 2019 blooms | WQ database | Field ammonia database	Spatial extent: Filamentous algae or cyanobacteria blooms throughout the UFR, particularly WCT overwintering areas and possibly summer rearing areas, in both depositional and erosional habitats Duration: Low flows would have to persist from summer through fall into winter that allowed a persistent bloom, with conditions in the 2018 growing season of greatest importance Location: Algae bloom(s) would have to be persistent at key WCT locations RG_MP1 (Rkm 58.5), FR_FR2 (Rkm 56) through S6 to FR_FR5 (Rkm 36) Timing: Growing season periphyton production and TSS accumulation not cleared by fall spate (≥ ~2 – 5 m3/s) prior to winter. Winter 2019 is of special concern within the decline window Intensity: Bioreactor-driven transformations where nitrogen (nitrate nitrite ammonia) MAC guidelines exceeded during low DO and/or DO <3 mg/L and/or significant selenium or metals MAC exceedances detected in water samples would be required	Spatial extent: Yes (based on extrapolation from extensive Didymo filamentous algae bloom on mainstem UFR observed in fall 2019 and detected in Feb 2020 samples, and frequent aqueous Se exceedances were detected at several mine-affected sites) Duration: Yes. (based on flow data showing no fall 2018 flushing flows, but no algae measurements or samples from 2017 – 2019 to confirm) Location: No. (by extrapolation from existing periphyton samples Sept 2015 and Feb 2020; not all important WCT sites in UFR were likely to be affected, however, no samples from 2017-2019 to confirm). Timing: Yes. (based on extrapolating from existing periphyton and sediment data, and on available hydrometric data and anecdotal observations) Intensity: No (the Didymo bloom was not triggered by the Maxam spill; no unusual spikes in Se or MeHg or other metal forms arising from periphyton/hyporheic zones that could account for WCT decline were detected)	Hyporheic field sampling to understand hyporheic exchange with groundwater was not available, necessitating extrapolation from shallow groundwater studies in the Greenhouse side channel conducted by SNC Lavalin (2020). Additional uncertainty also arises from infrequent periphyton sampling and infrequent tissue sampling for organic/inorganic percentages (indicates amount of algae vs sediment + calcite in sample), tissue metals and PAH associated with tissues. Similarly, the organic component of calcite and sediment samples were infrequently assessed, obscuring the potential role of periphyton in the UFR WCT decline.	Friable biogenic calcite (porous calcite-periphyton crusts) and periphyton biomass can gradually accumulate between strong freshets or floods. They are expected to measurably lower hyporheic exchange in low velocity areas of depositional reaches. When hyporheic exchange is restricted, periphyton and bacterial bioreactor processes that act to sequester metals and nutrients may be affected, leading to higher concentrations in solution. These water quality changes are likely attributable first to the effects of stable low flows on dilution and second on lower bioreactor functioning. A gradual and localized reduction in hyporheic exchange through bio-clogging is unlikely to account for the WCT decline or contribute to it unless a threshold or tipping point was reached. There is no evidence to suggest that periphyton-driven water chemistry changes critical to WCT health were reached within the Decline Window. Fines trapped in the periphyton layer included organic debris, calcite and dark particulates (coal fines). These materials can increase periphyton tissue PAH and metal concentrations. Passive adsorption to periphyton surfaces may decrease metal trophic transfer while uptake into periphyton cell structures may increase it. Dry Creek results indicated that elevated Se in Didymo blooms may be concurrent with elevated Se in benthic invertebrate tissues. However, periphyton bioaccumulated Se did not measurably impact benthic invertebrate density, thus the requisite conditions for Se periphyton bioaccumulation to be the sole cause of the WCT decline were not met. Similarly, fines entrapment may reduce periphyton palatability to scraping invertebrate grazers but fines did not result in a measurable impact on UFR benthic invertebrates. This work provides an indirect line of evidence indicating that trapped fines, PAHs and adsorbed metals were not the sole cause of the WCT decline.	The strength of evidence for hypothesis 3A (PER3), 3B (PER4) and 3C(PER5) is weak. Although UFR periphyton sampling is limited with no sampling during the decline window, extensive and systematic water quality analyses as well as research into UFR bioreactor functioning contributed to Hypo 3 analyses.	(A) Yes. (B) No. (C) No.	(A) Negligible /Minor (B) Negligible (C) Negligible	Bloom-induced changes to WQ such as pH, redox and DO can alter metal behavior, and physical entrapment of coal dust or other TSS can adversely affect invertebrate grazing, with possible consequences for WCT. The total metal burden of benthic invertebrates in UFR could increase during winter low flows by exposure to higher aqueous metal concentrations (although the main exposure routes are dietary),adding to cold water and other stressors. Trophic transfer and direct uptake of metals during the growing seasons could add to other stresses including Se burden and nitrogen species stress. These may alter WCT repsonse to other stressors such as predation. Stress from periphyton decomposition leading to winter low DO in February 2019 would be concurrent with low water temperature stress, anchor/frazil ice formation, and would co-occur with potential biogenic calcite dissolution release of cyanotoxins.
MAC			Aquatic macrophytes and bryophytes	Aquatic macrophyte and bryophytes mediate impacts on WCT	A. Did constituents of interest accumulate on or be taken up into macrophyte tissues and from there into grazer tissues, thus exposing WCT during the decline window? B. Did oxygen demand from decomposing macrophytes, periphyton and sediments combined with ice-impeded oxygen influxes to S6 pools during the unusually cold Winter 2018/2019 cause low oxygen stress to WCT?	A. (MAC1): Benthic invertebrate grazers that are food for juvenile/adult WCT can biomagnify some metals after grazing macrophytes but only at sites with macrophyte stands or sites with significant bryophyte coverage. B. (MAC2): Decomposing macrophytes may contribute to low DO for overwintering juvenile/adult WCT in extreme cold Feb 2019. Sediment deposition caused by macrophyte drag in pools, shallows may restrict use by early life stage WCT. This may be occurring at sites such as RG_FC1, RG_CLODE, RG_MP1.	RAEMP and LAEMP field note macrophyte and bryophyte coverage (Minnow 2019) | LAC bench notes of fragments of moss leaflets in periphyton samples | field observations by S. Cope | February 2020 underwater drone videos of Henretta Lake and S6 pools showed a viable macrophytes (FRO) | In-situ temp/pH/DO logger data from winter 2020 |DO field meter data from above and belw S6 | Algae data 2015 - review for fines entrapment | Samples from February 2020 were examined and photographed for TSS/coal fines | drive-point data (SNC Lavalin) | Sediment oxygen demand research done elsewhere | photography odf substrates at selected mainstem sites in decline window from Minnow	Spatial extent: Macrophytes would have to occupy most slow-flowing key WCT reaches, bryophytes occupying most shaded reaches Duration: Macrophyte stands would have to expand from year to year in depositional UFR sites Location: Macrophyte stands would have to occup key WCT habitat such as S6 (Rkm44.5 to 36), Henretta Lake, etc. Timing: Macrophyte stands would have to expand during growing seasons leading to senescent plant material decomposing in winter Intensity: Dense scenecent stands would be required in slow flowing reaches to have a measurable effect	Spatial extent: No. (Macrophyte distribution is limited but expanding in UFR pools since 2013 – they are in several key WCT rearing/overwintering habitats) Duration: Yes. (Stands expanding since 2013 flood, through the decline window) Location: No. (Well-established stands are expanding in pools; but ROV did not show macrophytes occupying >50% of videoed substrates in key WCT rearing/overwintering habitats) Timing: Yes. (Anecdotal evidence suggests a gradual expansion since the 2013 flood) Intensity: No. (Although stands are expanding, underwater drone showed patchy stands of viable plants in winter 2020)	No formal macrophyte survey or herbarium was available. Macrophytes may be more prevalent than anecdotal observations suggest, however macrophytes are unlikely to ever achieve problematic density in UFR. A systematic and co-ordinated sampling of macrophyte and bryophyte tissue sampling was not available. Although BOD from macrophyte decomposition could be important in depositional UFR sites with persistent ice cover (as in Winter 2019), a data gap exists involving temp / DO /pH /redox under those conditions. Should another intensely cold winter period like Winter 2019 occur, assessing reduced oxygen production + increased consumption with ice/snow shading and comparing those results to winters with open water would clarify effects of long-term ice cover at UFR depositional sites. Measurements of sediment oxygen demand to benefit assessments of WCT overwintering habitats from a DO and a water chemistry perspective were not available	Aquatic macrophytes and bryophytes are native to the UFR system, indicating adequate water and sediment quality to support their growth. Macrophyte stands have redeveloped in slow flowing UFR reaches following the 2013 flood. Bryophytes are more widely distributed and extensive than macrophytes in the lotic-dominated UFR watershed. Bryophytes can accumulate metals through cation exchange, but their growth was not observed to be unusual during the Decline Window. Based on the literature and studies of Elk Valley lentic sites, the highest metal concentrations are likely to occur in macrophyte root zones where bioaccumulated metals would be unavailable to benthic invertebrates or WCT. Submerged macrophyte rhizospheres host a bacterial consortium that can decompose some PAHs and attenuate metals, although selenate reduction with subsequent uptake into aquatic food chains is also known to occur. The benefits of aquatic macrophytes and bryophytes and their slow expansion following the 2013 flood provides evidence against impacts mediated by these plants as the sole cause of, or a significant contributor to the WCT decline. Although it is uncertain at this time, stable low flows in summer and fall 2018, followed by the extremely cold winter with very low flows may have led to a cascade of winter effects. These winter effects involving deep frost, extensive ice formation, and increased oxygen demand exerted by decomposing macrophytes and periphyton may have been unusually strong in Winter 2018/2019 because a fall flush that would remove organic material from the UFR did not occur prior to this winter. The measured DO sag in Winter 2019 was part of a declining trend unique to the Decline Window, but it did not reach critical thresholds for WCT survival. If DO was depleted in late winter 2019 at lower S6, it could be an important factor in the WCT loss, or lowered DO could contribute to overwintering WCT stress and induce them to move locations, however the strength of evidence supporting this hypothesis is weak.	The strength of evidence for hypothesis 4A(MAC1) and 4B(MAC2) is weak due to a lack of macrophyte/bryophyte surveys in the mainstem UFR and intermittent temperature/DO/pH/redox sampling during the WCT decline window.	(MAC1) No. (MAC2) No in typical winter, but Yes in ice-affected winter at lower S6 but still unlikely at Henretta Lake	(MAC 1) Negligible (MAC 2) Negligible at lower S6 in normal winter but Moderate in an extremely cold ice-affected winter and Negligible at Henretta Lake in a typical winter and minor under xxxxx	In years between large freshet or flood flushes sediment can accumulate in depositional reaches both assisting and being assisted by macrophyte population expansion. In these depositional conditions,with finer textured sediments (e.g., S6, pools) hyporheic exchange slows and temporary anoxic sediment conditions can occur, possibly allowing localized nitrogen species build-up at the same time as dissolved oxygen production is slowed by winter conditions. SOD may deplete DO if oxygen influxes are prevented by extensive and long-term surface and anchor ice with deep frost.
FAV	**Patti Orr (Minnow Environmental)**	Orr, P. and Ings, J. 2021. Subject Matter Expert Report: Food Availability. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc.	Food Availability	Starvation caused by reduction in aquatic or terrestrial food	Did starvation cause or contribute to the Westslope Cutthroat Trout population decline?	Any externally feeding life stage (fry, juvenile, adult). Any locations within UFR utilized by WCT. Occurance after September 2017 because WCT were in good condition in September 2017 compared to previous years and other upper Kootenay populations (Cope et al. 2016, Cope 2020).	-Juvenile body condition (assessed as condition factor [K] and mean weight-at-length) throughout upper Fording River 2019 compared to previous years. -Juvenile mean weight-at-length lower Greenhills Creek and lower LCO Dry Creek 2018 compared to 2017. -Adult condition factors (K) September 2018 and February-March 2019 compared to previous years. -Degree days and extreme temperatures (<1°C and >18°C) 2018 and 2019 compared to previous years.	-Reduced mean weight-at-length or condition factor after September 2017 compared to previous years.	No.	-Juvenile body condition was assessed in August-September, but starvation is more likely in fall-winter; however summer condition is an indicator of overwinter survival and juveniles are particularly vulnerable. - Juvenile condition data were spatially limited in 2018; however, juvenile condition in lower Greenhills Creek and lower LCO Dry Creek in 2018, degree-days in 2018, and temporal consistency of juvenile and adult condition factors, suggested against reduced condition in 2018.	The condition of juvenile Westslope Cutthroat Trout throughout the upper Fording River in 2019 was comparable to previous years. Juvenile condition in lower Greenhills Creek and lower LCO Dry Creek in 2018 was comparable to 2017 and there were more degree-days in 2018 than 2019 suggesting favorable growth conditions in 2018. However, most (75%) of the 16 mature trout captured in September 2018 had condition factors less than the 10th percentile of condition factors for 668 fish > 200 mm in length sampled in late summer 2012 to 2014. Eight of nine fish sampled in Henretta Lake in Feb-Mar 2019 had condition factors below the 35th percentile of fish sampled 2012-2014.	Weak/none	Yes	Negligible to moderate for winter 2018-2019 (high uncertainty due to limited data)	Low flow and early drying in summer-fall 2018, plus low flow and extreme cold in February 2019, which may have combined to result in above-average energy deficits in the winter of 2018-2019.
					Did aquatic invertebrates decrease sufficiently to cause or contribute to Westslope Cutthroat Trout population decline through starvation		-Hess biomass and density September 2018 and 2019 compared to 2017. -Kick sample total abundance and abundances of dietary organisms (Ephemeroptera, Tricoptera, Plecoptera [collectively EPT], Diptera) in September 2018 and 2019 compared to previous years back to 2012. -Total and EPT abundances in June, September, and December 2018 and 2019 at mine-exposed compared to reference areas monitored in the same month.	Spatially broad reduction in abundance of aquatic prey organisms (total, EPT, and chironomids) after September 2017, or in overwinter areas, compared to previous years (i.e., trout had good body condition in September 2017 and can move in search of food during ice-free period).	No.	Benthic abundance does not necessarily represent drift abundance; however, benthic organisms represent the source of aquatic invertebrates to drift. Also trout can shift feeding behaviours among aquatic and terrestrial organisms in drift and benthic organisms and they will move in search of food. Summer benthic invertebrate abundances have been stable since 2012. In other seasons (e.g., June, December 2018 and 2019), abundances were comparable to upstream reference area(s).	-The total abundance of aquatic invertebrate food organisms, and abundances of taxa that are important dietary items, in September 2018 and 2019 were comparable to previous years throughout the upper Fording River. Total and EPT abundances were generally comparable to or higher than in reference area(s) in other seasons (e.g., June, December of both years) including the overwintering area upstream from Chauncey Creek. -Fish body condition data did not indicate food limitations.	Weak/none	No	Not applicable	Not applicable
					Did terrestrial invertebrates decrease sufficiently to cause or contribute to Westslope Cutthroat Trout population decline through starvation?		-Total riparian habitat in 2019 compared to 2015. -Total undisturbed habitat in 2019 compared to 2015.	Large reduction (e.g., >10%) in total riparian or undisturbed habitat after September 2017 compared to previous years.	No.	Potential changes in terrestrial drift abundance were inferred from landscape indicators rather than direct measurement and did not consider potential localized effects. However, the diet of Westslope Cutthroat Trout in Elk Valley is dominated by aquatic invertebrates and trout can shift foraging behaviour from terrestrial to aquatic invertebrates in the drift or to benthic organisms, and will also move in search of food. Also, terrestrial organisms may be consumed far downstream from the point of input.	-Changes in riparian habitat and the area disturbed by mining and other factors were not large enough to expect that Westslope Cutthroat Trout starved, especially considering their ability to also forage on aquatic invertebrate drift and benthic invertebrates. -Fish body condition did not indicate food limitation.	Weak/none	No	Not applicable	Not applicable
POA	**Denis Dean (VAST Resource Solutions Inc.)**	Dean, D. 2021. Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.	Poaching	Illegal fishing by human anglers	Can illegal fishing (poaching) activities along the UFR cause or contribute to the UFR fish population decline during the Decline Window?	Primarily adult life stages, but also juveniles. Anywhere along the UFR. Most likely during the snow-free period; however, potential for illegal harvest during the winter period.	Documented BCCOS violations, review of Teck Coal's trail camera database, enquiries with Teck Coal personnel and their consultants on known or suspected poaching activities, literature identifying poaching on UFR. Review of fish capture methods during poaching activities to evaluate plausibility of them explaning fish population decline.	Spatial Extent: poaching activities on the WCT population occurred throughout the UFR and its associated tributaries. Duration: poaching activities on the WCT population must occur during the Decline Window. Location: poaching activities would target specific areas where WCT are known to congregate. Timing: poaching activities occurred during time periods when WCT were congregated. Intensity: poaching activities were at a high enough rate to substantially decrease the UFR fish population.	Spatial extent: No - any evidence of suspected poaching activities were limited to specific location along the UFR. Duration: No - limited evidence of fish poaching activities during the Decline Window. Location: No - no evidence of poaching activities occurring where fish are known to congregate, making them easier to catch. Timing: No - poaching activities were not identified during time periods when fish are known to congregate. Intensity: No - no evidence of poaching activities occurring that resulted in a substantial decrease in the UFR fish population.	Potential that a poaching event occurred that is not known to the BCCOS or found to have occurred; however, its highly unlikely that any unknown poaching activity would have removed 93% of the adult fish population from the UFR.	Poaching is not likely to be a causative agent or a contributor to the overall UFR fish population decline.	Weak	No	N/A	N/A

