Elk River Watershed Group Fish Passage Restoration Planning 2022

Prepared for
Nupqu Resource Limited Partnership

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New Graph Environment Ltd.

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new graph environment
Research & Consulting

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Acknowledgement

Modern civilization has a long journey ahead to acknowledge and address the historic and ongoing impacts of colonialism that have resulted in harm to the cultures and livelihoods living interconnected with our ecosystems for many thousands of years.

```
knitr::opts_chunk$set(echo=identical(gitbook_on, TRUE), message=FALSE,
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# knitr::knit_hooks$set(webgl = hook_webgl)
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options(knitr.kable.NA = '--') #'--'
options(knitr.kable.NAN = '--')
```

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source('scripts/packages.R')
source('scripts/functions.R')
source('scripts/tables.R')
```

```
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```

```
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```

1 Introduction

Since 2020, the Canadian Wildlife Federation (CWF) has been working on a watershed connectivity remediation plan for the Elk River watershed that incorporates the provincial Strategic Approach protocol (Fish Passage Assessment, Habitat Confirmation, Design and Remediation), evolution of the `bcfishpass` analysis tools (Norris [2020] 2023) and local knowledge of the watershed to prioritize barriers and restore connectivity for westslope cutthroat trout and other species in a strategic manner. Nupqu Resource Limited Partnership (Nupqu) was retained by the CWF in the summer of 2022 to conduct fish habitat, fish sampling assessments, temperature monitoring and discharge monitoring at sites related to road-stream crossings within the Elk River watershed group as part of this connectivity restoration planning. Subject streams included Brule Creek and Weigert Creek. New Graph Environment Ltd. was sub-contracted by Nupqu to assist with project delivery.

Assessments conducted in 2022 complement work completed in 2020 (72 fish passage assessments and 15 habitat confirmation assessments) and 2021 (92 fish passage assessments and 15 habitat confirmation assessments) which can be viewed interactively online at https://newgraphenvironment.github.io/fish_passage_elk_2020_reporting_cwf/ (Irvine 2021) and https://newgraphenvironment.github.io/fish_passage_elk_2021_reporting/ (Irvine 2022).

The health and viability of freshwater fish populations can depend on access to tributary and off channel areas which provide refuge during high flows, opportunities for foraging, overwintering habitat, spawning habitat and summer rearing habitat (Bramblett et al. 2002; Swales and Levings 1989; Diebel et al. 2015). Culverts can present barriers to fish migration due to low water depth, increased water velocity, turbulence, a vertical drop at the culvert outlet and/or maintenance issues (Slaney, Zaldokas, and Watershed Restoration Program (B.C.) 1997; Cote et al. 2005).

As the costs and effort required for works to remediate fish passage issues through the replacement of road/stream crossings can be significant, acquisition of detailed habitat, fish sampling, water temperature and discharge data is a prudent measure to help ensure there is a reasonable understanding of current conditions, including species composition/density upstream and downstream of the crossings as well as the value and suitability of associated habitats for target fish species (westslope cutthrout trout) before investments in infrastructure to improve connectivity are made. This work helps build our understanding of the extent of the issues present that may be a result of subject culverts as well as providing baseline data for assessing the benefits of remedial work post-fish passage remediation.

2 Background

Study areas for 2022 field work included Brule Creek and Weigert Creek. Although portions of the Elk River watershed group flow into the Flathead River, streams included in 2022 fieldwork were within the portion of the Elk River watershed group that flows into the Elk River (Figure 2.1). The Elk River has a mean annual discharge of 26 m^3/s at station 08NK016 near Sparwood and 47.3 m^3/s at station 08NK016 near Fernie with flow patterns typical of high elevation watersheds on the west side of the Rocky Mountains which receive large amounts of precipitation as snow leading to peak levels of discharge during snowmelt, typically from May to July (Figures 2.2 - 2.4) (Environment and Canada 2020).

```
knitr::include_graphics("fig/Overview_ELKR.png")
```

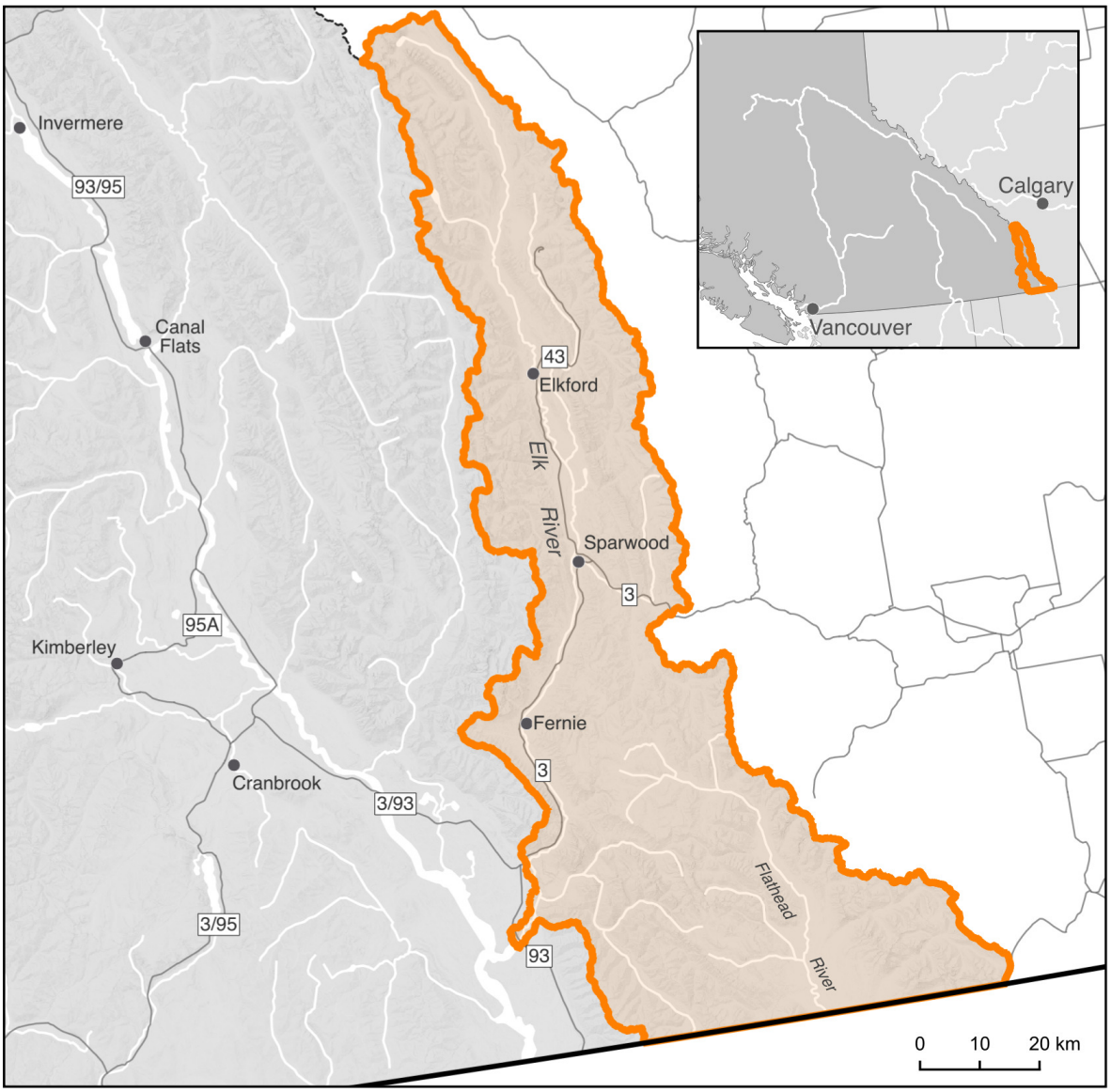

Figure 2.1: Overview map of Study Area

```
knitr::include_graphics("fig/hydrograph_08NK016.png")
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics("fig/hydrograph_08NK002.png")
```

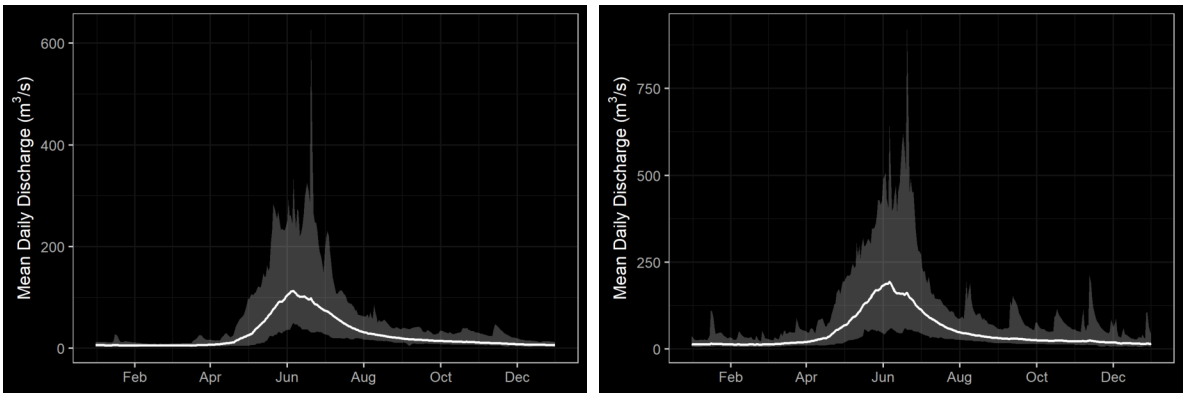

Figure 2.2: Hydrograph for Elk River near Sparwood (Station #08NK016) and near Fernie (Station #08NK002).

```
knitr::include_graphics("fig/hydrology_stats_08NK016b.png")
```

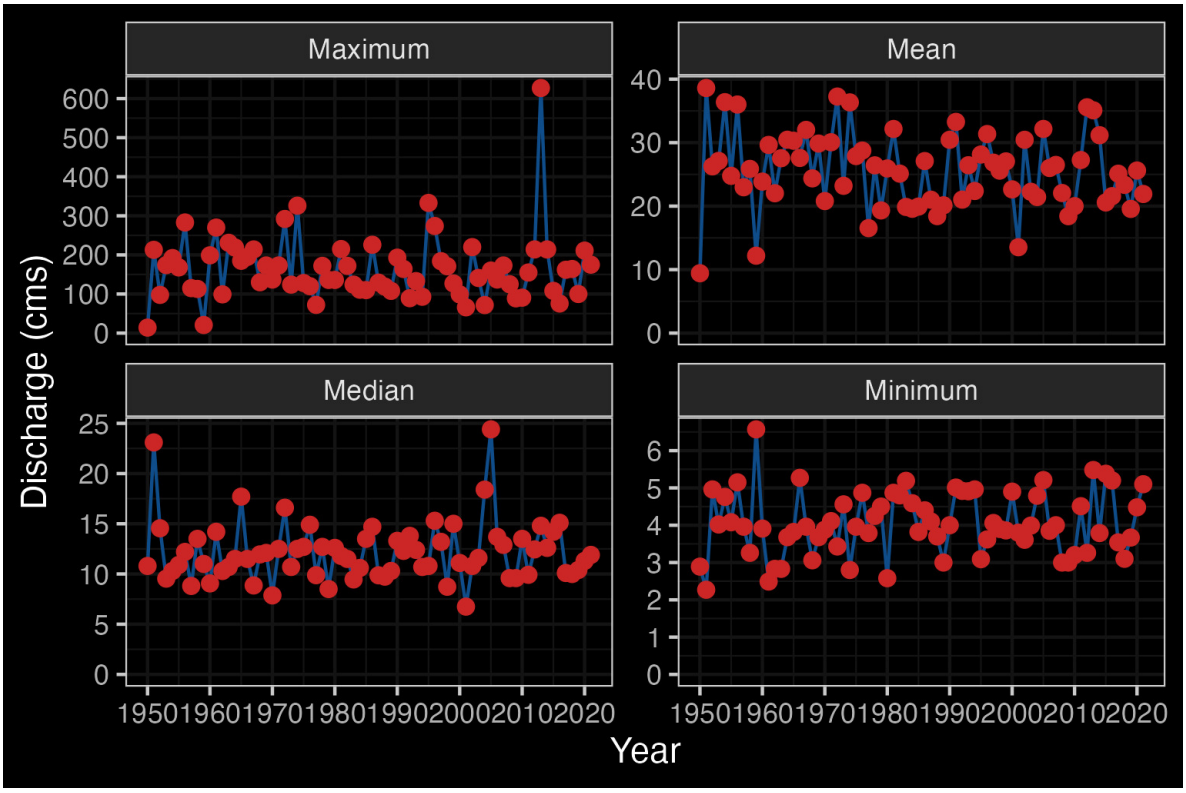

Figure 2.3: Elk River Near Sparwood (Station #08NK016 - Lat 49.86562 Lon -114.86868). Available daily discharge data from 1950 to 2020.