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	SME	Citation for SME's Analysis	Stressor	Potential Causal Pathways (= pathway of effect that could be the cause of the observed effect)	Impact Hypotheses (= an overarching way to describe how a stressor may have influenced the WCT population)	Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)	Endpoints (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	What are the "requisite conditions" for this impact hypothesis to be explanatory? (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	Are the requisite conditions for this impact hypothesis met? (Based on information the SME has and professional judgement)	Uncertainties or Data Gaps (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	Summary of Findings	What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)? (strong, possible, weak/none, indeterminant)	If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?	If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline? (major, moderate, minor/negligible)	If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?
PRD	**Denis Dean (VAST Resource Solutions)**	Dean, D. 2021. Subject Matter Expert Report: Wildlife Predation. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc.	Predation	Mortality from foraging by wildlife predators	Can wildlife predators' foraging activities cause or contribute to the UFR WCT fish population decline?	All life stages, spawning areas, overwintering areas, locations where there are barriers to fish passage causing fish congregations. Some predators potentially reside year round, while others are present just during growing season.	Video of otter kills, trapper data and knowledge, wildlife feature data (dens, lodges, etc.), wildlife occurrence forms. Predation data during telemetry study. Winter track survey. Literature reviews. Theoretical feed consumption calculations.	Spatial Extent: wildlife predation of the WCT population occurs throughout the UFR located upstream of Josephine Falls and its associated tributaries. Duration: wildlife predation of the WCT population must occur during the Decline Window. Location: wildlife predators target specific areas for foraging activities where WCT are known to congregate. Timing - predation by wildlife predators occurs during time periods when WCT are known to congregate. Intensity: foraging pressure at a high enough rate to substantially decrease the WCT population in the UFR.	Spatial Extent: Yes - predators were identified to occur throughout the UFR based on winter track survey results. Duration: No - no evidence of predator occupancy rates and limited knowledge of foraging rates along the UFR. Location: No - predators are present but no evidence of targeting specific areas where fish are known to congregate. Timing: No - no evidence of wildlife predation during time periods when fish are known to congregate. Intensity: Yes - theoretical feed consumption calculations show that fish-specialist wildlife predators like river otter can exhibit foraging pressure at a rate that could potentially impact the UFR fish population.	Data gap - evidence of predator occupancy rates within the UFR during the Decline Window. This data gap results in a high level of uncertainty as to a predator's foraging impacts. Theoretical feed consumption calculations provide potential evidence of a different foraging rate than what was previously documented during the telemetry study. This is all driven by the lack of understanding predator occupancy rates in the UFR. Assumption of percent of harvested fish consumed may have underestimated actual predation rate on juvenile fish (i.e. fish <200 mm) as literature shows a large portion of a river otter's diet is smaller fish, and literature on mink supports preying on smaller fish vs. larger fish. No evidence of predators foraging on fish during key time periods when fish are congregated (e.g. spawning areas, overwintering areas, barriers to fish passage). Anecdotal observations of predators foraging on fish at FRO cannot be quanitified into a meaningful understanding of predation rates. Literature does not support the assessed wildlife predators having a substantial impact on reducing fish populations.	Impact hypothesis is indeterminant that foraging activities by wildlife predators caused the UFR fish population decline. Lack of understanding wildlife predator occurrence, abundance, and occupancy rates during the Decline Window creates a high level of uncertainty on the overall effect wildlife predation may have on the UFR fish population. Wildlife predators could potentially be a contributing stressor to a multi-stressor impact on the UFR fish population. Fish stressed from other stressors could be easier prey for predators to harvest, thereby contributing to the fish population decline.	Indeterminant	Yes - wildlife predators could potentially harvest more fish that are impacted by other stressors as they become easier to catch, resulting in more fish being harvested by wildlife predators.	Minor/negligible - fish predators have existed in the UFR throughout the life of the UFR. There is no evidence to support a change in predation rate based on previously documented rates that would result in an increase loss of fish due to wildlife predation.	The impact from another stressor on the UFR fish population may increase the catchability of a fish by a wildlife predator. This in turn could potentially result in an increased predation rate on UFR fish by wildlife predators.
SED	**Maggie Branton (Azimuth Consulting Group & Branton Environmental Consulting)**	DiMauro, M., Branton, M., Franz, E., 2021. Subject Matter Expert Report: Coal Dust and Sediment Quality. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Azimuth Consulting Group Inc.	Metals and PAHs in Sediment	Direct mortality to WCT by toxicity (chemical stressor)	Were concentrations of metals and/or PAHs in sediment present during the Decline Window sufficient to result in adverse effects to WCT that could have caused or contributed to the population decline?	WCT Life stages: All life stages. UFR Location/Relevant habitat: Overwintering and rearing areas. Temporal: During the Decline Window	Concentrations of metals and PAHs in sediment during the Decline Window compared to sediment quality guidelines and historical sediment concentrations.	Spatial extent: Widespread across the UFR (causal) or in some river segments (contributing factor). Location: Present in rearing and overwintering habitats. Duration: Constituents in sediment are assumed to represent exposure of a sufficient duration to induce adverse effects if intensity is sufficient. Timing: Constituent must be elevated during the Decline Window period relative to historical conditions. Intensity: Stressors would need to be present at sufficient concentrations to cause adverse effects, be bioavailable and have the potential to cause adverse effects that could result in the population decline (i.e., mortality of juvenile and adult life stages).	Spatial extent: No-cause; Yes-contribute. There was limited evidence indicating changes in sediment quality in the upper reaches of the UFR in 2018; (no sediment data were collected in Henretta Lake in 2019) and substantial evidence indicating probable changes in sediment quality in the middle and lower reaches (i.e., S7-S8, S6, S1-S3). Given the distribution of juvenile and adult WCT throughout the UFR and in particular S6 and S8 (EOC Appendix D), this spatial extent meets the requisite condition for a contributing factor that changes in sediment quality were widespread. Location: Yes. Changes in sediment quality occurred in areas with juvenile rearing habitat and overwintering habitat for juveniles and adults. Duration: Yes. Constituent concentrations in sediment were generally consistent between 2018 and 2019 where data were available for both years. On that basis, concentrations of constituents that WCT could be exposed to appear to be somewhat stable during the Decline Window. Timing: Yes. There were changes in sediment quality during the Decline Window period relative to historical conditions. Intensity: No - cause. Exceedances of sediment quality guidelines (SQGs) for some constituents but limited bioavailability. Acute effects typically mediated through aqueous exposure, sub-lethal effects unlikely to result in substantial mortality of juveniles and adults. Yes - contribute. Sub-lethal effects for early life stages associated with exposure to PAHs and metals could reduce fish condition and increase susceptibility to other stressors, however low bioavailability makes this unlikely.	Data Gap: Direct measurement of sediment toxicity during the Decline Window.Site specific sediment toxicity study was conducted but results have not been finalized and were not available for this evaluation. Uncertainty and Data Gap: Sediment can be dynamic and change seasonally or daily. Sediment only collected once or twice each year therefore provides limited temporal coverage of sediment quality data.	There is evidence based on site specific sediment data that there were changes in sediment quality during the Decline Window primarily in the middle and lower reaches of the UFR. Site specific studies and the literature indicate that the bioavailability of metals and PAHs from sediment in the UFR is likely limited. Low bioavailability suggests that aquatic organisms' exposure to metals and PAHs in sediment is low relative to measured bulk sediment concentrations, and in turn, the potential for adverse effects indicated by exceedances of SQGs may be lower than indicated by the SQG screening. It is not possible to preclude the possibility that sub-lethal effects in early life stages could have occurred in the UFR where constituent concentrations were elevated in sediment and bioavailable. However, those effects, such as reduced energetic fitness or developmental abnormalities, may cause individual mortalities, particularly in the early life stages, but would be unlikely to cause the population level mortality of juveniles and adults observed in the population decline.	**Weak/none.** Concentrations of metals and PAHs were only elevated in some locations relative to sediment quality guidelines and historical concentrations. Furthermore, literature and site specific studies (for metals) indicate PAHs and metals in coal dust and sediment may have low bioavailability. Acute toxicity to juvenile and adult life stages unlikely via exposure to metals and PAHs in sediment.	Cannot preclude the possibility that concentrations of some constituents in some areas could cause sub-lethal adverse effects in early life stages that could reduce individual fitness making WCT more susceptible to other stressors.	Minor/negligible	Effects may be additive to other stressors. Other factors would be required to account for the large decline observed.
GRW	**Stefan Humphries (SNC-Lavalin)**	Henry, C., & Humphries, S. 2021. Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population. Report Prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc.	Groundwater Quality and Quantity	a) changes in groundwater quantity (i.e., flow regime)	a) were there changes in upgradient groundwater flows that may have resulted in either a change in the dischare areas, spatial distribution of surface water or its flows?	Life stage: not restricted; but spawning and overwintering may have higher exposure	Groundwater elevation data from 2012 to 2019; surface water flow data from 2015 to 2019; seepage data from 2018, 2019 and 2020	Spatial extent: Large sections of UFR main stem must contain substantial groundwater discharge zones to impact the number of fish Duration: Base flow conditions (i.e., October to March) with greatest groundwater contribution to surface flows Location: Reaches where groundwater discharge is known to have significant contribution to base flows that overlap with WCT overwintering and spawning areas such as S6 and S8. Timing: spawning and overwintering periods Intensity: Prolonged exposure of WCT to surface water fed by groundwater.	Spatial extent: No, limited to sections S6 and S8 Duration: Yes, base flow conditions present during decline window Location: yes, in S6 and S8 Timing: yes, spawning and overwintering periods Intensity: No, although variable with flow. Intensity greatest during flow flows	Data Gap: No groundwater data in vicinity of groundwater discharge zones Data Gap: No surface water data in discharge zone Data Gap: Lack of water quality data for Henretta Lake, which may receive mine-influenced groundwater discharge, particularly at depth. Data Gap: Lack of upgradient groundwater data during decline window in S8	No anomalous changes in upgradient groundwater flows during and prior to decline window, meaning surface water flows not significantly altered	**Weak.** Groundwater flows typically do not change significantly year over year. Also, groudnwater flows highly linked to surface water flows and climate.	Unlikely	Negligible.	Effects may influence water temperature and ice, ramping, and drying reaches
				b) changes in groundwater quality	b) was there a change in upgradient groundwater quality that may have resulted in a change to hyphoreic or surface water quality?	Life stage: not restricted; but spawning and overwintering may have higher exposure	Groundwater quality data from 2012 to 2019; surface water quality data from 2012 to 2019; seepage data from 2018, 2019 and 2020	Spatial extent: Large sections of UFR main stem must contain substantial groundwater discharge zones to impact the number of fish Duration: Base flow conditions (i.e., October to March) with greatest exposure to mine-affected groundwater Location: Reaches where groundwater discharge is known to have significant contribution to base flow and contain mine-affected affected groundwater that overlap with WCT overwintering and spawning areas such as S6 Study Area, S8 Study Area, and Henretta Lake (S10 Study Area). Timing: spawning and overwintering periods Intensity: Prolonged exposure of WCT to mine-affected groundwater.	Spatial extent: No, limited to sections S6 and S8. Uncertain in S10 Duration: Yes, base flow conditions with mine-affected groundwater present during decline window Location: yes, in S6 and S8 Timing: yes, spawning and overwintering periods Intensity: No, although variable with flow. Intensity greatest during low flows		No anomalous changes in upgradient groundwater quality during and prior to decline window, meaning surface water quality not significantly altered. Trends suggest gradual increasing mine-infleunce in groundwater over time in S6.	**Weak.** Discharge zones of mine-affected groundwater are localized. Only one significant area of mine-influenced groundwater discharge within S6 Study Area (orginiting from Kilmarnock Creek), where higher concentrations are higher than surface water. Surface water may also be locally influenced by groundwater discharge along a less significant and seasonal pathway.	Unlikely	Minor	Effects may influence habitat quality, including water temperature and surface water quality
HAN	**Scott Cope (Westslope Fisheries)** **Josh Korman (Ecometric Research)** **Maggie Branton (Azimuth Consulting Group, Branton Environmental Consulting)**	Cope. S. 2021. Subject Matter Expert Report: Fish Handling. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Westslope Fisheries Ltd. & Korman, J., & Branton, M. 2021. Effects of Capture and Handling on Westslope Cutthroat Trout in the Upper Fording River: A Brief Review of Cope (2020) and Additional Calculations. Report prepared for Teck Coal Limited. Prepared by Ecometric Research.	Fish handling: sampling, salvage, and relocation	Scientific sampling (electro-shocking, angling, trapping, Floy tags, PIT tags, radio tags, and tissue sampling); *SME report combines all handling however, this row was completed for scientific sampling only*	Could mortality (immediate or latent) associated with fish sampling have resulted in the observed decrease in fish population?	Not restricted; depends on sampling type and study locations.	Literature on the effects of sampling. Scientific Fish Collection Permit and Fish Salvage data submissions from 2012 through 2019 were compiled and reviewed by sample method (i.e., Electrofishing, Angling, Seine Netting, Baited Traps) and fish handling protocols (none, length and weight only, Floy tags, PIT tags, radio tags, tissue sampling, salvage and relocation). •2012 - 2019 Fish Salvage Summaries (Teck Coal 2019); •2012 - 2019 Scientific Fish Collection Permit Data submission summaries (Teck Coal 2020); •2017 Fish Salvage Summary Table (Teck Coal 2019); •2019 Fish Salvage Summary Table (Teck Coal 2019); •2017 Fish Relocation at Lake Mountain Creek Reaches 4 and 5 FRO (Vast 2017); •Fish Relocation at Greenhills Primary Pond, Greenhills Creek Sediment Pond Spillway and Thompson Creek Primary Pond, Greenhills Creek Operations (Vast 2017); •Fish Relocation at Greenhills Creek Sediment Pond Spillway Stilling Basin Greenhills Operations (Vast 2019); and •FRO Fish Salvage and Relocation Report 2019 (Nupqu 2020).	Spatial extent: Not restricted; Widespread handling throughout the UFR or specific location if intensity large enough. Duration: Not resticted; events could be short in duration or long depending on intensity. Location: Not restricted within the UFR. Timing: Not restricted; events could be throughout the year or a portion depending on intensity. Intensity: Not restriced; High for short duration/infrequent events. Low for frequent or long duration.	No: The requisite conditions do not exist temporally, spatially, or for all life stages to the extent documented in the 2019 monitoring report (Cope 2019)	Electrofishing has considerable negative physiological and behavioral impact on trout that is not apparent externally. These latent effects remain unreported. The experience of the technician or biologist applying tags is not reported in the databases provided and these effects remain unreported. There is a lack of long-term mortality studies demonstrating differences in survival between electrofished and control samples and when the small fraction of the entire population sampled, and the even smaller fraction harmed, are considered in the context of the entire stream population, the influence of electrofishing induced injury in a few habitats becomes insignificant when compared to natural mortality	There is a high degree of certainty that fish capture and handling in general does not represent the primary or acute influence on annual population estimates to the degree observed within the Decline Window between 2017 and 2019 (Cope 2019).	weak/none	Yes	There is a high degree of certainty the requisite conditions do exist to contribute to mortalities at the individual level and the scale likely contributes to reduced population productivity. There was a high degree of uncertainty in the population level impacts due to difficulties in estimating total habitat availability by life stages, juvenile population abundance, and uncertainties in latent mortality rates.	Given the scale (i.e., thousands of fish captured and handled annually), the potential for fish handling generally as a stressor and cumulative impact to population productivity is plausible. Ongoing salvage and scientific fish sampling at the scale documented has the potential to represent a stressor within a cumulative impact framework. This would be particularly true at the currently very low population abundance estimates.
				Salvage and relocation	Could mortality (immediate or latent) associated with fish salvage/relocation have resulted in the observed decrease in fish population?	Juveniles primarily, tributaries and isolated pools (salvage locations) & relocation habitats, timing of salvage/relocation events	Literature on the effects of salvage/relocation Teck Coal databases for 2017 and 2019 were reviewed for fish mortality events and fish salvage events including project timing, numbers of fish salvaged, and number of fish relocated; by life stage (fry, juveniles, adults) and release location. Where overlap was identified the potential to influence population estimates was investigated further. •2012 - 2019 Fish Salvage Summaries (Teck Coal 2019); •2017 Fish Salvage Summary Table (Teck Coal 2019); •2019 Fish Salvage Summary Table (Teck Coal 2019); •2017 Fish Relocation at Lake Mountain Creek Reaches 4 and 5 FRO (Vast 2017); •Fish Relocation at Greenhills Primary Pond, Greenhills Creek Sediment Pond Spillway and Thompson Creek Primary Pond, Greenhills Creek Operations (Vast 2017); •Fish Relocation at Greenhills Creek Sediment Pond Spillway Stilling Basin Greenhills Operations •FRO Fish Salvage and Relocation Report 2019 (Nupqu 2020).	Spatial extent: Not restricted; Widespread handling throughout the UFR or specific location if intensity large enough. Duration: Not resticted; events could be short in duration or long depending on intensity. Location: Not restricted within the UFR. Timing: Not restricted; events could be throughout the year or a portion depending on intensity. Intensity: Not restriced; High for short duration/infrequent events. Low for frequent or long duration.	No: Based on the salvage databases provided there is a high degree of certainty that it was not possible for salvage operations during the Decline Window to represent the primary or acute influence on annual population estimates to the degree observed.	Fish salvage and relocation can induce mortality at various stages of the operation and are by no means a benign mitigation measure. Although the reported mortalities are very low; typically in the 0% to 3% range, these mortalities represent immediate trauma due to capture or handling and do not account for: •Mortality (acute and latent) due to environmental conditions, stress, and predation susceptibility that precipitated the salvage necessity; •Salvage inefficiency (i.e., less than 100% fish recovered); •Relocation mortality; and •Latent mortalities due to stress/trauma due to capture and handling (including PIT tagging).	There was strong evidence that the requisite conditions (i.e., timing, spatial extent, mature life history stages) were not present or at a scale that is explanatory for the Westslope Cutthroat Trout population decline. Uncertainty is low and this conclusion is unlikely to change, unless there were salvage events and/or mortality events on a large scale specific to the adult life stages that were unreported.	weak/none	Yes		

		DETAILED METHODS AND RESULTS FOR ANALYSES	INPUTS TO PLAN THE ANALYSES						FINDINGS: EVALUATE OVERARCHING HYPOTHESIS #1				PRELIMINARY ASSESSMENT: STRENGTH OF CURRENT EVIDENCE TO EVALUATE OVERARCHING HYPOTHESIS #2		
# FigX	**SME**	**Citation for SME's Analysis**	**Stressor**	**Potential Causal Pathways** (= pathway of effect that could be the cause of the observed effect)	**Impact Hypotheses** (= an overarching way to describe how a stressor may have influenced the WCT population)	**Relevant WCT life-stage, UFR location, habitat, or temporal information (duration/frequency)**	**Endpoints** (= measure, observation or the like that provides evidence. These are the data sources and methods used in the analysis)	**What are the "requisite conditions" for this impact hypothesis to be explanatory?** (= the conditions that would have needed to occur for the impact hypothesis to have resulted in the observed decline of the UFR WCT, including spatial extent, duration, location, timing, intensity)	**Are the requisite conditions for this impact hypothesis met?** (Based on information the SME has and professional judgement)	**Uncertainties or Data Gaps** (Uncertainties may include aspects such as: natural variability, random measurement error, systematic measurement error, structural or model uncertainty, and ignorance)	**Summary of Findings**	**What is the strength of the evidence to support this impact hypothesis as the potential sole cause (without considering other potential impact hypotheses, could this impact hypothesis explain the WCT population decline)?** (strong, possible, weak/none, indeterminant)	**If not solely explanatory, could this impact hypothesis be a contributing causal factor to the WCT population decline?**	**If yes, what is the SME's best professional judgement on the relative contribution of this impact hypothesis to the WCT population decline?** (major, moderate, minor/negligible)	**If judged to be a potential contributing factor, what other impact hypothesis(es) is this hypothesis likely to be combined with?**
INF	**Trent Bollinger (TKB Ecosystem Health Services)**	Bollinger, T. 2021. Subject Matter Expert Report: Infectious Disease. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.	Infectious Disease	(a) Viral diseases: direct mortality to fish	Was infectious disease the cause of the WCT decline through direct mortality to fish?	Life Stage - all life stages but younger age classes more susceptible UFR Location - Not restricted. Timing - Not restricted	Presence of sick or dead fish in UFR Literature documenting effects on fish.	Spatial extent: widespread Duration: weeks to months Location: widespread, not restricted Timing: seasons other than winter Intensity: severe	No	Note: As no die-off events were identified during the population decline and only a few carcasses were found during this time period, none of which underwent complete necropsies, there is no information on diseases present within the WCT population on the UFR or any assessment of chronic health issues. Therefore, the assessment of disease as a potential cause of the population decline is based on a review of the literature of pathogens of trout that have been reported to cause die-offs and population declines in wild populations, and a review of other etiologies of concern identified by SMEs.	Viral diseases were viewed as being a highly unlikely cause of the UFR population decline and therefore none were reviewed in detail. This was based on the absence of reports of viruses being a cause of wild trout population declines elsewhere in western North America, the lack of sick fish being detected in the UFR, and the propensity for viral diseases to most severely affect younger age classes, which was not consistent with the demographics of the decline in WCT in the UFR.	weak/none	No	NA	
				(b) Bacterial diseases: direct mortality to fish		Life Stage - stressed fish more susceptible. UFR Location - Not restricted. Timing - More likely in warm summer months.		Spatial extent: widespread Duration: days to weeks Location: widespread, not restricted. Timing: all seasons Intensity: severe	No		Bacterial diseases are very unlikely the sole cause of the WCT trout population decline as these infections typically occur in warm summer months when fish are stressed due to spawning or there is decline in water quality. The trout in the UFR are monitored and observed frequently and no disease or die-offs suggestive of bacterial infections have been reported.	weak/none	Indeterminant, other stressors could suppress immune system allowing bacterial infection to develop and potentially act as the direct cause of mortality	Minor/Negligible	Lesions may be difficult to detect especially during certain times of the year and bacterial diseases may be part of the mortality associated with post-spawning, winter mortality and predation reported by Cope 2016.
				(c) Oomycete diseases: direct mortality to fish		Life stage - Not restricted; all life stages. UFR Location - Not restricted. Timing - Outbreaks occur after a drop in temperature or during the winter when fish are thermally stressed.		Spatial extent: Not restricted; for example, widespread and chronic, or concentrated in overwintering areas. Duration; days to weeks Location; widespread, not restricted. Timing; all seasons Intensity; severe	No		There have been no reports of Saprolegnia infections in the UFR, although infected fish may have been missed. Fish developing this disease under the ice, as part of a winter kill event, would likely go undetected. It is likely water molds have been the direct cause of death of some WCT in the UFR but would not be a major case of the WCT population decline, and if present, it would have been the result of other more significant indirect causes or stressors .	weak/none	Indeterminant, other stressors could suppress immune system allowing bacterial infection to develop and potentially act as the direct cause of mortality	Minor/Negligible	Lesions may be difficult to detect especially during certain times of the year and fungal diseases may be part of the mortality associated with post-spawning, winter mortality and predation reported by Cope
				(d) Parasitic diseases (Whirling): direct mortality to fish		Life Stage - Not restricted; all life stages, would have to infect at all early life stages for population effects. UFR Location - Not restricted Timing - Warmer temperatures promote disease development.		Spatial extent: widespread Duration; years Location: widespread, not restricted. Timing; all seasons Intensity; severe	No		As a potential cause for population decline of WCT in the UFR I would access it as very unlikely. Fish are monitored by visual counts and capture and there have been no reports of deformed fish or fish with abnormal swimming behaviour. A total of 5 WCT from the UFR have been necropsied along with light microscopic evaluation of nervous and skeletal system with no evidence of myxosporean infection.	weak/none	No	NA	
				(e) Parasitic diseases (Proliferative Kidney Disease): direct mortality to fish		Life Stage - not restricted all life stages UFR Location - Eutrophication and environmental degradation have also been shown to promote disease and these combined factors likely explain its emergence. Timing - Warmer temperatures promote disease development.		Spatial extent: widespread Duration: years Location: widespread, not restricted. Timing; all seasons Intensity: severe	No		Given the short-time period of population decline in the UFR, involving primarily adult fish and in the absence of any detectable sick or dead fish it is very unlikely Proliferative Kidney Disease was responsible for the UFR WCT population decline	weak/none	No	NA	
NOI	**Trent Bollinger (TKB Ecosystem Health Services)**	Bollinger, T. 2021. Subject Matter Expert Report: Pathophysiology of Stressors in Fish. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd.	Anthropogenic Noise	(a) Direct mortality to fish (barotrauma)	Was noise the cause of the WCT decline through direct mortality to fish?	Life Stage - all life stages UFR Location - not restricted, dependent on mine activity Temporal Information - Not restricted, dependent on mine activity. If during overwintering (fish concentrated) effects would potentially be larger	Literature documenting effects on fish. Summary of blasting events during Decline Window provided by Teck Coal (Sword, G and Fitzgerald, R. personal communications 2020)	Spatial extent: localized Duration: not restricted Location: restricted to areas of blasting Timing; any season, dependent on min activity Intensity: severe	No	Decibels of blasting activity is not recorded; pulse pressure waves from ground to water associated with blasting activity also not recorded	Although there is still a lot to learn about the effects of anthropogenic noise in aquatic environments, particularly as it pertains to fish, there is no evidence pile driving or explosive detonations onshore would have been directly responsible for fish mortality, and blasting setback on the UFR is within guidelines. Although it may have affected fish behaviour and movement, it is unlikely this could have contributed to the population decline.	weak/none	No	NA	
				(b) Indirect mortality to fish (movement from preferred habitats to suboptimal locations to avoid noise, prolonged stress responses)	Was noise the cause of the WCT decline through indirect mortality to fish?	Life Stage - all mobile life stages (movement), all life stages (stress) UFR Location - not restricted, dependent on mine activity Temporal Information - Not restricted, dependent on mine activity.						weak/none	No	NA	Depending on the time period overwhich the increased noise occurred and the intenstiy fish could be forced to move to less suitable habitat contributing to mortality: ie.contributing to overwinter mortality and others. There is no direct evidence to support this supposition.
SEW	**Maggie Branton (Azimuth Consulting Group, Branton Environmental Consulting)**	Branton, M. & B. Power. 2021. Stressor Evaluation – Sewage. In Van Geest et al. 2021. Subject Matter Expert Report: Industrial Chemicals, Spills and Unintended Releases. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.	Unauthorized Sewage Discharge	Reduced Water Quality due to TSS, reduced oxygen or potentially toxic levels of chemicals in sewage.	1. Did the unauthorized sewage discharges result in an acutely toxic event that resulted in the WCT population decline?	Given the timing of the discharges (August and February), the life stages that would be present in the UFR would be egg/alevin and fry (August 2017), or juveniles and adults (February 2020). The discharge would have to reach tributary or mainstem habitat where WCT may occur.	1. Map with the location of the February 2020 unauthorized discharge. 2. Water quality data from discharge location and upstream and downstream monitoring locations including TSS, BOD and chemical parameters - compared to discharge permit and BCWQG for the February 2020 discharge. 3. Record of August 2017 spill from Teck Coal site specific database "Siteline".	Spatial extent: Large sections of UFR mainstem, lentic areas downstream of the discharge point. Duration: Sufficient to cause acute or chronic effects to juvenile and adult WCT (varies by BOD, TSS and chemical). Location: Rearing or overwintering habitat. Timing: Effluent would need to reach rearing or over-wintering habitats with a large aggregation of early-life stages/ juveniles and adults. Intensity: At the point it reaches the habitat, diluted effluent would need to have concentrations of TSS, BOD and COPCs high enough to result in adverse acute (< 7 days)or chronic (>7 days exposure) effects on WCT.	Spatial extent: No. Duration: No. Location: No. Both discharges were contained on land. Timing: No. Neither discharge occurred during the Decline Window Intensity: No. Neither discharge occurred during the Decline Window.	Based on the documented timing and extent of the unauthorized discharges there are no uncertainties with respect to their potential to impact the WCT population in the Decline Window.	Teck Coal provided records of two relatively recent unauthorized discharges, one which occurred before the Decline Window and one after. The timing of each of these discharges, as well as their specific characteristics with respect to size, location and potential impacts on water quality, is not consistent with the potential for WCT to be exposed to, or negatively impacted by, the discharges	None. There is no evidence that this unauthorized discharge caused the decline in WCT in the UFR.	No.	NA.	NA.

Appendix C: Information Summaries

Fish Periodicity Chart

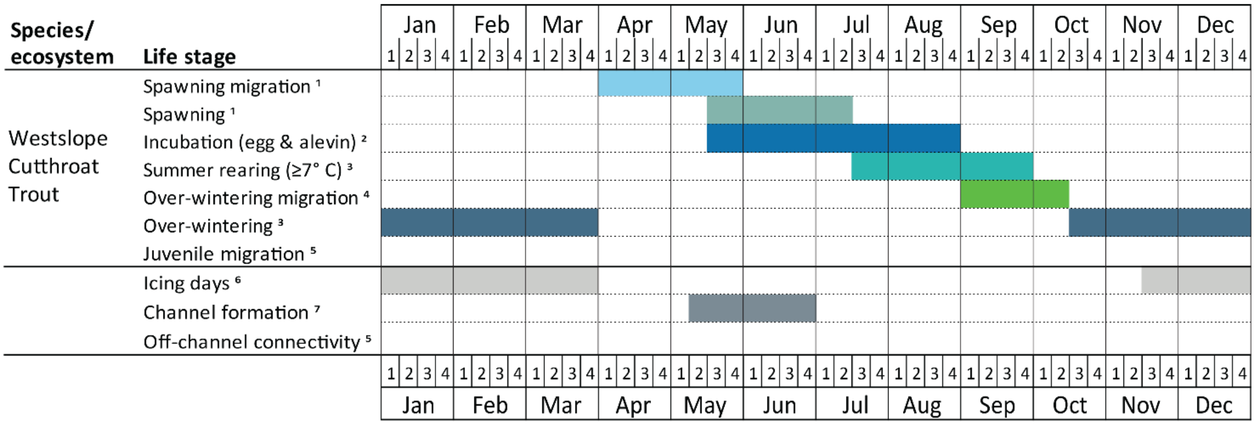
The Fish Periodicity Chart (Figure C-1) introduced in Chapter 3 was developed to support consistency across SME reports, for work relating to fish life.