```
knitr::include_graphics("fig/hydrology_stats_08NK0022.png")
```

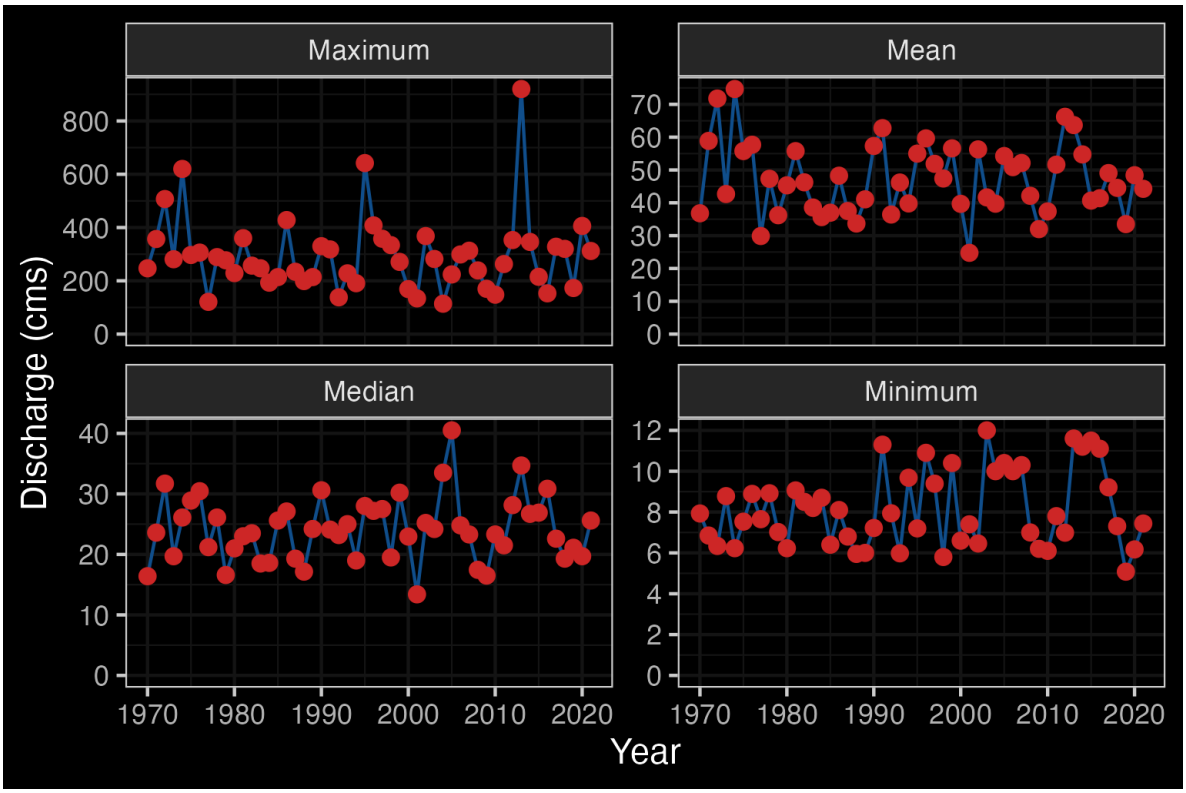

Figure 2.4: Elk River At Fernie (Station #08NK002 - Lat 49.50347 Lon -115.07013). Available daily discharge data from 1970 to 2020.

2.0.1 Ktunaxa Nation

The project location is within the traditional territory of the Ktunaxa Nation ("Ktunaxa Nation" 2020) with Elk River components within an area known as Qukin ?amak?is, or Raven's Land (Ministry of Forests 2020). When Europeans settled in the Kootenay Region around 200 hundred years ago, the Indian Reserves were created which lead to the seven Indian Bands:

- ?akisq̓nuk- Columbia Lake Band (Windermere, BC);
- ?aq̓am- St. Mary's Band (Cranbrook, BC);
- ?akink̓um‡asnuq‡i?it- Tobacco Plains Band (Grasmere, BC);
- yaqan nu?kiy- Lower Kootenay Band (Creston, BC);
- kyaknuq‡i?it- Shuswap Band (Invermere, BC);
- ?aq̓anqmi- Kootenai Tribe of Idaho (Bonners Ferry, Idaho);
- k̓upawiȼq̓nuk- Ksanka Band (Elmo, Montana)

“Ktunaxa Nation” (2020) report the vision statement of the Ktunaxa as:

“K¢maḵqa ksukɬuɬa·k kuḵqani ¢ ḵitqakiɬ haqa ksi?ɬ ¢xa ?a·kɬukqa?is ksukiɬq̓uka?mi·k ki?in Ktunaxa na?s ?amaḵ?is. Qus piḵaks¢ na?s ¢xaɬ yaqanakiɬ haqa?ki. Ḵitqawi¢mu kakiɬwi¢kiɬ ?amak?is ḵisnik¢ik k¢xaɬ qa kiɬkḵaxuxami·k ḵitqakiɬ haqa ¢ ḵis?in ?aknumu¢tiɬ?is.”

The vision statement has been translated to english as:

“Strong, healthy citizens and communities, speaking our languages and celebrating who we are and our history in our ancestral homelands, working together, managing our lands and resources, within a self-sufficient, self-governing Nation.”

2.0.2 Elk Valley Cumulative Effects Management Framework

```
# Coal deposits are located in the Elk River and Flathead coalfields
        which extend fromthe Canada-USA border to the northwest for
        175km along the Rocky Mountains with cumulative coal
        thickness ranging up to 70m. Subsurface resource exploration
        and develpment is prohibited in the Flathead River watershed
        due to legislation enacted in 2011.  At the time of reporting
        there were four active coal mines in the Elk River watershed
        (Fording River, Greenhills, Line Creek and Elkview), one
        closed mine (Coal Mountain) as well as multiple exploration
        projects and proposed new mines
        [@ministryofenergy2020EastKootenay].
```

First Nations, stakeholders, proponents and provincial and municipal governments have recognized that the region has been impacted by historic and current coal operations as well as other stresses such as forestry operations, wildfire, residential development, recreational activities and transportation. To assess the historic, current and potential future conditions of valued ecosystem components and to support resource management decisions within the region, the Provincial Cumulative Effects Framework and the Elk Valley Cumulative Effects Management Framework (EV-CEMF) have been formed under joint management between the Ktunaxa Nation Council and the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD). A working group consisting of the Ktunaxa Nation Council, industry, community, organizations, and provincial government ministries has been formed to provide guidance and oversight for EV-CEMF activities. Valued component technical reports for Grizzly Bear, Riparian and westslope cutthroat trout (Davidson et al. 2018), bighorn sheep, and old and mature forest have been drafted, integrated into an overarching Cumulative Effects Assessment and Management Report (Elk Valley Cumulative Effects Management Framework Working Group 2018) and endorsed by the Working

Group. These reports describe the historical, current, and future assessment of cumulative effects in the Elk Valley and provide management and mitigation recommendations. Next steps for the framework include the development of an Implementation Plan to identify priority actions and spatial locations to focus management and mitigation of cumulative effects in the valley which may include actions to address aquatic habitat connectivity issues (Ministry of Forests 2020).

2.1 Fisheries

Fish species recorded in the upper Elk River watershed group (streams that drain into the Elk River) are detailed in Table 2.1 (MoE 2020a). Bull trout and westslope cutthrout trout are considered of special concern (blue-listed) provincially and westslope cutthrout trout (Pacific populations) are are listed under the *Species at Risk Act* by the Committee on the Status of Endangered Wildlife in Canada as a species of special concern (BC Species & Ecosystem Explorer 2020b, 2020a; Schweigert et al. 2017).

```
fiss_species_table <- readr::read_csv(file = paste0(getwd(),
        '/data/inputs_extracted/02_prep_report/fiss_species_table.csv'))
  # filter(`Species Code` != 'CT') %>%
fiss_species_table %>%
  filter(`Upper Elk` != '--') %>%
  select(-`Upper Elk`, -Flathead) %>%
  # rename(Elk = `Upper Elk`) %>%
  fpr::fpr_kable(caption_text = 'Fish species recorded in the study
        area (FISS 2020).')
```

Table 2.1: Fish species recorded in the study area (FISS 2020).

Scientific Name	Species Name	Species Code	BC List	Provincial FRPA	COSEWIC	SARA
Catostomus catostomus	Longnose Sucker	LSU	Yellow	–	–	–
Catostomus columbianus	Bridgelip Sucker	BSU	Yellow	–	–	–
Catostomus commersonii	White Sucker	WSU	Yellow	–	–	–
Oncorhynchus clarkii	Cutthroat Trout	CT	No Status	–	–	–
Oncorhynchus clarkii lewisi	Westslope Cutthroat Trout	WCT	Blue	Y (Jun 2006)	SC (Nov 2016)	1-SC (Feb 2010)
Oncorhynchus mykiss	Rainbow Trout	RB	Yellow	–	–	–
Oncorhynchus nerka	Kokanee	KO	Yellow	–	–	–
Prosopium williamsoni	Mountain Whitefish	MW	Yellow	–	–	–
Rhinichthys cataractae	Longnose Dace	LNC	Yellow	–	–	–
Richardsonius balteatus	Redside Shiner	RSC	Yellow	–	–	–
Salvelinus confluentus pop. 26	Bull Trout	BT	Blue	–	–	–
Salvelinus fontinalis	Brook Trout	EB	Exotic	–	–	–
–	Cutthroat/Rainbow cross	CRS	–	–	–	–
–	Sucker (General)	SU	–	–	–	–

2.1.1 Westslope Cutthrout Trout

There are multiple life history strategies for westslope cutthrout trout including stream-resident, fluvial and adfluvial. All have habitat requirements during life history stages that include cold clean water and varied forms of cover (undercut banks, pool-riffle habitat and riparian vegetation). Stream-resident fish inhabitat headwater streams above barriers, complete their life cycle within a relatively small range and typically remain relatively small (i.e. <200mm in length). Fluvial fish are migratory subpopulations that migrate between small spawning/rearing tributaries and larger adult rearing rivers. Lengths of fluvial fish generally reach more than 400mm. Finally, adfluvial subpopulations rear in lakes and migrate to spawning/rearing tributaries with lengths often exceeding 500mm (Schweigert et al. 2017).

Spawning habitat for resident and fluvial subpopulations are documented as within the tailouts of deep pools at moderate to high-flow events within small, low-gradient streams with cold well-

oxygenated water and clean unsilted gravels (Schmetterling 2001). Proximity to large woody debris, boulder or bedrock cover is important for spawning fish while residing in spawning tributaries as high mortality may result when suitable cover is lacking. The dominant substrate used for spawning is gravel (1.8 - 3.3cm diameter) with spawning occurring in late May and June towards the end of the spring freshet with rising water temperatures between 7-11°C.

References within Thorley et al. (2022) indicate that emergence of hatchery reared westslope cutthrout trout occurs after the eggs have accumulated 570 to 600 thermal units (Celsius degree days) which is consistent with estimates by Coleman and Fausch (2007b) of 570 to 600 Celsius degree days for Colorado Cutthroat Trout.

Nine of 11 westslope cutthrout trout radio-tagged in the Blackfoot River drainage, Montana by Schmetterling (2001) made movements to tributaries presumable for spawning. While in tributaries, fish movements to spawning sites averaged 12.5km where they stayed within an approximately 100m reach during the spawning period for between 15 and 63 days.

Small perennial streams with a diversity of cover are important for juvenile rearing with young-of-year fish inhabiting low energy lateral habitats (i.e. shallow riffle or backwatered areas) with cover available. Larger juveniles move into pools with social dominance behaviors prevalent and based on fish size. Availability of pool habitat is important and limiting for parr which have large territories (Schweigert et al. 2017; Schmetterling 2001). The suitability of overwintering habitat is determined by groundwater influx and the absence of anchor ice with fluvial adults congregating in slow deep pools in the winter. Boulders and other large in-stream structures or off-channel habitat (beaver bonds and sloughs) provide cover for juveniles with adfluvial fish overwintering in lakes (Schweigert et al. 2017; Brown and Mackay 1995; Cope, Schwarz, and Prince 2017).

Cold water temperatures have been demonstrated to provide recruitment bottlenecks in early life stages of westslope cutthrout trout with temperature days during the growing season above an average of 5°C a key determinant in growth and subsequent fry survival during overwintering (Coleman and Fausch 2007a, 2007b). Ranges of Celsius degree-days during the growing season have been correlated to translocation success governed by recruitment and related to growth and subsequent overwintering survival for greenback cutthroat trout (_Oncorhynchus__clarkii__stomias) and Colorado River cutthroat trout (_O.__c._*pleuriticus*) in north-central Colorado headwater streams. Research detailed in Coleman and Fausch (2007b) indicates that for translocations of greenback cutthroat trout and Colorado River cutthroat trout in north-central Colorado headwater streams - streams that provide 800–900 degree-days *probably* sustain recruitment in some years, and report that streams with less than 800 degree-days are generally unsuitable for translocations because of the smaller sizes attained by fry before the onset of winter and the associated greater risk of recruitment failure.

In a swimming performance study conducted in an open-channel flume Blank et al. (2020) estimated the overall average swim speeds of westlope cutthrout trout (150mm - 290mm in length) at 0.84m/s with a maximum observed swim speed of 3.55m/s.

The greatest threats to westslope cutthrout trout have been identified as hybridization with non-native rainbow trout and degradation of the environment due to forestry, hydroelectric development, mining, urbanization and agriculture (Schweigert et al. 2017). Lamson (2020) sampled over 2000 trout in the Upper Kootenay watershed from 2014 to 2019 with results of genotyping indicating consistently high levels of westslope cutthrout trout allele purity (i.e. very low levels of rainbow trout, yellowstone cutthrout trout or coastal cutthrout trout genetic introgression) throughout the Elk River watershed areas upstream of the Elko Dam. Boyer, Muhlfeld, and Allendorf (2008) sampled 31 sites in the upper Flathead River system within the United States (27 sites) and Canada (4 sites). Genetic introgression declined with latitude with no evidence of rainbow trout allelles within any westslope cutthrout trout sampled within the Canadian portion of the upper Flathead River.

```
# load the csv built with R/02_prep_fig/analyze_fish_wct.R
wct_elkr_grad <- readr::read_csv(file = paste0(getwd(),
        '/data/inputs_extracted/02_prep_report/wct_elkr_grad.csv'))
```

Gradient of streams is an important determinant of habitat suitability for salmonids with lower gradient habitats often providing the most productive environments for both rearing and spawning while high gradient sections typically present upstream migration barriers and less available habitat. A summary of historic westslope cutthrout trout observations in the Elk River watershed group delineated by average gradient category of associated stream segments where they were captured is provided in Figure 2.5. Of 4003 observations, 93% were within stream segments with average gradients ranging from 0 - 8%. A total of 73% of historic observations were within stream segments with gradients between 0 - 3%, 12% were within stream segments with gradients ranging from 3 - 5% and 8% were within stream segments with gradients between 5 - 8% (MoE 2020a; Norris 2020).

```
##bar graph
plot_wct_elkr_grad <- wct_elkr_grad %>%
  ggplot(aes(x = Gradient, y = Percent)) +
  geom_bar(stat = "identity")+
  theme_bw(base_size = 12)+
  labs(x = "Stream Gradient", y = "WCT Occurrences (%)") +
  ggdark::dark_theme_bw()
plot_wct_elkr_grad
```

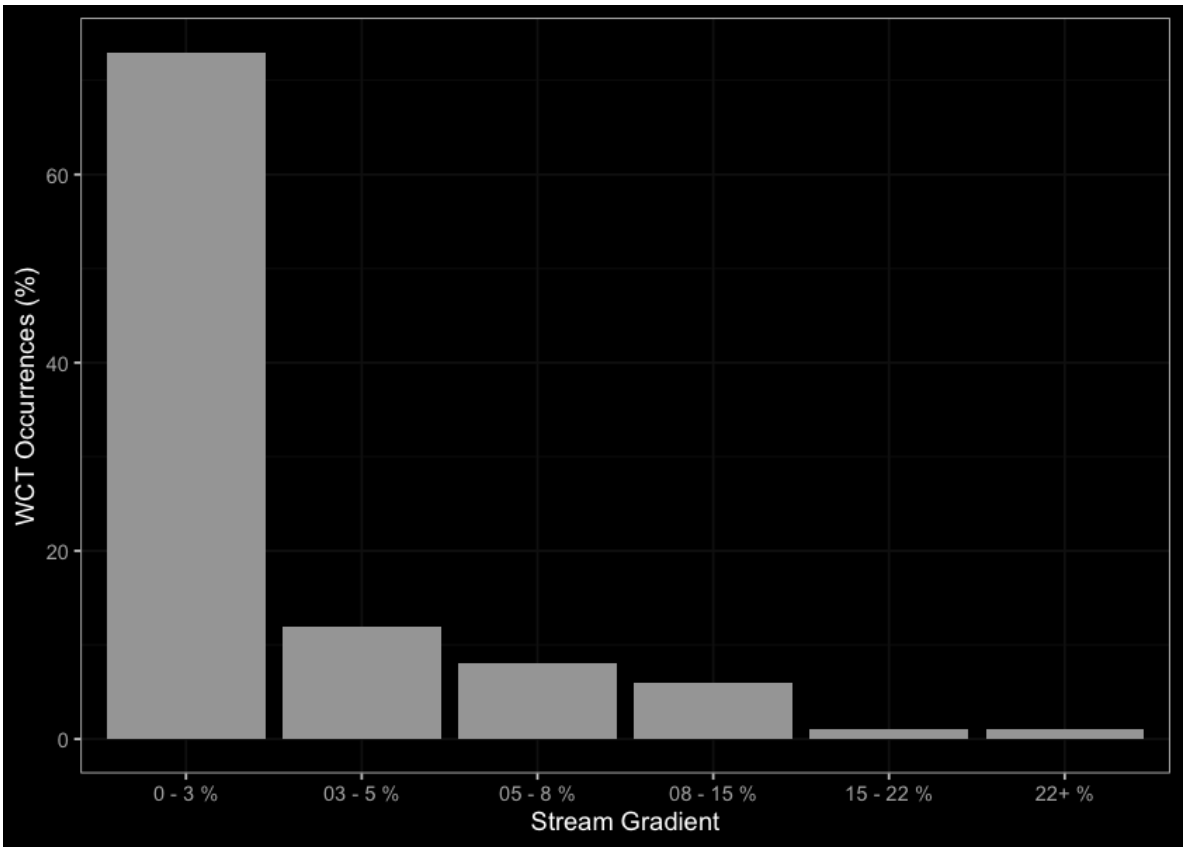

Figure 2.5: Summary of historic westslope cutthrout trout observations vs. stream gradient category.

3 Methods

3.1 Fish Sampling

Electrofishing was utilized for fish sampling according to stream inventory standards and procedures found in the Reconnaissance (1:20 000) Fish and Fish Habitat Inventory Manual (Resources Inventory Committee 2001). Individual captured fish were GPS'd, measured for fork length and released. A Fish Data Submission Spreadsheet Template - V 2.0, January 20, 2020 was populated for all sites and will be submitted to the provincial government under scientific fish collection permit CB22-755885. Habitat characteristics measured included water temperature, pH, conductivity, channel/wetted widths, pool depths, gradient, bankfull channel depth, stage, cover, large woody debris presence/abundance, channel bank characteristics, riparian vegetation type/structural stage, substrate and channel morphology. Downstream and upstream photographs were taken at each site and relevant features were recorded.

Habitat data associated with electrofishing sites was collated on "Site Cards" with habitat characteristics recorded included channel widths, wetted widths, residual pool depths, gradients, bankfull depths, stage, temperature, conductivity, pH, cover by type, substrate and channel morphology (among others). Any potential obstacles to fish passage were inventoried with photos, physical descriptions and locations recorded on site cards. Surveyed routes were recorded with time-signatures on handheld GPS units.

3.2 Fish Habitat Assessment

The Fish Habitat Assessment Procedures were developed by Johnston and Slaney (1996) to provide a standard framework for identifying needs and opportunities for fish habitat restoration. Field assessments in 2022 included Level 1 assessments - which are standardized protocols for characterizing average fish habitat conditions within stream reaches with the intent to identify scenarios that may limit fish production. Sample sites were divided into distinct geomorphic habitat units based on gradient, water flow characteristics, depth and size/position of the habitat unit relative to the main channel (habitat unit category). Habitat unit categories consisted of primary (occupy more than 50% of the wetted width of the main channel), secondary (side channels) and tertiary units (less than . These habitat units consisted of pools, glides, riffles and cascades which are described in more detail below:

- Pools - areas of slower, deeper water created by impoundment of water or scour (often associated with large woody debris) with a concave bottom profile and a water surface gradient near 0%. Minimum dimensions for the size of pools (miniumum area and associated minimum residual depth) are defined in Johnston and Slaney (1996) and based on the bankfull channel width of the stream.
- Glides were defined as areas of flat bottomed, fast-flowing and non-turbulent (laminar) flow.
- Riffles included areas of turbulent, fast flowing water usually consisting of shallow moderate-gradient areas with gravel or cobble bed material projecting above the water surface and

obvious surface turbulence.

- Cascades included steeper, stepped “riffles” of bedrock or emergent substrates in channels with gradient greater than ~4%. The water surface is usually very turbulent and frothy and white in appearance.

Sites were surveyed using a hip chain to track distance with the following attributes recorded for each habitat unit - gradient, mean water depth, mean wetted width, mean bankfull channel width, mean bankfull depth, pool characteristics (max depth, crest depth, residual depth), pool type (scour pool or impoundment), dominant/subdominant bed material type, large woody debris (total of all pieces >10cm in diameter as well as total number of “functional” pieces broken out into multiple size categories), cover (% by type), disturbance indicators, riparian vegetation type, riparian structural stage, overstream canopy closure and spawning gravel amount/type.

A clinometer was used to estimate gradient, channel measurements were taken using a tape measure and water depths measured using a measuring stick. Photographs were taken of representative habitats throughout the surveyed reaches. All field measurements were recorded on Level 1 Habitat Survey Data Form templates (Johnston and Slaney (1996)). GPS waypoints were collected at the beginning and end of all Primary habitat units to allow georeferenceing of field data.

3.3 Stream Discharge

Hydrometric transects were conducted in November of 2023 on days coinciding with fish habiatat assessments in Weigert Creek. Measurements were taken at points upstream and dowstream of Highway 43 at both Weigert Creek and Brule Creek.

3.4 Water Temperature

HOBO tidbit temperature logger were installed at locations approximatley 20m upstream of Highway 43 on Weigert Creek and immediately below the falls at approximatley 3.6km upstream of the Highway 43 culverts. Loggers on Weigert Creek were installed at 60% of the water depth on June 24, 2023 and pulled on November 17, 2023. Temperature ws taken at 30 minute intervals for the entire length of time installed. Unfortunately high flows with Brule Creek resulted in the dislodging of the logger installed under the falls and the subsequent loss of the logger and all associated data.

We defined the start of the growing season as per Coleman and Fausch (2007b) which delineate it as the beginning of the first week that average stream temperatures exceed and remain above 5°C in the spring and the end of the growing season as the last day of the first week that average stream temperature drops below 4°C. We specified Monday as the first day of the week and identified the week of the year based on the number of 7 day periods from January 1 plus 1. Celsius degree-days were calculated as the mean daily temperature (ex. 2 days with average temperatures of 7°C with sum to 14 Celsius degree-days).

4 Results

A map showing sample sites for fish sampling, fish habitat assessments and discharge in Weigert Creek and Brule Creek are summarized in Figure 4.1.