A periodicity chart graphically and concisely represents the timing and duration of life history stages for different species and life stages of fish and other flow sensitive species or ecological communities. A periodicity chart can also be used to describe the timing of ecologically important factors that influence habitat quality such as ice cover, channel-forming flows, connectivity to off-channel habitats and the low flow period during the growing season. Periodicity charts are a standard component of a modified-Tennant approach that has been used in BC for decades to set instream flow needs (Ptolemy & Lewis, 2002).

When developing a periodicity chart, it is important to consider and incorporate inter-annual variation, sampling error and the reliability of source information, and to communicate the level of uncertainty in the periods defined. In many cases, stream-specific data will not be available, which may necessitate using broader periods to account for uncertainty. Even when a great deal of stream-specific data has been collected, professional judgment is required to define periodicities, to integrate information from other sources and to account for inter-annual variance and sampling error.

In general, where stream-specific data are available, periods in the chart should describe most of the timing period in all years. For example, determining the spawning migration period should account for annual run timing variation, and it should account for the early and late arrivals. This approach may not account for outliers, but it should account for most fish in all years. A similar approach should be employed to define other periods in the periodicity chart (i.e., account for inter-annual variability in timing but not outliers).

Life stage timing can also differ annually in response to environmental conditions. For example, specific behaviours may be triggered by changes in flows and temperature (e.g., spawning migration, spawning, overwintering) and this variation should be considered to the extent feasible when developing a periodicity chart. The period used in the periodicity chart should encompass all inter-annual variability, by including the range of period start and end dates. When defining these periods, the resiliency of the target species needs to be considered. Some fish species and specific populations are resilient to delays, and some are not. The stream-specific information can be used to define entire periods and critical periods that account for the resiliency of the target species.



Notes

[1] based primarily on information in Cope et al., 2016

[2] assumed to start coincident with spawning

[3] defined in Cope et al., 2016

[4] Nov 1 - Feb 28 is the core season defined in Cope et al., 2016; shoulder seasons have been added where there is likely to be ice cover in some areas

[5] no defined periodicity

[6] based on typical ice cover in most years

[7] typical maximum freshet occurs in this period

Figure C-1. Fish periodicity chart for Westslope Cutthroat Trout in the upper Fording River.

Location Concordance Table

A Location Concordance table (Table C-1) was developed early in the Evaluation of Cause process to align the naming conventions for the SMEs to use when interpreting and describing the data from Teck Coal's various monitoring programs in the UFR, including 422 active monitoring locations between rkm 18 and 70 (Michael Moore, pers. comm. 2020).

Table C-1. Location concordance table.

Table C-1 is presented on the following pages

km1	Half_km	sys_loc_code	loc_desc	loc_type
18	17.5	RG_FO9	d/s Josephine falls, u/s Grace Cr. and Line Cr.	LOT
25	24.5	RG_R5-2	Fording River Lower Reach 5 Site 2 (20m adjacent)	LOT
	24.5	RG_GHPFR	Greenhills pond beside Fording River	LEN
	25	RG_R5-1	Fording River Lower Reach 5 Site 1 (40m adjacent)	LOT
	25	RG_GHWFR	Greenhills wetland beside Fording River	LEN
	25	GH_GHWFR	Wet land area west of Fording River D/S of GH Creek	SEEP
	25	GH_E1A	Downgradient of E1 Seep below GH road culvert	LOT
26	25.5	RG_R6-2	Fording River Upper Reach 6 Site 2 (Anthropogenic)	LOT
	25.5	RG_GRE-CA01	Greenhill's Creek Calcite Biological Effect Site 1	LOT
	25.5	RG_FODGH	Fording River d/s GHO	LOT
	25.5	GH_WELL15-B	New Well drilled - Well15B Approx. 215m north of FR1 surface water sampling site	WELL
	25.5	GH_POTW15	Potable Water Well #15	WELL
	25.5	GH_POTW10	Potable Water Well #10	WELL
	25.5	GH_POTW06	Potable Water Well #6	WELL
	25.5	GH_GH2	Greenhills Creek just before the confluence with FR	LOT
	25.5	GH_FR1	Fording River D/S of Greenhills Creek (order/Compliance)	LOT
	26	RG_GRE-CA02	Greenhill's Creek Calcite Biological Effect Site 2	LOT
	26	RG_GHCKD	Greenhills Creek d/s sediment pond	LOT
	26	RG_GHBP5	Below the settling pond	LOT
	26	RG_GHBP3	Below the settling pond	LOT
	26	RG_GHBP1	Below the settling pond	LOT
	26	RG_GHBP	Below Greenhills Creek sediment pond.	SW
	26	GH_SPBS	Greenhills Creek Stilling Basin	LOT
	26	GH_POTW17	Potable Water Well # 17	WELL
	26	GH_GHBP	Lower Greenhills Creek downstream of Greenhills Pond	LOT
	26	GH_GH5	Calcite monitoring location between the pond and the river	LOT
	26	GH_GH1	Greenhills Creek Sed. Pond Decant	SPD
	26	GH_FRUSGC	Fording river just upstream of Greenhills creek confluence	LOT
	26	GH_FRB	Fording river just upstream of Greenhills creek confluence	LOT
27	26.5	GH_RLP	Rail Loop Sed. Pond Decant	SPD
	26.5	GH_POTW09	Potable Water Well #9	WELL
	26.5	GH_MW-RLP-1D	Monitoring Well in load out rail loop	WELL
	26.5	GH_MW-RL-1D	Monitoring well in ral loop on NW edge of Rail loop pond	WELL
	26.5	GH_MW_RLP-A	Monitoring Well in load out rail loop	WELL
	26.5	GH_MW_RL-A	Monitoring well in rail loop on NW edge of Rail loop pond	WELL
28	28	RG_R6-12	Fording River Upper Reach 6 Site 12 (20m adjacent)	LOT
29	28.5	RG_R6-14	Fording River Upper Reach 6 Site 14 (10m adjacent)	LOT
	29	RG_SFR	Side Channel beside Fording River	LEN
	29	RG_R6-15	Fording River Upper Reach 6 Sites 15A & 15B	LOT
	29	RG_PSFRR	Pond south of Fording River Road	LEN
	29	RG_FO29B	Wetland between Fording River Road and railway tracks	LEN
	29	RG_FO29	Fording River d/s Dry Creek (at hwy bridge)	LOT
30	29.5	RG_FO29A	Pond beside Fording River Road	LEN
	29.5	LC_FRB	Fording River Bridge downstream of FRdsDc	LOT
	29.5	FR_FR6	FORDING RIVER AT HIGHWAY BRIDGE	LOT
31	30.5	RG_SDRCKW	Wetland south of DRCKW	LEN
	30.5	RG_DRCKW	Dry Creek wetland	LEN
	30.5	LC_FRDSDC	Fording river down stream of Dry Creek	LOT
32	31.5	RG_LCDRY-CA01	LCO Dry Creek Calcite Biological Effect Site 1	LOT
	31.5	RG_FRUSDC	BIC data	LOT
	31.5	RG_FO28	BIC data	LOT
	31.5	RG_DRCK	Dry Creek	LOT
	31.5	LC_SPFR	Dry Creek sedimentation ponds effluent to Fording River	SPD
	31.5	LC_FRUSDC	Fording River upstream from Dry Creek, 100m downstream of conveyance outfall	LOT
	31.5	LC_FRUS	Fording River 100m upstream of conveyance outfall	LOT
34	33.5	RG_FWDEC	Fording River side-channel	LEN
35	34.5	RG_ECWFR	Ewin Creek wetland above Fording River	LEN
	34.5	LC_EWINTODD	Three culverts below confluence of Ewin Creek and Todd Hunter creek.	LOT
	35	RG_R6-35	Fording River Upper Reach 6 Site 35	LOT
36	35.5	RG_R6-36	Fording River Upper Reach 6 Site 36 (10m adjacent)	LOT
	35.5	RG_R6-34	Fording River Upper Reach 6 Site 34	LOT
	35.5	RG_FRSCW	Fording River side-channel wetland	LEN
	36	FR_FR5	Fording River Downstream of Chauncey Creek	LOT
37	36.5	RG_FRSCP	Fording River side-channel pond	LEN
40	40	RG_WFR	Wetland beside Fording River	LEN
41	41	RG_R6-44	Fording River Upper Reach 6 Site 44	LOT
	41	RG_FOUEW	Fording River upstream of Ewin Creek	LOT
42	42	RG_FORD7-75	BIC data	LOT
43	42.5	FR_FRDSCH1	Monitoring location approx 200m DS of confluence with Chauncey Creek	LOT
	43	RG_R7-47	Fording River Upper Reach 7 Site 47 (25m adjacent)	LOT
	43	RG_FRWUCH	Fording River wetland upstream of Chauncey Creek	LEN
	43	RG_CH1	Chauncey Creek - Shared sampling location	LOT
	43	FR_FV12	Confluence of Fording River and Chauncey Creek Dustfall	AIL
	43	FR_FRABCH	FR ABOVE CHAUNCEY	LOT
44	44	RG_R7-49	Fording River Upper Reach 7 Site 49 (90m adjacent)	LOT
	44	RG_PFR	Pond beside Fording River	LEN
	44	RG_FMUCK	Meadow area u/s Chauncey Creek	GRN
45	44.5	RG_R7-48	Fording River Upper Reach 7 Site 48 (150m adjacent)	LOT
	44.5	RG_FOXCF	Wetland along Fording River Road	LEN
	44.5	RG_FO22	Fording River upstream of Chauncey Creek	LOT
	44.5	FR_FRABCHF	Water survey of Canada approved flow monitoring site approximately 1 km north of FR_FRABCH	LOT
	45	RG_SFRR	Side Channel beside Fording River Road	LEN
	45	RG_R7-51	Fording River Upper Reach 7 Site 51 (500m adjacent)	LOT
	45	FR_CASW6B	Unnamed tributary to the Fording River, east side of FRO site 8.0km south of FRO Gatehouse	LOT
	45	FR_CASW6A	Unnamed tributary to the Fording River, east side of FRO site 7.8km south of FRO Gatehouse	LOT
46	45.5	RG_FRIM	Fording River impoundment	LEN
	45.5	RG_FOXL	Fording River pond	LEN
	45.5	FR_FRABCHUS1	Fording River Upstream of FRABCH	LOT
47	46.5	FR_FRABCHUS2	Fording River Upstream of FRABCHUS1	LOT
48	47.5	RG_R7-64	Fording River Upper Reach 7 Site 64	LOT
	47.5	RG_FO10-SP1	BIC data	LOT
	47.5	RG_FO10	Fording River Oxbow	GRN
	48	RG_FRDPO	Fording River downstream of Porter Creek	LOT
	48	RG_FOUFO	Requires description and location type.	
	48	RG_FODPO	Fording River Downstream of Porter	LOT
	48	FR_FRDSPORT2	DS DS pf Porter (New Site)	LEN
49	48.5	RG_POCK	BIC data	LOT
	48.5	GH_PC2	Fording River D/S of Porter	LOT
	48.5	GH_PC1B	Porter Creek Inlet end of Sediment Pond	SPI
	48.5	GH_PC1A	Porter Cr Bypass and Inlet	SPI
	48.5	GH_PC1	Porter Creek Sed. Pond Decant	SPD
	48.5	GH_MW-PC	Monitoring Well at Porter Creek Pond	WELL
	48.5	GH_MW_PC	Monitoring Well at Porter Creek Pond	WELL
	48.5	FR_PC1A	Porter Creek Bypass and Inlet	LOT
50	49.5	FR_FRRDDS	Located upstream of Fording River Road sampling site	LOT
	49.5	FR_CASW4	Unnamed tributary to the Fording River east side of FRO site 6.1km south of FRO Gatehouse	LOT
	50	RG_FRUPO	Fording River upstream of Porter Creek	LOT
	50	FR_MW-FRRD1	Location near surface water location FRRD1	WELL
	50	FR_FRRD	Fording River Near Fording River Road	LOT
	50	FR_FRCP1DS4	Downstream of FRCP1, Feb 26 sampling to establish river flows for CP1	LOT
	50	FR_FRCP1DS3	Downstream of FRCP1, Feb 26 sampling to establish river flows for CP1	LOT
51	50.5	RG_FRCP1SW	Fording River 1km southwest of Compliance Point	LOT
	50.5	FR_FRCP1SW	Fording river, downstream, on main channel	LOT
	51	RG_FRSP6	Seep monitoring station in the Fording River valley bottom part of the Mass Balance Investigation	SEEP
	51	RG_FRSP5	Seep monitoring station in the Fording River valley bottom part of the Mass Balance Investigation	SEEP
	51	RG_FRSP4	Seep monitoring station in the Fording River valley bottom part of the Mass Balance Investigation	SEEP
	51	RG_FRSP3	Seep monitoring station in the Fording River valley bottom part of the Mass Balance Investigation	SEEP
	51	RG_FRSP2	Seep monitoring station in the Fording River valley bottom part of the Mass Balance Investigation	SEEP
	51	RG_FRSP1	Seep monitoring station in the Fording River valley bottom part of the Mass Balance Investigation	SEEP
	51	FR_R9-P1	Jan 2020 Isolated pool in drying section (calcite reach 9) upstream of FR_FRCP1SW	LOT
	51	FR_FRCP1DS5	Approximately 1km downstream of FR_FRCP1 on the fording river main channel.	LOT
	51.5	FR_FRCP1DS1	Downstream of FRCP1, Feb 26 sampling to establish river flows for CP1	LOT

52	52	RG_FOBCP	Fording River Compliance Point	LOT
	52	FR_GHSW	Greenhouse Soft Water	TAP
	52	FR_GHMET	Greenhouse Meteorological Station	MET
	52	FR_GHHW	GREENHOUSE HARD WATER	TAP
	52	FR_GH_WELL4	Greenhouse Well #4	WELL
	52	FR_FRCP1	2014 Elk Valley Permit Compliance Point - Fording River Downstream of Cataract Creek	LOT
	52	FR_CASW3	Unnamed tributary to the Fording River,east side of FRO 4.3km south of FRO Gatehouse	LOT
53	52.5	RG_CATCK	BIC data	LOT
	52.5	GH_CC1SEEP	Seepage from Cataract pond during construction	SEEP
	52.5	GH_CC1H	Cataract Creek in pond sample	LEN
	52.5	GH_CC1A	Cataract Cr Sediment Pond Inlet	SPI
	52.5	GH_CC1_SO	Soil from Cataract pond system (at GH_CC1H)	LEN
	52.5	GH_CC1	Data Located in the FRO Equis Facility - Cataract Creek Sed. Pond Decant	SPD
	52.5	GH_CC1	Cataract Creek Sed. Pond Decant	SPD
	52.5	FR_FR4A	FORDING RIVER UPSTREAM OF CATARACT	LOT
	52.5	FR_CATCRK	Cataract Creek	SPD
	52.5	FR_CASW2	Unnamed tributary to the Fording River, east side of FRO site 3.7km south of FRO Gatehouse	LOT
	53	RG_FO52_DS	Fording d/s Kilmarnock	LOT
	53	GH_FR	Fording River U/S of Cataract Creek (D/S of Swift Cr.)	LOT
	53	FR_FR4	Fording River D/S of Swift Cr. U/S Cataract Cr	LOT
	53	FR_CASW2A	Unnamed tributary to the Fording River, east side of FRO 3.5km south of FRO Gatehouse	LOT
54	53.5	RG_FOBSC	Fording River between Swift and Cataract Creek	LOT
	53.5	GH_SC4	SC and FR mixing zone	
	53.5	GH_SC1US	Swift Cataract Upstream of the antiscalant addition system	LOT
	53.5	GH_SC1	Swift Creek Sed. Pond Decant	SPD
	53.5	FR_SKP2H	Inside South Kilmarnock Phase 2 Pond at Decant	LEN
	53.5	FR_SKP2	Decant from S Kilmarnock Sediment Pond-Phs 2	SPD
	53.5	FR_MW-SK1B	Monitoring well on the east side of south kilmarnock phase 2 pond. Of the pair, this well is the northern and deeper well.	WELL
	53.5	FR_MW-SK1A	Monitoring well on the east side of south kilmarnock phase 2 pond. Of the pair, this well is the southern and shallower well.	WELL
	53.5	FR_09-02-B	Kilmarnock Groundwater Well located S of SKP2 - Deep	WELL
	53.5	FR_09-02-A	Kilmarnock Groundwater Well located S of SKP2 - Shallow	WELL
	53.5	FR_09-01-B	Kilmarnock Groundwater Well located SE of SKP2 - Deep	WELL
	53.5	FR_09-01-A	Kilmarnock Groundwater Well located SE of SKP2 - Shallow	WELL
	54	RG_SWCK	BIC data	LOT
	54	RG_SCOUTDS	Fording River d/s Swift-Cataract treatment outfall	LOT
	54	RG_KSP	Kilmarnock Settling Pond	LEN
	54	RG_FOBKS	Fording River downstream of the proposed AWTF discharge	LOT
	54	GH_SC-SH	Old Swift secondary settling pond. In pond sample	LOT
	54	GH_SC3	100m below waterfall on Swift creek	
	54	GH_SC2.5	Swift Creek upstream of waterfall	LOT
	54	GH_SC2	Swift Creek Sed. Pond Bypass	PBS
	54	GH_FRSP	Fording R d/s of Smith Ponds	LOT
	54	GH_FR3	Fording River Bridge above Swift Creek	LOT
	54	FR_USSWFTCRBRDG	50m Upstream of Unauthorized discharge at the Swift Creek Bridge	LOT
	54	FR_UDSWFTCRBRDG	Runnoff water falling from bridge, later entering the Fording River	LOT
	54	FR_UDAWTFBRDG	Under active water treatment facility outfall bridge	LOT
	54	FR_UD07042019	Sample collected in response to an unauthorized discharge on the west side of Swift Creek Bridge	LOT
	54	FR_SCRDSEEP1	Seep from marshy area near Swift Creek Rock Drain. Discharges into Swift Creek primary pond.	SEEP
	54	FR_SCOUTDS	Fording River d/s Swift-Cataract treatment outfall	LOT
	54	FR_SCNCC	Swift Creek North Collection Channel	LOT
	54	FR_SCFSBPD	Swift Creek Fish Salvage Bipass Pond Discharge	LOT
	54	FR_SCBRDGSUMP	Sample collected from sump on North side of road on the west side of the swift creek bridge	SMP
	54	FR_FR3	Fording River at the Swift Creek Bridge.	LEN
	54	FR_DSSWFTCRBRDG	50m Downstream of Unauthorized discharge at the Swift Creek Bridge	LOT
	54	FR_AWTFSWI	Active water treatment facility Swift Creek intake structure	LOT
55	54.5	FR_FRUSOF	upstream of current AWTF-S outfall location	LOT
	54.5	FR_FR2D	D/s of Outfall	LEN
	54.5	FR_FR2.3	downstream of AWTF-S outfall location	LOT
	55	FR_OXBDSSKP1POOL3	In Pool 3 of Fording River Oxbow Downstream of SKP1	LOT
	55	FR_FR2.2	old AWTF-S outfall location	LOT
	55	FR_FR2.1	upstream of old AWTF-S outfall	LOT
56	55.5	RG_FOUKI	Fording River upstream of the proposed AWTF discharge	LOT
	55.5	RG_FOFR2W	Fording River wetland	LEN
	55.5	RG_FO52_US	Fording u/s Kilmarnock	LOT
	55.5	FR_STPSWSEEP	SOUTH TAILINGS POND SOUTH WEST SEEP	SEEP
	55.5	FR_STPBARGE	SOUTH TAILS POND BARGE	TF
	55.5	FR_SROUT	Seepage return well outlet near STP Barge walkway	WELL
	55.5	FR_SKP1H	Inside South Kilmarnock Phase 1 Pond at Decant	LEN
	55.5	FR_SKP1	Decant from S Kilmarnock Sediment Pond-Phs 1	SPD
	55.5	FR_MW_STPSW-B	Downstream of the STP, adjacent to the Fording River; nested pair shallow	WELL
	55.5	FR_MW_STPSW-A	Downstream of the STP, adjacent to the Fording River; nested pair deep	WELL
	55.5	FR_FR2	Fording River U/S of Kilmarnock Cr.	LOT
	55.5	FR_FO52_US	Regional location is RG_FO52_US. Merge data from RG_FO52_US to this new location.	LEN
	55.5	FR_BH-04-16	Monitoring well 04-16 southwest of Southern Active Water Treatment Facility Footprint	WELL
	55.5	FR_BH-03-16	Monitoring well 03-16 southwest of Southern Active Water Treatment Facility Footprint	WELL
	55.5	FR_AWTFTANK	Active water treatment facility tank inside building	BLD
	55.5	FR_09-04-B	Kilmarnock Groundwater Well located between SKP2 & STP- Deep	WELL
	55.5	FR_09-04-A	Kilmarnock Groundwater Well located between SKP2 & STP- Shallow	WELL
	55.5	FR_09-03-B	Kilmarnock Groundwater Well located between SKP2 & STP- Deep	WELL
	55.5	FR_09-03-A	Kilmarnock Groundwater Well located between SKP2 & STP- Shallow	WELL
	56	FR_STPWSEEP	SOUTH TAILINGS POND WEST SEEP	SEEP
57	56.5	FR_STPNSEEP	South Tailings Pond Noth Seep	SEEP
	56.5	FR_SPSEEP1	Seep from rehandle at Smith Ponds. Discharges into Smith Ponds.	SEEP
	56.5	FR_SP1H	Inside Smith Pond at Decant	LEN
	56.5	FR_SP1	Smith Pond Decant aka "SMITHPD	SPD
	56.5	FR_MW_STPNW	North west of STP, adjacent to the Fording River	WELL
	56.5	FR_FRVWSEEP4	Seep from rehandle ~90m north of Smith Ponds. Discharges to Fording River.	SEEP
	57	RG_FOUSH	Fording River downstream of North Tailing Pond	LOT
	57	FR_WWC2	Decant of FR_WWC2 (southern wastewater cell)	LEN
	57	FR_WWC1INCELL	In-pond sample of WWC1 cell	LEN
	57	FR_WWC1	Waste Water Cells North Pond Decant	CELL
	57	FR_STPSPILL103117C	Monitoring location related to tailings spill on 10/31/2017. Monitoring location at ditch south of FR_NL1 decant.	LEN
	57	FR_STPNWWELL6A	NW end of South Tailings Pond Monitoring Wells Row A Well 6	WELL
	57	FR_STPNWWELL5C	Monitoring well along northwest side of STP southernmost row well 5	WELL
	57	FR_STPNWWELL5A	NW end of South Tailings Pond Monitoring Wells Row A Well 5	WELL
	57	FR_STPNWWELL4C	Monitoring well along northwest side of STP southernmost row well 4	WELL
	57	FR_STPNWWELL4B	NW end of South Tailings Pond Monitoring Wells Row B Well 4	WELL
	57	FR_STPNWWELL4A	Monitoring well along northwest side of STP northernmost row well 4	WELL
	57	FR_STPNWWELL3C	Monitoring well along northwest side of STP southernmost row well 3	WELL
	57	FR_STPNWWELL3B	Monitoring well along northwest side of STP middle row well 3	WELL
	57	FR_STPNWWELL3A	Monitoring well along northwest side of STP northernmost row well 3	WELL
	57	FR_STPNWWELL2C	Monitoring well along northwest side of STP southernmost row well 2	WELL
	57	FR_STPNWWELL2B	Monitoring well along northwest side of STP middle row well 2	WELL
	57	FR_STPNWWELL2A	Monitoring well along northwest side of STP northernmost row well 2	WELL
	57	FR_STPNWWELL1C	Monitoring well along northwest side of STP southernmost row well 1	WELL
	57	FR_STPNWWELL1B	Monitoring well along northwest side of STP middle row well 1	WELL
	57	FR_STPNWWELL1A	Monitoring well along northwest side of STP northernmost row well 1	WELL
	57	FR_STPNWP	small pond at NW corner of STP	LEN
	57	FR_STPNSEEPPOND	North Loop Discharge Pond South of Maxam Yard	LOT
	57	FR_FRVWSEEP3	Seep from rehandle ~350m north of Smith Pond. Discharges to Fording River. Calcite present.	SEEP
	57	FR_FRVWSEEP2	Seep from rehandle ~450m north of Smith Pond. Discharges to Fording River.	SEEP
	57	FR_FRDSMAX	FORDING RIVER DOWNSTREAM OF THE MAXAM BRIDGE	LOT
	57	FR_3PIT	Greenhills Pit Water Discharge - GIS Map Location Name	PIT
	57.5	FR_TP3SD	Monitoring location related to site drainage spill at FR_TP3 during tailings line extension 12/6/2017	LOT
	57.5	FR_TP3	Tailing Slurry to South Tailings Pond	TF
	57.5	FR_STPSPILL103117B	Monitoring location related to tailings spill on 10/31/2017. Monitoring location at puddle on road near southern Maxam gate.	LEN
	57.5	FR_STPSPILL103117A	Monitoring location related to tailings spill on 10/31/2017. Monitoring location at puddle north of FR_WWC1	LEN
	57.5	FR_RTV	EMS ID: E297831 - Reclaim Tunnel Ventilation	
	57.5	FR_NLSED	Sediment sampled collected from inside North Loop Pond	LEN
	57.5	FR_NL2	North Loop Pond Inlet	LOT
	57.5	FR_NL1H	Inside North Loop Pond at Decant	LEN
	57.5	FR_NL1BYPASS	Bypass from FR_NL1.5 to downstream of FR_NL1 collected at end of pipe before going into ditch.	LOT
	57.5	FR_NL1.5	Sump at north end of Maxam yard that North Loop Pond flows into. Water then flows underneath Maxam yard to exfiltration ditch.	SMP