```
knitr::include_graphics("fig/elk_fish_passage_2022.png")
```

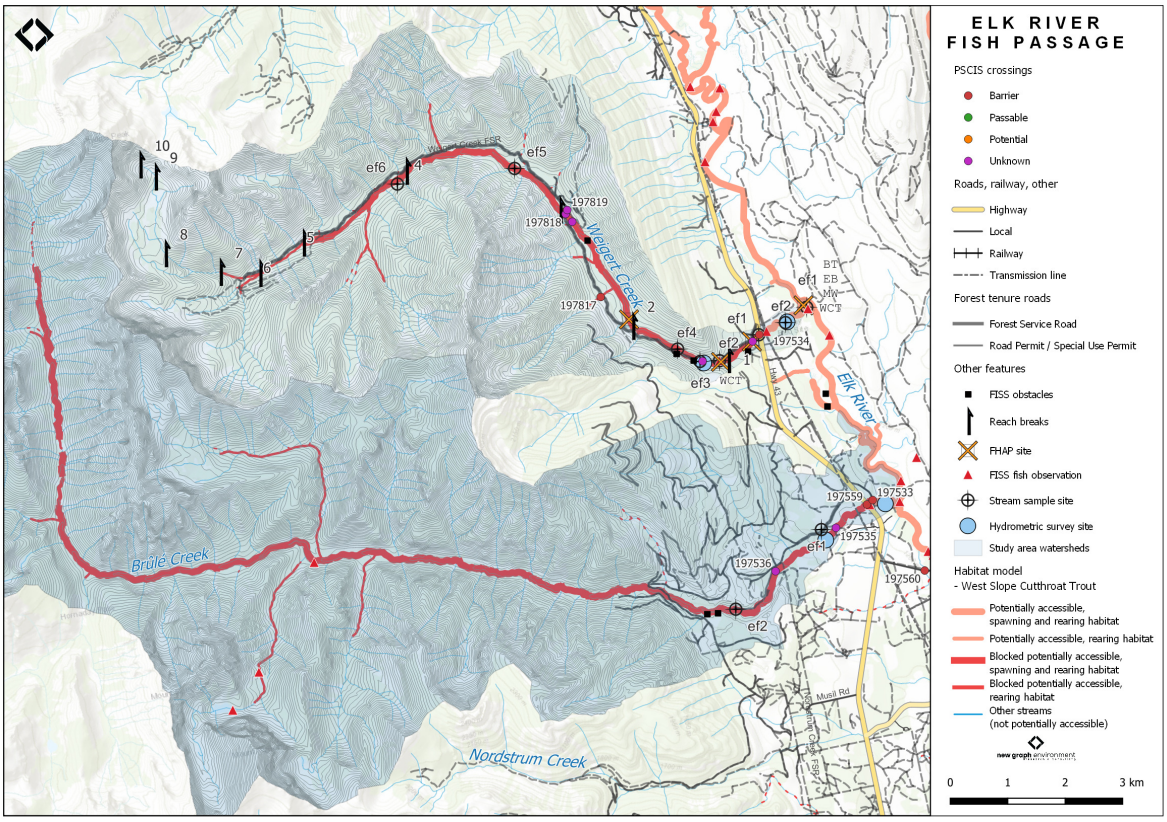

Figure 4.1: Map of Survey Sites

```
# **Habitat Model Parameters**
# * Spawning max gradient: 5.0%#
# * Spawning discharge min (mean annual, m^3^/s): 0.05#
# * Spawning discharge max (mean annual, m^3^/s): 76.00#
# * Rearing max gradient:                          7.0%#
# * Rearing discharge min  (mean annual, m^3^/s): 0.02#
# * Rearing discharge max  (mean annual, m^3^/s): 30.00
```

4.1 Weigert Creek - PSCIS crossing 197534

```
my_site <- 197534
```

PSCIS crossing 197534 is located on Highway 43, approximately 23.5km north of the town of Sparwood approximately 1.3km upstream from the confluence with the Elk River. Elk Valley Park recreation site is located downstream of the crossing adjacent to the right bank of the river and the watershed upstream of the crossing is a habitat protection area with motor vehicle restrictions. The highway culverts are the responsibility of the Ministry of Transportation and Infrastructure.

At crossing 197534, Weigert Creek is a fourth order stream with a watershed area upstream of the crossing of approximately 43.3km^2. The elevation of the watershed ranges from a maximum of 2938m to 1253m at the crossing (Table 4.1). Although multiple upstream survey sites are recorded within provincial databases, before 2022 there were no fish recorded upstream (MoE 2020b). Although all upstream crossings on the mainstem of Weigert Creek have been assessed as fords, Vast Resource Solutions engineers were present at the site in the fall of 2022 and were conducting the surveys for bridge installation at the crossing located approximately 1.2km upstream of Highway 43.

```
fpr::fpr_table_wshd_sum(site_id = my_site) %>%
  fpr::fpr_kable(caption_text = paste0('Summary of derived upstream
        watershed statistics for PSCIS crossing ', my_site, '.'),
           footnote_text = 'Elev P60 = Elevation at which 60% of the
        watershed area is above',
           scroll = F)
```

Table 4.1: Summary of derived upstream watershed statistics for PSCIS crossing 197534.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
197534	43.3	1253	1319	2938	2019	1929	SE

* Elev P60 = Elevation at which 60% of the watershed area is above

PSCIS crossing 197534 was assessed in 2020 by (Irvine 2021) and ranked as a barrier for upstream fish migration. A detailed write up of habitat details and stream characteristics can be found in the 2021 report memo linked here. Updated photos of the crossing are provided in Figure 4.2 and a map of the watershed is provided in map attachment 082G.123.

```
my_photo1 = fpr::fpr_photo_pull_by_str(str_to_pull = 'crossing')

my_caption1 = paste0('Photos of Highway 43 crossing on Weigert Creek
        in October 2022.')

grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.2: Photos of Highway 43 crossing on Weigert Creek in October 2022.

```
# A summary of habitat modelling outputs is presented in Table
        \@ref(tab:tab-culvert-bcfp-197534) and a
fpr::fpr_table_bcfp(scroll = gitbook_on)
```

4.1.1 Temperature

Temperature data was collected at 30 minute intervals between June 24, 2023 and November 2, 2023 from a station located approximately 20m upstream of Highway 43 with results are summarized in Figure 4.3, Table and raw data available here. The growing season at the location of the logger in 2023 was determined to be from June 7 to October 16. A summary of weekly water temperatures in Weigert Creek along with average air temperatures (averaged from hourly values) at Sparwood climate station ID 1157632 are presented in Figure 4.2. Average weekly water temperatures were at or above 7°C for only four of the 16 week growing season with a total of 693.5 Celsius degree-days calculated from the data for this period. Some caution should be applied to the interpretation of this data as the first week of water temperature data collected only consisted of three days worth of data (June 24 - June 26) so there is some potential that temperatures in the days and weeks before were high enough that the growing season could be considered longer.

```
knitr::include_graphics("fig/weigert_temp.png")
```

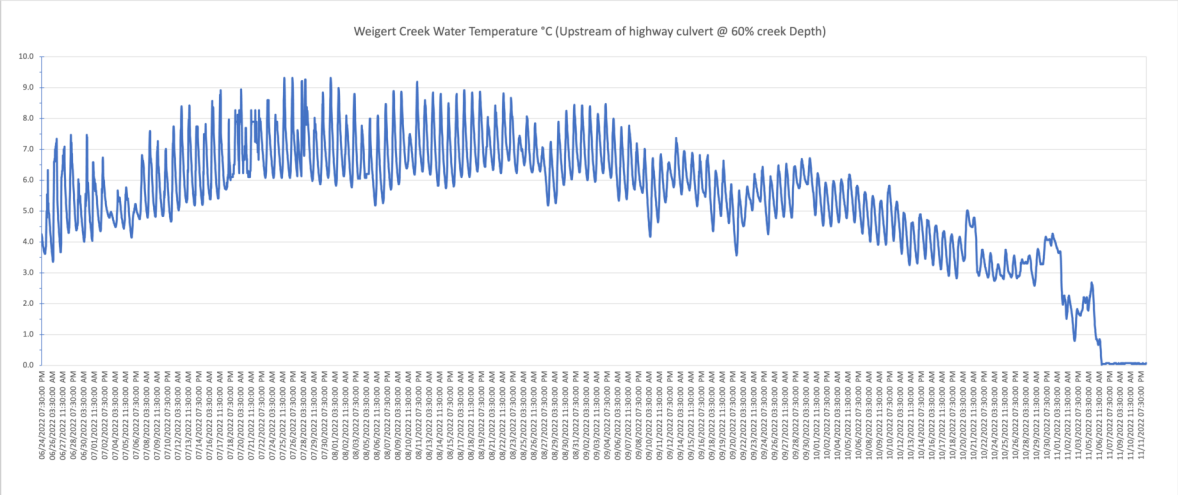

Figure 4.3: Temperature profile for Weigert Creek taken at station located approximately 50m upstream of Highway 43

```
source('scripts/tidy_temp.R')

my_caption = 'Summary of average water temperature by week for Weigert
        Creek and average air temperature for Sparwood at climate
        station ID 1157632.'

left_join(
  w_week,
  temp_week %>%
    select(week, ave_temp_h20)
) %>%
```

```
  mutate(week = as.character(week),
         week = case_when(week == 25 ~ '*25', T ~ week)) %>%
  fpr::fpr_kable(scroll = gitbook_on,
                 caption = my_caption,
                 footnote_text = '* the first week of water
        temperature data collected only consisted of three days worth
        of data (June 24 - June 26)')
```

Table 4.2: Summary of average water temperature by week for Weigert Creek and average air temperature for Sparwood at climate station ID 1157632.

week	day_first	day_last	ave_temp_air	ave_temp_h20
13	2022-04-03	2022-04-03	2.9	–
14	2022-04-04	2022-04-10	1.8	–
15	2022-04-11	2022-04-17	-4.5	–
16	2022-04-18	2022-04-24	3.5	–
17	2022-04-25	2022-05-01	5.2	–
18	2022-05-02	2022-05-08	7.7	–
19	2022-05-09	2022-05-15	5.9	–
20	2022-05-16	2022-05-22	6.5	–
21	2022-05-23	2022-05-29	9.2	–
22	2022-05-30	2022-06-05	10.9	–
23	2022-06-06	2022-06-12	12.0	–
24	2022-06-13	2022-06-19	11.5	–
*25	2022-06-20	2022-06-26	12.9	4.8
26	2022-06-27	2022-07-03	15.4	5.2
27	2022-07-04	2022-07-10	14.5	5.4
28	2022-07-11	2022-07-17	18.9	6.4
29	2022-07-18	2022-07-24	17.4	7.0
30	2022-07-25	2022-07-31	21.2	7.2
31	2022-08-01	2022-08-07	18.0	6.7
32	2022-08-08	2022-08-14	20.6	7.1
33	2022-08-15	2022-08-21	19.6	7.1
34	2022-08-22	2022-08-28	15.9	6.9
35	2022-08-29	2022-09-04	17.7	6.9

4.1.2 Discharge

Discharge was measured upstream and downstream of the crossing on October 18, 2023. Stations locations and discharge recorded are presented in Table 4.3.

```
my_caption <- 'Discharge recorded at Weigert Creek upstream and
        downstream of Highway 43.'

hydrometrics %>%
```

```
  filter(stringr::str_detect(gazetted_name, 'Weigert')) %>%
  select(-gazetted_name, -`dd/mm/yy & time`) %>%
  mutate(location = str_to_title(location)) %>%
  purrr::set_names(c('Location', 'Discharge (m3/s)', 'Zone',
        'Easting', 'Northing')) %>%
  relocate(`Discharge (m3/s)`, .after = last_col()) %>%
  fpr::fpr_kable(scroll = F,
                 caption_text = my_caption,                 )
```

Table 4.3: Discharge recorded at Weigert Creek upstream and downstream of Highway 43.

Location	Zone	Easting	Northing	Discharge (m3/s)
Upstream	11	649110	5531723	0.183
Downstream	11	650657	5532197	0.252

4.1.3 Stream Characteristics Downstream

The stream was surveyed at two different sites downstream of crossing 197534 (sites shown in Figure 4.1). The first site was located at the confluence to the Elk River where Weigert Creek redirects to the south. This section was surveyed for 520m. The stream was very fast flowing in sections. The average channel width was 4.38m, the average wetted width was 3.48m, and the average gradient was 3.1%. There were clumps of large woody debris that added complexity to stream habitat. Total cover was rated as moderate with cobbles dominating the in stream substrate. There were some sections that contained gravels suitable for westslope cutthroat and bull trout spawning. Habitat quality was rated as medium. The second site was located at the top of the first site, and was surveyed for 450m. Total cover was rated as moderate. The dominant substrate was cobbles with gravels sub dominant. Hydrometric flow data was taken at the bottom of this site, approximately 550m downstream of crossing 197534.

4.1.4 Stream Characteristics Upstream

The stream was surveyed at six different sites upstream of crossing 197534 (sites shown in Figure 4.1). Hydrometric flow data was taken at the ford (PSCIS crossing 197727). Total measured flow was 0.016m^3/s. The bottom of the first site was located immediately upstream of crossing 197534 and was surveyed for 350m. The second site was in reach two and was surveyed for 300m to the ford. This section had a wide channel with fast flow. Many larger fish were caught (>200mm). Some deep pools were present at the time of survey that are suitable for overwintering. The dominant in stream substrate was cobbles, followed by boulders. The third site was located upstream of the ford and was surveyed for 550m. Site four was also in reach two and was surveyed for 350m. This section had good flow with abundant boulders and large woody debris. There were some deep pools and abundant gravels suitable for spawning. The fifth site was in reach four and was surveyed for 330m. The stream was steep at some sections, with measured gradients up to 10.5%. The channel was wide with good flow. There were many deep pools suitable for rearing. Some gravels

were present suitable for salmonid spawning. A couple of high cascades and large woody debris jams approximately 1m in height were seen that would be a barrier for the upstream migration of smaller fish. At site six in reach five, the stream was dry so the surveyors worked their way back to where the water began and surveyed 300m upstream. The stream channel was frequently confined and there was abundant cover. Overall, the habitat value upstream of crossing 197534 was medium to high for salmonid rearing and spawning. There were locations in each reach with patches of suitably sized gravels, deep pools, undercut banks, and stable debris; all of which are essential for the fish population.

4.1.5 Fish Sampling

Electrofishing was conducted at eight sites with results summarised in Tables 4.4 - 4.8 and Figure 4.4. Habitat details are summarized in Table 4.6. Although westslope cutthrout trout, mountain whitefish, bull trout and brook trout were captured downstream of the Highway, only westslope cutthrout were captured above. Also of note, numerous westslope cuthrout trout were captured downstream and upstream of the crossing with a notable presence of only adult fish upstream of the crossing and also a significant increase in the density of adult fish upstream of the crossing.

```
# `r if(gitbook_on){knitr::asis_output("<br>")} else
        knitr::asis_output("\\pagebreak")`
# A total of `r hab_site %>% filter(str_detect(alias_local_name,
        '_ef')) %>% nrow()` sites were electrofished within `r
        hab_site %>% filter(str_detect(alias_local_name, '_ef')) %>%
        distinct(gazetted_name) %>% nrow()` streams.
hab_site %>%
  select(gazetted_name,
         alias_local_name,
         reach_number,
         utm_easting,
         utm_northing,
         comments
         ) %>%
  # filter out two sites that weren't electrofished
  filter(str_detect(alias_local_name, "ef", negate = FALSE)) %>%
  filter(str_detect(gazetted_name, "Weigert")) %>%
  arrange(alias_local_name) %>%
  fpr::fpr_kable()
```

Table 4.4:

gazetted_name	alias_local_name	reach_number	utm_easting	utm_northing	comments
Weigert Creek	197534_ds_ef1	1	650985	5532436	Electrofishing commenced at point where Weigert almost touches Elk River then redirects to the south (approximately 210m upstream of mapped confluence). Very fast flowing in parts. Some LWD providing functionality and cover. 12:50
Weigert Creek	197534_ds_ef2	1	650627	5532190	No comments provided. 12:00:00 PM
Weigert Creek	197534_us_ef1	1	650134	5532055	No comments provided. 12:36:42 PM
Weigert Creek	197534_us_ef2	2	649387	5531718	High value habitat. Wide channel with fast flowing water. Many larger fish captured (>200mm). Some deep pools suitable for overwintering. Cobbles and boulders providing cover. 12:26:06
Weigert Creek	197534_us_ef3	2	649050	5531760	Electrofishing site was the first 400 to 450 m and then approximately 100 m further was assessed to gather more habitat characteristics. Most fish captured were observed by the crew before they were captured and all were adults. 12:20:59
Weigert Creek	197534_us_ef4	3	648699	5532036	High value habitat. Good flow with lots of boulder cover and LWD. Some deep pools with abundant gravels suitable for spawning. No fish were caught. 11:00

```
my_caption = 'Summary of results of electrofishing in Weigert Creek.'

 # sum of all the fish per site and the electrofishing seconds
fish_samp_sum <- left_join(
  hab_fish_indiv %>%
    mutate(nfc = case_when(species_code == 'NFC' ~ 'true', T ~
        NA_character_)) %>%
    mutate(ef_width_m = round(ef_width_m, 1)) %>%
    group_by(local_name, ef_length_m, ef_width_m, ef_seconds, nfc)
        %>%
    summarise(count_fish = n())  %>%
    mutate(count_fish = case_when(nfc == 'true' ~ 0, T ~ count_fish))
        %>%
    select(-nfc) %>%
    arrange(local_name),
```

```
          hab_site %>%     select(gazetted_name,
           alias_local_name, reach_number),
  by = c('local_name' = 'alias_local_name')) %>%      relocate(
    gazetted_name, .before = local_name  ) %>%    relocate(
    reach_number, .after = local_name  ) %>%
  mutate(CPUE = round(count_fish/(ef_seconds / 1000), 1))
fish_samp_sum %>%   filter(str_detect(gazetted_name, 'Weigert')) %>%
  fpr::fpr_kable(caption_text = my_caption,
                 footnote_text = 'CPUE = Catch per unit effort (fish
        captured/1000s of electrofishing).',
                 scroll = F)
```

Table 4.5: Summary of results of electrofishing in Weigert Creek.

gazetted_name	local_name	reach_number	ef_length_m	ef_width_m	ef_seconds	count_fish	CPUE
Weigert Creek	197534_ds_ef1	1	520	3.5	4459	11	2.5
Weigert Creek	197534_ds_ef2	1	–	–	2995	7	2.3
Weigert Creek	197534_us_ef1	1	–	4.4	–	0	–
Weigert Creek	197534_us_ef2	2	300	5.0	2120	13	6.1
Weigert Creek	197534_us_ef3	2	550	4.9	1521	4	2.6
Weigert Creek	197534_us_ef4	3	–	4.4	1466	0	0.0
Weigert Creek	197534_us_ef5	4	330	2.0	1495	0	0.0
Weigert Creek	197534_us_ef6	5	300	1.5	–	0	–

* CPUE = Catch per unit effort (fish captured/1000s of electrofishing).

```
tab_hab_summary %>%
  filter(Site %like% my_site) %>%
  fpr::fpr_kable(caption_text = paste0('Summary of habitat details for
        electrofishing sites upstream and downstream of PSCIS
        crossing ', my_site, '.'),
                 scroll = F)
```

Table 4.6: Summary of habitat details for electrofishing sites upstream and downstream of PSCIS crossing 197534.