58	57.5	FR_NL1	Decant from North Loop Sedimentation Pond	SPD
	57.5	FR_MW_NTPSE	South east side of the NTP berm, at toe, adjacent to the Fording River	WELL
	57.5	FR_MS1	Decant from Maintenance & Service Sediment Ponds	SPD
	57.5	FR_MAXYDSUMPE	Eastern sump at south end of Maxam yard. Catches localized Maxam yard drainage and directs water to CIL sump.	SMP
	57.5	FR_MAXPRILLSUMP	Sump located approx 10m SE of the prill load out silos at the north end of the Maxam yard.	SMP
	57.5	FR_MAXDECON	Water sample taken during decontamination of a maxam tanker truck	LEN
	57.5	FR_MAXANSCON	Sample location inside Maxam ANS containment	SMP
	57.5	FR_LCSK	EMS ID: E210281 - Loadout Conveyor Drive House Stack	SK
	57.5	FR_CSK	EMS ID: E210283 - Product storage building (Cathedral) stack	SK
	57.5	FR_CILSPILL0822	Pooled water on roadway south of the maxam explosives facility	LEN
	57.5	FR_CILSPILL020619	Water sample taken from drainage collection ditch south of Maxam CIL sump during a spill event on 2-6-2019	LEN
	57.5	FR_CILH	Water sample taken from inside CIL sump (sump with pumping infrastructure) at south end of Maxam yard	SMP
	57.5	FR_CIL	CIL Explosives Sump	SMP
	57.5	FR_BXLBDG	BXL BRIDGE	LOT
	58	FR_TIREBAYSW	Sump located at the southwest corner of the FRO tirebay concrete yard pad	SMP
	58	FR_SPRWSEEP4	Seep spoil from below Spawn Road south of Breaker. Discharges to raw coal bench, likely enters site drainage to STP.	SEEP
	58	FR_SPRWSEEP3	Seep from spoil below Spawn Road south of Breaker. Discharges to raw coal bench, likely enters site drainage to STP.	SEEP
	58	FR_SPRWSEEP2	Seep from spoil below Spawn Road south of Breaker. Discharges to raw coal bench, likely enters site drainage to STP.	SEEP
	58	FR_PVPV	EMS ID: E210284 - Coal Wash Plant Vacuum Pump Vents	
	58	FR_POTABLE	Mine Potable Water	TAP
	58	FR_OWS5	OIL WATER SEPARATOR 5	OWS
	58	FR_OWS4	OIL WATER SEPARATOR 4	OWS
	58	FR_OWS2	OIL WATER SEPARATOR 2	OWS
	58	FR_OWS1	OIL WATER SEPARATOR 1	OWS
	58	FR_MAINTANKFARM	Main tankfarm south of maintenance shops inside containment	GRN
	58	FR_KEROTANKFARM	Kerosene tankfarm north of processing plant inside containment	GRN
	58	FR_FRNTP	Fording River Upstream of SMITHPD	LOT
	58	FR_DRYSTKS	Dryer Stack South	SK
	58	FR_DRYSTKN	Dryer Stack North	SK
	58	FR_DRYSTKAVG	Average of Both Dryer Stacks - Used for BC MOE Reporting	SK
	58	FR_DBV	EMS ID: E210287 - Dryer Building Vents	SK
59	58.5	RG_MP1	Fording River - Multiplate	LOT
	58.5	FR_TP1	Tailings Slurry to North Tailings Pond	TF
	58.5	FR_MW_NTPNE	North east side of the NTP berm, at toe, adjacent to the Fording River	WELL
	58.5	FR_MULTIPLATE	FR MULTI PLATE CULVERT GREENHILLS ACCESS ROAD	LOT
	58.5	FR_LP-3B	Liverpool Pond	WELL
	58.5	FR_LP-3A	Liverpool Pond	WELL
	58.5	FR_LP-2B	Liverpool Pond	WELL
	58.5	FR_LP-2A	Liverpool Pond	WELL
	58.5	FR_LP1UD03162019	Monitoring location for source of unauthorized discharge that occurred near FR_LP1 on 03-16-2019	LOT
	58.5	FR_LP1H	Inside Liverpool Pond at Decant	LEN
	58.5	FR_LP-1B	Liverpool Pond	WELL
	58.5	FR_LP-1A	Liverpool Pond	WELL
	58.5	FR_LP1	Liverpool Sediment Pond Decant	SPD
	58.5	FR_FRDSLP1	downstream of the liverpool ponds discharge	LOT
	58.5	FR_EAGLEINSEEPSB	Steam bay location of Eagle North Seep Truck Wash Water	LOT
	58.5	FR_30MUSLP1	30m Upstream of LP1	LOT
	58.5	FR_100MUSLP1	100m Upstream of LP1	LOT
	59	FR_RMBV	EMS ID: E297830 - Run of Mine Coal Building Vent	
	59	FR_FRABEC1	FORDING RIVER ABOVE EC1 OUTLET	LOT
	59	FR_EC1H	Inside Eagle Pond at Decant	LEN
	59	FR_EC1	Decant from Eagle SettlingPond	SPD
	59	FR_EAGLENORTH	EAGLE NORTH FLOW	SEEP
	59	FR_EAGLE1SSEEP	EAGLE 1 SOUTH SEEP	SEEP
	59	FR_EAGLE1NSEEP2	Seep from spoil at northeast corner of Eagle primary pond. Discharges to Eagle pond.	SEEP
	59	FR_EAGLE1NSEEP	EAGLE 1 NORTH SEEP	SEEP
	59	FR_CCBV	EMS ID: E210282 - Coal Breaker Building Vent	
	59	FR_BRKDITCH	BREAKER DITCHES TO EAGLE	DIT
	59	FR_BB1	Breaker Building discharge from Eagle Pond Diversion Pipe	DPO
	59	FR_ASPOILMET	Aspoil Weather Station	MET
60	59.5	FR_MW-1B	Groundwater monitoring well near NGD1 access road	WELL
	59.5	FR_FRVESEEP1	Seep from spoil ~60m north of Eagle secondary pond. Discharges to Fording River valley bottom.	SEEP
	60	RG_LPLML	Lower pond near Lake Mountain Lake	LEN
	60	RG_FOUNGD	Fording River upstream of North Greenhills Diversion	LOT
	60	RG_FODNGD	Fording River downstream of North Greenhills Diversion	LOT
	60	FR_NGD1	North Greenhills Diversion Ditch	LOT
	60	FR_LMP1	Lake Mt Sed Pond Decant	SPD
	60	FR_LM-3B	Lake Mountain Pond	WELL
	60	FR_LM-3A	Lake Mountain Pond	WELL
	60	FR_LM-2B	Lake Mountain Pond	WELL
	60	FR_LM-2A	Lake Mountain Pond	WELL
	60	FR_LM-1B	Lake Mountain Pond	WELL
	60	FR_LM-1A	Lake Mountain Pond	WELL
	60	FR_FRVWSEEP1	Seep from west bank of Fording River valley ~170m southwest of Lake Mountain Creek converges with Fording River.	SEEP
	60	FR_FRUSLP1	upstream of the liverpool ponds discharge	LOT
	60	FR_FRUSLMP1	Fording River Upstream of Confluence with Lake Mountain Creek	LOT
	60	FR_FRDSLMP1	downstream of the lake mountain ponds confluence	LOT
	60	FR_FRDSLMC	FR_downstream of lake mountain ponds. Merge data from RG_FODNGD to this new location.	LEN
	60	FR_CCSEEPSE2	Seep ~720m southeast of Clode Pond decant. Discharges to Fording River valley bottom	SEEP
	60	FR_CCSEEPSE1	Seep ~750m southeast of Clode Pond decant. Discharges to Fording River valley bottom	SEEP
61	60.5	FR_LMESEEP1	Seep on east side of Lake Mountain in Fording River valley bottom ~180m northeast of Pump Shed.	SEEP
	60.5	FR_GC3	approx 75m downstream of FR_GC2 on grassy creek	LOT
	60.5	FR_GC2	approx 50m downstream of FR_GC1 on grassy creek	LOT
	60.5	FR_CCSEEPSE3	Seep ~450m southeast of Clode Pond decant. Discharges to Fording River valley bottom	SEEP
	61	RG_R7-109	Fording River Upper Reach 7 Site 109 (100m adjacent)	LOT
	61	RG_PCLSP	Pond beside Clode Settling Pond	LEN
	61	FR_ZVI_01G	Approimately 100m downstream from the culvert that drains out of the west side of the Clode Creek Settling Pond	WTR
	61	FR_WED1	West Exfiltration Ditch of Clode Pond Upstream of Fording River	SEEP
	61	FR_LMESEEP2	Seep on east side of Lake Mountain in Fording River valley bottom ~400m northwest of Pump Shed.	SEEP
	61	FR_GCMW-2	Monitoring well 2 south of Clode pond for monitoring subsurface Grassy Creek water	WELL
	61	FR_GCMW-1B	Monitoring well 1B south of Clode pond for monitoring shallow subsurface Grassy Creek water	WELL
	61	FR_GCMW-1A	Monitoring well 1A south of Clode pond for monitoring deep subsurface Grassy Creek water	WELL
	61	FR_GC1A	Furthest north location on grassy creek.	LOT
	61	FR_GC1	GRASSY CREEK AT SEEP	SEEP
	61	FR_FRDSCC1	Fording River Downstream of Clode Ponds Discharge	LOT
	61	FR_CCSEEPSE4	Seep ~300m southeast of Clode Pond decant. Discharges to Fording River valley bottom	SEEP
62	61.5	RG_R7-114	Fording River Upper Reach 7 Sites 114A & 114B	LOT
	61.5	RG_FOUCL	Fording River u/s Clode Creek	LOT
	61.5	RG_FOBC	Fording River beside Clode Pond.	LOT
	61.5	RG_CLODE	Clode Creek near mouth	LOT
	61.5	RG_CL11	Clode Settling Pond	GRN
	61.5	FR_WED1B	approx 100m south of WED1A on the west exfiltration ditch	LOT
	61.5	FR_WED1A	north end of west exfiltration ditch	LOT
	61.5	FR_FOUCL	Fording River u/s Clode Creek	LOT
	61.5	FR_CCSEEPSE5	Seep on southeast side of Clode Secondary Pond. Discharges to Clode Primary Pond.	SEEP
	61.5	FR_CCSEEPE3	Seep on northnortheast side of Clode Primary Pond. Discharges to Clode Primary Pond	SEEP
	61.5	FR_CCSEEPE2	Seep on eastnortheast side of Clode Primary Pond. Discharges to Clode Primary Pond	SEEP
	61.5	FR_CCSEEPE1	Seep on east side of Clode Primary Pond. Discharges to Clode Primary Pond	SEEP
	61.5	FR_CC4	Clode Creek at discharge of primary pond	LOT
	61.5	FR_CC1H	Inside Clode Pond at Decant	LEN
	61.5	FR_CC1	Decant from Clode Sediment Pond	SPD
	61.5	FR_CB-6B	South of clode ponds, between CB2 and CB5 wells - shallow well	WELL
	61.5	FR_CB-6A	South of clode ponds, between CB2 and CB5 wells - deep well	WELL
	61.5	FR_CB-5C	South east end of clode ponds - shallow well	WELL
	61.5	FR_CB-5B	South east end of clode ponds - intermediate well	WELL
	61.5	FR_CB-5A	South east end of clode ponds - deep well	WELL
	61.5	FR_CB-4B	south end of clode ponds between primary and secondary ponds - shallow well	WELL
	61.5	FR_CB-4A	south end of clode ponds between primary and secondary ponds - deep well	WELL
	61.5	FR_CB-3B	North end of clode ponds - shallow well	WELL
	61.5	FR_CB-3A	North end of clode ponds - deep well	WELL
	61.5	FR_CB-2A	Clode Pond	WELL
	61.5	FR_CB-2	Clode Pond	WELL
	61.5	FR_CB-1C	Clode Pond	WELL

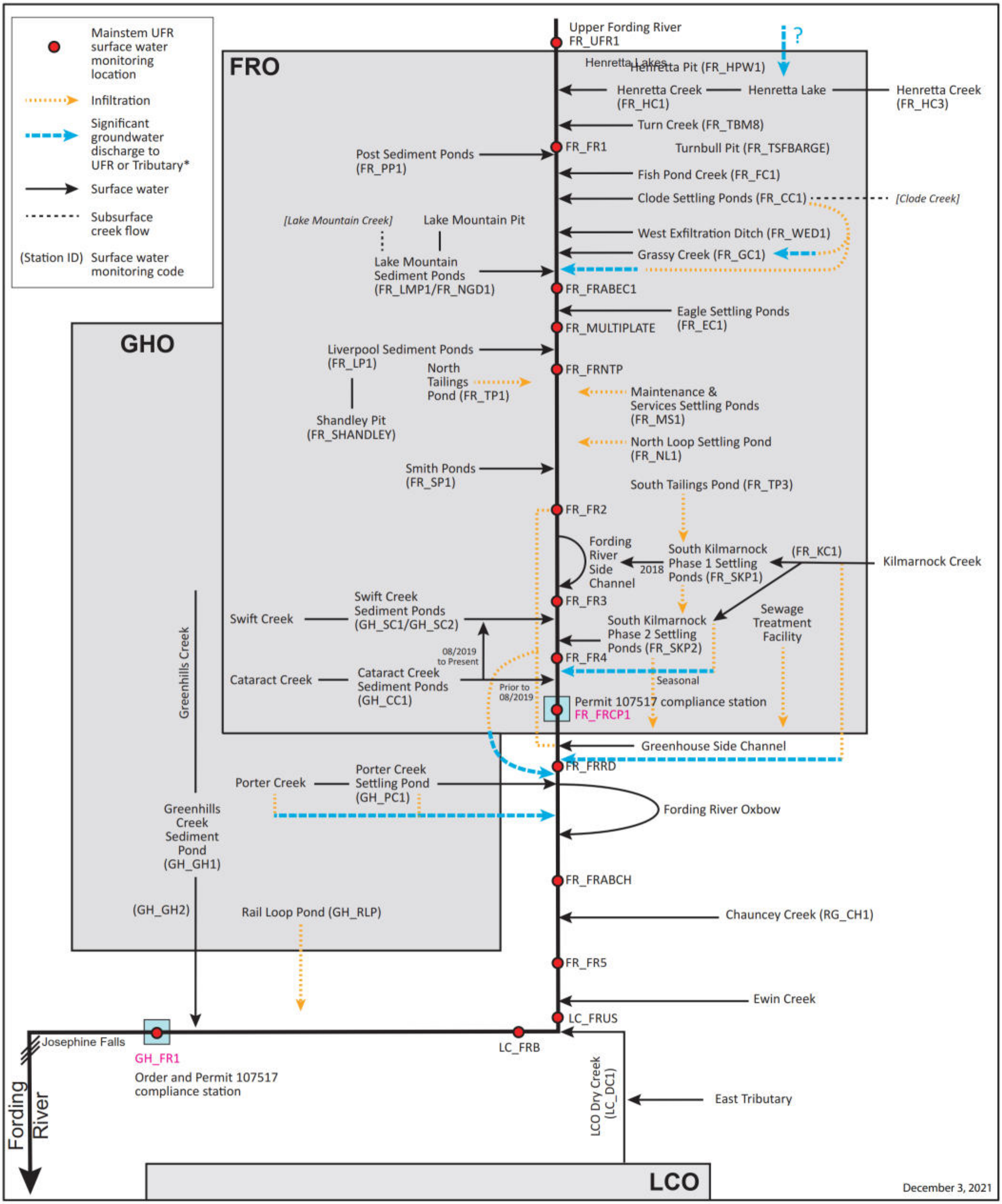
	61.5	FR_CB-1B	Clode Pond	WELL
	61.5	FR_CB-1A	Clode Pond	WELL
	62	RG_R7-119	Fording River Upper Reach 7 Site 119	LOT
	62	RG_FRLP	Fording River lower pond	LEN
	62	RG_FC1	Fish Pond Creek near mouth	LOT
	62	FR_TURNSEEP2	Seep from ground in valley bottom ~250m of Turnbull spoil. Discharges to Fording River.	SEEP
	62	FR_PP1BYPASS	Monitoring location for bypass line of FR_PP1	LOT
	62	FR_FRDSFC	on Fording River, downstream of the confluence of fording/fish creek	LOT
	62	FR_FR400MDSPP	Downstreatm of PP pipeline outfall/upstream of clode ponds	LEN
	62	FR_FCWP1	Fish Pond Creek west lower pond	LOT
	62	FR_FC1	Fish Creek at Culvert	LOT
63	62.5	RG_FRUP	Fording River upper pond	LEN
	62.5	FR_TBWSEEP1	Seep along southeastern toe of Turnbull spoil. Discharges to Fording River valley bottom.	SEEP
	62.5	FR_PP1H	Post Ponds	SPD
	62.5	FR_PP-1A	Post Pond / PP Rock Drain	WELL
	62.5	FR_PP1	Pond Sediment Ponds Decant	SPD
	62.5	FR_FRUSPP1BYPASS	Upstream of Post pond rock drain bypass outfall into fording.	LOT
	62.5	FR_FRUPP	Upstream post pond influence	LOT
	62.5	FR_FR200MUSPP	Fording upstream of PP pipeline Outfall	LEN
	63	FR_TB-2B	Turnbull Castle	WELL
	63	FR_TB-2A	Turnbull Castle	WELL
	63	FR_R11-P1	Fording River. Dec 2019 Isolated pool in drying section (calcite reach 11)	LOT
	63	FR_POTWELLS	PRE-CHLORINATION POTABLE WATER	GRN
	63	FR_FV1	Turnball Dustfall - 35m SE of potable Water Wells	AIL
	63	FR_FCSEEP2	Seep at north end of Fish Creek west channel. Discharges to Fish Creek.	SEEP
	63	FR_FCSEEP1	Seep at north end of Fish Creek east channel. Discharges to Fish Creek.	SEEP
	63	FR_A1	Turnball HighVol - 35m SE of potable Water Wells	AIL
64	63.5	RG_FODHE	Fording River downstream of Henretta Creek confluence	LOT
	63.5	FR_TSFBARGE	Turnbull Storage Facility at Barge	LEN
	63.5	FR_TB-1B	Turnbull Castle	WELL
	63.5	FR_TB-1A	Turnbull Castle	WELL
	63.5	FR_FR1SEEP	Seep discharging from spoil in depression ~90m southeast of FR_FR1. Seep then re-enters spoil ~50m to the south.	SEEP
	63.5	FR_FR1	Fording River D/S of Henretta Cr.	LOT
	64	FR_TBSSMW-2	Monitoring well 2 at northeastern corner of Turnbull spoil near valley bottom. Shallow.	WELL
	64	FR_TBSSMW-1	Monitoring well 1 at northeastern corner of Turnbull spoil near valley bottom. Deep.	WELL
	64	FR_FRDSHCC	Just Below Fording/Henretta confluence on Fording	LEN
	64	FR_FRDSHC1	on fording river, just below fording/henretta confluence	LOT
65	64.5	RG_HEN-CA02	Henretta Creek Calcite Biological Effect Site 2	LOT
	64.5	RG_HEN-CA01	Henretta Creek Calcite Biological Effect Site 1	LOT
	64.5	FR_TURNSEEP1	Seep ~160m southwest of FR_HC1. Discharges to ditch then ground before entering Henretta Lake	SEEP
	64.5	FR_HCUSFR	Henretta Creek upstream of Fording River Confluence	LOT
	64.5	FR_HC1	Henretta Cr. U/S of Fording River	LOT
	65	RG_UFR1	Fording River upstream of Henretta Creek	LOT
	65	FR_UFR2	500m upstream of Fording/Henretta Confluence	LOT
	65	FR_UFR1UD03182019	Monitoring location for source of unauthorized discharge that occurred near FR_UFR1 on 03-18-2019	LOT
	65	FR_UFR1DS50M	Monitoring location in the Upper Fording River Approximately 50m downstream of FR_UFR1	LOT
	65	FR_UFR1	Fording River U/S of Henretta Cr.	LOT
	65	FR_HENSSEEP2	Seep discharging from ditch ~140m southeast of FR_UFR1. Discharges to ground.	SEEP
	65	FR_HENSSEEP1	Seep discharging from ditch ~200m northeast of FR_UFR1. discharges to ground.	SEEP
	65	FR_FR200MDSUFR1	500m Upgradient of the Fording/Henretta Confluence	LEN
	65	FR_FR150MUSUFR1	Upgradient of the PP discharge/Fording confluence	LEN
66	65.5	FR_HENSSEEP3	Seep discharging from ground and pooling ~400m northeast of FR_UFR1. Discharges to ground.	SEEP
70	69.5	RG_FO26	Fording River upstream of FRO	LOT

Water Connections Figure

The need to standardize place names and summarize water connections in a watershed context was identified during the Evaluation of Cause. The water connections figure, Figure C-2, shows known surface water and subsurface water transport pathways. It was modified with input from the Evaluation of Cause Team and Teck Coal, from figures generated by Regional Aquatic Effects Monitoring Program reporting and prepared by Minnow Environmental Inc. For more information on subsurface flows, see Henry and Humphries (2021). For example, in Figure C-2 subsurface connections through bedrock from pits are not shown due to (1) relatively long travel times from pits to surface water, and (2) not all pits store water (i.e., Lake Mountain Pit).

Figure C-2. Water connections: surface water and subsurface water transport pathways.

Figure C-2 is presented on the following page.



* Known or potential zones of significant groundwater discharge to the Fording River or major tributaries are shown. It is noted that there are numerous minor or unknown discharge zones throughout the UFR as well.

Decline Window Events Table

The Decline Window Events table (Table C-2) documents significant operational (e.g., construction) and environmental (e.g., fire) events that occurred in the UFR during the decline window (September 2017–2019) by river segment (as defined in Cope et al., 2016). It does not include monitoring, wildlife mortalities or changes in water chemistry. This table was prepared by Azimuth and Teck Coal for use in the Evaluation of Cause. It is intended for use as a "back-check" for SMEs in the Evaluation of Cause, to confirm that they are aware of the major events that might affect the stressors they are evaluating.