Site	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197534_ds_ef1	520	4.4	3.5	0.8	3.1	moderate	medium
197534_ds_ef2	450	–	–	–	–	moderate	–
197534_us_ef1	350	6.2	4.4	–	6.6	–	–
197534_us_ef2	300	5.6	5.0	0.5	5.2	moderate	high
197534_us_ef3	550	7.0	4.9	0.4	4.0	abundant	–
197534_us_ef4	350	6.4	4.4	0.6	3.8	–	high
197534_us_ef5	330	5.0	4.0	0.7	6.7	moderate	medium
197534_us_ef6	300	4.9	–	–	–	abundant	–

```
fpr_table_fish_site()
```

Table 4.7: Fish sampling site summary for 197534.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
197534_ds_ef1	1	520	3.480	1809.6	open
197534_ds_ef2	1	–	–	–	open
197534_us_ef1	1	–	4.400	–	open
197534_us_ef2	1	300	4.960	1488.0	open
197534_us_ef3	1	550	4.900	2695.0	open
197534_us_ef4	1	–	4.440	–	open
197534_us_ef5	1	330	2.040	673.2	open
197534_us_ef6	1	300	1.525	457.5	open

```
fpr_table_fish_density()
```

Table 4.8: Fish sampling density results summary for 197534.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
197534_ds_ef1	BT	adult	1	0.1	FALSE
197534_ds_ef1	EB	fry	1	0.1	FALSE
197534_ds_ef1	EB	parr	1	0.1	FALSE
197534_ds_ef1	EB	juvenile	1	0.1	FALSE
197534_ds_ef1	MW	juvenile	1	0.1	FALSE
197534_ds_ef1	WCT	parr	3	0.2	FALSE
197534_ds_ef1	WCT	juvenile	2	0.1	FALSE
197534_ds_ef2	WCT	adult	1	–	FALSE

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
197534_us_ef1	NFC	–	0	–	TRUE
197534_us_ef2	WCT	juvenile	1	0.1	FALSE
197534_us_ef2	WCT	adult	6	0.4	FALSE
197534_us_ef3	WCT	juvenile	1	0.0	FALSE
197534_us_ef3	WCT	adult	1	0.0	FALSE
197534_us_ef4	NFC	–	0	–	TRUE
197534_us_ef5	NFC	–	0	0.0	TRUE
197534_us_ef6	NFC	–	0	0.0	TRUE

* nfc_pass FALSE means fish were captured in final pass indicating more fish of this species/lifestage may have remained in site.
Mark-recaptured required to reduce uncertainties.

```
my_caption <- paste0('Densites of fish (fish/100m2) captured upstream
        and downstream of PSCIS crossing ', my_site, '.')

fpr_plot_fish_box()
```

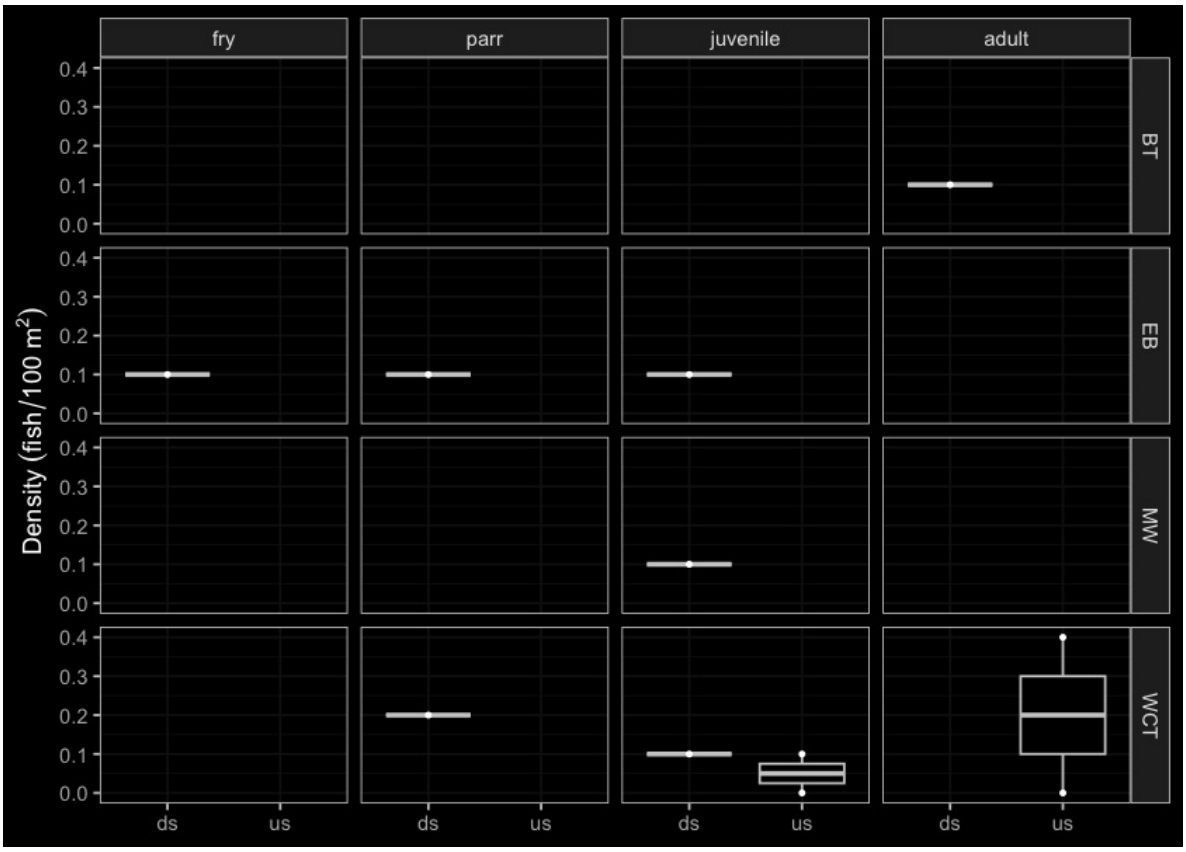

Figure 4.4: Densites of fish (fish/100m2) captured upstream and downstream of PSCIS crossing 197534.

4.1.6 Fish Habitat Assessment

Fish habitat was assessed at four sites within three reaches of Weigert Creek (Tables 4.9 - 4.10).

```
my_caption = 'Site locations for fish habitat assessment within
        Weigert Creek.'


tab_fhap_site %>%
  select(
    Site,
    Reach,
    Easting,
    Northing,
    Comments
  ) %>%
  arrange(Site) %>%
```

```
    fpr::fpr_kable(caption_text = my_caption,
                   scroll = F)
```

Table 4.9: Site locations for fish habitat assessment within Weigert Creek.

Site	Reach	Easting	Northing	Comments
1	1	650985	5532436	Start approximately Elk River
2	1	649996	5531958	Started at ford crossing (PSCIS 197820) located at downstream route measure 1248m.
3	2	649409	5531694	Discharge Estimated
4	3	647948	5532684	–

```
my_caption = 'Summary of results from fish habitat assessment within
        Weigert Creek.'


tab_fhap_hu_sum %>%
  arrange(Site) %>%
  fpr::fpr_kable(caption_text = my_caption,
                 footnote_text = 'Results for habitat units presented
        as percent of total area. LWD = large woody debris.',
                 scroll = F)
```

Table 4.10: Summary of results from fish habitat assessment within Weigert Creek.

Site	Length Surveyed (m)	Average Channel Width (m)	Total Area (m2)	Total Functional LWD	LWD per Bankfull Width	Cascade	Glide	Pool	Riffle
1	688	6.1	83457	173	1.5	44	14	5	37
2	311	6.5	17931	37	0.8	46	1	4	49
3	356	6.3	17262	119	2.1	60	5	3	32
4	266	5.9	15395	168	3.7	42	17	8	33

* Results for habitat units presented as percent of total area. LWD = large woody debris.

```
my_photo1 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_d1_')

my_caption1 = paste0('Typical habitat downstream of PSCIS crossing ',
        my_site, ', in reach 1.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.5: Typical habitat downstream of PSCIS crossing 197534, in reach 1.

```
my_photo2 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u2_')

my_caption2 = paste0('Typical habitat upstream of PSCIS crossing ',
        my_site, ' , in reach 2.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo2))
```

Figure 4.6: Typical habitat upstream of PSCIS crossing 197534 , in reach 2.

```
my_caption <- paste0('Left: ', my_caption1, ' Right: ', my_caption2)

knitr::include_graphics(my_photo1)
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics(my_photo2)
```

```
my_photo1 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u3_')

my_caption1 = paste0('Typical habitat upstream of PSCIS crossing ',
        my_site, ' in reach 3.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.7: Typical habitat upstream of PSCIS crossing 197534 in reach 3.

```
my_photo2 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u4_')

my_caption2 = paste0('Typical habitat upstream of PSCIS crossing ',
        my_site, ' in reach 4.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo2))
```

Figure 4.8: Typical habitat upstream of PSCIS crossing 197534 in reach 4.

```
my_caption <- paste0('Left: ', my_caption1, ' Right: ', my_caption2)

knitr::include_graphics(my_photo1)
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics(my_photo2)
```

```
my_photo1 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u5_')

my_caption1 = paste0('Typical habitat upstream of PSCIS crossing ',
        my_site, ' in reach 5.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.9: Typical habitat upstream of PSCIS crossing 197534 in reach 5.

```
my_photo2 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_ef1_')

my_caption2 = paste0('Brook Trout captured downstream of PSCIS
        crossing ', my_site, ' in reach 1.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo2))
```

Figure 4.10: Brook Trout captured downstream of PSCIS crossing 197534 in reach 1.

```
my_caption <- paste0('Left: ', my_caption1, ' Right: ', my_caption2)

knitr::include_graphics(my_photo1)
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics(my_photo2)
```

```
my_photo1 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_ef2_')

my_caption1 = paste0('Mountain Whitefish captured downstream of PSCIS
        crossing ', my_site, ' in reach 1.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.11: Mountain Whitefish captured downstream of PSCIS crossing 197534 in reach 1.

```
my_photo2 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_ef3_')

my_caption2 = paste0('Westslope Cutthroat Trout captured upstream of
        PSCIS crossing ', my_site, ' in reach 2.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo2))
```

Figure 4.12: Westslope Cutthroat Trout captured upstream of PSCIS crossing 197534 in reach 2.

```
my_caption <- paste0('Left: ', my_caption1, ' Right: ', my_caption2)

knitr::include_graphics(my_photo1)
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics(my_photo2)
```

4.2 Brule Creek - PSCIS crossings 197533 and 197559

```
my_site <- 197559
my_site2 <- 197533
```

PSCIS crossings 197533 and 197559 are located on Brule Creek approximately 20km north of the town of Sparwood. Crossing 197533 is located on Busato Road 600m upstream from the confluece with the Elk River and crossing 197559 is located approximately 725m upstream from the confluence with the Elk River. Both crossings are the responsibility of the Ministry of Transportation and Infrastructure. Both crossings on Brule Creek as well as habiatt upstream and downstream was assessed in 2020 by (Irvine 2021). Two fords (PSCIS 197535 and 197536) were documented 700m and 2km upstream of crossing 197559 respectively.