Table C-2. Decline window events table.

Table C-2 is presented on the following pages.

Legend:

- offsetting
- fish salvage [J = juvenile, A = adult, NM = not measured]
- operational events
- Fish stranding
- other*

Note to Reader -
This table documents significant operational and environmental (e.g., fire) events that occurred in the upper Fording River during the Decline Window (Sept 2017-2019) by river segment as defined in Cope et al. (2016). Note that this does not include monitoring, wildlife mortalities, or changes in water chemistry. This table was prepared by Azimuth Consulting Group based on information provided by Teck Coal. It is one of a number of tools that were prepared for use for use by Subject Matter Experts in the Evaluation of Cause.

***only spills that were categorized as high likelihood of exposure or, in the case of the Maxam event, because Teck identified this event as a high-potential incident are included in this table. See Van Geest et al. (2021) for a full evalutaion of spills during the Decline Winow. Likewise, only total suspended solid (TSS) events that had very high potential effects are listed. See Durston et al. (2021) for a full evaluation of TSS effects during the Decline Window.**

River Location | **Material Events/Changes**

Time:	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18
Periodicity:	Rearing	Overwintering							Spawning		Rearing			
	Fall (overwintering) Migration							Spawning migration					Fall (overwintering) Migration	
	Summer 2017 Significant Fire Season								**Summer 2018 Significant Fire Season**					
S1														
S2	Sept 6-8, 2017 Greenhills Creek Primary Pond Fish Relocated to Greenhills Creek Reach 2 = 21 (J8, A13) Fish Mortalities = 0													Oct 9, 2018 Greenhills Pond Spillway Stilling Basin Fish Relocated to Greenhills Creek Reach 2 = 11 (J4, A7) Fish Mortalities = 0
	Sept 6 & 24, 2017 Greenhills Spillway Stilling Basin Fish Relocated to Henretta Lake = 110 (J29, A51, NM30) Fish Mortalities = 0													
S3														
S4														
S5														
S6														

Legend:

offsetting
fish salvage [J = juvenile, A = adult, NM = not measured]
operational events
Fish stranding
other*

River Location											
Time:	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19
Periodicity:	Overwintering Oct 15 - April 1						Spawning		Rearing		
						Spawning migration					Fall (overwintering) Migration Sep 1 - Oct 15
				Extreme Cold Event (preceded by warm winter and low snow)							
S1											
S2									Jul 10, 2019 Greenhills Pond Spillway Stilling Basin Fish Relocated to Greenhills Creek Reach 2 = 11 (J11) Fish Mortalities = 0	12 August 2019, approximately 1,500 L of wash water from the overland clean conveyer at GHO was spilled to rocky ground. Although the spill location is estimated to be approximately 116 m from surface water, the washing and cleaning around the conveyer resulted in water flowing across the road and into Greenhills Creek	
										23 August 2019, approximately 2,000 L of wash water from Eagle 6 at GHO was spilled into the ditch system on the northeast side of the wash plant, which discharges into the Site A sediment pond	
S3											
S4											
S5											
S6											

Legend:

- offsetting
- fish salvage [J = juvenile, A = adult, NM = not measured]
- operational events
- Fish stranding
- other*

Note to Reader -
This table documents significant operational and environmental (e.g., fire) events that occurred in the upper Fording River during the Decline Window (Sept 2017-2019) by river segment as defined in Cope et al. (2016). Note that this does not include monitoring, wildlife mortalities, or changes in water chemistry. This table was prepared by Azimuth Consulting Group based on information provided by Teck Coal. It is one of a number of tools that were prepared for use for use by Subject Matter Experts in the Evaluation of Cause.

***only spills that were categorized as high likelihood of exposure or, in the case of the Maxam event, because Teck identified this event as a high-potential incident are included in this table. See Van Geest et al. (2021) for a full evalutaion of spills during the Decline Winow. Likewise, only total suspended solid (TSS) events that had very high potential effects are listed. See Durston et al. (2021) for a full evaluation of TSS effects during the Decline Window.**

River Location														**Material Events/Changes**
Time:	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18
Periodicity:	Rearing	Overwintering							Spawning		Rearing			
	Fall (overwintering) Migration							Spawning migration					Fall (overwintering) Migration	
	Summer 2017 Significant Fire Season								**Summer 2018 Significant Fire Season**					
S7					Jan 23 - May 29, 2018 South Swift Soil Salvage. Swift Sediment Pond Area Area = 410,000 m²			Jan 23 - May 29, 2018 South Swift Soil Salvage. Swift Sediment Pond Area Area = 410,000 m²						Oct 15-19, 2018 Swift Creek Fish Relocated to Fording River = 786 (J786) Fish Mortalities = 4 (J1, NM3)
													September 10, 2018 15 WCT mortalities were found in a 800 m section of the UFR mainstem near FR_FRCP1SW. WCT ranged in size from 80 to 190 mm.	
									May 2018 (single event) TSS concentrations had potential to cause very high effects to eggs and larvae at FR_FRCP1. This site is located in Segment 7, which contains ~10% of fish use during the season such that any effects from these conditions are only relevant to a small portion of the population.	June - November 2018. New Swift Sediment Ponds - Off stream construction of the new ponds. Once new ponds were constructed the old ponds were diverted into the new ponds to allow them to fill over a couple days and discharge back to the same location. Swift Creek Reach 1 was still in use at this time and Teck Coal installed a fish fence and did a fish salvage prior to the diversion of the old ponds into the new ponds later in the year. Swift Creek Reach 1 was not connected to the Fording River via surface water (i.e. flow went subsurface) when the diversion was completed. Fence was removed prior to freshet 2019 and dates have been provided on that previously.				
												Aug 30-Sept 5, 2018 Fording River Side Channel/South Kilmarnock P1 Settling Pond Fish Mortalities Prior to Rescue = 109 (J109) Fish Mortalities During Rescue = 107 (J107)		
												Aug 10-Nov 2, 2018 Swift: Fording River Rehab near Swift Creek Instream Construction = 1493m		
												Aug 10-Oct 3, 2018 Active Water Treatment Facility - South Fording River Rehab near Swift Creek Extension. Instream Construction = 171m		

Legend:

- offsetting
- fish salvage [J = juvenile, A = adult, NM = not measured]
- operational events
- Fish stranding
- other*

River Location											
Time:	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19
Periodicity:	Overwintering Oct 15 - April 1							Spawning		Rearing	
						Spawning migration					Fall (overwintering) Migration Sep 1 - Oct 15
				Extreme Cold Event (preceded by warm winter and low snow)							
S7						Apr 1 - May 8, 2019 South Swift Soil Salvage. Cataract Sediment Pond Area Area = 75,000 m^2					Sept 20-Oct 4, 2019 Swift Creek Fish Relocated to Fording River =995 (J995) Fish Mortalities = 21 (J21)
								June - December 2019. Cataract Creek Diversion to Swift Sediment Ponds - This work consisted of installed a temporary pipe diversion around the ponds to Swift Creek in August, building the new head pond to take the cataract creek water to the new Swift Creek Sediment Ponds via a pipeline, and diverting the water back into the new head pond. The water from Cataract has been flowing to Swift since August 2019 and no water has been flowing over the cascade falls into the Fording River since.			
									20 July 2019, approximately 900 L of water discharged to the Fording River from a localized drainage west of the Swift Creek Sediment Pond discharge channel approximately 120 m downstream of the Swift Creek Sediment Ponds permitted discharge location	August 2019 - April 2020. Active Water Treatment Facility - South: Swift Creek Intake/Outfall (August 2019 through April 2020) and the Kilmarnock Creek Intake/Outfall (August 2019 through May 2020). This included the construction of the Fording River Outfall structure to discharge Swift Creek/Cataract Creek water to the Fording River, removing flow from Swift Creek Reach 1. To complete the work in this are a temporary bypass was installed to take the Swift Creek Sediment Pond water through a pipeline directly to the Fording River and not down Swift Creek Reach 1. Prior to installing the temporary diversion a fish salvage was completed and fish fences installed in Swift Creek Reach 1. Once construction was completed in early 2020, the temporary diversion was removed and water from Swift Creek Sediment Ponds discharges to the Fording River via the new outfall structure. The temporary bypass discharged to the Fording River approximately 20 meters downstream of the new outfall structure so essentially Swift Creek Sediment Ponds (including Cataract Creek water) has been discharging to the Fording River since the installation of the temporary bypass pipeline.	
								June - December 2019. Swift Sediment Ponds additional work - This consisted of constructed a channel to tie in to the rock drain above the old ponds, a channel built towards the spoils north of the ponds, a new head pond to take those two new channels to the ponds constructed in 2018 via a pipeline. That work disconnect the old ponds from the Swift Creek Rock Drain and they now only collect local flow.			
									July 4, 2019 TSS concentrations with the potential to cause >40-60% mortality occurred at Swift Bridge. TSS concentration of uncontained road runoff entering the upper Fording River was measured at 46,200 mg/L. TSS samples from 150 to 200 m downstream of the Swift Bridge measured 4 mg/L during the event, suggesting the event had a		

Legend:

offsetting

fish salvage [J = juvenile, A = adult, NM = not measured]

operational events

Fish stranding

other*

Note to Reader -
This table documents significant operational and environmental (e.g., fire) events that occurred in the upper Fording River during the Decline Window (Sept 2017-2019) by river segment as defined in Cope et al. (2016). Note that this does not include monitoring, wildlife mortalities, or changes in water chemistry. This table was prepared by Azimuth Consulting Group based on information provided by Teck Coal. It is one of a number of tools that were prepared for use for use by Subject Matter Experts in the Evaluation of Cause.

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River Location | **Material Events/Changes**

Time:	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18
Periodicity:	Rearing	Overwintering							Spawning		Rearing			
	Fall (overwintering) Migration							Spawning migration					Fall (overwintering) Migration	
	Summer 2017 Significant Fire Season								**Summer 2018 Significant Fire Season**					
S8	July - October 2017. Phase 1 Diversion - Upgrades to a historic diversion above the Swift Pit and south of Jason Creek in preparation to tie this into the overall Tower Diversion that gets constructed in 2018. Water essentially continued to flow to the same area from this diversion and continued to go the historic Swift Pits.									June - November 2018. Tower Diversion – Clean Water Diversion that captured the surface drainage west of the Swift Pit (Phase 1 Diversion from 2017) and above the spoils to the west of Lake Mountain Pit. Previously the drainage above the Swift Pit entered the pit area and was stored by the historic pits in that area. That catchment west of the Swift Pit now traveled through a pipeline from Jason Creek to the Lake Mountain Sediment Ponds and flows to the Fording River. The drainage above the spoils west of Lake Mountain Pit used to flow to the Lake Mountain Ponds after flowing through the spoils, now flows to the Lake Mountain Ponds via a pipeline without flowing through the spoils.				
	July - October 2017. Liverpool Sediment Ponds - Upgrades to Lee's Lake to enlarge it, this is no longer called Lee's Lake and is referred to as the Liverpool Sediment Ponds – Secondary Pond. No change in discharge location, just an expansion to the pond.							April 26-30 Anionic and cationic liquid flocculants were added at a total dosage concentration up to 3 mg/L (~10 to 24 hours/day) in Lake Mountain Creek Sediment Pond system (inaccessible to fish) in the channel that connects the primary and secondary ponds in response to TSS permit exceedances (72 mg/L TSS).	May 5 - July 30 Flocculant blocks (Clearflow products Water Lynx (WL) 360 and WL 494 - stable, anionic flocculants) Upstream of the primary sediment pond and between the primary and secondary sediment ponds on Lake Mountain Creek 11 Water Lynx (WL) 360 and 22 WL 494 were added May 2; 60 WL 360 and 32 WL 494 added May 5; all removed July 30					
	July - October 2017. Lake Mountain Reach 1 Bypass Pipeline – No change in discharge to the river but this work removed the lower reach of Lake Mountain Creek (below the haul road) and installed the current fish exclusion structure. This loss of habitat was approved and offset.													
	Sept 19-22, 2017 Lake Mountain Creek. Reach 4 & Reach 5 Fish Relocated to Greenhills Creek Reach 2 = 184 (J184) Fish Mortalities = 1 (J1)												Sept/Oct, 2018 Lake Mountain Creek. (Reach 2-Reach 5) Fish Relocated to Henretta Lake = 7 (J5, A2) Fish Mortalities = 0	
	Feb 1- Oct 31, 2017 North Swift Soil Salvage North Swift Area P1-P3 Area = 486,000 m²		Nov 1-30, 2017 North Swift Soil Salvage Lake Mountaint. Area P4 Area = 40,000 m²		Jan 22- Feb 22, 2017 North Swift Soil Salvage North Swift Area Area = 590,000 m²									Oct 9-11, 2018 Smith Creek Fish Relocated to Fording River = 108 (J103, A5) Fish Mortalities = 0

Legend:

offsetting

fish salvage
[J = juvenile, A = adult, NM = not measured]

operational events

Fish stranding

other*

River Location											
Time:	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19
Periodicity:	Overwintering Oct 15 - April 1						Spawning		Rearing		
						Spawning migration					Fall (overwintering) Migration Sep 1 - Oct 15
				Extreme Cold Event **(preceded by warm winter and low snow)**							
								June - September 2019. Tower Diversion Extension - Extension of the clean water diversion from Harold Creek to John Creek. Similar to the area captured in 2018, the drainage captured used to flow to the Lake Mountain Ponds after flowing through the spoils, now flows to the Lake Mountain Ponds without flowing through the spoils.			
S8									20 to 21 July 2019, approximately 594,000 L of water discharged from the FRO site near Liverpool pond to the Fording River		
				Feb 5 - Feb 26, 2019 1,578,000 L released over 22.5 days. The groundwater modelling conducted by Humphries and Henry (2020) indicated that ammonia concentrations were predicted to be below the long-term BC WQG at the point of release to fish accessible waters under the base-case scenario, and that the maximum concentrations would have occurred outside the decline window. Ammonia concentrations were predicted to marginally exceed the long-term BC WQG within the decline window under alternate scenarios that were simulated. However, the predicted concentrations would meet the long-term BC WQG when factoring in dilution that occurs within the mixing zone between groundwater and surface water. Moreover, the alternate release scenarios are highly conservative and considered unlikely. Therefore, the Maxam event is not expected to have contributed to or caused the WCT population decline.							
										Aug 27, 2019 South Tailings Pond Sump Fish Relocated to Fording River = 4 (2J, 2A) Fish Mortalities = 0	Sept 3-Oct 3, 2019 Smith Creek Fish Relocated to Fording River at Smith Creek =692 (J521, A111, NM60) Fish Mortalities = 4 (J1, NM3)

Legend:

offsetting

fish salvage [J = juvenile, A = adult, NM = not measured]

operational events

Fish stranding

other*

Note to Reader -
This table documents significant operational and environmental (e.g., fire) events that occurred in the upper Fording River during the Decline Window (Sept 2017-2019) by river segment as defined in Cope et al. (2016). Note that this does not include monitoring, wildlife mortalities, or changes in water chemistry. This table was prepared by Azimuth Consulting Group based on information provided by Teck Coal. It is one of a number of tools that were prepared for use for use by Subject Matter Experts in the Evaluation of Cause.

***only spills that were categorized as high likelihood of exposure or, in the case of the Maxam event, because Teck identified this event as a high-potential incident are included in this table. See Van Geest et al. (2021) for a full evalutaion of spills during the Decline Winow. Likewise, only total suspended solid (TSS) events that had very high potential effects are listed. See Durston et al. (2021) for a full evaluation of TSS effects during the Decline Window.**

River Location **Material Events/Changes**

Time:	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18
Periodicity:	Rearing	Overwintering							Spawning		Rearing			
	Fall (overwintering) Migration							Spawning migration					Fall (overwintering) Migration	
	Summer 2017 Significant Fire Season								**Summer 2018 Significant Fire Season**					
S9	Aug 22-Oct 23, 2017 Swift: Fish Pond Creek Instream Construction = 548m									June - November 2018. Post Sediment Ponds - New discharge location approximately 850 meter upstream of Clode Creek and downstream of the northern drying stretch. Flow was brought to this location via the North Tributary Rock Drain and the Post Ponds Rock Drain. The drainage captured by the North Tributary Rock drain used to flow through Lake Mountain Sediment Pond. As the Lake Mountain Pit mines out Lake Mountain Creek, the North Tributary Rock Drain was installed to divert flow away from the active pit and discharge it through the Post Sediment Ponds. The Post Ponds Rock Drain extends to the north and captures the drainage under our north spoil to discharge it through the ponds. The drainage captured by the Post Ponds Rock Drain previously traveled through the Turnbull Bridge Spoil and went to ground or potentially had limited surface water connection with the Fording River during high flows.				
	Aug 22-Sept 26, 2017 Fish Pond Creek. Offset Work Fish Relocated to Fording River = 1167 (J590, NM577x40-450mm) Fish Mortalities = 3 (NM3)											Aug 20-Oct 13, 2018 Henretta Offsetting Work Fish Relocated to Henretta Creek. = 1903 (NM1903) Fish Mortalities = 12 (NM12)		
	Sept 19-Oct 17, 2017 Swift: Henretta Lake/Outlet Instream Construction = 1364m											Aug 2-Oct 3, 2018 Swift: Henretta Inlet Rehab Instream Construction = 928m		
S10														
S11														

Legend:

- offsetting
- fish salvage [J = juvenile, A = adult, NM = not measured]
- operational events
- Fish stranding
- other*

River Location											
Time:	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19
Periodicity:	Overwintering Oct 15 - April 1							Spawning		Rearing	
						Spawning migration					Fall (overwintering) Migration Sep 1 - Oct 15
				Extreme Cold Event (preceded by warm winter and low snow)							
S9								June - November 2019. Post Ponds Rock Drain Extension - Extension of the rock drain to the north to cover the full planned footprint of the North Spoil. Similar to the area captured in 2018, the drainage captured by the Post Ponds Rock Drain extension previously traveled through the Turnbull Bridge Spoil and went to ground or potentially had limited surface water connection with the Fording River during high flows.			
					March 23 Liquid flocculants were added to the Post Sediment Pond system (inaccessible to fish) in the channel that connects the primary and secondary ponds. Flocculants were added at a total dosage concentration of 2 mg/L (~18 hours) in response to a TSS permit exceedance (59 mg/L TSS)						
S10								June - November 2019. North Spoil Diversion - New discharge location into the Fording River approximately 160 meter upstream of FR_UFR1. This is a clean water diversion that captures flow prior to contact with the North Spoil. Currently only captures localized drainage with plans to extend the channel in future years.			
S11											

“Eyes on the river” & Fish Mortality Observations

A question that came up repeatedly was: Why did no one see any fish carcasses in the river? This question was asked in part because Teck Coal’s extensive presence on the river made it likely that a large mortality event would have been noticed (particularly between rkm 52 and 63, which is the heart of the FRO property). The Eyes on the River figure was therefore developed to show the activities that took place along the UFR during the decline window. The table highlights activities that may have provided field crews with opportunities to detect fish carcasses.

A number of Teck Coal activities take place along the UFR and provide field crews with opportunities to detect fish carcasses. These activities include (but are not limited to) monitoring programs for fish, surface water, groundwater, calcite, benthic invertebrates, sediment and instream flow measurement. The Eyes on the River figure (Figure C-3) shows these activities by month (x-axis) and river kilometre (y-axis) throughout the decline window (September 2017 – September 2019). Grey columns highlight the winter months (as described in Chapter 4, November – March, inclusive), and white columns are the spring/summer. Blue horizontal bars show where there is a higher presence of field crews and mine staff on the river, regardless of season. Spatially there are gaps in coverage in certain sections of the river, due to the large size of the system and less monitoring in areas with lower land use.

Fish carcasses can be difficult to locate, and their detection can depend on multiple environmental/biological factors such as number of carcasses, body size, water clarity, turbulence, flow rate (e.g., during spring high flows), scavenger activity in the area, large woody debris, ice cover in winter months and the characteristics of the mortality event, such as intensity over time. For example, the probability of carcass recovery has been shown to increase with increasing fish size and decreasing stream flow (Zhou, 2002). Also, crews would be more likely to see carcasses if the mortality event was large enough to overwhelm scavengers and affect larger fish (Bollinger, 2021a). Moreover, detecting carcasses may be particularly challenging in the winter and under ice.

When field crews and mine staff observe fish carcasses in the UFR watershed, the events are reported to Teck Coal, documented in a database and reported to regulatory agencies and KNC. Between the three Teck Coal operations in the UFR watershed, 18 WCT mortality incidents were reported within the decline window, all of which fell between May and October in a given year. Of these, all but two involved less than five WCT carcasses. The two larger mortality events documented by Teck Coal both occurred in early September 2018, due to fish stranding. They are described as follows:

1. Westslope Cutthroat Trout carcasses were reported prior to and during a salvage effort to collect fish from waterbodies (Fording River side-channel and South Kilmarnock Settling Ponds Phase 1 Discharge Channel) that had become isolated from the Fording River main channel following a decline in flows. A total 216 dead fish were collected and 881 live fish were relocated. For more information on this event, refer to Hatfield et al. (2021) and Hocking et al. (2021).
2. Westslope Cutthroat Trout carcasses were found and reported by a field crew in the UFR between FOBCP and FRCP1SW. The dead fish were found just upstream of FRCP1SW in an area that had become dry. A total of 15 dead fish were collected. For more information on this event, refer to Hocking et al. (2021).

It is acknowledged that Teck Coal's incidental fish mortality database only reports those mortalities that have been observed by field crews, so this information is considered anecdotal. Based on fish population monitoring data, a large mortality event occurred and went undetected, despite the number of people working on the river (Table C-3). This is not surprising, given the factors identified here, which affect our ability to detect fish carcasses.

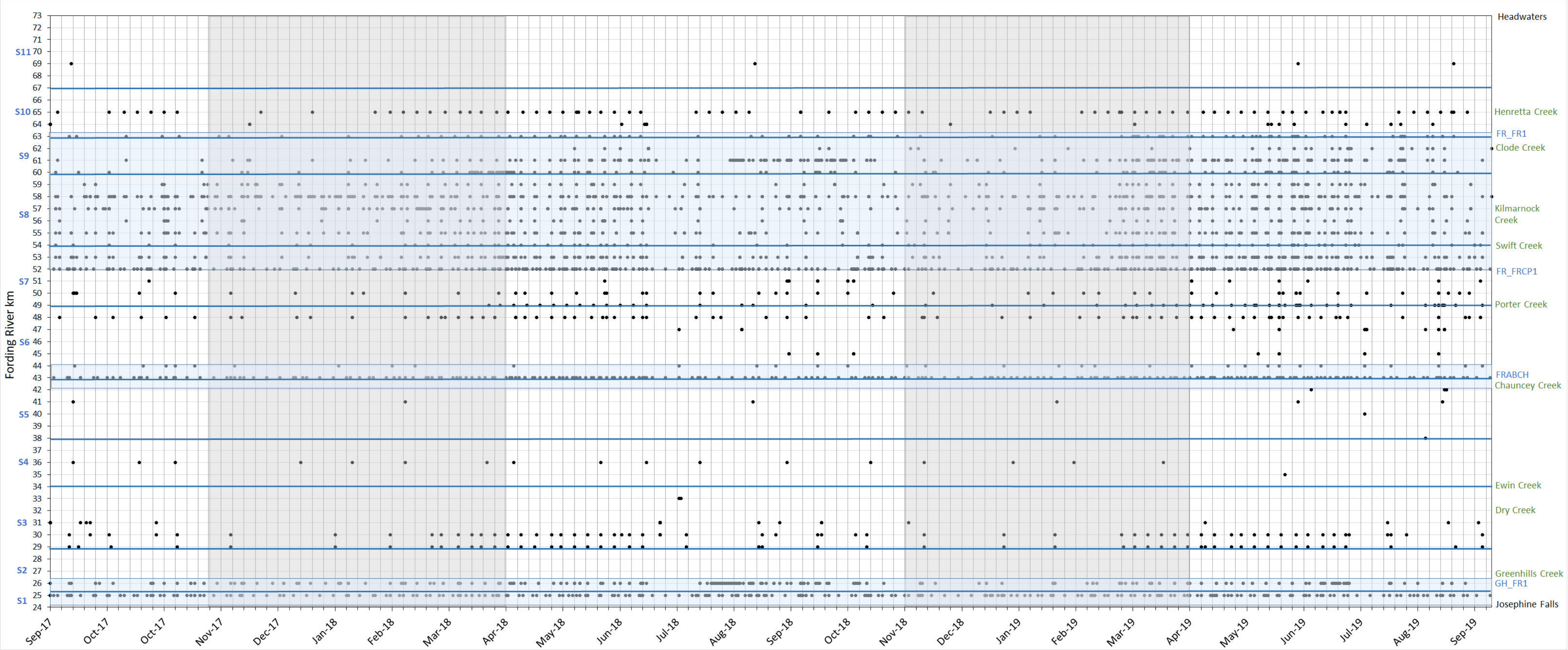


Figure C-3. Eyes on the River, a representation of observers on the upper Fording River.