At the highway, Brule Creek is a 5th order stream with watershed characteristics detailed in Table 4.11. Brule Creek is known to contain westslope cutthrout trout, rainbow trout and bull trout downstream of the subject culverts and westslope cutthrout trout and rainbow trout above (MoE 2020b). On the south side of the upper watershed, at an elevation of 2000m, is the 5ha Josephine Lake (also known as Big Lake). The lake was stocked with westslope cutthrout trout from 1983 - 2000 (MoE 2020b; “Fish Inventories Data Queries” 2020). PSCIS stream crossings 197533 and 197559 were ranked as high priorities for follow up with new structures designs following habitat confirmations by Irvine (2021) due to the large size of the stream network upstream of the highway. Detailed reporting can be found here. In 2020, the channel was noted as dewatered immediately upstream of Highway 43 with intermittent pools only to a distance approximately 670 m upstream. Assessments in 2022 demonstrated that the culvert on Busato Road was in extremely poor condition with deformations of the inlet and extensive corrosion. Both the Busato Road and Highway 43 culverts are extremely undersized which is evidenced by the severe down cutting below their outlets, the large outlet drops (>1m) and the deep and wide outlet pools.

```
fpr::fpr_table_wshd_sum(site_id = my_site) %>%
  fpr::fpr_kable(caption_text = paste0('Summary of derived upstream
         watershed statistics for PSCIS crossing ', my_site, '.'),
            footnote_text = 'Elev P60 = Elevation at which 60% of the
         watershed area is above',
            scroll = F)
```

Table 4.11: Summary of derived upstream watershed statistics for PSCIS crossing 197559.

Site	Area Km	Elev Site	Elev Min	Elev Max	Elev Median	Elev P60	Aspect
197559	82.1	1229	1225	2938	1966	1872	SSE

* Elev P60 = Elevation at which 60% of the watershed area is above

A map of the watershed is provided in attachment 082G.123.

```
# A summary of habitat modelling outputs is presented in Table
        \@ref(tab:tab-culvert-bcfp-197559) and a
fpr::fpr_table_bcfp(scroll = gitbook_on)
```

4.2.1 Discharge

Discharge was measured upstream and downstream of Highway 43 on October 18, 2023. Stations locations and discharge recorded are presented in Table 4.12.

```
my_caption <- 'Discharge recorded at Weigert Creek upstream and
        downstream of Highway 43.'

hydrometrics %>%
  filter(stringr::str_detect(gazetted_name, 'Brule')) %>%
  select(-gazetted_name, -`dd/mm/yy & time`) %>%
  mutate(location = str_to_title(location)) %>%
  purrr::set_names(c('Location', 'Discharge (m3/s)', 'Zone',
        'Easting', 'Northing')) %>%
  fpr::fpr_kable()
```

Table 4.12:

Location	Discharge (m3/s)	Zone	Easting	Northing
Upstream	0.016	11	650707	5528331
Downstream	0.036	11	651833	5528789

4.2.2 Stream Characteristics

Habitat characteristics were gathered at two sites upstream of Highway 43 where electrofishing was conducted in 2022 (Figure 4.1 and Table 4.13.

The first site was located approximately 1km upstream from the culvert. This section was surveyed for 600m. The average channel width was 6.0m, the average wetted width was 3.5m, and the average gradient was 2.8%. The dominant streambed substrate was cobbles, with gravels sub-dominant. Total cover from overhanging vegetation and large woody debris was abundant. The habitat quality was rated as medium with moderate value for bull trout and westslope cutthrout trout and pockets of spawning gravels suitable for resident salmonids.

The second site electrofished on Brule Creek was located approximately 3.2km upstream of Highway 43. This section was surveyed for 310m to the location of a waterfall shown in Figure 4.16. This waterfall was approximately 7m in height, and blocks upstream migration for all species and life stages potentially present. At the time of survey, the average channel width was 7.5m, the average wetted width was 4.9m, and the average gradient was 2.1%. The dominant substrate was cobbles with boulders sub dominant. The habitat quality was considered moderate with abundant gravels suitable for resident and fluvial westslope cutthroat and bull trout spawning but few pools present that would be suitable for overwintering.

Monitoring of the stream immediately upstream of Highway 43 was conducted throughout 2022 to give an indication for the amount of time that dewatering occurs at this location. In 2022, dewatering was noted within the first approximatley 400m from May 5th to October 15th. Upstream of the first 400m the stream was noted as flowing year round.

```
tab_hab_summary %>%
  filter(Site %like% my_site) %>%
  fpr::fpr_kable(caption_text = paste0('Summary of habitat details for
        electrofishing sites upstream of PSCIS crossing ', my_site,
        '.'),
                 scroll = F)
```

Table 4.13: Summary of habitat details for electrofishing sites upstream of PSCIS crossing 197559.

Site	Length Surveyed (m)	Channel Width (m)	Wetted Width (m)	Pool Depth (m)	Gradient (%)	Total Cover	Habitat Value
197559_us_ef1	600	6.0	3.5	0.6	2.8	abundant	medium
197559_us_ef2	310	7.5	4.9	0.6	2.1	moderate	high

4.2.3 Fish Sampling

The stream was electrofished at two sites upstream of crossing 197559 in 2022 with no fish captured at either site (Tables 4.14 - 4.16). However, an adult fish (approximately 30cm long) was observed in an isolated pool on August 4, 2022 approximately 350m upstream of the Highway 43 culverts within a pool within and area that was primarily dewatered.

```
# `r if(gitbook_on){knitr::asis_output("<br>")} else
        knitr::asis_output("\\pagebreak")`
# A total of `r hab_site %>% filter(str_detect(alias_local_name,
        '_ef')) %>% nrow()` sites were electrofished within `r
        hab_site %>% filter(str_detect(alias_local_name, '_ef')) %>%
        distinct(gazetted_name) %>% nrow()` streams.
hab_site %>%
  select(gazetted_name,
         alias_local_name,
         utm_easting,
         utm_northing,
         comments
         ) %>%
  # filter out two sites that weren't electrofished
  filter(str_detect(alias_local_name, "ef", negate = FALSE)) %>%
  filter(str_detect(gazetted_name, "Brule")) %>%
  arrange(alias_local_name) %>%
  fpr::fpr_kable()
```

Table 4.14:

gazetted_name	alias_local_name	utm_easting	utm_northing	comments
Brule Creek	197559_us_ef1	650662	5528524	No comments provided. 1:32:43 PM
Brule Creek	197559_us_ef2	648968	5527392	High value habitat. Abundant gravels suitable for residential and fluvial WCT and BT. Few pools suitable for overwintering. Top of site is 7m high cascade waterfall not passable in an upstream direction. 12:12:58

```
my_caption = 'Summary of results of electrofishing in Weigert Creek.'

 # sum of all the fish per site and the electrofishing seconds
fish_samp_sum <- left_join(
  hab_fish_indiv %>%
    mutate(ef_width_m = round(ef_width_m, 1)) %>%
    group_by(local_name, ef_length_m, ef_width_m, ef_seconds) %>%
    summarise(count_fish = n()) %>%
    arrange(local_name),

  hab_site %>%
    select(gazetted_name,
           alias_local_name, reach_number),

  by = c('local_name' = 'alias_local_name')
```

```
) %>%      relocate(    gazetted_name, .before = local_name  ) %>%
  relocate(    reach_number, .after = local_name  ) %>%
  mutate(CPUE = round(count_fish/(ef_seconds / 1000), 1))
fish_samp_sum %>%   filter(str_detect(gazetted_name, 'Brule')) %>%
  fpr::fpr_kable(caption_text = my_caption,
                 footnote_text = 'CPUE = Catch per unit effort (fish
        captured/1000s of electrofishing).')
```

(#tab:fish_samp_sum-brule)Summary of results of electrofishing in Weigert Creek.

gazetted_name	local_name	reach_number	ef_length_m	ef_width_m	ef_seconds	count_fish	CPUE
Brule Creek	197559_us_ef1	–	600	3.5	–	1	–
Brule Creek	197559_us_ef2	–	310	4.0	1626	1	0.6

* CPUE = Catch per unit effort (fish captured/1000s of electrofishing).

```
fpr_table_fish_site()
```

Table 4.15: Fish sampling site summary for 197559.

site	passes	ef_length_m	ef_width_m	area_m2	enclosure

site	passes	ef_length_m	ef_width_m	area_m2	enclosure
197559_us_ef2	1	310	3.96	1227.6	open

```
fpr_table_fish_density()
```

Table 4.16: Fish sampling density results summary for 197559.

local_name	species_code	life_stage	catch	density_100m2	nfc_pass
197559_us_ef1	NFC	–	0	0	TRUE
197559_us_ef2	NFC	–	0	0	TRUE

* nfc_pass FALSE means fish were captured in final pass indicating more fish of this species/lifestage may have remained in site.
Mark-recaptured required to reduce uncertainties.

```
my_photo1 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u1_')

my_caption1 = paste0('Typical habitat upstream of PSCIS crossing ',
        my_site, ', on first electrofishing survey.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.13: Typical habitat upstream of PSCIS crossing 197559, on first electrofishing survey.

```
my_photo2 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u2_')

my_caption2 = paste0('Typical habitat upstream of PSCIS crossing ',
        my_site, ' , on second electrofishing survey.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo2))
```

Figure 4.14: Typical habitat upstream of PSCIS crossing 197559 , on second electrofishing survey.

```
my_caption <- paste0('Left: ', my_caption1, ' Right: ', my_caption2)

knitr::include_graphics(my_photo1)
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics(my_photo2)
```

```
my_photo1 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u3_')

my_caption1 = paste0('Habitat immediately downstream of waterfall.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo1))
```

Figure 4.15: Habitat immediately downstream of waterfall.

```
my_photo2 = fpr::fpr_photo_pull_by_str(site = my_site, str_to_pull =
        '_u4_')

my_caption2 = paste0('Waterfall at end of second electrofishing
        survey, upstream of PSCIS crossing ', my_site, '.')
```

```
grid::grid.raster(jpeg::readJPEG(my_photo2))
```

Figure 4.16: Waterfall at end of second electrofishing survey, upstream of PSCIS crossing 197559.