Locations (river km shown on y-axis) and weeks (x-axis) between September 1, 2017 and September 21, 2019 when biologists and technicians were present on the upper Fording River (as denoted by •) and could potentially have observed fish mortalities.

Regional Populations Table

During engagement with KNC, agencies and committees, there was discussion about whether fish population survey information from other watersheds in the region would be useful to the Evaluation of Cause. The Team therefore prepared a summary of meta-information about the various studies (Table C-3) and, from that, determined if there were any populations that have been studied intensively enough (e.g., over multiple years or at multiple sites) to be comparable. After consideration by fish SMEs, this was not determined to be the case, at least for adult fish.

Table C-3. Summary of regional WCT populations.

Table C-3 is presented on the following page

Evaluation of Regional WCT Populations

21-Sep-20

Purpose:

In an effort to close the loop (both within the EoC team and with agencies/KNC) on the topic of the EoC evaluating “regional” WCT data, Azimuth prepared this summary table. This table lists all the creeks/rivers that have been mentioned as potential sources of additional data. Some are within the UFR (i.e., are "fragmented" WCT populations) and some are outside of the UFR. Some might be considered “references” and others are considered mine-influenced; depending on the nature of the data, such information about regional populations might be useful (e.g., if reference shows similar decline in adults, if reference does not show similar decline to adults, if other mine-affected sites has comparative juvenile densities to UFR, etc.).

Where:
1. Fragmented: downstream movement possible, but upstream movement not possible for any life stage or at any flow
2. Permanently Fragmented: no movement. Both upstream and downstream migration fully cut-off for all month and flows.
3. Impeded: some bi-directional movement, but potential seasonal/flow or life stage barrier.

Fragmented, Permanently Fragmented, Impeded, Mainstem, or Outside UFR	**Location**	**Life Stage**	**Years of Data**	**Number of Sites**	**Methods (i.e., snorkel or electrofishing)**	**Owner of data/location**	**Level of disturbance (i.e., mine-influenced? reference site?)**	**Notes**
Outside UFR	44 different streams in Aberta	?	from 1970-2009	55	electrofishing	Alberta Government: The Alberta Athabasca Rainbow Trout Recovery team	?	Starting on page 94, see Appendix 4 for data. These are data for rainbow trout, Athabasca rainbow trout, and brook trout
Outside UFR	Lower Fording River	adult >30cm	2020	5?	snorkel	FLNRORD		within presentation shared by Teck
Outside UFR	Line Creek	Juvenile & adult	Since 1993, possibly since 1970s	Ranged from 2-4	snorkel, electrofishing	Lotic, Teck, hard copies of older reports	mine-influenced	Westslope Cutthroat Trout and Brook Trout
Outside UFR	Wigwam	adult	2008, 2018	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	2018 data are in "Lower Fording WCT results.pptx"
Outside UFR	Skookumchuck Creek	adult	2014/2015, 2019	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	data are in "Lower Fording WCT results.pptx"
Outside UFR	Middle White River	adult	2011, 2014, 2018	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	2011 and 2018 data are in "Lower Fording WCT results.pptx"
Outside UFR	Upper St. Mary River	adult	2008, 2011, 2014, 2019	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	NA
Outside UFR	Upper Bull River	adult	2005, 2010, 2019	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	NA
Outside UFR	North Fork White River	adult	2010/2011, 2014, 2018	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	data are in "Lower Fording WCT results.pptx"
Outside UFR	Lussier River	adult	2019	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	data are in "Lower Fording WCT results.pptx"
Outside UFR	East Fork White River	adult	2012	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	NA
Outside UFR	Michel Creek	adult	2008, 2020	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	2020 data are in "Lower Fording WCT results.pptx"
Outside UFR	Lower St. Mary River	adult	2008	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	NA
Outside UFR	Elk River	adult	2008	?	snorkel	Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: 2019. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 48 p. + 2 app. page 22	?	NA
Outside UFR	Elk River watershed Fording River Harmer Creek Line Creek Michel Creek Andy Good Creek Elk River Forsythe Creek Lizard Creek Morrissey Creek Wheeler Creek	Juvenile	2010, 2012, 2013	in order: 4 exposed, 6 reference	electrofishing	Robinson, M.D. 2014. Elk River Juvenile Westslope Cutthroat Trout (Oncorhynchus clarkii lewisi) Population Assessment. Prepared by Lotic Environmental Ltd for Teck Coal Ltd. 30 pp.	mine-influenced reference	Data from 2010, 2012 are in Robinson 2011 and 2013 respectively.
Outside UFR	Elk River watershed	Juvenile	2010 (more of the data referenced in the line above)	26	electrofishing: single pass, four sites depletion removal	Robinson, M.D. 2011. Elk River fish distribution and longnose dace tissue assessment. Prepared for the Elk Valley Selenium Task Force. Prepared by Interior Reforestation Co. Ltd. 21 pp +app.	15/26 = reference	
Outside UFR	Oldman River watershed Vicary Creek - Reach 1 Vicary Creek - Reach 2 Racehorse Creek Oldman River	Juvenile	2010, 2012, 2013	reference	electrofishing	Robinson, M.D. 2014. Elk River Juvenile Westslope Cutthroat Trout (Oncorhynchus clarkii lewisi) Population Assessment. Prepared by Lotic Environmental Ltd for Teck Coal Ltd. 30 pp.	reference	Data from 2010, 2012 are in Robinson 2011 and 2013 respectively
Outside UFR	Elk River Tributaries (Upper Elk drainage) Harmer Creek Line Creek Wilson Creek Forsyth Creek Elk River		2006, 2005	1 - 6 sample locations. Year dependent	electrofishing	Wilkinson, C. E. 2009. Sportfish Population Dynamics in an Intensively Managed River System. Masters Thesis, University of British Columbia.	not defined	Westslope Cutthroat Trout and Brook Trout
Outside UFR	Elk River Tributaries (Michel drainage) Michel Creek Erikson Creek Leach Creek Wheeler Creek		2006, 2006	1 - 6 sample locations. Year dependent	electrofishing	Wilkinson, C. E. 2009. Sportfish Population Dynamics in an Intensively Managed River System. Masters Thesis, University of British Columbia.	not defined	Westslope Cutthroat Trout and Brook Trout
Outside UFR	Elk River Mainstem	adult	2006, 2007	4	snorkel	Wilkinson, C. E. 2009. Sportfish Population Dynamics in an Intensively Managed River System. Masters Thesis, University of British Columbia.	not defined	Westslope Cutthroat Trout and Brook Trout
Outside UFR	Harmer Creek	adult, juvenile	2017, 2018, 2019	25, 24, 24	snorkel, electrofishing	Cope, S.1 and A. Cope1. 2020. Harmer and Grave Creek Westslope Cutthroat Trout Habitat and Population Assessment: Final Report. Report Prepared for Teck Coal Limited2, Sparwood, B.C. Report Prepared by Westslope Fisheries Ltd., Cranbrook, B.C. 121 p. + 2 app.	mine-influenced	
Outside UFR	Grave Creek	adult, juvenile	2017, 2018, 2019	24, 24, 24	PIT, radio, electrofishing	Cope, S.1 and A. Cope1. 2020. Harmer and Grave Creek Westslope Cutthroat Trout Habitat and Population Assessment: Final Report. Report Prepared for Teck Coal Limited2, Sparwood, B.C. Report Prepared by Westslope Fisheries Ltd., Cranbrook, B.C. 121 p. + 2 app.	"reference" to Harmer population but mine-influenced WQ	
UFR mainstem	Fording River - four sites	general (whatever stayed in the sites) but mostly juveniles caught	2012	4	Electrofishing. long mark recap sites (300-400 m), closed - awesome sites!	Robinson, MD. 2012. Fording River fish and fish habitat survey. Prepared for Teck Coal Ltd. – Fording River Operations. Prepared by Lotic Environmental Ltd. 53 pgs.	3 exposed 1 reference	
UFR mainstem	Fording River Fish Offsetting sites (2015)	Juvenile	2015	10	electrofishing. meso-habitat style, depletion removal. Same as Cope's technique	Smithson, J. 2015. Fording River Fry and Juvenile WCT Density Assessment 2015 – Letter Report	exposed	
Fragmented UFR	Chauncey Creek	NA	NA	NA	NA	NA	NA	Data is within Cope population assessments.
Fragmented UFR	Upper Greenhills Creek	fry, juveniles	2017, 2018, 2019	4 areas (3 closed stations per area)	electrofishing	Minnow 2020 - Greenhills Creek Aquatic Monitoring Program 2019 Report.	mine-influenced	Upper Greenhills Creek is where the isolated population is located, although fish in lower Greenhills Creek, which are part of the broader Fording River population, have also been monitored in this program.
Impeded UFR	Dry Creek (LCO)	adult, juvenile	2016, 2017, 2018, 2019	5 sites / yr.	electrofishing	Faulkner, S., J. Ammerlaan, N. Swain, K. Ganshorn, and T. Hatfield. 2019. Dry Creek Fish and Fish Habitat Monitoring Program Year 4 Summary Report. Consultant’s report prepared for Teck Coal Limited by Ecofish Research Ltd., April 24, 2020.	mine-influenced	
Permanently Fragmented UFR	Kilmarnock Creek (above spoils)	adult	1983, 2007, salvage 2011. No fish 2018, 2019	?	electrofishing/ angling	Summarized in Brown M., and Harwood, A.. 2019. Kilmarnock Clean Water Diversion DFO Request for Review. Consultant's report prepared for Teck Coal Limited by Ecofish Reseach Ltd.	mine-influenced	Ecofish sampled upper Kilmarnock Creek in 2018 and 2019 and did not observe or capture any fish despite sampling much of the remaining habitat. Consequently, we conclude that there is not a viable fish population in upper Kilmarnock Creek and the population present in August 2007 (Arnett and Berdusco 2008)is likely already extirpated; however, we cannot rule out the possibility that a few fish remain.
Permanently Fragmented UFR	Brownie Creek (within Kilmarnock drainage)	?	2002	2	?	Edeburn, A. 2003. Brownie Creek and Tributaries Habitat Assessment. Prepared for Greg Sword, Fording Coal Ltd. Elkford, B.C. Prepared by Interior Reforestation Co. Ltd. Cranbrook, B.C. 3 p.	?	Brownie Creek flows into Kilmarnock Creek above the rock drain
	Unspecified Kootenays							
	Unspecified Alberta							

Key:	
?	Unknown at this time
NA	Not applicable

Fish Use Maps

The Fish Use Maps were created by Teck Coal using data collected by Westslope Fisheries during the 2012–2015 WCT population study in the UFR (Cope et al., 2016). These maps show telemetry data for key times when fish use spawning, summer rearing and overwintering habitats. There are four maps, one for the overwintering period, one for the rearing period and two for the spawning period. One of the spawning maps shows scanned radio tagged observations of fish, and the other shows visual observations of spawning locations (redds) in the stream bed.

Relative percentage fish usage was then calculated for each river segment by counting all scans of radio tagged fish, or observed redds, in each segment and dividing by the total number of scanned fish over a three-year-period between 2012 and 2015. The percentage of fish use in each segment is displayed in the segment label on the map and represents the total number of fish that were tagged, not the whole estimated population of adult and sub-adult fish in the UFR.

All maps and relative percentages of fish use were developed based on the information provided in the 2012–2016 WCT population study. Use of these maps carries the implicit assumption that fish usage during the decline window followed the same temporal and spatial patterns as in 2012–2016.

When comparing the overwintering fish use estimates to those reported in Cope et al. (2016), we note some differences, particularly in the estimates for Henretta Lake. While Cope et al. (2016) noted ~20% of fish use Henretta Lake for overwintering, our estimate is lower, ranging from 10.9–16.7% across years. It is likely this discrepancy is driven by two factors: (1) our definition of overwintering runs from October 15 to March 31, whereas Cope et al. (2016) excludes the “shoulder season” portions, and covers November 1 to February 28; and (2) our fish use estimates assume that each detection only persists up to a maximum of 30 days. During overwintering, it is likely that movement of fish away from Henretta Lake is minimal, thereby preventing these fish from being detected at the fixed receiver station downstream of Henretta Lake frequently enough to be persistently captured in our analysis. SMEs discussed the underlying dataset and differences in the overwintering fish use estimates, and they decided that, for the purposes of the Evaluation of Cause, the differences were not material, particularly given other cautions that apply to using these data.

Table C-4. Relative fish use numbers

Segment	M v T	Description	WQ Station Code	Biological Area Code	Overwintering - Fish Use (n=264)_Count	Rearing - Fish Use (n=742)_count	Radio Tagged Spawing (n=130)_count	Observed Redds (n=154)_Count	Overwintering - Fish Use (n=264)_Percent	Rearing - Fish Use (n=742)_Percent	Radio Tagged Spawning (n=129)_Percent	Observed Redds (n=154)_Percent
S-11	Mainstem			FO26	4	2	1	0	**2%**	**0%**	**1%**	**0%**
S-10	Mainstem	*u/s Henretta Cr. and FRO*	*FR_UFR1*	FO26	6	50	9	0	**2%**	**7%**	**7%**	**0%**
S-9	Mainstem	d/s Henretta Cr.	FR_FR1	FODHE	9	52	13	19	**3%**	**7%**	**10%**	**12%**
	Mainstem	u/s Clode Cr.		FOUCL								
S-8	Mainstem	u/s North Greenhills Diversion		FOUNGD	52	89	26	18	**20%**	**12%**	**20%**	**12%**
	Mainstem	d/s North Greenhills Diversion	FR_FRABEC1	FODNGD								
	Mainstem	Multiplate Culvert	FR_MULTIPLATE	MP1								
	Mainstem	u/s Shandley Cr.		FOUSH								
	Mainstem	u/s Kilmarnock Cr.	FR_FR2	FOUKI								
S-7	Mainstem	d/s Kilmarnock & u/s Swift Cr.	GH_FR3	FOBKS	7	74	4	2	**3%**	**10%**	**3%**	**1%**
	Mainstem	d/s future AWTF-S		SCOUTDS								
	Mainstem	d/s Swift Cr., u/s Cataract Cr.	FR_FR4	FOBSC								
	Mainstem	d/s Cataract, u/s Porter	FR_FRCP1	FOBCP								
	Mainstem	1 km SW of Fording R Compliance		FRCP1SW								
S-6	Mainstem	u/s Porter	FR_FRRD	FRUPO	105	119	28	73	**40%**	**16%**	**22%**	**47%**
	Mainstem	Fording River side channel		FO10-SP1								
	Mainstem	d/s Porter Cr., u/s Chauncey Cr.	GH_PC2	FODPO								
	Mainstem	u/s Chauncey Creek	FR_FRABCH	FO22								
S-5	Mainstem	d/s Chauncey Cr.	FR_FR5		7	58	5	5	**3%**	**8%**	**4%**	**3%**
S-4	Mainstem	Fording River u/s Ewin Cr.		FOUEW	6	67	7	4	**2%**	**9%**	**5%**	**3%**
S-3	Mainstem	Fording River u/s Dry Creek	LC_FRUS	FO28	6	57	5	1	**2%**	**8%**	**4%**	**1%**
S-2	Mainstem	d/s Dry Cr., u/s GHO	LC_FRB	FO29	11	54	12	14	**4%**	**7%**	**9%**	**9%**
S-1	Mainstem	d/s GHO and Greenhills Cr.	GH_FR1	FODGH	20	46	6	2	**8%**	**6%**	**5%**	**1%**
S-9	Tributary	Henretta Creek	FR_HC1	HENFO	31	72	4	2	**12%**	**10%**	**3%**	**1%**
S-9	Tributary	Fish Pond Creek	FR_FC1	FR_FC1	0	0	1	2	**0%**	**0%**	**1%**	**1%**
S-9	Tributary	Clode Creek	FR_CC1	CLODE	0	0	8	2	**0%**	**0%**	**6%**	**1%**
S-7	Tributary	Kilmarnock Creek	FR_KC1	KICK	0	0	1		**0%**	**0%**	**1%**	**0%**
S-6	Tributary	*Chauncey Creek*	*RG_CH1*	*CHCK*	0	2			**0%**	**0%**	**0%**	**0%**
S-3	Tributary	LCO Dry Creek	LC_DC1	LC_DC1	0	0		9	**0%**	**0%**	**0%**	**6%**
S-2	Tributary	Greenhills Creek	GH_GH1	GHCKD	0	0		1	**0%**	**0%**	**0%**	**1%**

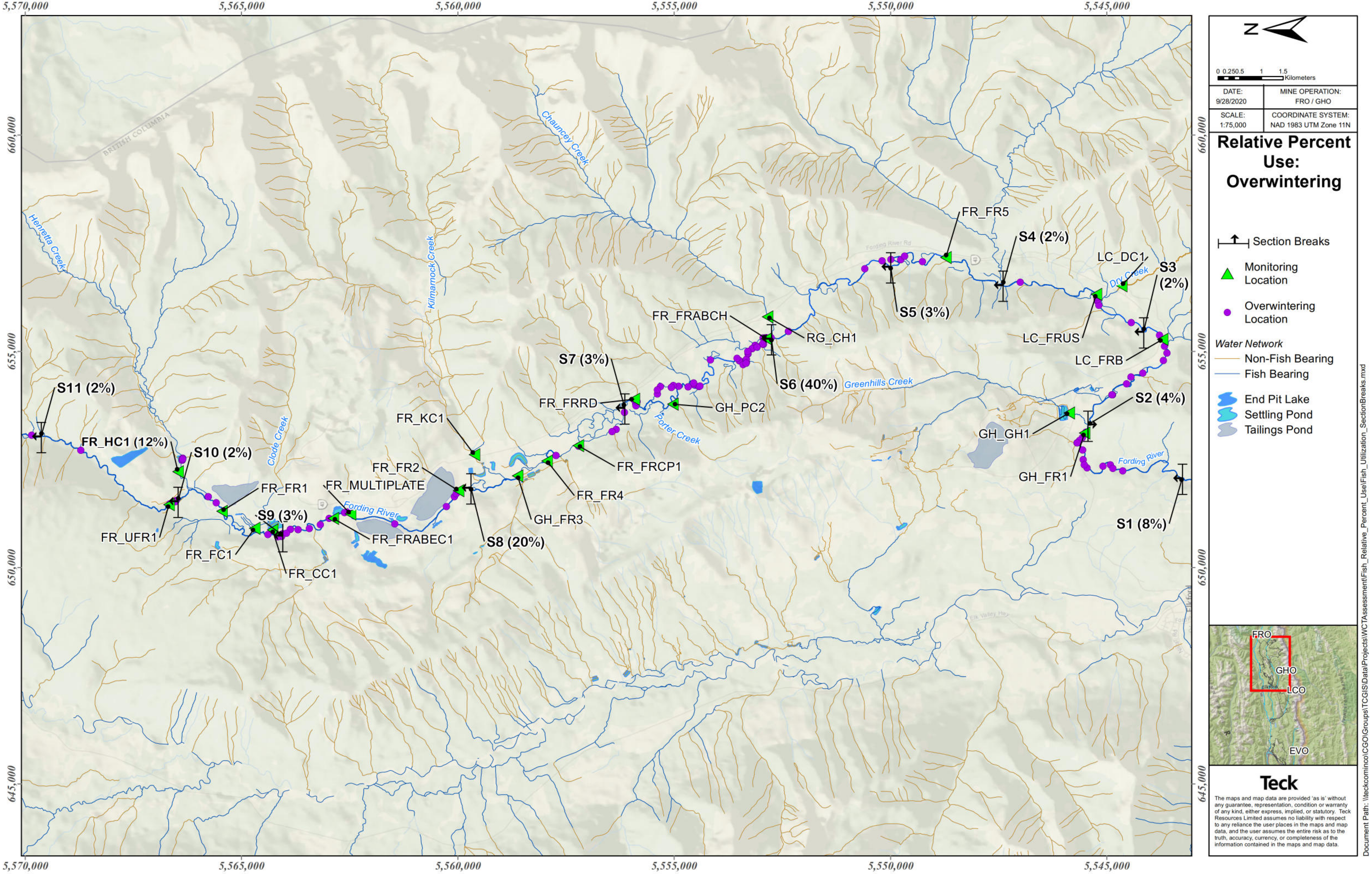
Fish utilization maps for overwintering, rearing, redds and spawning are included on the following pages. Their captions are:

Figure C-4. Fish utilization — overwintering.

Figure C-5. Fish utilization — rearing.

Figure C-6. Fish utilization — redds.

Figure C-7. Fish utilization — spawning.

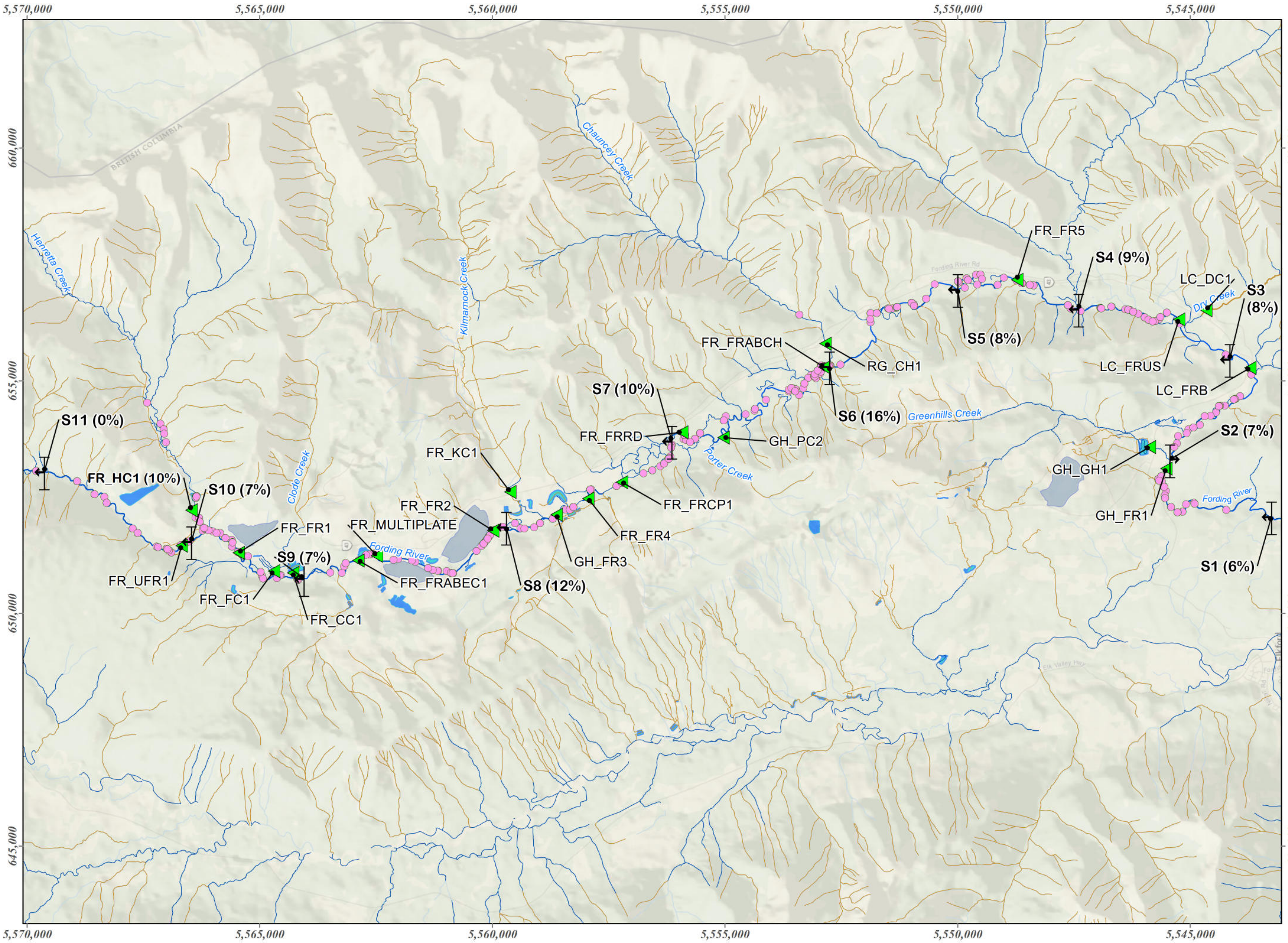


DATE:	MINE OPERATION:
9/28/2020	FRO / GHO
SCALE:	COORDINATE SYSTEM:
1:75,000	NAD 1983 UTM Zone 11N

Relative Percent Use: Overwintering

Teck

Document Path: \\teckcominco\CGO\Groups\TCGIS\Data\Projects\WCTAssessment\Fish_Relative_Percent_Use\Fish_Utilization_SectionBreaks.mxd



N

0 0.25 0.5 1 1.5 Kilometers

DATE: 9/28/2020	MINE OPERATION: FRO / GHO
SCALE: 1:75,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

Relative Percent Use: Summer Rearing

Section Breaks

▲ Monitoring Location

● Summer Rearing Location

Water Network

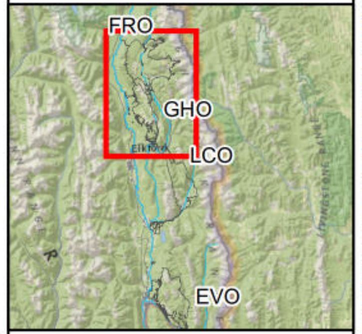
Non-Fish Bearing

Fish Bearing

End Pit Lake

Settling Pond

Tailings Pond



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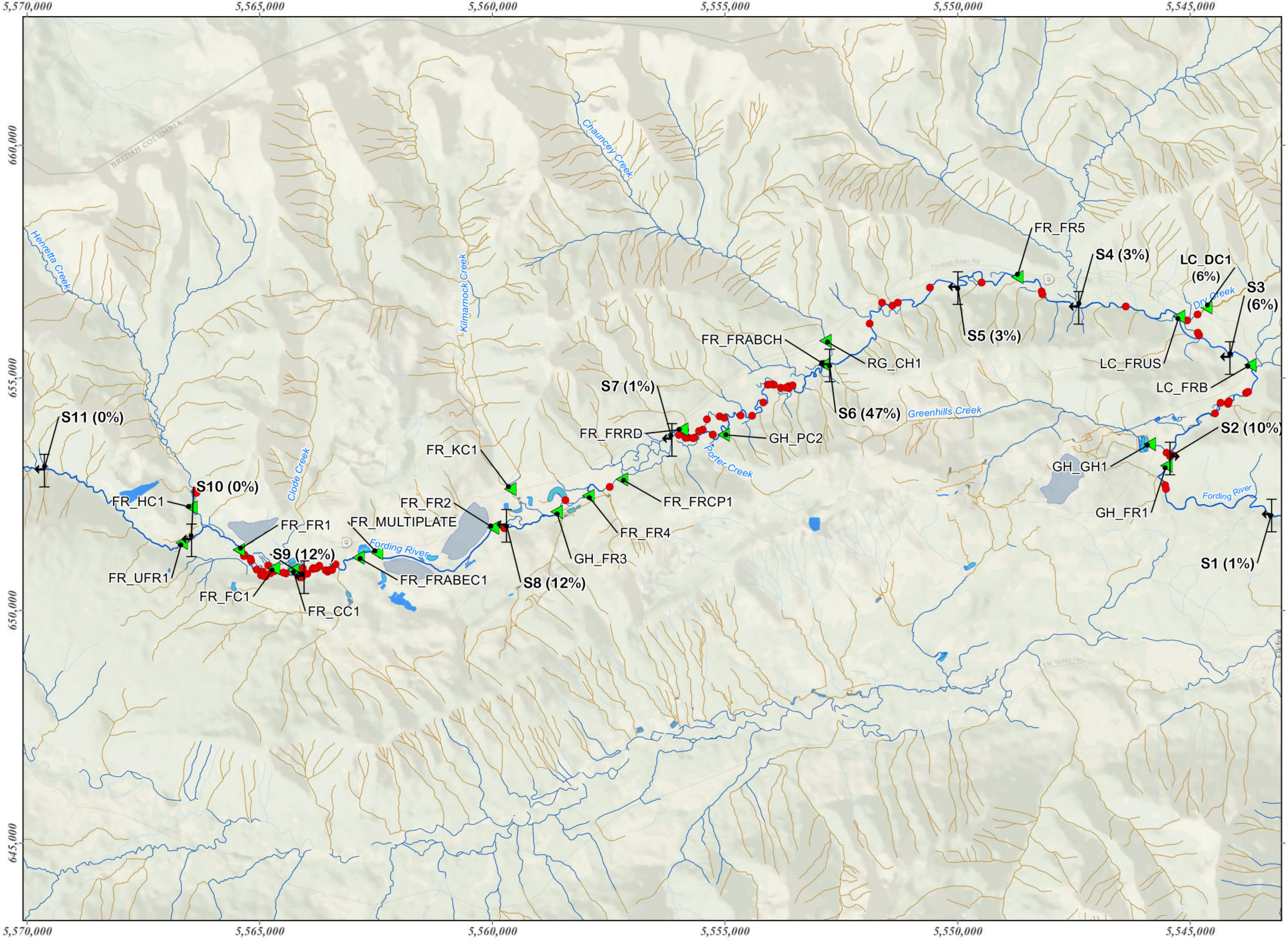


N

0 0.25 0.5 1 1.5 Kilometers

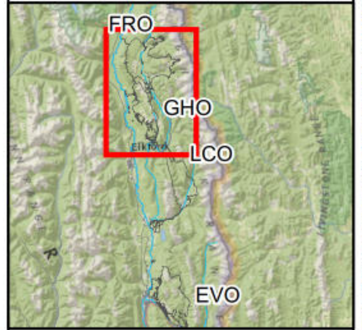
DATE: 9/28/2020	MINE OPERATION: FRO / GHO
SCALE: 1:75,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

Relative Percent Use: Spawning (Redds)

- ▲ Monitoring Location
- ⊢ Section Breaks
- ● Observed Redds Location

Water Network

- Non-Fish Bearing
- Fish Bearing
- End Pit Lake
- Settling Pond
- Tailings Pond



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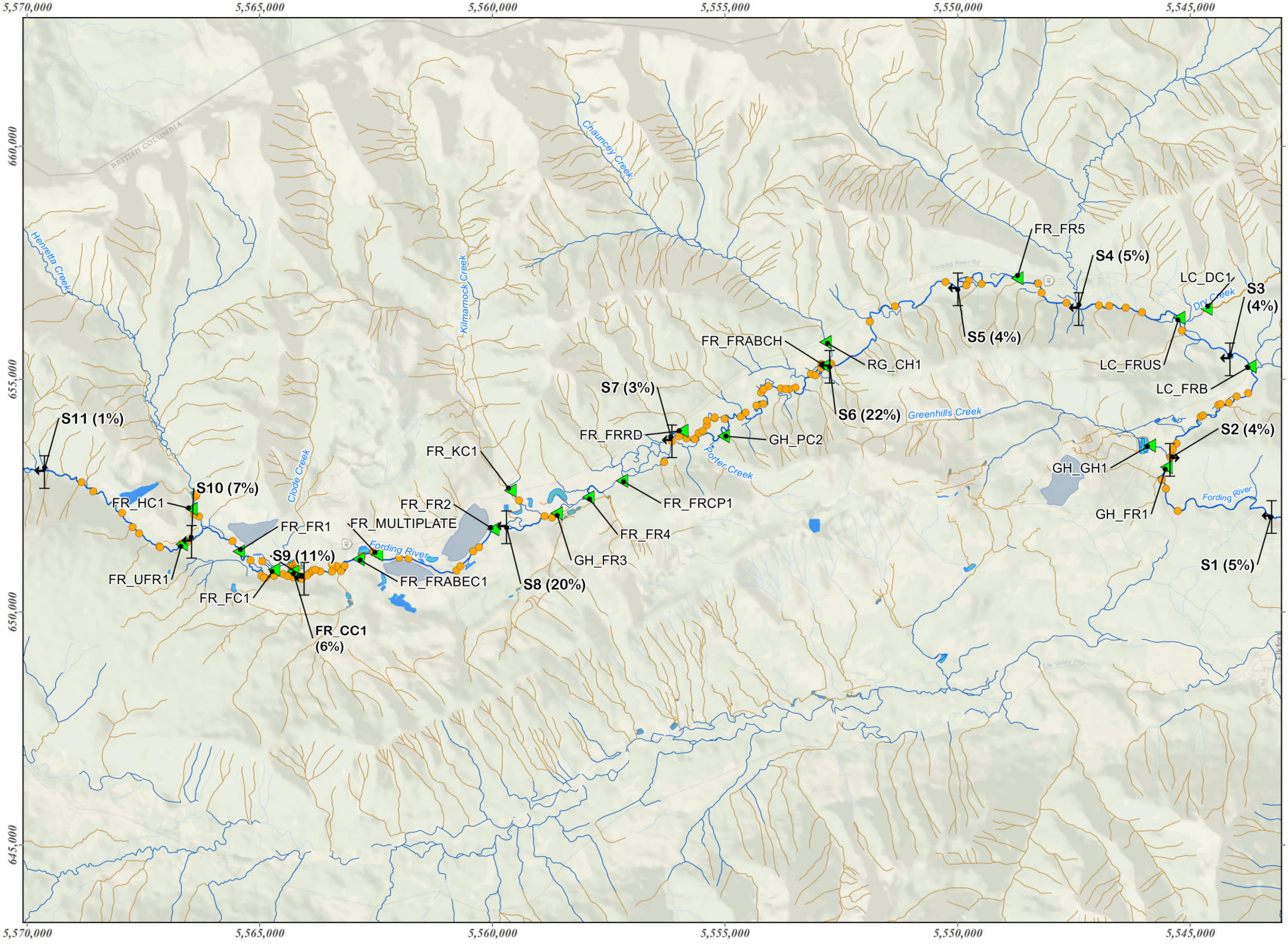


N

0 0.250.5 1 1.5 Kilometers

DATE:	MINE OPERATION:
9/28/2020	FRO / GHO
SCALE:	COORDINATE SYSTEM:
1:75,000	NAD 1983 UTM Zone 11N

Relative Percent Use: Spawning (Radio Tagged)

▲ Monitoring Location

⊢ Section Breaks

● Spawning Location

Water Network

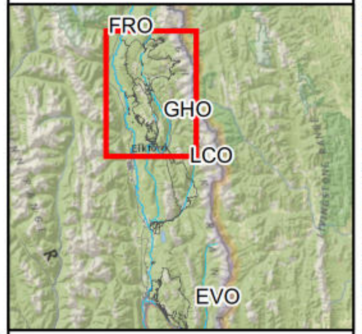
— Non-Fish Bearing

— Fish Bearing

End Pit Lake

Settling Pond

Tailings Pond



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Appendix C References

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Zhou, S. (2002.) Size-Dependent Recovery of Chinook Salmon in Carcass Surveys, *Transactions of the American Fisheries Society, 131*, 6, 1194–1202, DOI: 10.1577/1548-8659(2002)131<1194:SDROCS>2.0.CO;2

Appendix D: Synthesis of Information in Subject Matter Expert Reports Related to Winter Dissolved Oxygen in the UFR

To support the Evaluation of Cause (EoC; Evaluation of Cause Team, 2021) for the upper Fording River Westslope Cutthroat Trout (WCT) population decline, this appendix:

1. Synthesizes information about dissolved oxygen detailed in various Subject Matter Expert (SME) reports (see Table D-1), and
2. Provides additional related analyses.

This synthesis of the potential effects of low dissolved oxygen focuses on the WCT decline window (September 2017 to September 2019) and further narrowed it to November 2018 to March 2019 (determined as the most likely period of the fish decline; Evaluation of Cause Team, 2021).

1 Background

Overwinter survival of WCT depends on interrelated factors such as food availability, body energy reserves, habitat conditions and predation. For example, seasonal low flow and ice conditions may confine fish to limited habitat areas (Brown et al., 2011) and increase competition for space, oxygen and food (Huusko et al., 2007). When environmental factors change, fish can move to find more suitable conditions; however, a diversity of connected habitat types is required for fish to relocate to find optimal environments. During the Evaluation of Cause, SME work (Harwood et al., 2021) identified that habitat connectivity/fish passage may have been restricted, possibly concentrating fish in suboptimal overwintering areas. Moreover, in certain suboptimal conditions, the oxygen concentrations experienced by fish may be less than expected relative to ideal conditions. For example, constituents such as nitrite can change hemoglobin to methemoglobin, which is unable to carry oxygen, and exacerbate hypoxia (reviewed in Bollinger, 2021a). This appendix evaluates the possibility that low dissolved oxygen conditions occurred during winter 2018/2019, and/or that fish experienced hypoxia for other reasons.

Although less well documented than in lentic water bodies, low dissolved oxygen conditions can occur in rivers where water flow is reduced or absent (i.e., depositional sites such as pools and oxbows), and water volume is constricted by ice. Low winter flows are common in BC Interior streams and some experience periods of ice cover that restrict aeration. Cold temperatures reduce the metabolic rate of poikilothermic animals such as WCT (whose internal body temperatures tend to fluctuate with the environment), which slows their oxygen demand. If animal densities are high and there is sufficient decomposition of macrophytes, periphyton, cyanobacteria and other aquatic organisms, oxygen levels can decline to levels where fish become stressed (Barica & Mathias, 1979). In low oxygen situations, fish must rely on anaerobic metabolism, which can cause them to die through acidosis or by depleting their glycogen stores (reviewed in Bollinger, 2021a).

2 Dissolved Oxygen in the Evaluation of Cause

Because of dissolved oxygen's importance and connection to multiple impact hypotheses, it was pertinent to numerous lines of inquiry for the EoC many SMEs pursued (Table D-1). Information presented here was drawn from the following six SME reports and combined with relevant literature to support the Evaluation of Cause report (Chapter 8). In addition, we reanalyzed field meter dissolved oxygen data and conducted a hypothetical evaluation of sediment oxygen demand (SOD) at Segment S6 overwintering reach.

Table D-1. SME reports used to support this appendix.

Report Citation	Major Section(s)*
Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water Quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Golder Associates Ltd.	Releases of Mine-Influenced Water: 2.3 Fish Accessible Water: 3.3.2.7
Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological Stressors. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report Prepared for Teck Coal Ltd. by SNC-Lavalin Inc.	3.5.6 & 4.5.1
Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.	3.1.3
Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, Periphyton and Aquatic Macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Larratt Aquatic Consulting Ltd.	Algae blooms and DO 2.2.4, UFR oxygen demands 2.3.4 and organic decomposition oxygen demands 2.4.4
Bollinger, T. (2021a). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd.	"Hypoxia"
Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Minnow Environmental Inc.	3.5.4
Evaluation of Cause Team. (2021). *Evaluation of Cause — Decline in upper Fording River Westslope Cutthroat Trout*	Chapter 8

Report Citation	Major Section(s)*
population. Report prepared for Teck Coal Ltd. by Evaluation of Cause Team.	

3 Key Learnings

Screening of Empirical Dissolved Oxygen Data

Costa and de Bruyn (2021) screened surface water quality data to evaluate the potential for acute and chronic effects in surface water that was 1) mine-influenced (i.e., at the point of release, prior to mixing into surface waters) and 2) fish-accessible (i.e., after the mine-influenced releases enter surface waters), considering season and the overlap, spatially and temporally, with fish use. Dissolved oxygen concentrations were evaluated and their findings are summarized here:

- Potential acute effects of low dissolved oxygen were identified for one sample from Turn Creek (November 2018), one sample from Fording River station FR_FRCP1 (December 2018), and three samples from Fording River station RG_UFR1 upstream of mining (February 2019). Potential acute effects of dissolved oxygen in these five samples met the requisite conditions to contribute to the WCT decline via effects to juveniles and adults (but not early life stages which are present from mid-May to late August), but not to be the sole cause.
- For buried embryos/alevins, the majority of assessed habitat in the decline window indicated no chronic effects of dissolved oxygen in spring (95% to 99%) and summer-fall (62% to 84%), with most or all of the remaining habitat indicating a potential for low-level effect from dissolved oxygen on early life stages. Early life stages of WCT are not present in winter. Potential low-level effects of dissolved oxygen overlapped with WCT redds (buried embryos/alevins) in mainstem segments S9 (summer-fall), S8 (summer-fall), S7 (summer-fall), S6 (spring and summer-fall), as well as Henretta Creek downstream (summer-fall), Fish Pond Creek (summer-fall), Clode Creek (spring and summer-fall) and Greenhills Creek (spring and summer-fall). For early life stages (redds), these areas represent approximately 77% of fish use in spring. Costa and de Bruyn (2021) concluded that dissolved oxygen met the requisite conditions to contribute to the WCT decline via potential chronic effects on early life stages of WCT; however, the majority of assessed habitat indicated a negligible potential for effects, or a potential for low-level

effects on early life stages. Dissolved oxygen did not meet the requisite conditions for being the sole cause of the WCT decline.

- For adult and juvenile WCT, dissolved oxygen could have contributed to effects at one mainstem station (FR_FRCP1 sample collected in December 2018). However, this location has elevated uncertainty regarding the available overwintering habitat and accounted for a small portion of the assessed habitat (≤4%). At other locations, dissolved oxygen would not be expected to affect adults or juveniles because assessed habitat indicated no chronic effects. Costa and de Bruyn (2021) concluded that dissolved oxygen could have contributed to effects at one mainstem station in winter 2018. Dissolved oxygen did not meet the requisite conditions for being the sole cause of the WCT decline.

Summary of Overwintering Dissolved Oxygen Conditions at UFR Sites

The UFR has predominantly lotic environments with lentic habitats restricted to only 7% of its area (8.4 ha). Like many rivers in this region, winter flows are typically low. Key overwintering areas on the UFR behave differently in winter (see Evaluation of Cause Team, 2021, Chapter 3 for more information on overwintering areas). The most important WCT overwintering areas include Henretta Lake, Segments S8 and S6 (Figure D-4). The large size, depth to volume ratio and inflows of Henretta Lake restrict its winterkill potential, despite annual winter-long ice cover. Within Segment S8 (FR_Multiplate, FR_FR2, FR_FR4), available data do not indicate a likely DO depletion scenario during the decline window, but monitoring was sparse with only FR_FR2 having results within the decline window. These results showed some DO depletion down to 62% (8.68 mg/L) on March 11 2019, but this reading is within the tolerance of adult WCT. Winterkill is also unlikely in the upper half of Segment S6 overwintering area due to a large inflow of oxygen-bearing groundwater from unconfined aquifers that provide groundwater to the UFR along its length (Henry & Humphries, 2021). In lower Segment S6, groundwater influxes are smaller and the substrates include more fines than upper Segment S6. Oxygen demand from decomposition during winters with long-term ice cover, coupled with anchor ice and deep frost penetration that could act together to restrict oxygenated hyporheic inflow, may reduce dissolved oxygen concentrations to the point that could stress WCT in lower Segment S6 depositional pools under dark conditions. However, the scale of this effect in winter 2018/2019 is unknown. To explore this possibility, lines of evidence regarding an oxygen deficit at lower Segment S6 were drawn from SME reports and presented in Table D-2.

Table D-2. Lines of evidence for dissolved oxygen depletion at lower Segment S6.

Line of Evidence	Key Assumptions
Flows	Stable low flows through the 2018 growing season that favour periphyton and macrophyte growth were followed by a fall with stable seasonal low flows. Together, these permitted decomposition of accumulated periphyton and aquatic macrophytes biomass (biological oxygen demand; BOD), during winter 2018/2019 (seasonal winter low flows of 0.36 m^3/s discharge; see Hatfield & Whelan, 2021; Larratt & Self, 2021 for details.)
Ice formation	As detailed in Hatfield and Whelan (2021), the very cold weather in February and early March 2019 combined with seasonal winter low flows induced significant ice formation. Surface ice (observed throughout Segment S6) prevents the movement of atmospheric oxygen into the water and decreases photosynthesis, while anchor ice and deep frost can locally restrict hyporheic oxygen delivery (may have occurred in the S6 region or immediately upstream of it). Frazil ice likely occurred in the UFR between early February and mid-March 2019 (refer to Hatfield and Whelan, 2021, for more detail). Frazil ice can occupy a large portion of the water column, blanket the substrate, contribute to ice dams that deflect flows, and it can stress fish by forcing adults and juveniles to move to another location (see Bollinger, 2021a, for more on the effects of frazil ice on fish).
Retention time	The calculated theoretical instream water residence time in Segment S6 is a relatively slow ~9 hours per kilometre due to the seasonal winter low flows. Water will travel faster than this mid-channel and be delayed in more stagnant meanders/perimeters and in macrophyte beds along Segment S6, providing more opportunity for oxygen to become depleted in the slowest flowing habitats, especially at night (see Larratt and Self, 2021, for details).
Groundwater dissolved oxygen	Interrupted shallow groundwater inflow may have contributed to very low surface flows through Segment S6 in early March 2019. This shallow groundwater normally delivers oxygenated water to Segment S6. If a deepening frost line occurred, it could have temporarily interrupted groundwater influx to the hyporheic zone in the lower half of Segment S6. Interrupted groundwater is not anticipated to occur in the upper half of the Segment S6 region, due to significant upwelling of relatively warm groundwater there. (See Henry and Humphries, 2021 for details.)
Dissolved oxygen screening	During the cold period from February to early March 2019, daytime dissolved oxygen concentrations in Segment S6 were above the long-term BC water quality guidelines (WQG) of 8 mg/L, except at FR_FRABCH on 12 March 2019 (dissolved oxygen = 7.14 mg/L) and RG_FO22 on 14 February 2019 (dissolved oxygen = 7.13 mg/L).