```
my_caption <- paste0('Left: ', my_caption1, ' Right: ', my_caption2)

knitr::include_graphics(my_photo1)
knitr::include_graphics("fig/pixel.png")
knitr::include_graphics(my_photo2)
```

5 Discussion and Recommendations

5.1 Weigert Creek - PSCIS crossing 197534

Fish were captured upstream of the highway only to within the first two reaches to within 300m upstream of the first ford on the Weigert Creek FSR that is located at an elevation of 1320m approximately 1.5km above Highway 43. Above this location, although significant electrofishing effort was conducted at a location approximately 3km upstream of the Highway within Reach 3, no fish were captured. In the fall of 2022 the entire channel width within Reach 5 was dewatered at a location approximately 8km upstream of Highway 43.

Although physical habitat characteristics (pool depths, presence of gravels/LWD, etc) appeared suitable to support westslope cutthrout trout in Reach 3 approximately 5km upstream of Highway 43 and in fact had more complexity than lower reaches due to large woody debris abundance and percent composition of pools, there were no fish captured in the area sampled. This was not expected, as the entire section of stream between where was sampled in Reach 3 and where fish were captured in Reach 2 was surveyed and although some smaller large woody debris jams from 60 - 70cm were observed, no permanent barriers were present that we would expect to block upstream migration of adult westslope cutthrout trout.

Cold water temperatures have been demonstrated to provide recruitment bottlenecks in early life stages of westslope cutthrout trout with days during the growing season above an average of 5°C a key determinant in growth and subsequent fry survival during overwintering (Coleman and Fausch 2007a, 2007b). Furthermore, ongoing programs of temperature modelling for Teck in the region are revealing that the single best predictor variable of westslope cutthrout trout density is temperature (pers. comm. Joe Thorley, Poisson Consulting Ltd.). Although there is some potential that the lack of fish captured in Reach 3 could be related to the potentially hindered upstream migration at the highway culverts, temperature information taken within Reach 1 at approximately 20m upstream of Highway 43 at an elevation of 1260m demonstrated that temperatures close to 5°C prevailed at this elevation from May - November 2023 indicating that temperatures at higher elevations in the watershed (ie. Reach 3 begins at 1460m) may preclude fish use of these areas. Research detailed in Coleman and Fausch (2007b) indicates that for translocations of greenback cutthroat trout and Colorado River cutthroat trout in north-central Colorado headwater streams - streams that provide 800–900 degree-days *probably* sustain recruitment in some years, and report that streams with less than 800 degree-days are generally unsuitable for translocations because of the smaller sizes attained by fry before the onset of winter and the associated greater risk of recruitment failure.

Average weekly water temperatures in Weigert Creek were at or above 7°C for only four of the 16 week growing season when the temperature logger was present in the stream with a grand total of 693.5 Celsius degree-days estimated from the dataset. Some caution should be applied to the interpretation of this data (because the first week of data collected fell under the average weekly water temperature threshold of 5°C and only consisted of three days worth of data - June 24

through June 26) so there is some potential that temperatures in the days and weeks before were high enough that the growing season could be considered longer. However, although subject to change during the drafting of this report (due to ongoing research), at this point in time it seems very conservative to assume that water temperatures were not likely above an average weekly temperature of 5°C for more than 5 weeks before temperature logging began. If it is assumed that average temperature was at 5.0°C during those 5 extra weeks, the Celsius degree-days would sum to 808.5 which is just barely in the range of *probable* for sustaining recruitment even at this low elevation in the watershed. Therefore, cold temperatures during the growing season at locations near the Highway where only adult fish were captured could be an indication that only adult fish are able to survive year to year in these locations as the 570 to 600 Celsius degree days required for fry emergence would leave little time for growth in the system. This leads us to wonder if fry in these cold systems have evolved to migrate downstream upon emergence seeking warmer rearing temperatures in the first years of life. Although more data is necessary to derive conclusions, this train of thought builds the case that improved passage at the Highway could result in more fish in the areas immediately upstream of the highway as 2+ and 3+ fish may wish to populate these areas if they could access them and currently it seems unlikely that small fish could do so.

Although difficult to determine cause, presence of only adult fish upstream of the Highway 43 crossing on Weigert Creek and a significant increase in the density of adult fish upstream when compared to downstream could be related to swim speed ability and the associated increased potential for larger fish to migrate from downstream to upstream of the culvert. The fact that fish of the size captured (up to over 30cm long) were within this system so late in the year indicates that they were resident and not merely in the system to spawn. This is particularly interesting as we would not have expected fish of this size to be resident within a system of this relatively small size (average channel width in Reach 2 of 5.5m).

Recommendations going forward include:

- To understand current patterns of movement within the stream, conduct electrofishing within currently fish bearing reaches both upstream and downstream of the crossing, pit tag all captured fish (>50mm long) and resample in future years. As there are extensive tagging programs throughout the Elk River watershed including tagging programs conducted by Nupqu as well as numerous guiding companies, this could give an idea of fish movement not only within Weigert Creek but also allow confirmation of habitat use within the mainstem of the Elk River by fish tagged in Weigert Creek as well as of utilization of habitat in Weigert Creek by fish originally tagged in the Elk River.
- Collect Weigert Creek temperature data at points known to support westslope cutthrout trout (ie. immediately upstream of the highway and adjacent to the first ford located approximately 1.5km upstream of Highway 43) as well as at areas further upstream (Reach 3 and Reach 4). Coordinate with other programs in the watershed to help determine the best locations for loggers, best timing from installation, contribute data to regional databases and leverage/improve temperature modelling in the region.

    - Attempt to predict temperature for the weeks prior to the date that the temperature logger was installed based on modelling aided by data from other water temperatures in area as well as air temperature data taken at these times.

- To quantify habitat quality further up in the watershed collect more detailed fish habitat information in Reach 3 and Reach 4.
- To build an understanding of spawning cutthrout use and timing within the system conduct redd surveys in the spring/summer.
- To quantify flow characteristics and help build an understanding of how discharge and spawning timing relate to access through the highway crossing, build a stage discharge curve for the watershed and measure flow speeds through the culverts at varying stream discharge rates.

5.2 Brule Creek - PSCIS crossings 197533 and 197559

The waterfall located upstream from Highway 43 limits the amount of potential habitat gained by remediation of stream crossing structures on Busato Road and Highway 43 to 3.6km. Although potentially a result of aggredation related to the Highway 43 culverts and road alignment, the seasonal dewatering in the first 300 - 500m of habitat immediately upstream of Highway 43 (May 5 - October 15 in 2023) is not a desirable habitat characteristic with potential implications for fish stranding. However, the presence of numerous mountain whitefish and westslope cutthrout trout holding in outlet pools downstream of both Bosato Road and Highway 43 along with the visual observaton of a fish in a pool upstream of the crossing in 2022 indicate that fish use of the area upstream would likely occur if the culvert barriers are removed.

As cold water temperatures could be limiting within stream habitats upstream of the Highway with effects likely increasing in severity with elevation rise, the amount of habitat viable for westslope cutthrout trout may not be any greater (or could in fact be even less) than the 3.6km of habitat present before the falls.

Recommendations going forward include:

- Collection of temperature data at points known to support westslope cutthrout trout (ie. within the outlet pools of Bosato Road and Highway 43 culverts) as well as at areas of potential access (below the falls at 3.6km) if fish passage were to be remediated at the sites.
- Capture and pit tagging of fish holding in the pools below Highway 43 and transplanting to underneath the falls at 3.6km. Following one or two growing seasons, attempts could be made to recapture these fish from the vicinity of where they have been transplanted. This would provide valuable insight into fish movement as well as the ability of upstream habitats to support westsloope cutthrout rearing and overwintering.
- Remove the severely damaged Busato Road crossing and restore riparian areas between the two roads to a more functional state would be a cost effective solution to resolve passage

into and increase the value of the 125m of habitat located between the two crossings. Vehicular access to all areas adjacent to Busato Road would not be significantly impacted by removal of the culvert as traffic can access either end of Busato Road from Highway 43. A stepped approach to restoration on this stream would provide opportunities to understand fish movement and haiatat suitability through pit tagging and recapture of fish relocated from areas of construction site salvage to upstream of the Highway as well as downstream of Busato Road. At the time of 2022 surveys, riparian areas between the two roads were heavily degraded and fish passage remediation works at Busato Road would provide opportunities for improvement of soils and riparian vegetation that would have benefits for downstream populations. In addition, restoration of this first piece of stream would help build momentum for works upstream and build awareness for riparian health issues related to range use of the land adjacent to the stream present on private lands both upstream of Highway 43 and downstream of Busato Road.

- Quantify habitat quality in the watershed by collecting detailed fish habitat information between the confluence with the Elk River and the falls at 3.6km..

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```
#https://github.com/rstudio/bookdown/issues/8 how to put the
        references wherever we want.

# `r if (knitr::is_html_output()){ '
# # References {-}
# <div id="refs"></div>
# '}`
```

Session Info

```
xfun::session_info()
```

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Platform: aarch64-apple-darwin20 (64-bit)
Running under: , RStudio 2022.12.0.353

Locale: en_US.UTF-8 / en_US.UTF-8 / en_US.UTF-8 / C / en_US.UTF-8 /
en_US.UTF-8

Package version:
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backports_1.4.1          base64enc_0.1-3          bcdata_0.4.0
  BH_1.81.0.1              bibtex_0.5.1             bit_4.0.5
bit64_4.0.5              bitops_1.0-7             blob_1.2.3
  bookdown_0.32            boot_1.3.28.1            broom_1.0.3
bslib_0.4.2              cachem_1.0.7             callr_3.7.3
  cellranger_1.1.0         chk_0.8.1.9002           chron_2.3-59
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geojsonsf_2.0.3          geometries_0.2.1         ggdark_0.2.1
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glue_1.6.2               googledrive_2.0.0
googlePolylines_0.8.2
  googlesheets4_1.0.1      googleway_2.7.6          graphics_4.2.2
grDevices_4.2.2          grid_4.2.2               gridExtra_2.3
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  httpcode_0.3.0           httpuv_1.6.9             httr_1.4.5
```

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  kableExtra_1.3.4         Kendall_2.2.1            KernSmooth_2.23-20
knitr_1.42               labeling_0.4.2           later_1.3.0
  lattice_0.20-45          lazyeval_0.2.2           leafem_0.2.0
leaflet_2.1.1            leaflet.extras_1.0.0
leaflet.providers_1.9.0
  lifecycle_1.0.3          listenv_0.9.0            lubridate_1.9.2
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  plyr_1.8.8               png_0.1-8
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protolite_2.2.0          proxy_0.4-27             ps_1.7.2
  purrr_1.0.1              qpdf_1.3.0               R6_2.5.1
ragg_1.2.5               rapidjsonr_1.2.0         rappdirs_0.3.3
  raster_3.6-14            rayimage_0.9.1           rayshader_0.24.10
RColorBrewer_1.1.3       Rcpp_1.0.10
RcppArmadillo_0.12.0.1.0
  RcppEigen_0.3.3.9.3      RcppRoll_0.3.0           readr_2.1.4
readwritesqlite_0.2.0    readxl_1.4.2             RefManageR_1.4.0
  rematch_1.0.1            rematch2_2.1.2           remotes_2.4.2
reprex_2.0.2             rgdal_1.6-4              rgeos_0.6-1
  rgl_1.0.1                RgoogleMaps_1.4.5.3      rlang_1.0.6
rmarkdown_2.20           RPostgres_1.4.5          RPostgreSQL_0.7-5
  RSQLite_2.3.0            rstudioapi_0.14          rvest_1.0.3
s2_1.1.2                 sass_0.4.5               scales_1.2.1
  selectr_0.4.2            servr_0.25               sf_1.0-9
sfheaders_0.4.0          shiny_1.7.4              shinyjs_2.1.0
  slippymath_0.3.1         snakecase_0.11.0
sourcetools_0.1.7.1      sp_1.6-0                 splines_4.2.2
stats_4.2.2
  stringi_1.7.12           stringr_1.5.0            survival_3.5.3
svglite_2.1.1            sys_3.4.1                systemfonts_1.0.4
  terra_1.7-3              terrainmeshr_0.1.0       textshaping_0.3.6
tibble_3.1.8             tidyhydat_0.5.9          tidyr_1.3.0
  tidyselect_1.2.0         tidyverse_2.0.0          timechange_0.2.0
```

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tzdb_0.3.0              units_0.8-1             urltools_1.7.3
utf8_1.2.3              utils_4.2.2             uuid_1.1.0
  V8_4.2.2                vctrs_0.5.2             viridis_0.6.2
viridisLite_0.4.1       vroom_1.6.1             webshot_0.5.4
  websocket_1.4.1         withr_2.5.0             wk_0.7.1
xfun_0.37               XML_3.99.0.13           xml2_1.3.3
  xtable_1.8-4            yaml_2.3.7              yesno_0.1.2
zip_2.2.2               zyp_0.11
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