Line of Evidence	Key Assumptions
	FR_FRABCH rolling 30-day period[1] dissolved oxygen (average of 9.2 mg/L) was above the long-term BC WQG and all dissolved oxygen measurements were above the level 1 screening value of 6 mg/L[2]. At FR_FRABCH, dissolved oxygen concentrations were within the range observed prior to the decline window (5.97 to 12.4 mg/L) (Refer to Costa and de Bruyn, 2021, for dissolved oxygen screening details.)
Periphyton and macrophytes	More stable mainstem UFR flows since 2013 would allow the observed macrophyte bed expansion at Segment S6. Many years have a fall flush (~2-5 m^3/s at FRNTP) but 2018 did not, and growing season low flows persisted into the 2018/2019 winter low flow period. It is therefore possible that BOD from the decomposition of the summer 2018 macrophyte and periphyton crop was greater than normal during the exceptionally cold February 2019, and that it instigated the observed anomalously low dissolved oxygen of ~55% of saturation (~7 mg/L) at FR_FRABCH (Figure D-2). Based on 2020 light logger data, this daytime DO meter data would drop by approximately 1 mg/L at night (~6 mg/L). A ~50% reduction in light penetration occurs under ice cover relative to open water; thus, at Segment S6, lower photosynthesis (lower oxygenation) by macrophytes is expected during this period. (Refer to Larratt and Self, 2021, for additional information.)
Sediment oxygen demand	Suspended sediment has been observed to settle out in UFR depositional areas. In lower Segment S6 pools, fine sediments are >50 cm thick and may have accumulated since the last major flood in 2013, encouraged by macrophyte drag. This bedded sediment is expected to exert gradually increasing oxygen demand. Winter SOD in northern rivers ranges from 0.1-4.0 $g/m^2/day$ with the 0.3-2 $g/m^2/day$ range reported frequently. (Refer to Larratt and Self, 2021 for additional information.)
Oxygen-sensitive parameters	Indirect evidence for the scale of SOD at Segment S6 is provided by measured declines in dissolved oxygen, oxidation reduction potential, pH and increased decomposition products (ammonia, dissolved organic carbon, methyl-mercury). Redox levels fluctuated seasonally between 0 and 300mV at FRABCH, whereas the UFR mainstem averaged 200–550 mV. Fall/winter 2019 had lower pH, higher ammonia (atypical ammonia spike to 0.1 – 0.3 mg/L in and around S6) and higher dissolved organic carbon, indicating organic decomposition. Detectable

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[1] An average period approach is consistent with BC ENV (2019) for long-term BC WQGs. BC ENV (2019) states that this approach "allows concentrations of a substance to fluctuate above and below the guideline provided that the short-term acute is never exceeded and the long-term chronic is met over the specified averaging period (e.g., 5 samples in 30 days)".

[2] rationale is provided in Appendix E of Costa and de Bruyn (2021).

Line of Evidence	Key Assumptions
	methyl-mercury at FRABCH (met all guidelines) indicated anoxic sulphur reducing bacteria activity. These parameters align with elevated SOD from the fine sediments at FRABCH in the decline window. (Refer to Larratt and Self, 2021 for background information.)
Physiological dissolved oxygen tolerances of WCT	Hypoxia tolerance of trout tends to converge at ~3 mg/L. Four cutthroat trout stocks tested in flow-through tanks at 13 and 18°C with fish, which were allowed access to the water surface to gulp air, found that the 24-hour LEC_{50} was 2.34 mg O_2/L (27% dissolved oxygen) for all stocks combined (Wagner et al., 2001). (LEC_{50} – lower limit of dissolved oxygen causing loss of equilibrium). Refer to Bollinger (2021a) for additional information on WCT tolerance to dissolved oxygen.

Reanalysis of Dissolved Oxygen Data

Reanalysis of the dissolved oxygen data in Larratt and Self (2021) involved descriptive statistics and trend analysis and is presented below. Additionally, a hypothetical winter SOD scenario was developed to determine if oxygen depletion at Segment S6 was theoretically possible under low winter flow conditions, in answer to questions about dissolved oxygen winter stress to WCT.

A simple time series plot of field meter dissolved oxygen readings showed a dissolved oxygen sag in winter 2019 at FRABCH and adjacent sites (Figure D-1). This sag did not reach critical dissolved oxygen levels for WCT and confirms the findings of the empirical dissolved oxygen measurements screened by Costa and de Bruyn (2021). A declining dissolved oxygen trend at Segment S6 over the two-year (2018 and 2019) decline window at Segment S6 was detected (Mann-Kendall dissolved oxygen % p=0.003; dissolved oxygen mg/L p=0.018). However, between 2013 and 2019 no trend in dissolved oxygen was detected, which suggests that the observed dissolved oxygen sag in winter 2019 was not associated with any long-term trends (Figure D-2).

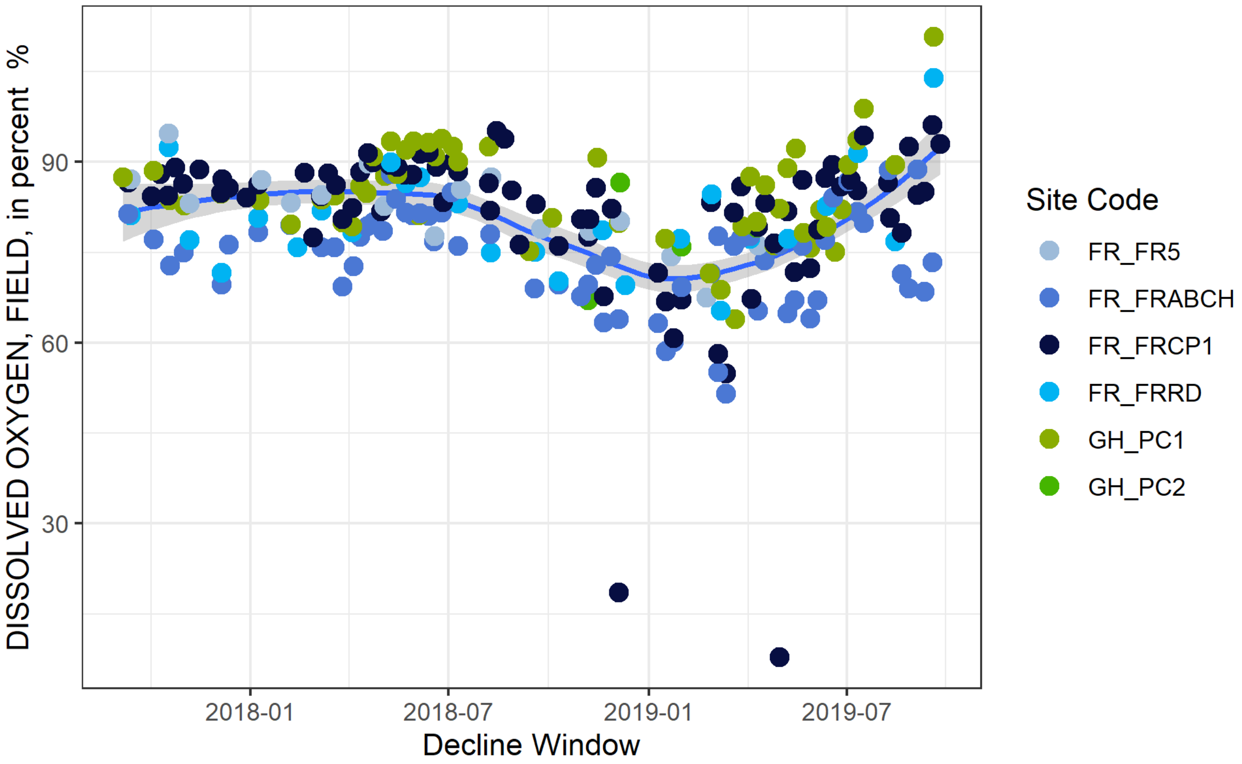

Figure D-1. Dissolved oxygen measurements at sites within or adjacent to Segment S6 within UFR mainstem during the decline window (Loess trend line).

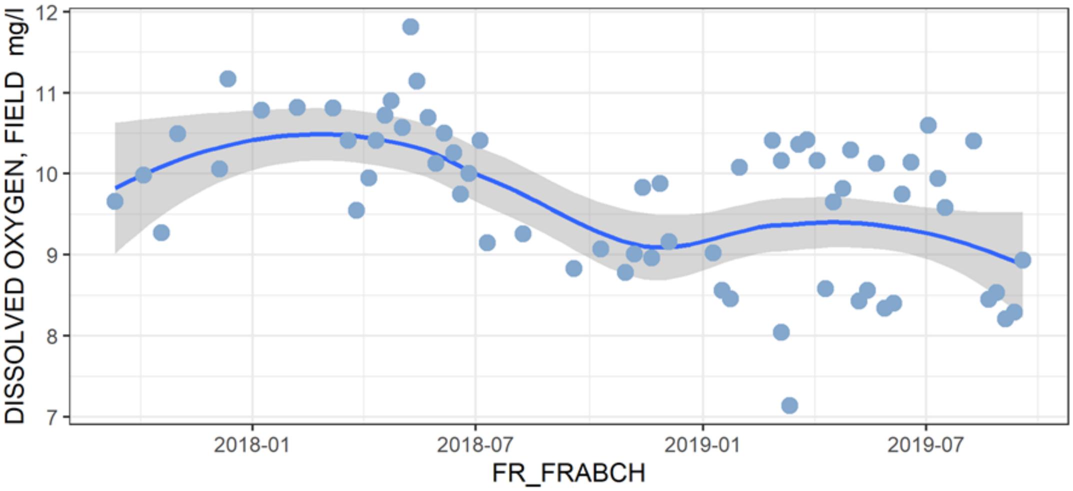

Figure D-2a.

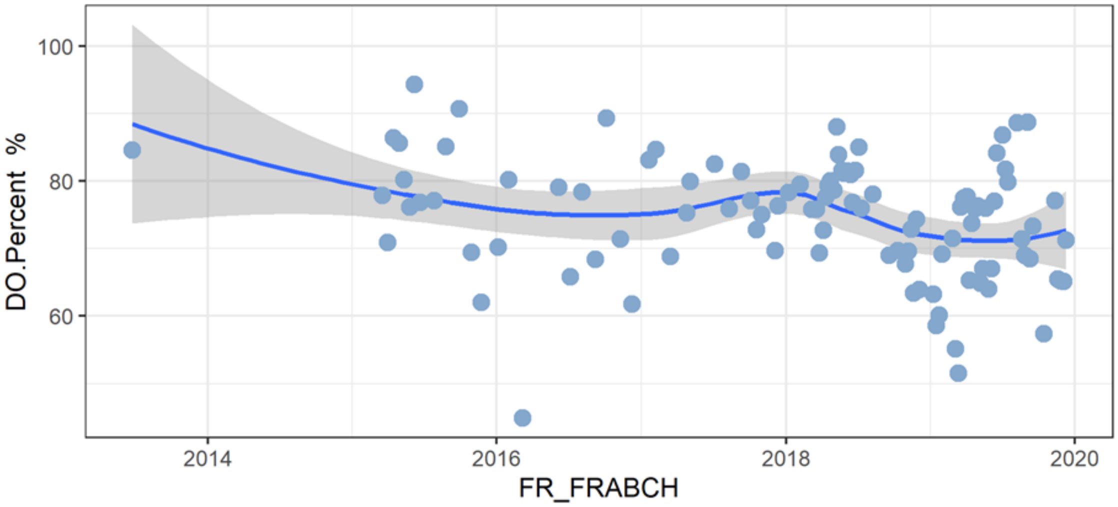

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Figure D-2b

Figure D-2. UFR field meter measurements of dissolved oxygen (DO) at FRABCH.

At FRABCH (located in Segment S6) between 2018 and 2019, there was a declining dissolved oxygen trend (in mg/L), (b) but from 2013 to 2019 there was no detectable trend (in % DO; Loess trend line). See text.

Sediment Oxygen Demand Scenario

Based on the above information, SMEs worked together to explore a scenario that could explain impacts to amount of dissolved oxygen present. The composite of some or all of the winter conditions depicted in Figure D-3 (possible interruption of suboxic subsurface drainage by deep frost + biological oxygen demand from decomposition of large periphyton crop + typical winter sediment oxygen demand + chemical oxygen demand from ammonia degradation + lengthy surface ice cover + frazil and anchor ice impacts in winter 2019) may have progressed to the point that reduced the amount of dissolved oxygen to below the tolerance of overwintering WCT in low flow segments of lower Segment S6 during February through early March 2019.

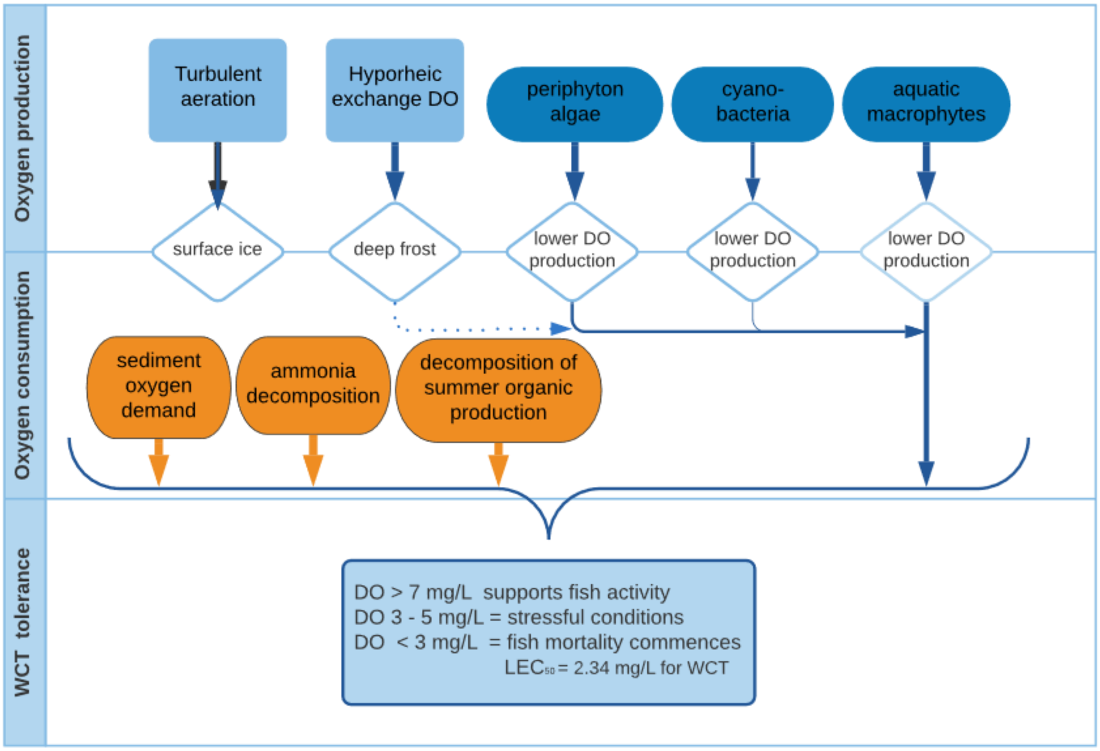

Figure D-3. Theoretical winter dissolved oxygen production and consumption in UFR.

NOTE: Arrow thickness depicts the approximate scale of the relative contribution. DO = dissolved oxygen.

If all dissolved oxygen sources to lower Segment S6 were cut off by ice and/or deep frost, a simplistic calculation of SOD alone can be performed to determine how long it would take for the Segment S6 water to become fully depleted of oxygen. This calculation (see insert) was approached in two ways. The first approach assumed near-zero flow or stagnant conditions. The second approach assumed that water continued to flow at the winter flow rate of 0.36 m^3/sec. Under stagnant conditions, full dissolved oxygen depletion of the Segment S6 volume would take between 30 days and as little as 2 days. Under continuous flow, depletion was calculated as a rate per kilometre of river. In this case, it was calculated that it would take between 80 km under minimum depletion rates (i.e., water oxygen would remain above 8 mg/L[3] throughout

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[3] For this calculation it was assumed that inflowing water would contain 10 mg/L of dissolved oxygen

Segment S6) to only 4.8 km under a maximum depletion rate; that is, water within Segment S6 could become depleted of oxygen under a high SOD scenario. Working backwards from the length of the Segment S6 reach (~10 km), a depletion rate of 2.4 g/m^2/day would be required to progressively deplete the dissolved oxygen to 0 mg/L while passing through Segment S6 with complete surface ice; this depletion rate is in the middle of the expected range of SOD for this region (0.3 – 4 g/m^2/day). Theoretical progressive dissolved oxygen depletion is illustrated in Figure D-4. These calculations were made to explore the possibility of a dissolved oxygen deficit at lower Segment S6 during the unusually cold six weeks in winter 2019.

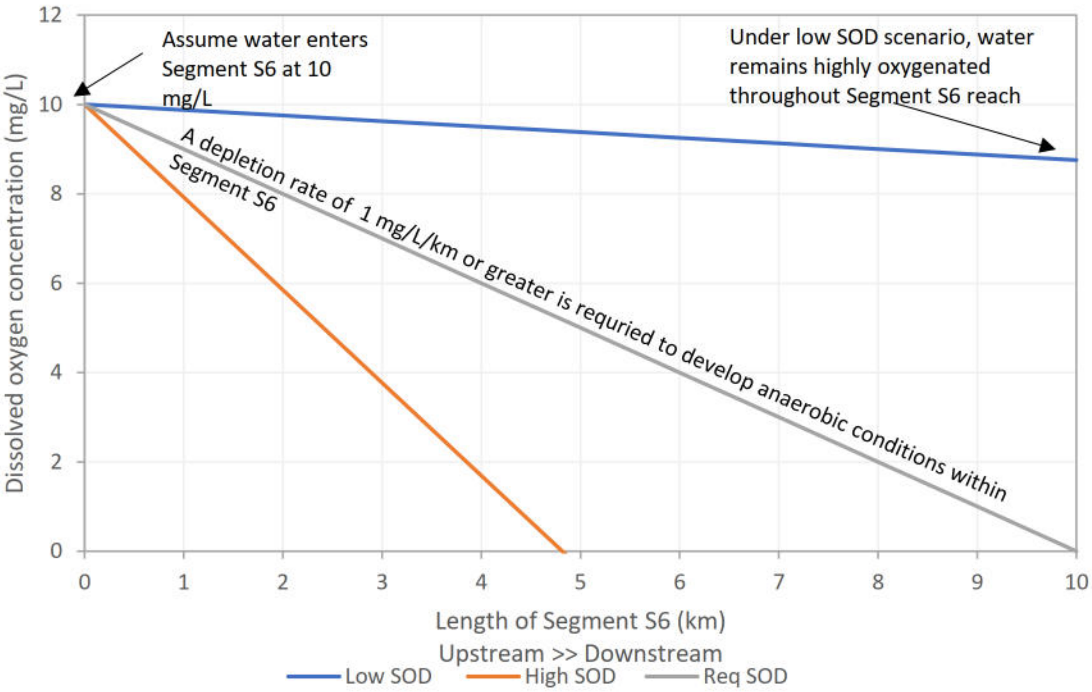


Figure D-4. Theoretical dissolved oxygen within Segment S6 reach under ice cover with range of sediment oxygen demand (SOD) scenarios.

Summary — Was Winter Dissolved Oxygen Relevant to the WCT Decline?

This appendix explores the possibility that low dissolved oxygen conditions could have occurred under winter 2018/19 conditions in lower Segment S6, contributing to the decline in UFR WCT. The following conclusions are reached:

1. The measured dissolved oxygen sag in winter 2018/19 was part of a declining trend in dissolved oxygen unique to the decline window within Segment S6. However, the detected sag in weekly to monthly daytime dissolved oxygen measurements did not reach critical thresholds for WCT survival.
2. Theoretically, sediment oxygen demand could be responsible for localized dissolved oxygen consumption to adverse concentrations (<3 mg/L) when prolonged, very cold winter conditions and seasonally low flows lead to extensive ice formations and deep frost at UFR Segment S6 overwintering site. This hypothesis remains unconfirmed by empirical data.
3. After evaluating several lines of evidence (Table D-2), the possibility that dissolved oxygen concentrations were reduced to levels considered stressful (< 3 – 6 mg/L) to overwintering WCT could not be ruled out, but if this occurred, it would be localized and transient.

Dissolved Oxygen Depletion Calculations:

Static Flow Scenario:

Per km of lower Segment S6:

Discharge: 0.36 m^3/s
Pool Length: 1000 m Pool Width: 12.9 m* Pool Depth: 0.91 m*
Pool volume = 11812 m^3 = 11812000 L

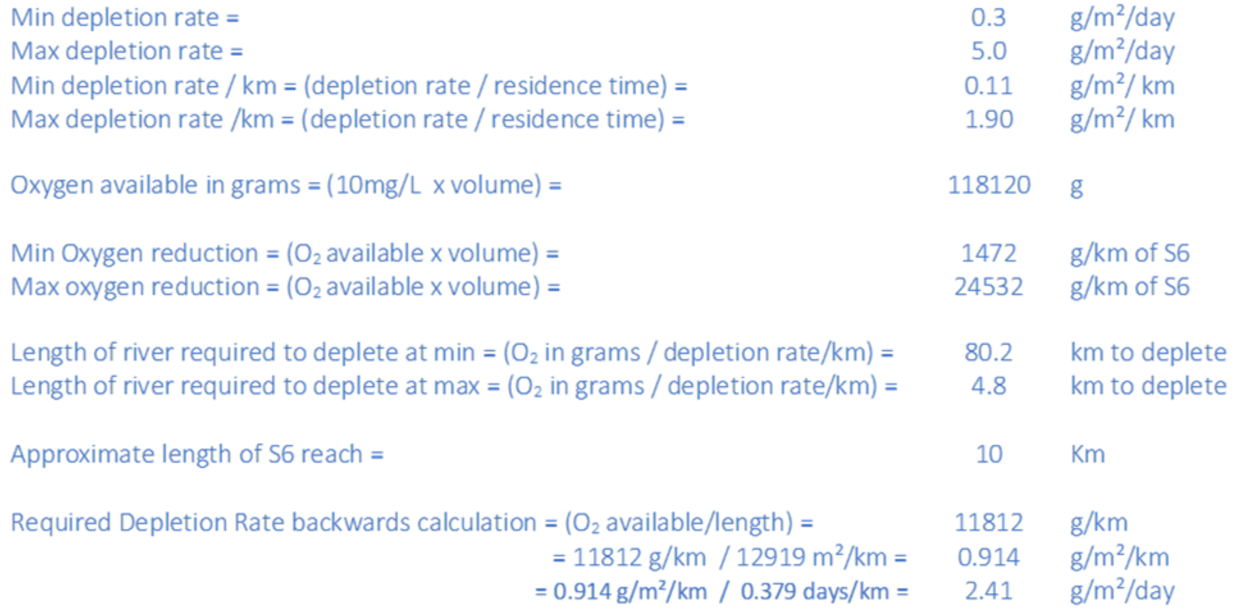
Pool residence time = 547 min* = 9.15 h = 0.38 days
Pool surface area = 12919 m^2 ~sediment surface area
Available dissolved oxygen at 10 mg/L x volume = 118120 g oxygen

Typical winter sediment oxygen demand (SOD) range is 0.3 to 4 g/m2/day
SOD x sediment surface area / available dissolved oxygen = days to 0 mg/L dissolved oxygen
Thus 0.3 g/m2/day x 12919 m^2 / 118120 g dissolved oxygen = 30.5 days

4.0 g/m2/day x 12919 m^2 / 118120 g dissolved oxygen = 2.3 days

* from Ecofish UFR Segment S6 pool residence time calculator (Healey et al., 2020).

Continuous Flow Scenario



Min depletion rate =	0.3	g/m²/day
Max depletion rate =	5.0	g/m²/day
Min depletion rate / km = (depletion rate / residence time) =	0.11	g/m²/ km
Max depletion rate /km = (depletion rate / residence time) =	1.90	g/m²/ km
Oxygen available in grams = (10mg/L x volume) =	118120	g
Min Oxygen reduction = (O_2 available x volume) =	1472	g/km of S6
Max oxygen reduction = (O_2 available x volume) =	24532	g/km of S6
Length of river required to deplete at min = (O_2 in grams / depletion rate/km) =	80.2	km to deplete
Length of river required to deplete at max = (O_2 in grams / depletion rate/km) =	4.8	km to deplete
Approximate length of S6 reach =	10	Km
Required Depletion Rate backwards calculation = (O_2 available/length) =	11812	g/km
= 11812 g/km / 12919 m²/km =	0.914	g/m²/km
= 0.914 g/m²/km / 0.379 days/km =	2.41	g/m²/day

Appendix D References

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